

LONDON HEAT NETWORK MANUAL

MAYOR OF LONDON



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LONDON HEAT NETWORK MANUAL

GREATER LONDON AUTHORITY

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PREFACE

A year has passed since the GLA launched the original District Heating Manual for London and the industry has continued to develop through the efforts of utilities, institutions, government programmes, local authorities, commercial entities and other stakeholders committed to the development of decentralised energy infrastructure in London. Reflecting trends in the industry, the Manual has been launched with the new title 'London Heat Network Manual'.

This year the Manual contains additional technical guidance in respect to control of heat networks, low return temperatures, low grade heat networks, building network design and control, thermal storage design and the carbon intensity of heat sources.

A key new feature in this edition is guidance on the role of Special Purpose Vehicles, in the commercial development of major decentralised energy systems in London at scale.

Finally, the Manual has been updated to reflect developments in the London Plan and the latest planning guidance.

GLOSSARY

AMR	Automatic Meter Reading	LDF	Local Development Framework
CCME Strategy	Climate Change Mitigation and Energy Strategy	LDO	Local Development Order
CHP	Combined Heat and Power	MW	Megawatt (unit of power)
CIL	Community Infrastructure Levy	MWh	Megawatt hour (unit of energy)
CV	Calorific Value	NBP	National Balancing Point
D&B	Design and Build	NJUG	National Joint Utilities Group
DBO Contract	Design, Build, Operate Contract	NPV	Net Present Value
DE	Decentralised Energy*	NRSWA 1991	New Roads and Street Works Act 1991
DH	District Heating	O&M	Operation and Maintenance
DHN	Decentralised Heat Network	Pa	Pascal (equivalent to one newton per square metre)
DHW	Domestic Hot Water	PFI	Private Finance Initiative
DUKES	Digest of United Kingdom Energy Statistics	PI Diagram	Process and Instrument diagram
EMP	Energy Master Plan	RHI	Renewable Heat Incentive
EPR	Environmental Permitting Regulations	ROC	Renewables Obligation Certificate
ESCo	Energy Services Company	SLA	Service Level Agreement
GLA	Greater London Authority	SPD	Supplementary Planning Document
GSHP	Ground Source Heat Pump	SPG	Supplementary Planning Guidance
HE	Heat Exchanger	SPV	Special Purpose Vehicle
HIU	Heat Interface Unit	UIP	Utility Infrastructure Provider
IGT	Independent Gas Transporter		
kW	Kilowatt (unit of power)		
kWh	Kilowatt hour (unit of energy)		

INTRODUCTION

Heat remains the single biggest reason we use energy in our society. We use more energy for heating than for transport or the generation of electricity. The vast majority of our heat is produced by burning fossil fuels - around 80% from gas alone - and as a result heat is responsible for around a third of the UK's carbon dioxide emissions.

This is unsustainable. If London is to play its part in the global effort to combat climate change, we will need our buildings to be virtually zero carbon by 2050. The transformation of our heat-generation and heat-use will require and create new markets and new opportunities. Heat networks operating as part of a decentralised energy system have the potential to supply market competitive low to zero carbon energy in dense urban areas whilst providing long-term flexibility to accommodate new and emerging heat production technology and energy sources.

Demonstrating leadership in climate change mitigation, London has implemented targets that go beyond those at national and international level. In October 2011, the Mayor of London published his revised Climate Change Mitigation and Energy (CCME) strategy, entitled 'Delivering London's Energy Future'¹. The strategy focuses on reducing carbon dioxide emissions to mitigate climate change, securing a low carbon energy supply for London, and transforming London into a thriving low carbon capital. The CCME strategy reiterates the Mayor's target to source 25% of London's energy supply from decentralised energy sources by 2025.

At the national level, through the passing of the Climate Change Act 2008 the UK set legally binding targets to cut its net carbon dioxide emissions to at least 80% lower than the 1990 emissions by 2050, with at least 34% reduction to be achieved by 2020. Further to this, the

2009 Renewable Energy Directive sets the UK a legal commitment to source at least 15% of its energy consumption from renewable sources by 2020, while the 2010 Energy Performance of Buildings Directive requires all new buildings developed from 2021 to be nearly zero energy buildings. Under these agreements the UK government has implemented a series of policies and tools to meet these obligations.

With energy at the heart of our major cities' transformation to sustainable, resilient low-carbon communities, the delivery of new energy infrastructure will be critical to securing our energy future. It is in this context that the Mayor of London has produced the London Heat Network Manual. The Manual is intended to provide guidance to the development and delivery of large scale heat networks in London.

1.1 Status of the London Heat Network Manual

The Manual is intended to provide practical, accessible and consistent guidance. It is not intended to supersede other published technical standards or good practice or mandatory guides, but its use is recommended for all projects supported by the Mayor's Decentralised Energy for London programme and is commended to the London boroughs, the public and private sector developers and the decentralised energy industry as a whole.

In order to ensure future flexibility, the Manual will not be published by the Mayor as formal supplementary planning guidance (SPG). Nevertheless, it may be suitable as a standard to be used in planning conditions and obligations, or to be referenced by local planning authorities within their own supplementary planning documents on sustainable design or infrastructure delivery.

¹ <https://www.london.gov.uk/priorities/environment/publications/delivering-londons-energy-future-the-mayors-climate-change-mitigation-and-energy-strategy>

1.2 Context of the guidance

The primary focus for the Manual is in the development of heat networks entailing the use of large scale decentralised energy. Development of large scale decentralised energy been specifically selected as it represents a market segment where guidance and understanding has shown the greatest need for improvement.

The Mayor’s Climate Change Mitigation and Energy (CCME) strategy defines decentralised energy as ‘generation of local electricity and recovery of low and zero carbon heat delivered within London.’ This definition covers a wide range of technology and scales, from single building schemes using micro-generation technologies to area-wide schemes connected to local power stations and large energy centres serving thousands of customers.

The Mayor’s Decentralised Energy for London programme is centred on delivering

decentralised energy at scale to maximise market competitiveness and quantum of carbon emission reduction. It focuses on ensuring that smaller projects are designed from the beginning to enable their growth and future connection into larger systems to achieve more economic and efficient operation. The term District Energy, as detailed in Table 1 taken directly from the CCME, is used in this context to distinguish between single building or single customer systems and those heat networks which serve multiple customers across an urban district or sub-region.

These initial networks are expected to form the major building blocks of what will over time become an interconnected London-wide decentralised energy network. Building networks to a common set of standards will allow systems to operate at their most economic and enable interconnection, increasing the opportunities for further development of system integration, efficiency, reliability and resilience.

District Energy	
District Energy	<p>Type 1: Single development (small scale)</p> <p>Energy is generated and distributed to a single development that may include a large single building and/or a number of buildings and customers (up to around 3,000 domestic customers). The plant may or may not be owned and operated by the energy users. This would include smaller communal heating schemes. It would also include larger onsite networks with CHP generation equipment in the order of 3MWe capacity and project capital costs in the region of £10 million. The Cranston Estate regeneration project in Hackney is a typical example.</p>
District Energy	<p>Type 2: Multi-development (medium scale)</p> <p>Medium scale schemes supply energy to more than one site, for which heat networks are a necessary requirement. A wide range of customers and demand types may be involved, with a number of different generation systems connected typically totalling up to 40MWe in capacity. This scale could support up to 20,000 homes, public buildings, and commercial consumers. It is very likely that the plant would be owned and operated by a third party. The system could cost up to £100 million. The Olympic Park and Stratford City project is a recent example.</p>
District Energy	<p>Type 3: Area-wide (large scale)</p> <p>Area wide networks are large infrastructure projects constructed over a long period. Such schemes typically involve several tens of kilometres of heat pipe supplying 100,000 customers or more, and providing connection to multiple heat generators such as power stations. Capital costs of piping could exceed £100 million. It is likely that separate bodies would own and be responsible for different parts of the system. Such systems can take from five to ten years to deliver. The proposed London Thames Gateway Heat Network is an example.</p>

Table 1: Three scales of decentralised energy, adapted from the CCME

1.3 Scope of the London Heat Network Manual

The Manual covers the following aspects of developing heat networks:

- The technical design principles and concepts for the physical infrastructure of a heat network focusing on interfaces between heat sources and the network, distribution and consumer installations;
- Guidance on contract structures and management to help inform developers and project sponsors of appropriate options and the key issues to be considered when establishing delivery vehicles and determining procurement strategies;
- Guidance on the build-up of tariff structures and associated charges that can reasonably be incorporated as part of a project's revenue streams; and
- Guidance on the relevant planning policy and typical requirements of local planning authorities.

The final section of the Manual considers future development opportunities to deliver more efficient, more viable heat networks through technical, commercial and policy innovations. This section is intended to provide insight to the future role of heat networks and to demonstrate the technology's flexibility.

The Manual specifically excludes detailed guidance of heat supply technologies as there are many potential alternatives and the appropriate heat source for a network will vary by developer and project. Furthermore the heat source utilised for a heat network is likely to change over the life span of the network as advancements in low carbon heat source technologies are developed.

DISTRICT HEATING IN LONDON

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The Mayor's first Energy Strategy was published in 2004, highlighting the growing issues of energy security and fuel poverty in London in the context of the global problem of climate change and resource constraints. It outlined the energy hierarchy of 'Be Lean, Be Clean, Be Green' promoting reduction in energy consumption and efficient supply of renewable energy. The strategy committed to supporting the growth of decentralised energy generation as a core component of sustainable energy supply, and developing the electricity distribution network so that it could accommodate and facilitate increased decentralised generation.

2.1 The evolution of heat networks in London

Support for decentralised energy led to the first ever strategic decentralised energy planning across London and the realisation of the London Heat Map⁴ (2009/10). The London Heat Map revealed that good opportunities for the creation of heat networks exist across the capital and it laid the foundations for detailed feasibility studies and the development of planning policies to support heat networks, particularly with a view to connect new developments to those networks.

Further work to understand the technical and commercial elements needed to deliver heat networks led to the publication of a decentralised energy prospectus for London entitled 'Powering Ahead'⁵ in 2009. Powering Ahead detailed the size of schemes envisaged and the commercial and contractual structures that would be needed to make each project happen. The document provided evidence that projects were beginning to take shape.

In 2010-2011 the Mayor undertook a major study, 'London Decentralised Energy Capacity Study – Phases 1-3'⁶ to assess the potential for low and zero carbon energy supply in London. The results showed the following:

- There is considerable opportunity for London to generate its own energy, reducing the city's reliance on the national grid;
- Over half of the overall opportunity for decentralised energy in London is in medium and large-scale heat networks;
- A significant proportion of the opportunity for decentralised energy in London relies upon the use of Combined Heat and Power (CHP) generation; and
- There is also significant potential for micro-generation technologies in London.

⁴ <http://www.londonheatmap.org.uk>

⁵ <https://www.london.gov.uk/priorities/environment/publications/powering-ahead-delivering-low-carbon-energy-for-london>

⁶ https://www.london.gov.uk/sites/default/files/de_study_phase1.pdf
https://www.london.gov.uk/sites/default/files/de_study_phase2.pdf
https://www.london.gov.uk/sites/default/files/de_study_phase3.pdf

This early work continued to shape the direction of the decentralised energy programme and as such, the greatest focus for the GLA had been on developing heat networks. Through this period barriers to the development of city-scale decentralised energy projects were identified; in particular for the type of schemes capable of delivering the quantum of carbon dioxide emission reductions necessary at market-competitive prices. Efforts were focused on addressing this market failure.

Modern heat networks are built upon the use of low cost heat sources and their economic evolution in the urban environment depends on ensuring the ability to interconnect smaller scale schemes. The focus of the GLA support aimed to ensure that smaller schemes evolve into larger-scale networks able to benefit from lower cost heat, more efficient plant and utilisation of cheaper primary fuels.

The London Plan⁷ (July 2011) established the requirement for London boroughs to embed policies and proposals within their Local Plans in support of establishing decentralised energy network opportunities, with particular focus on heat networks. This has been instrumental in the promotion and development of heat networks in London. [Proposed further alterations to the London Plan were published in January 2014. The proposed alterations retain the adopted plan's principles for energy and climate change but place more emphasis on the transition from gas and configuring networks for lower temperature secondary heat sources. The updated plan is expected (at the time of writing) to be approved in 2015].

The Mayor's Decentralised Energy for London programme, launched in October 2011, began to engage with sponsors of potential decentralised energy projects, building on the legacy of earlier work. The programme has a key role in delivering the decentralised energy target by providing technical, commercial and financial advisory support to help bring decentralised energy opportunities to market. These actions will contribute to an increase in London's installed capacity and will build confidence in the market, catalysing sustained investment in an expanding network of decentralised energy schemes across the capital.

2.2 Introduction to heat sources

Large scale decentralised energy schemes incorporating heat networks offer an affordable way of achieving low carbon energy supply in densely populated areas such as London, meeting domestic, commercial and some industrial space heating and domestic hot water requirements. It achieves this through the supply of low cost low carbon sources of heat distributed in bulk via heat networks.

This section introduces some of the potential heat sources that are commonly considered in heat network developments across the capital. The Manual does not assesses or recommend specific technologies for the supply of heat into heat networks; rather, it discusses numerous alternatives available and provides guidance on how the merits of any particular scheme design might be assessed.

⁷ <http://www.london.gov.uk/priorities/planning/london-plan>

For more than a decade the use of gas fired Combined Heat and Power (CHP) with small scale heat networks has provided a highly reliable and efficient use of fuel, with primary energy savings of 30-45% compared with the conventional separate generation to achieve the same quantity of heat and power. As technologies improve and the electricity grid begins to decarbonise the bar is set ever higher and efficiency gains through better design, reduction of losses, improvements in technology and the selection of new energy sources presents both challenges and opportunities that can be met by the flexibility of heat networks.

Over the past few years there has been an increase in the range of technologies selected for the supply into heat networks, particularly as the scale of networks increases. The selection of technology will depend on a range of considerations but will primarily be influenced by the economics of the project. A number of technologies may be used within a single energy centre to ensure efficient and reliable operation across the range of heat demands. The heat supply sources will affect the economics and carbon intensity of the heat network.

A principle of resilience should be applied to the heat production to ensure that should any particular heat source fail there is sufficient alternative heat supply available to meet consumer demands. In practice this commonly means gas boilers are used for back-up and peak heat supply, however other sources can be considered provided minimum service levels can be maintained.

The diagrams on the opposite page depict a small sample of combined heat and power (CHP) heat sources that offer potential as suppliers to heat networks. The diagrams indicate potential arrangements for the off-take of heat and are provided solely to demonstrate the variety and versatility of heat networks.

2.3 Introduction to heat distribution

The transportation of heat from the heat source to the end consumers involves the use of a distribution system, made up of a network of hot water flow and return pipes, delivering hot water to the consumers and returning water at reduced temperature back to the heat source. It is a closed system, therefore the water is continuously recirculated and it is the energy in the water that is transferred to the consumer to meet their heating and domestic hot water requirements.

In combination, the distribution system and ancillary equipment is referred to as the heat network. When installed correctly, heat networks represent reliable, long life assets that can deliver heat to consumers regardless of the type of heat source. Indeed the heat source on a network may change over time as the energy market and technologies change to favour new generation technologies or other more economic heat sources.

The flow and return heat network pipes are typically installed through public streets in much the same way as water and gas infrastructure, with the main differences being that the pipe are insulated and run in pairs and so tend to require more space within the utility corridor. Branch connection pipes to supply each building or estate served by the network would also be buried under pavements or estate roads and would emerge directly into a development plant room or energy centre.

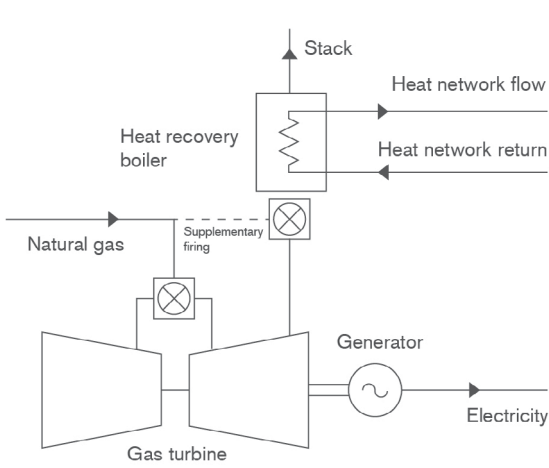


Figure 1: Typical heat off-take arrangement from a gas turbine CHP plant

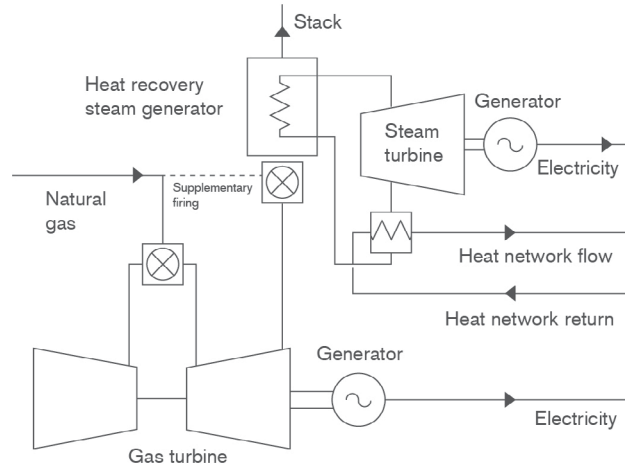


Figure 2: Typical heat off-take arrangement from an energy from waste or biomass CHP plant

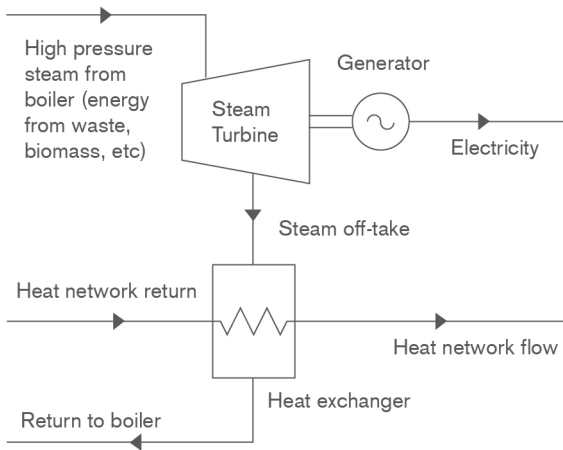


Figure 3: Typical heat off-take arrangement from a gas fired CHP plant

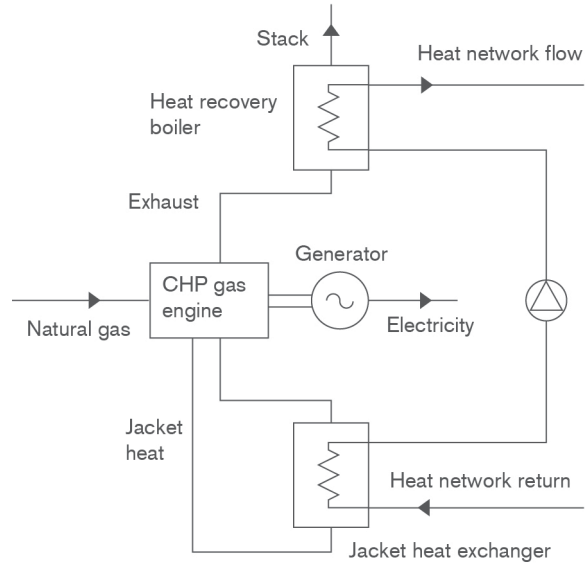


Figure 4: Typical heat off-take arrangement from combined cycle gas turbine CHP plant

As smaller networks are interconnected to enable access to lower cost heat sources the flexibility of heat networks is increased since the wider network hosts alternative connection points for energy supply. It may be possible over time to decommission smaller energy centres and supply the interconnected network from larger more efficient energy centres with reduced maintenance cost. This would allow the decommissioned energy centre to be put to other use. In order to realise these benefits it is important to ensure that networks are built with a common design basis to facilitate their interconnection. The Manual outlines design standards for heat network equipment that should enable these future benefits to be achieved.

2.4 Introduction to heat consumption

The main consumers of heat in London are the residents of London, who consume energy for the heating of homes and for their domestic hot water needs. There are other consumers such as commercial buildings, offices, community centres, schools and hospitals. Overall, as a city we consume 66 TWh/year for our heating needs, while there may be as much as 50 TWh available from existing heat sources in and around London to supply our heat networks⁸.

Customers of a well designed and installed heat network should not perceive any difference in the delivery of space heating and domestic hot water when compared with a conventional building heating system. For most consumers, the key difference is in the replacement of their gas boiler with a heat interface unit which transfers heat from the heat network to their heating and hot water systems.

The heat interface unit controls the delivery of heat to the consumer, and normally incorporates billing meters which measure, record and communicate heat consumption. Larger consumers, such as social housing estates, may also include a heat exchange substation which hydraulically separates the building heat distribution from the heat network. Heat exchange substations represent a convenient commercial boundary between the heat network operator and its consumers; for example where a private heat network operator supplies heat to an estate managed by a social housing provider.

The operating temperatures of a heat network and its consumers' heating systems need to correspond to ensure the efficient and effective delivery of heat. Low operating temperatures in consumer buildings can mean that the operating temperature of the heat network may also be decreased. This may open up opportunities to take advantage of low grade, low carbon and low cost sources of heat such as that recovered from electrical substations, while still meeting the heat demands of consumers and addressing Legionella requirements.

It is also possible to serve commercial heat demands via a heat network where an appropriate heat source is available. This is reflected in the aspirations of the London Sustainable Industries Park, which is to link industrial heat consumers with neighbouring heat supplies in order to reduce overall carbon emissions and improve economic efficiency.

⁸ <http://data.london.gov.uk/datastore/package/decentralised-energy-capacity-study>

2.5 Benefits of heat networks

Heat networks offer a range of benefits over conventional heating methods for consumers, developers and for London and the environment. These benefits are summarised in Table 2.

In addition to the overall energy system efficiency and associated economic and carbon benefits, heat networks offer a number of other advantages over the conventional stand-alone approaches to building energy supply:

- They facilitate the deployment of embedded CHP that has the potential to reduce some of the pressure on electrical network infrastructure and offset additional peaking plant that would otherwise be necessary in areas of development growth;
- They can be supplied by a number of different heat sources, either operating alone or as a combination of plant types.
- Heat network infrastructure enables the recovery, transfer and utilisation of heat sources that may otherwise be lost to the environment. This heat may then be used to displace alternative energy sources such as the combustion of natural gas in domestic boilers.

Heat networks with thermal storage can be used to decouple the timing of generation from that of demand by the consumer. Using a thermal store may allow the efficient operation of the CHP irrespective of heat demand. Thermal stores are commonly located near to the CHP plant, as it is easier to ensure that only CHP heat is used to charge the store, however they can also be installed at other locations on the network where deemed appropriate for the system. Heat from the store can then balance the hourly variations on heat demand, minimising the need for operation of the heat only boilers.

The current reliance on fossil fuels for energy creates a vulnerability to energy price volatility. Heat networks offer an opportunity to reduce this exposure which is increasingly important as future energy supply shocks will have a significant impact on the costs of living and doing business in the city.

Through smarter use of the energy that we already consume and opportunities such as large scale waste heat capture and distribution via heat networks, London can meet its domestic energy needs while reducing the total fuel consumption, thereby delivering some protection against fuel capacity issues and fuel price fluctuation.

Beneficiary	Benefits of heat networks	Additional benefits of strategic interconnected heat networks
For the Consumer	<ul style="list-style-type: none"> Heat networks can address fuel poverty and give peace of mind to vulnerable consumers by: <ul style="list-style-type: none"> ensuring the efficient management of heat provision; providing lower and more stable prices; offers lower costs than for micro renewables in achieving low or zero carbon energy supply. Resilient design to provide secure heat; system supported by multiple heat sources. Heat interface units require less space and are simpler and safer to operate than individual gas boilers; Metered supplies; tariff structures are often made up of a standing charge and a unit charges based on the metered supply. No maintenance is necessary for the consumer; the heat network operator can take care of energy and services 24 hours a day, typically without ever entering the house. 	<ul style="list-style-type: none"> Where networks are interconnected, a genuine heat market may develop allowing competition and lower costs. Greater security of supply as multiple heat sources in both type and number may supply the same network.
For the Developer	<ul style="list-style-type: none"> Lower cost solutions: a heat network may provide a lower cost method of achieving carbon targets than the equivalent deployment of micro renewables. Heat networks can be set up as an attractive ESCo offering, reducing the developer's up-front capital costs, adding development value and removing the developer's need for long term engagement in the project. Reduces labour and maintenance costs as compared to individual systems. May significantly reduce the developer's cost of compliance with Building Regulations. It may even be the factor that enables developments to go ahead. 	<ul style="list-style-type: none"> The opportunity to extract more value from existing energy centre assets. If a CHP engine can supply a greater heat load then it will generate a better return. If the energy centre economics have been eroded through market or technical advances then a heat network connection will allow cheaper heat to be purchased from elsewhere on the network than from a stranded asset on a small network. The potential to decommission the energy centre plant, and have consumers on the network supplied fully by another energy supplier. This would reduce costs and would free up space for alternative uses.
For London and the environment	<ul style="list-style-type: none"> Lower carbon dioxide emissions. Potential for low carbon economy. Allows a broad range of energy generation technologies to work together to meet demand for heat. Flexibility for fuel diversity, possibility to optimise fuel mix. Increases the fuel efficiency through use of CHP and recovered energy sources. Extending the reach of renewables, by using renewable heat efficiently and providing opportunities for the development of renewable technologies that otherwise wouldn't be viable. Utilisation of surplus and recovered heat which would otherwise be lost. Pipe work can last for many decades and transports heat regardless of the type of heat source. An energy centre could be converted from fossil fuels to renewables as the economic viability improves. 	<ul style="list-style-type: none"> As networks are connected together greater use of more efficient plant can be made, reducing emissions and lowering carbon emissions. Step changes in energy production efficiency can be made as new and lower carbon heat sources become available and are less site-specific. Incentive to make better use of surplus heat from energy waste plants. Enables the efficient transportation and use of heat for a wider variety of consumers. Reduces the number of smoke stacks throughout a city and allows easier control of emissions.

Table 2: Benefits of heat networks

2.6 Development of heat networks

The development of heat networks relies on the identification of projects with the right mix of heat demands, connecting buildings and a motivated project owner. The Energy Masterplanning (EMP) process has been developed to identify opportunities for new networks in an area, and to set out a long-term vision for heat network development.

The Masterplan sets out initial proposals for pipe routes and plant locations, as well as economic and environmental impacts of their implementation.

Energy masterplans should outline existing, planned and proposed developments that may be of potential interest for future interconnection and should therefore play a key role in the considerations of a development's network design, such as placement of energy centres and the capacity of pipes to interconnect with other heat loads.

The steps in the energy master planning process are:

- Mapping existing energy demands in the area and identifying ownership and control of these demands;
- Mapping planned new development in the area, considering development phasing;
- Mapping energy supplies in the area, including local heat and fuel sources;
- Mapping existing and planned heat networks;
- Identifying suitable locations for energy centre(s); and
- Identifying routes for potential heat networks.

Once the above information is assembled into the map, different network combinations of demand connected to potential energy centres can be evaluated using a techno-economic modelling techniques which provide indicative sizing of the network and indicative financial viability.

A number of London Boroughs are developing energy masterplans. These plans are developed from the data in the London Heat Map⁹ and identify opportunities for heat networks within the masterplan area both within the boroughs themselves and across borough boundaries. Energy Masterplans have resulted in the development of planning policies to promote heat networks and the connection of new developments to those networks. The completed Decentralised Energy Masterplans referenced in Table 3 are available to download at the website.

Following the production of an EMP, a feasibility study of an individual opportunity should be undertaken to assess it in more detail. The feasibility may consider the specific requirements of individual connecting buildings, the phasing of the network, and the route of the network. A feasibility study will produce a robust conclusion on the economics and feasibility of the proposed network, and give all the technical information required to enable decisions on commercial structures for network delivery and operation and to proceed with the procurement process.

9 <http://www.londonheatmap.org.uk>

Area	Boroughs included	Area type	Energy masterplan undertaken	Energy masterplan in progress or planned
Upper Lea Valley	London Boroughs of Enfield, Haringey, Waltham Forest	Opportunity Area	√	
Vauxhall, Nine Elms and Battersea	London Borough of Wandsworth, Lambeth	Opportunity Area	√	
Wembley	London Borough of Brent	Borough	√	
Kingston	London Borough of Kingston	Borough	√	
Westminster	City of Westminster	City	√	
Camden	Euston Area Energy Masterplan	Borough	√	
Redbridge	London Borough of Redbridge	Borough	√	
Kingston upon Thames	Royal Borough of Kingston upon Thames	Borough	√	
London Riverside	London Borough of Havering	Opportunity Area	√	
Wembley	London Borough of Brent	Borough	√	
Bexley	London Borough of Bexley	Borough		√
Haringey	London Borough of Haringey	Borough		√
Barnet	London Borough of Barnet	Borough		√
Greenwich	Royal Borough of Greenwich	Opportunity Area		√
Islington	London Borough of Islington	Borough		√

Table 3: Status of development of Energy Masterplans

DISTRICT HEATING PRINCIPLES OF DESIGN

3

This chapter covers the main technical features of heat network design, control and operation and includes guidance on the design requirements and options for secondary (building) side systems.

3.1 Components of heat networks

Heat networks comprise the physical infrastructure, as well as contracts, regulatory structures and organisations, for the generation, distribution and consumption of heat within a city. The boundaries of the physical network infrastructure as covered by the Manual extend from the heat generation at the low carbon energy source through the distribution network to the consumer heat interface and include:

- Heat source interface between heat production plants and network: The heat source interface will comprise the plant and equipment to accept the heat supplied by the Heat Supplier into the heat network;
- Heat network route (i.e. the pipes); and
- Consumer heat interface between the network and the heat consumer. The consumer heat interface will comprise the equipment to deliver the heat from the network to the customer.

3.2 Design considerations

There are a number of key design considerations that should be addressed when conceptualising and implementing heat network design and these cover consumer demand and connections, heat distribution networks and heat generation sources.

Typically, modern heat networks are constructed and operated based on sound economic criteria using standardised, technically proven and high quality solutions. Investments are made based on analysis of economic viability. The heat tariff structure reflects the actual costs, and the heat network must be competitive compared to alternative heating methods (e.g. individual gas boilers). The design and operation of heat networks should ensure that they are able to supply economic and reliable heat to customers under all conditions.

Good heat network design should be consumer-centric. The design of a heat network should first consider consumer connections and the consumer heat needs for space heating and domestic hot water, and any industrial heat use that may be connected. From this starting point the consumer connections of a system will determine temperature levels, temperature differences, pressure levels and the load profiles for the entire system.

From this key design information the heat network, distribution pumping equipment, heat transfer equipment and standby and top-up heating arrangements (forming the energy centre) can be designed according to the principles

outlined in this section. Figure 5 represents an example district energy heat network; it is indicative only and not representative of all potential network configurations.

3.3 Design life

Heat networks form substantial pieces of London's decentralised energy infrastructure which require significant planning, design, resource effort and investment in order to be delivered. This is particularly the case in dense urban environments where hard surfaces and busy routes will require excavating, at significant cost. The 'HM Treasury guidance for public sector bodies on how to appraise proposals before committing funds to a policy, programme or project'⁸ recommends that a design expectation of 25 years be considered for major project evaluation. However, the recommendation for design of heat network projects in London is 30 years, in accordance with the Sustainable Design and Construction (SD&C) Supplementary Planning Guidance (SPG)⁹. Where properly designed and installed it is reasonable to aspire to heat network life-spans of 50 years; a period well in excess of both the above evaluation periods.

⁸ <https://www.gov.uk/government/publications/the-green-book-appraisal-and-evaluation-in-central-government>

⁹ <http://www.london.gov.uk/priorities/planning/consultations/draft-sustainable-design-and-construction>

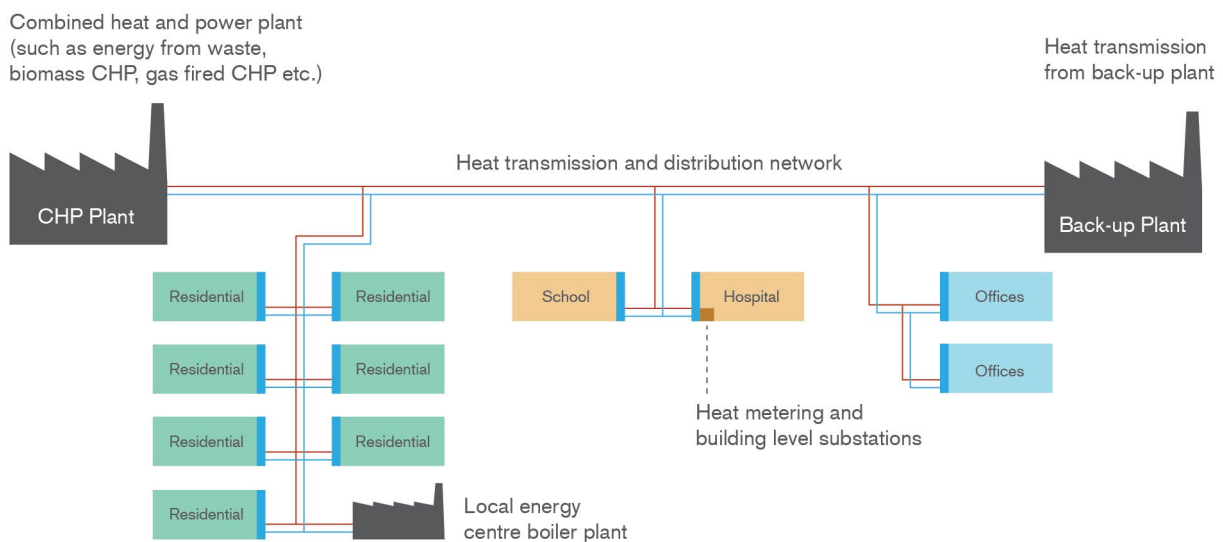


Figure 5: An example district energy heat network

Strict quality control through installation supervision is a key step in ensuring long network life span. Whilst a well-designed network should deliver very long asset life span, once trenches are back filled any shortcomings in the installation process may be hidden and are subsequently difficult and costly to locate and repair.

The 50 year life span is a not unreasonable aspiration for pre-insulated steel pipe work which is more commonly specified at the area-wide District Energy scale of the market where supply temperatures of approximately 110°C are not uncommon. Design life span for ancillary equipment including the heat generating plant, distribution and pressurisation equipment and heat interface units is dependent on the type of technologies applied. There are numerous sources for information recommending the life span of individual components; CIBSE Guide M is a useful place to start.

3.4 Principles of operation

This section sets out the basic design and control principles for the operation of modern heat networks. It covers 'variable flow variable temperature', the importance of low return temperatures for network efficiency and the benefits of low temperature heat networks.

3.4.1 Variable flow variable temperature

One of the main principles for efficient and cost effective heat network operation is for the supply flow rate and temperature to be controlled by variable flow and variable temperature functionality to accurately match the consumer heat demands on the system. This principle has been proven to give good economic performance over the lifetime of a heat network through a combination of lowering heat losses and improving distribution pump energy efficiency (utilising variable speed pumps), whilst minimising the pipe size installed across the network.

Under the variable flow variable temperature principle the system is designed to satisfy peak heat demand with the maximum temperature and flow rate, however during normal operation as the heat demand on the system reduces the supply temperature and flow rates are also reduced through the network to achieve energy savings.

Peak heat demand represents only a short duration in the normal daily and seasonal profile of heating demand by consumers. Reducing the supply temperature of heat networks provides significant reduction in thermal losses and reducing the flow rate of the service provides significant savings in pumping costs. Therefore in combination, reducing the supply temperature and the flow rate to match the amount of heat being demanded from the system at any point in time ensures that reliable and cost effective heating can be supplied for consumers.

Variable supply temperature is normally controlled at the heat source interface; however in the case where a number of heat sources are connected on the same network at different prices, lowest cost delivery can be maintained through heat source sequencing controls. In this case a lower cost low temperature heat source can be selected in preference over with a more expensive high temperature heat source via the control system. The higher cost heat source may then be enabled to operate when increased demand on the system is present.

Supply temperature is typically modulated to follow a pre-programmed supply temperature curve commonly linked to the outdoor temperature. The water flow rate is varied to meet the return temperature set point, ensuring pumping power costs are minimised.

The following curves in figures 6 and 7 show the variation in supply temperature and flow rate when air outdoor temperature varies over the seasons. It should be noted that vreturn temperature is only an estimate and is dependent on the secondary (customers') system temperatures and on the design and operation of consumer substations.

The heat network flow rate is a function of consumer demand, through the control of distribution pumps to maintain system pressure reflecting the aggregate position of the two-port valve controls in heat substations which are constantly adjusting to match the primary flow to meet the consumer demand. As outdoor temperature falls, consumer demand for heating increases, two-port valves open to draw heat from the network, resistance to network flow decreases resulting in a fall in system pressure which is monitored at the energy centre and the distribution pumps are modulated to deliver higher flow rate to satisfy the demand. This adjustment process is continuously occurring throughout seasonal and daily demand variations.

The variable volume flow is maintained above a predetermined minimum value to ensure the full heat supply service is maintained across the network. This makes certain that a minimum pressure difference is maintained at a reference consumer (usually the one furthest away from the circulation pumps) to provide adequate heat supply.

There are variations to the control mechanism by which variable flow variable temperature control is achieved; however, in all cases the control system

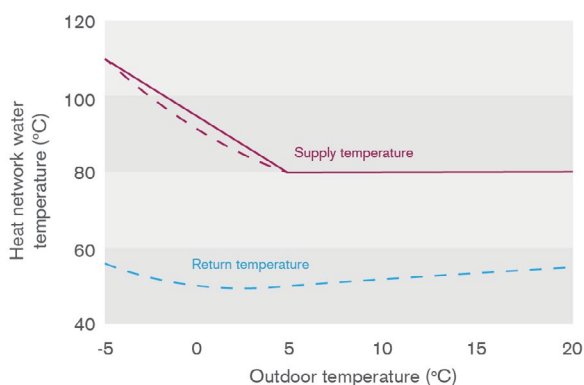


Figure 6: Heat network flow and return temperature variation with outdoor temperature

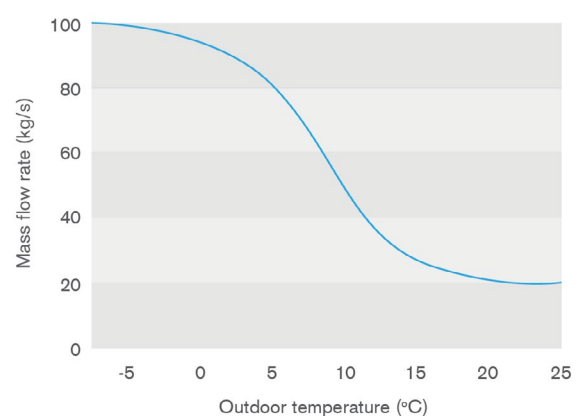


Figure 7: Heat network mass flow rate variations in relation to outdoor temperature

is designed such that the functions of variable flow and variable temperature do not interfere with each other, a scenario termed ‘hunting’.

3.4.2 Low return temperature

For a specified heat network pipe size, its capacity to distribute heat at a defined flow rate is primarily determined by the differential in supply and return temperature. Wider temperature differences allow more energy to be transported through the pipe. This means that heat networks with a greater temperature difference may be able to utilise smaller heating mains, leading to a reduction in capital costs.

As the cost of heat supplied to a system increases for higher supply temperatures, it is preferential for systems involving the transmission of heat over long distances to achieve wider temperature differences through the lowering of return temperatures. To improve the efficiency of standard heat networks and ensure low cost heat for consumers the Manual recommends that wherever possible, systems are designed with return temperatures of 50°C (or lower for low grade heat networks). This requires

that control systems and more importantly the heating and hot water systems of consumers on the network are compatible with low return temperature operation.

Internal heat emitters compatible with low temperature operation include underfloor heating and fan coils. In some cases it may be possible to achieve operation consistent with low return temperature on conventional radiators. Such conditions might exist in the event that energy conservation measures were applied on a building such as the installation of double glazing and additional insulation. In this case the existing radiators may be oversized for heating demand at their normal flow temperatures.

Traditional design conditions in the UK for heating systems with conventional radiators involve supply and return temperatures of 82 and 71°C respectively, giving a differential temperature between the radiator and the ambient room temperature (19°C) of approximately 55°C.

Understanding the characteristic heat transfer properties of the radiators in a building can be

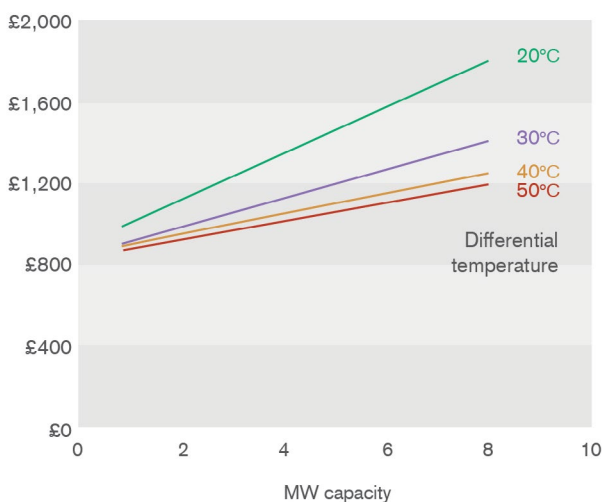


Figure 8: Relationship between cost of pipe work installation and differential temperature on a system

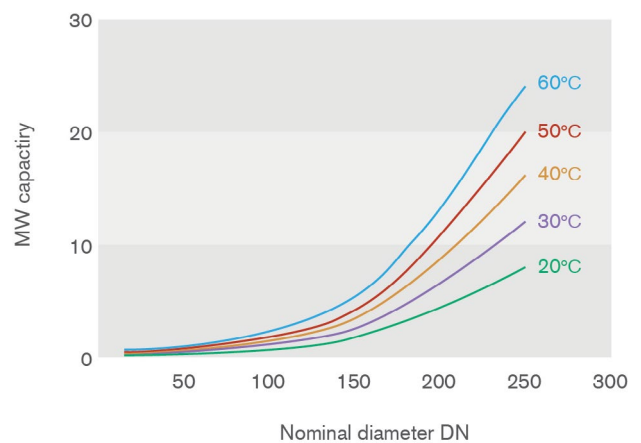


Figure 9: Heat network system capacity variation in relation to pipe diameter and temperature difference

used to establish the expected performance of the same radiators under lower temperature conditions, to determine whether it is feasible to make a system temperature adjustment without the need for retrofitting new heat emitters.

Where secondary systems are compatible and low return temperatures can be implemented, there is capacity for the transfer of greater volumes of heat via a heat network at smaller pipe sizes.

Figure 8 provides an indication of the relationship between the cost of pipe work infrastructure with its capacity to deliver energy. The different curves show the impact of increasing the differential temperature. As the differential temperature increases, the same heat content can be transmitted through the system using smaller pipe sizes, thereby offering a reduction in the cost of installation of the heat network.

Figure 9 presents the same concept in an alternative format. It shows the energy flow capacity that can be delivered in relation to pipe sizes and the different curves indicate the impact of increasing the differential temperature. Take a network pipe size of DN250 for example; lowering the return temperature to widen the temperature difference from 20°C to 40°C means that without changing the installed pipe work infrastructure the capacity for energy flow in the system may be doubled from 8MW to 16MW.

In addition to the potential for decreasing network capital costs through selection of smaller pipe sizes there are further gains to be realised through lowering the return temperature on heat networks. In many cases the economics of energy recovery from the heat source can be improved as the return temperature is decreased.

Great care should be taken in development since the performance of systems in design may be quite different in operation and the implication of failing to achieve the design temperature

differential is that the system pipes may be undersized. Pipe size selection is one key aspect of the design that must be established correctly the first time around. The opportunity to retrospectively increase pipe size is effectively nil once the pipes are in the ground.

Despite the potential pitfall, the flow and return temperature differential remains an important design consideration. For heat network designers, establishing reliable low return temperature performance in the operation of systems is essential in maximising cost effectiveness in the installation and operation of heat networks. Reflecting this design need, there are many manufacturers producing products and solutions specifically aimed at a reduction in return temperature.

3.4.3 Low grade heat networks

As the capacity for our buildings to operate at lower temperatures develops, then previously impractical heat sources may become viable. Typically such heat sources, considered medium to low grade, represent considerable future opportunity to heat networks as they are commonly lower cost and low carbon sources of heat with source temperatures at 55°C, or lower. Heat sources of this quality may be upgraded through the application of a heat pump to raise the temperature sufficient to deliver useful heat more commonly for space heating purposes. The use of London's indigenous heat sources such as water bodies, vents, sewers and electricity transformers, presents London with an exciting prospect for autonomous sourcing of space heating in our bid to lead the way globally in tackling climate change.

Incentivising the operational performance to ensure low temperature returns is especially important for low temperature networks.. As a commercial driver, it is recommended for consumer heat tariff charges to incentivise low return temperatures and to impose a higher

charge on consumers who return water over a return temperature threshold.

Side by side with the commercial drivers for behavioural change, technological developments are being established within the industry in the pursuit for heat networks with increased cost effectiveness and better environmental performance. Low temperature heat sources such as tube train vents, electrical substation transformers and heat recovery from sewers all represent potential low cost and low carbon heat supply opportunities. The industry is both innovative and eager to deliver, although the nature of large scale infrastructure projects is such that developments can frequently involve long gestation periods.

The London Borough of Islington is in the advanced stages of designing a low grade heat district heat network. The scheme recovers heat from a London underground ventilation shaft and a national grid power transformer. With the use of heat pumps, the heat is connected into an existing heat network scheme, which will operate at conventional temperatures. Managing the balance between heat sources requires sophisticated control techniques.

Low grade heat networks may still connect to district energy scale heat networks via use of a heat exchange substation to provide back-up or alternative heat sources transferring heat at parameters consistent with the low grade heat network requirements.

District energy schemes with supply temperatures of 110°C or higher remain practical where high heat volumes are transported long distances. In such instances, maximising the differential temperature remains the key design principle. In much the same way that electricity transmission is arranged in various voltages, the optimum arrangement for heat transmission is dependent upon the grade of heat, the distance to cover and ultimately the economics of transmission.

3.5 Primary side heat network design

This section sets out the requirements for the design of the primary heat network. The convention applied in the Manual regarding primary and secondary heat networks is that 'primary side' refers to the main heat network from the heat source through the heat network pipes up to the heat interfaces at the consumer connections. 'Secondary side' refers to equipment on the consumer side of the building connection.

3.5.1 Heat distribution network

A properly designed primary heat network is one which enables the operator to ensure that service is maintained and consumer demand is met at all times. The distribution equipment should be installed as near to the source of heat as practical, normally in a combined energy centre where the control system will monitor and control the pressure, flow rate and temperature of hot water through the pipe network matching the demand for heat from the system at any point in time. When there are multiple energy centres on a larger network there is normally a designated control energy centre that varies its output to follow the demand of the system (load follow), while the other energy centres provide base load by operating at constant output.

Figure 10 indicates the plant and main components / controls required for a variable flow and variable temperature heat network.

The energy centre flow control system is commonly based on maintaining a target pressure differential in the network at critical consumer points such that minimum flow rates can be maintained throughout the system.

In Appendix 2, a case study of the Danish approach to the design of heat transmission systems based on the average head concept is provided. The average head principle was adopted due to the many heat production units

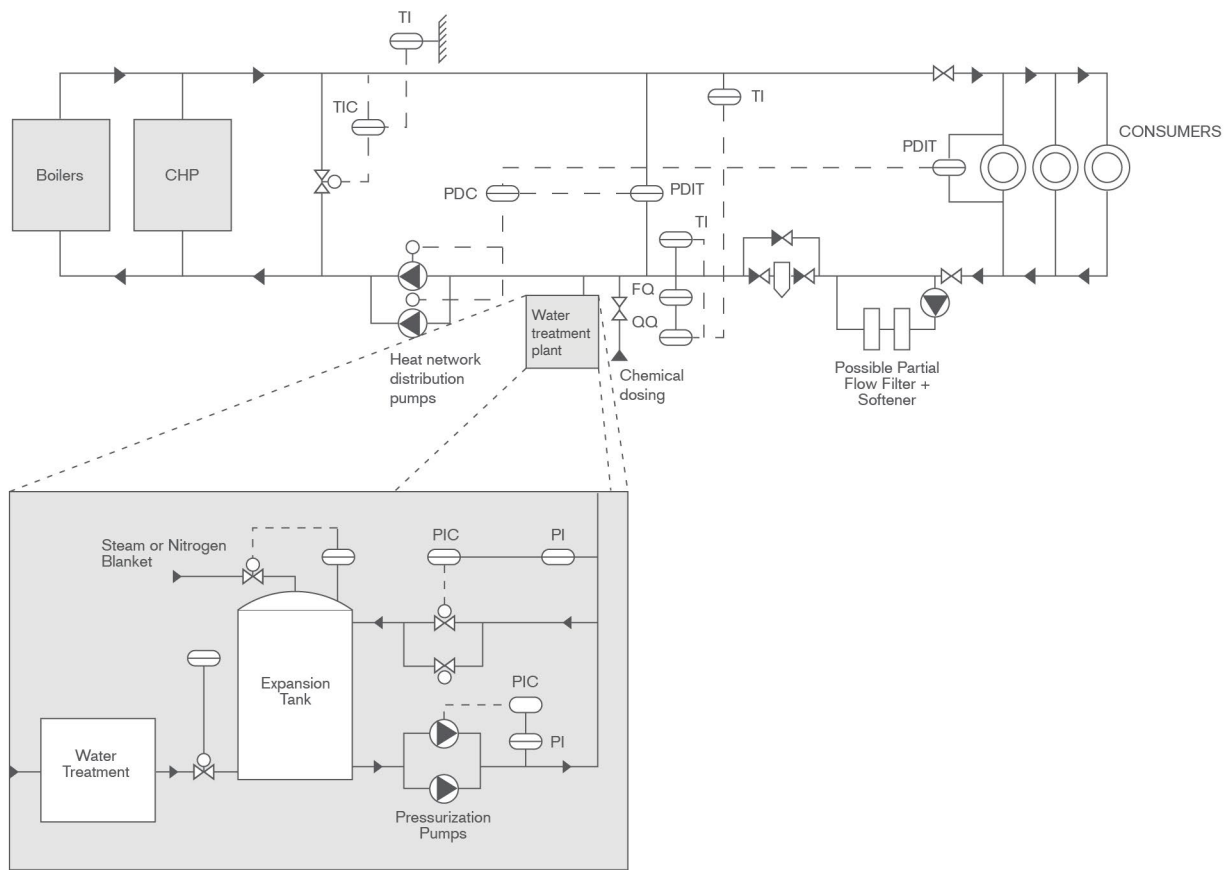


Figure 10: Typical plant arrangement for a variable flow, variable temperature heat network

geographically separated over large distances and the need for flexibility to allow the future connections. The heat transmission network was designed and optimised around a higher operating pressure, high velocity system to enable the use of low diameter pipe work to minimise construction costs. The high velocity concept is feasible where there are long, straight sections of network but it does introduce the risk of damage due to pressure surges. This risk is managed through the 'average head' hydraulic concept in which the static pressure of the network is maintained at a fixed level under all flow conditions.

3.5.2 Network design, routing and thermal expansion

This section explores the requirements for the design of networks, considering in particular their routing and thermal expansion. The key design criterion includes:

- The heat network must be capable of supplying hot water to the consumers with sufficient temperature and temperature difference to meet the heat demand;
- It must be designed to minimise heat losses;
- The pressure across the entire network must not allow hot water to boil at any time;

- Pressure differences between flow and return pipes must always be sufficient to meet the required flow rate at all consumers;
- The network route should be designed to ensure long pipe life span, through minimising pipe stresses and accommodating expansion;
- The network route should be practical and distances should be minimised; and
- The pipes in the network should have sufficient capacity for all heat loads that may reasonably be expected to connect in the future.

In practice heat network routes must be established by ensuring a route corridor can be found to all consumer points. Hydraulic modelling software is used to size pipes against the peak heat demand loads, with load profiling, heat load diversity and network phasing taken into account to determine a pipe network design. Reference consumers are identified for control of pressure, pressure difference, temperature and temperature difference from energy centres at specified locations. Typically this is located at the furthestmost point on the system from the heat source and distribution energy centre and would be the first consumer to experience loss of minimum required flow rate across their heat interface if the system pumps were throttled back.

Normally a pressure differential of 1 bar is selected as the set point for the reference consumer to provide a small margin for error given substation units are normally designed for 0.6 bar maximum pressure loss. If the 1 bar pressure differential is maintained at the reference consumer then at least 1 bar pressure differential is assumed to be achieved at all other consumer connection points on the system.

When preparing the mechanical design of a heat network pipe route, pipe work stress including thermal expansion stress must be taken into account, especially for larger diameter pipes. This design should be carried out by experienced engineers to avoid reducing pipe life span. Due to the nature of heat network installations at the District Energy scale involving typically long straight runs of pre-insulated steel pipe work, these pipes are subject to significant expansion forces when heated under normal operating conditions.

Techniques to compensate for thermal expansion are calculated and specified during design and applied in installation. The use of expansion joints and expansion loops are sometimes applied, however the ultimate design principle is to accommodate expansion of heat network pipe work within stress tolerances while reducing as far as reasonably practicable the need to access and maintain equipment such as expansion joints. An experienced thermal expansion design specialist in heat networks will attempt to achieve this naturally through the skilful arrangement of pipework bends as such may accommodate expansion with no additional equipment to maintain.

3.5.3 Pressure systems safety regulations

Typically, heat networks are designed to operate under Low Temperature Hot Water (LTHW) conditions with hot water temperature not greater than 110°C. Such a system would fall outside the Pressure Systems Safety Regulations (2000)¹⁰. However, since some networks consistently operate close to this qualifying mark and in some instances higher than 110°C it is essential to have an understanding of the regulations and requirements for the safe design and operation of such schemes.

¹⁰ <http://www.legislation.gov.uk/uksi/2000/128/contents/made>

There may be perfectly sound economic reasons for designing a heat network at elevated temperature/pressure conditions. In cases where the regulations apply, the relevant parts of the scheme will need to be designed and installed to the satisfaction of a Competent Person and a written scheme of examination will have to be maintained to ensure that the safety equipment is regularly maintained, inspected and tested. It is not the intention for the Manual to cover this issue in great detail; further information can be obtained in the regulations.

For general guidance, in situations where the Pressure Systems Safety Regulations may apply to a scheme or part of a scheme the designer may seek to minimise the extent of the scheme where such conditions might arise. For example, if the qualifying temperature/pressure conditions applied at the heat source only, the heat network designer may select to design and install a hydraulic break in the form of heat exchange equipment such that the boundary of the written scheme could be established and potentially minimised. In these cases, the cost burden may in fact be relatively negligible as the operators of these heat sources may already need to comply with the regulations and therefore are likely to have the knowledge and means to deal with the requirements.

3.5.4 Pipe line pressure loss

Heat networks are designed and pipe dimensions selected based on a maximum pressure loss per metre. This is normally achieved through software simulation of the entire heat network based on the designed connected heat demand profiles and expected supply and return temperatures taking in account the topography and distances of the proposed pipe routes.

The design trade-off associated with pressure loss per metre is the balance between pipe costs, pumping costs and heat losses. Designing systems at higher flow velocities allows smaller diameter pipes for a given temperature differential, resulting in lower heat losses and pipe cost. However, this will also result in greater frictional losses and therefore higher pumping costs.

The guideline pressure losses for design purposes are 100 Pa/m for main lines¹¹ and 250 Pa/m for network branches. This has been found generally to represent a good economic balance between heat loss and pumping energy. When applied in project specific situations different economic drivers may be present. For example in scenarios where the heat supply is exceptionally low cost low carbon an elevation in heat loss may present negligible loss. Equally, higher cost heat sources may demand additional investment in protection from thermal losses. Likewise, certain energy centres (such as those within power stations) may benefit from cheap electricity, making pumping costs negligible..

3.5.5 Thermal insulation

Reducing thermal losses in heat networks is one of the most important design considerations in the development process. In most circumstances it is false economy to settle for the minimum requirement under the British Standard¹²; it would be akin to buying a G rated kitchen appliance. In order to determine the optimum economic level of insulation for your pipe work, this assessment should take into account:

- Actual pipe work temperatures - not assumed averages; often differential levels of insulation may offer the best economic performance (i.e. more insulation on flow pipe work compared

¹¹ Heat network mains refer to the main heating flow and return pipes delivering bulk heat from the heat sources through the network. Heat network branches refer to the smaller connections off the mains that deliver the heat into individual consumer buildings or small subsets of consumer buildings.

¹² Annex G of BS5422:2009 provides a simple methodology for determining the economic level of insulation for pipe work.

to the return pipe work) but this will need to be balanced against practicalities of multiple pipe specifications on procurement, logistics and construction site factors;

- Accurate estimates of average annual ground temperature;
- The price of heat, adjusting for future fuel inflation over a 50 year (typical) life span; and
- Pipe work above ground and on secondary systems should also be considered, with the external temperature adjusted to a suitable still internal air condition, or exposed external air condition.

Figure 11 below indicates the relationship between insulation thickness and the heat loss from insulated pipes. The rate of heat loss depends upon a range of factors and in the production of figure 11, ambient temperature, fluid temperature have been set constant. The three curves show the influence of pipe sizing and the shape of the curves show the reduction of heat loss per metre of pipe as the thickness of insulation is increased. Note that the heat loss per unit length is on a log scale.

Heat network pipe insulation is categorised as Series 1, 2 or 3. In this categorisation, Series 3 offers the most effective heat insulation as it offers the lowest U value. Modern heat networks in the UK are commonly installed with Series 2 or Series 1 insulation.

Twin-pipe installations may be an option, whereby the flow and return pipes are housed in a single insulated casing. Such arrangements require a different calculation method in assessing the thermal losses; while some heat loss is recovered from the flow into the return line, this modest proportion of leaked heat is returned to the heat source rather than distributed to consumers.

There are some benefits with the selection of smaller diameter pipe work as the rate of thermal loss from a pipe is proportional to the surface area for heat transfer. While over sizing pipes may reduce friction and pumping power, it also increases surface area and heat loss. Understanding of the implications of this trade off on pipe selection is achieved through simulating the entire network in the design

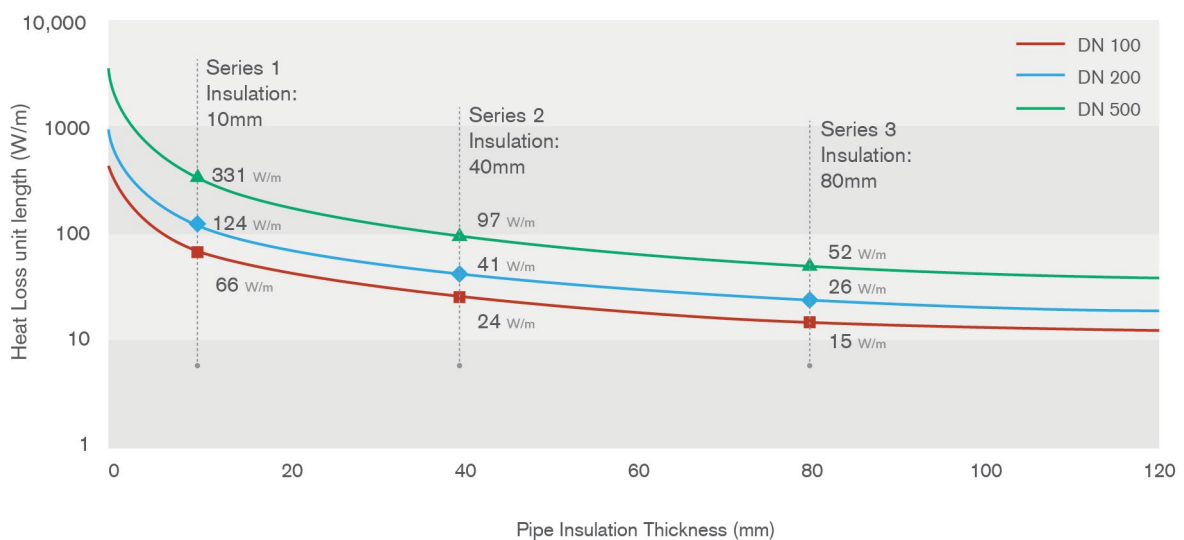


Figure 11: Indicative heat losses from insulated pipes and relative performance of series 1-3

process and establishing the balance between capital and operational expenditure for a design.

When developing heat networks, it is necessary also to consider the cost of heat supply in the network, which is used to establish monetary value of the heat loss from the pipes per metre; this is commonly different in different heat networks. From this information, a simple cost benefit analysis can be undertaken to compare the running costs associated with heat loss against the capital expenditure associated with higher specifications of pipe work insulation.

3.5.6 Primary side network system components

This section sets out the important system components that make up the balance of distribution plant for the primary side network. Figure 10, in section 3.5.1, indicates the typical arrangements of these components within the heat network system.

Distribution pumps

Distribution pumps are the most important plant item for distributing the heat through the heat network carried by the hot water from the heat source to the consumers. The pumps are commonly controlled for variable flow rate using variable speed drives (VSD) which adjust the frequency of electricity supply to the pump to enable the motor to slow down and speed up as the system demands. Without distribution pumps there can be no service, therefore these items are installed with back up capacity; there may be several pumps operating simultaneously while others are waiting and ready to operate if required. Various ancillary items including isolation valves, differential pressure gauges and strainers are installed around pumps to assist in monitoring, isolating for maintenance and protection of the impellers from particles that may be entrained in the flowing water.

System pressurisation / expansion

Pressure in the heat network must be maintained at all points to ensure that sufficient water is maintained within the system to distribute heat and to prevent water vaporising within the pipe at the lowest pressure point. For this reason pressurisation pumps are essential and commonly linked to an expansion tank which allows for the removal of excess water and pressure from the system when the temperature increases and the water expands. As the temperature of the system falls, the same water held in the expansion tank may be re-introduced into the system to re-stabilise the pressure. Capture and re-use of this water is important since it is likely to be treated water and may retain some useful thermal energy, as such it is more valuable than the alternative of making up the system with fresh cold water. In some cases, directly connected pressurised thermal stores may act as expansion vessels.

Water treatment

Establishing a good water quality standard is essential to maintaining the design life span of the heat network pipe work and ancillaries; poor water quality can damage the pipe work and equipment on the network through erosion, corrosion and the depositing of scale, significantly reducing the rate of heat transfer. The installer of the network should employ a water treatment specialist to establish a comprehensive water treatment regime to protect the pipe work and heat network components. The treatment regime including monitoring and maintenance should be continued throughout the life of the operation. The most important factors are correct pH value and the hardness of the heat network water.

A basic water treatment plant should be included to manage the network water quality including chemical dosing and strainers. Filtration and other treatment such as water softening are usually carried out to part of the water flow in a bypass. This greatly reduces pumping requirements and should be sufficient to control water quality.

Leakage and breakage monitoring

Monitoring for leaks and breakages along pre-insulated steel pipe networks is essential to guarantee a heat supply to customers and prevent unnecessary losses. Left unchecked, a leak in a heat network could lead to damage of other utilities, buildings, or the public realm. A leak detection system is therefore a key part of enabling the network to meet the key aims of energy efficiency and security of supply.

The leak detection system allows the operator to quickly establish the location of a pipe system leak. It is achieved through the connection of leak detection wires encased in the insulation layer surrounding pipes. The wires are connected across the entire system and back to a detection control box typically located in the operator energy centre. The wire circuit is monitored and maintains a constant electrical resistance while the conditions within the pipe casing remain constant. In the event a leakage occurs, the water penetration into the insulation layer enable the short circuiting of the detection wires changing the resistance monitored at the detection control box. The control system alarms to the operator and the new resistance level over the circuit informs the operator the approximate distance that the leak is from the energy centre.

It is common, once the leak is located and exposed, to find that the cause is external groundwater entering through damaged outer casing rather than fracture or other failure of the inner pipe work, regardless the cause, either

failure mode requires repair to maintain the life span of the network.



Figure 12: Heat network pre-insulated steel pipe indicating leak detection wires, courtesy of Logstor

Polymer pipes are increasingly being used on small scale schemes where systems may operate at lower temperature and pressures. As these pipes do not suffer from corrosion damage, leak detection systems on polymer pipes are not included as standard. Given that plastic pipe systems are typically used over shorter distances, the time required to identify the location of a pipe fracture is considerably reduced.

Valves

Isolation valves should be installed at regular intervals on the system and commonly at pipe work branches located in valve pits external to the consumer buildings to enable the supply to be controlled without having to enter the building.

Isolation valves improve the resilience of the network by enabling parts to be shut off and sometimes bypassed. This allows damaged sections to be investigated and repaired without

affecting the rest of the system, thereby minimising disruption to other consumers.

Isolation valves should be delivered as pre-insulated units and should be supplied and manufactured by the same supplier and manufacturer as the pre-insulated pipes. Insulation and outer casing material should fulfil the same quality requirements which apply to the pipe and all other components of the system.

3.5.7 Thermal storage

Thermal stores (or accumulators) are frequently used in heat networks. They are typically located at the heat source although they may be located elsewhere within the system design to meet specific requirements. A thermal store is essentially a store of a volume of hot water at a controlled temperature that can be held over a period of time and utilised at a later point when the demand is present. The amount of heat stored varies over time, and has a continuous heat loss to the environment. When correctly

designed and operated, the advantages of having a stored source of heat outweigh the heat lost during storage.

Thermal stores enable heat to be stored and then used at a later time when it is more commercially advantageous to do so. It is not economic to store heat for long periods; thermal stores are normally designed on the basis of charging and then discharging the stored heat either on a daily or multiple times per day basis. Heat storage utilisation will vary according to seasonal demand changes.

One of the major benefits of thermal stores is that they may be used to replicate the peak instantaneous demand capacity of the heat generating asset. Therefore the generating asset may be selected at a more economical size with a reduced capital cost. This has the added benefit of increasing the total annual running hours of the base load generating asset (such as a CHP engine, energy from waste facility or biomass boiler), thereby improving the economics of its operation. Thermal stores also

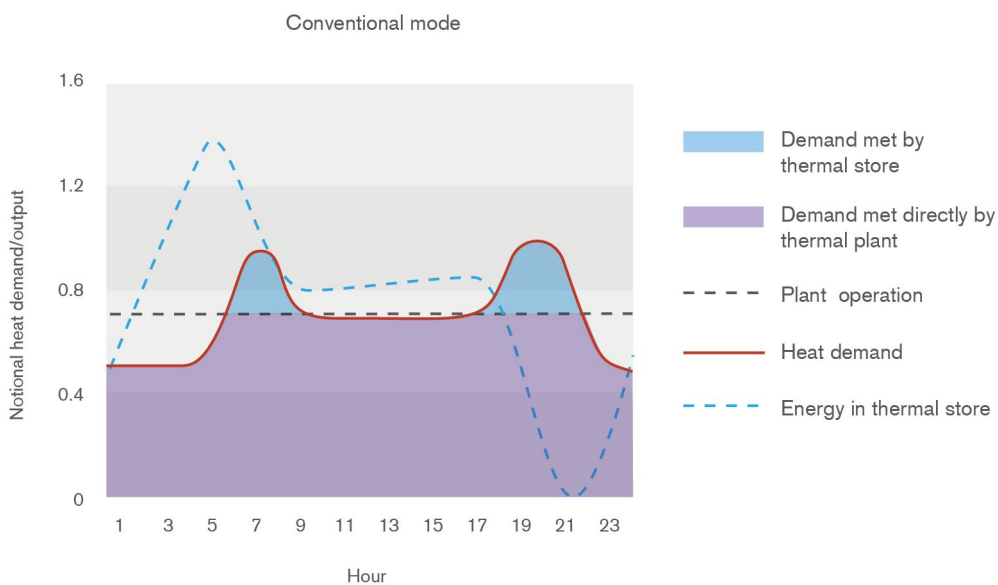


Figure 13: Typical mode of operation of conventional thermal stores

allow generating assets to operate more of the time at their maximum continuous rated output, and reducing part load operation. Generally, only the low carbon or low cost thermal generation assets should be used to charge the thermal store. Conventional heat raising plant such as gas boilers, which operate well at part load, should not be connected to a thermal store.

Figures 13 (on the previous page) and 14 indicate the function of thermal store in two different modes. The curves indicate plant operation, consumer heat demand and the energy level in the thermal store over time; it is simplest to think of this time period as one day.

In figure 13 the image represents a thermal store with partial storage capacity, able to charge an amount of cheap heat for discharge later at a more useful time. It operates in parallel with heat generating plant also operating during the period of heat demand. The benefits of such a system may be the ability to operate a CHP asset continuously throughout the day and night. The size of the thermal store is determined by

modelling to establish the desired degree of flexibility in heat source selection, limited by the practicalities of physical space for the thermal store itself.

In figure 14 the image represents a system with a large thermal store of sufficient size to decouple the time of heat generation to heat use. An example of such a system may be one involving a heat source that is available cheaply only at specified times of the night. In this instance the cheap heat is used to charge the thermal store, and then the thermal store used to supply the heat network throughout the day when the low cost heat is not available.

In designing a thermal store, dimensioning is very important. An effective store can hold any amount of hot water between the minimum and maximum capacities by taking advantage of thermal stratification in the store. For this reason, thermal stores are generally tall and thin in shape.

The two photographs at right and below are provided with thanks to Islington Council and

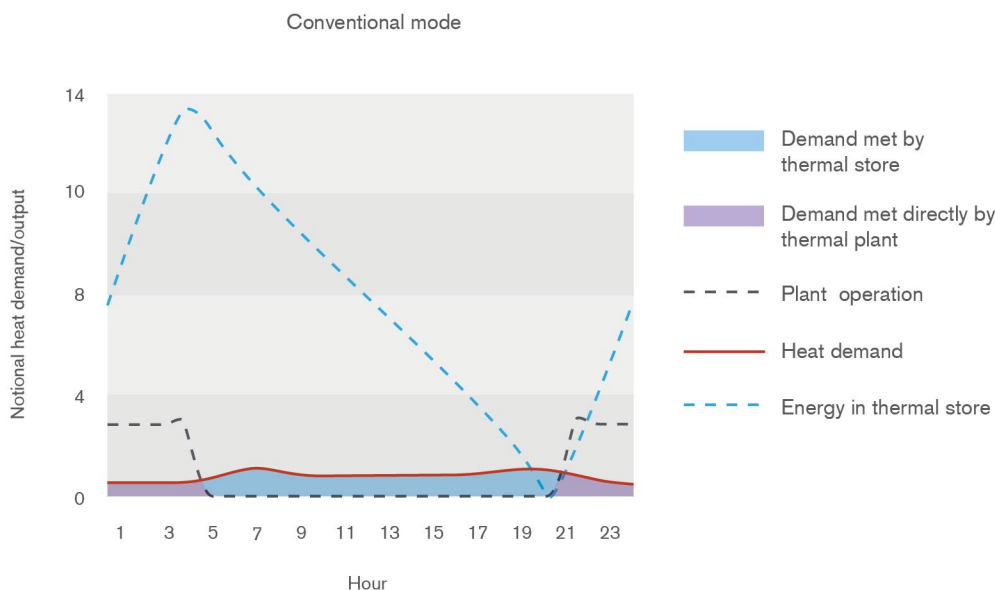


Figure 14: Mode of operation for large thermal store

show the thermal store installed at the Bunhill Energy Centre. It has a capacity over 100 m³, measuring approximately 15m tall and 3m in diameter. Figure 15 shows the vessel during installation before the insulation and finish was applied as visible in Figure 16.

Thermal stores can be connected to the heat network either directly or indirectly. For indirect connections, this store is hydraulically separated by a heat exchanger. Additionally, thermal stores can be installed to operate at atmospheric pressure, or be pressurised.

The system pressure within the heat network is a key consideration in the design and location of thermal stores. Directly connected thermal stores need to be installed at a point in the network where the local system pressure is lower than the thermal store pressure. In the case of a store



[right] Figure 15: Thermal storage vessel during early phase of installation

[below] Figure 16: Thermal storage completed installation at Bunhill Energy Centre



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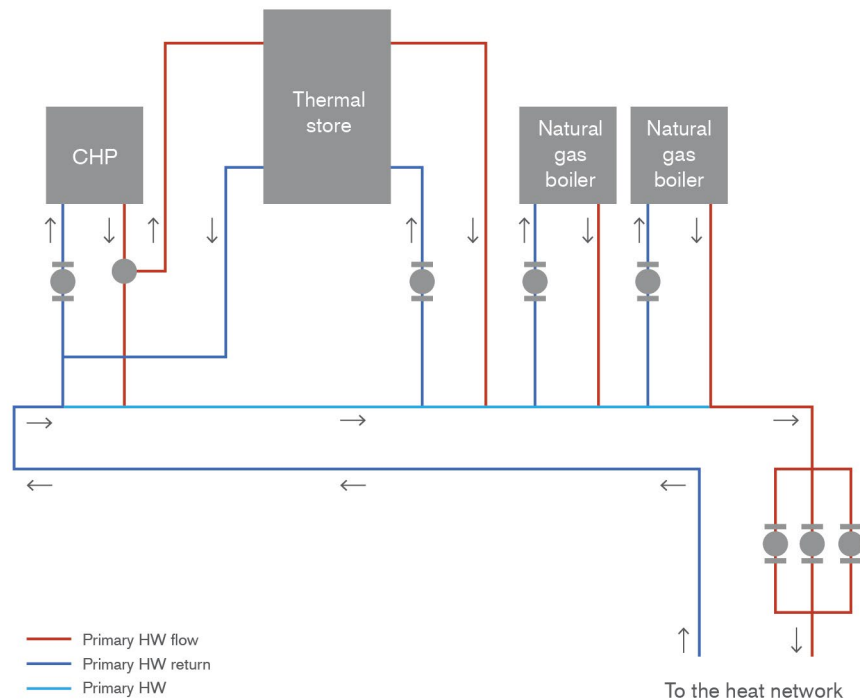


Figure 17: Indicative thermal store arrangement

operating at atmospheric pressure, this means that the hydrostatic pressure of the store must be higher than the network pressure at the point of connection. Similarly for a pressurised thermal store, the store pressure must be higher than the network pressure at the point of connection. If the stores are hydraulically separated via a heat exchanger, the store pressure does not require the same consideration.

Indirectly connected thermal stores have a lower operating efficiency due to reduction in thermal effectiveness for charging and discharging. Pressurised thermal stores are more expensive than stores operating at atmospheric pressure.

Given these design considerations, the advantages and disadvantages of a set of thermal

store configurations are set out in Table 4 on the opposite page.

Due to their typical size and dimensions, thermal stores are frequently installed outside the energy centre. This layout makes installation and later maintenance and replacement considerably easier than if the store were installed within an energy centre building. Alternative solutions such as sinking the vessels into underground or partially underground pits can reduce the visual impact and can offer additional benefits as the underground pit area may be structured to form a bund. However, in this case multiple routes for egress from the pit are essential as the contents of a thermal store can be dangerous in the case of rapid leakage.

Thermal Store Configuration	Advantages	Disadvantages
Atmospheric, direct connection	Least cost and most energy efficient configuration	Limited by the operating pressure at the point of connection
Pressurised, direct connection	More flexibility in connection point	More expensive than atmospheric pressure stores
Atmospheric, indirect connection	More flexibility in connection point	Indirect connection reduces thermal effectiveness for charging and discharging
Pressurised, indirect connection	More flexibility in connection point	More expensive than atmospheric pressure store, heat exchange reduces thermal effectiveness for charging and discharging

Table 4: Advantages and disadvantages of thermal store configurations

3.5.8 Stand by and back up plant

Heat network energy centres are normally designed and built with additional generation capacity which can be used to back up the heat supply in the event of planned or unplanned maintenance on the primary heat source equipment. The additional plant can also be used to supplement the main supply to the heat network during periods of peak demand. In some cases this back-up plant is installed remotely from the primary source; however the strategy for its operation remains the same. Back-up plant is installed in order that a supplier is able to maintain the service to consumers on the heat network at all times. Back-up and top-up is frequently provided by natural gas boilers since it is relatively simple, clean and does not require fuel storage; however, other solutions may be perfectly adequate for the same task.

An alternative arrangement for back-up and top-up plant is the locating of this plant within consumer buildings. The building will then utilise the network as its primary heat source and make up any shortfall at peak demand with its own plant. Schemes designed in this way may be able to reduce capital expenditure on the pipework infrastructure since the system would not need to be able to deliver the entire peak load

demand from the network, particularly as peak demand periods exist for quite short periods in the year. This may also apply well in schemes where existing buildings connecting to a heat network can retain and obtain value from existing plant which is not life expired.

3.5.9 Heat source carbon intensity

Heat carbon intensity is used here as a measure of the carbon footprint of an energy source, in particular for establishing the relative environmental benefit of selecting one particular source over another. The primary goal of decentralised energy market development and the Decentralised Energy for London programme is in establishing development of infrastructure for the supply of low cost low carbon heat at scale. Therefore the carbon intensity of a heat supply must a critical factor for the design of any new heat network in London.

Heat networks are able to take heat from a range of technologies, and generation plant can change over the lifetime of a network. Carbon calculations for heat networks in new developments should follow those required for developments to achieve regulatory compliance. In existing developments, the carbon calculations for schemes considering gas fired

CHP should follow CIBSE AM12:2013 or the calculations set out in the CHPQA.

Carbon calculations for heat networks using alternative technologies should be calculated based on the carbon intensity of the technology's primary energy consumption (i.e. grid electricity for heat pumps or biomass for a biomass boiler) for a given amount of heat delivered to the network. Heat networks which are made up of a number of technologies should be calculated based on their percentage contribution of the total heat delivered. All calculations should take into account the seasonal performance of the heating systems as well as the performance of the distribution networks.

Further guidance relating to specific technologies and the calculation of their seasonal efficiencies can be found in the Non-domestic Building Services Compliance Guide 2013¹³ and the HVCA TR/30 Guide to Good Practice on Heat Pumps.

As the grid decarbonises, it is anticipated that gas fired CHP, using the above calculations methodologies, will save a reducing amount of carbon. All heat networks should therefore be designed in such a way that alternative technologies can be connected. Some alternatives that should be considered are:

- Solar thermal;
- Heat pumps (ground, water or air sourced);
- Secondary (waste) heat;
- Energy from Waste (EfW);
- Waste heat from combustion power generation; and
- Biomass / biogas sources.

Some of these heat sources operate most efficiently at low temperatures; therefore designing networks in such a way that they can operate at low temperatures may be preferable.

On new developments this may require the use of low temperature heating systems such as under floor heating.

The maximum carbon intensity of a heat supply for heat network purposes should consider the regulatory requirements for notional calculations. For example it could be defined by the carbon dioxide equivalent emissions factor, on a gross CV basis, for direct emissions associated with natural gas used in heat only boilers with an efficiency of 85%. The maximum carbon intensity is therefore a function of the emissions factor (0.184 kgCO₂/kWh, source DEFRA¹⁴) and the energy conversion efficiency.

Using the DEFRA emissions factor and a boiler efficiency of 85%;

$$\frac{0.184 \text{ kgCO}_2/\text{kWh}}{85\%} = 0.216 \text{ kgCO}_2/\text{kWh}$$

This figure, 0.216kgCO₂/kWh, therefore represents the highest heat supply carbon intensity that should be considered for a heat network scheme in London. Note that alternative emissions factors are available, for instance, the 2013 Amendment to Part L of the Building Regulations for England states this to be 0.198 kgCO₂/kWh and alternate maximum carbon intensity may be determined.

The heat source carbon intensity of a heat network should be calculated inclusive of system losses (energy centre losses, connection losses and transmission losses). The system losses will vary among individual systems and buildings and can be factored in during the system design. Heat losses on the secondary side should not be included in the heat supply carbon intensity calculation, but will need to be reflected in the emissions calculation as part of a new

¹³ http://www.planningportal.gov.uk/uploads/br/non_domestic_building_services_compliance_guide.pdf

¹⁴ https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224437/pb13988-emission-factor-methodology-130719.pdf

development planning application energy assessment report.

3.6 Secondary side heat network design

This section, prepared with the assistance of Ramboll Energy and Danfoss A/S, explores the connection of the consumer to the heat network. It is divided into two sections. The first

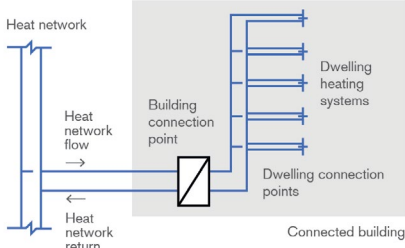
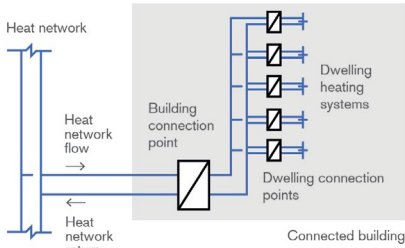
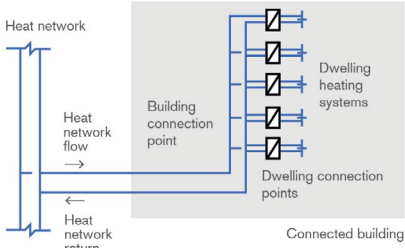
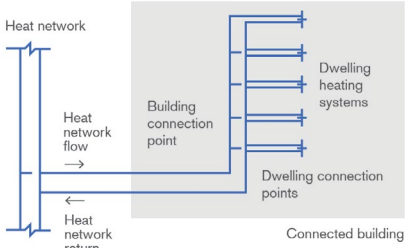
Connection Configuration	Advantages/Disadvantages
	<p>Primary to Secondary - INDIRECT Secondary to Consumer - DIRECT</p> <ul style="list-style-type: none"> + Building heating system is hydraulically separated from the primary heat network + Heat exchange substation is a convenient commercial separation between the building and the heat network for metering and billing + Heat network is protected from higher building heating system pressures - Individual consumers are not hydraulically separated in the building
	<p>Primary to Secondary - INDIRECT Secondary to Consumer - INDIRECT</p> <ul style="list-style-type: none"> + Building heating system is hydraulically separated from the primary heat network + Heat exchange substation is a convenient commercial separation between the building and the heat network for metering and billing + Heat network is protected from higher building heating system pressures - Heat exchange losses will occur at the building and consumer level
	<p>Primary to Secondary - DIRECT Secondary to Consumer - INDIRECT</p> <ul style="list-style-type: none"> + No heat exchange losses at the building level + Individual consumers are hydraulically separated from the primary heat network, allowing a convenient metering point for billing - Primary heat network water circulates in the building heating system, introducing new potential points of failure
	<p>Primary to Secondary - DIRECT Secondary to Consumer - DIRECT</p> <ul style="list-style-type: none"> + No heat exchange losses - Primary heat network water circulates in the consumer heating systems, introducing new potential points of failure - Consumer heating systems must be rated to the same temperature and pressure as the primary heat network, health & safety issue

Figure 18: Advantages and disadvantages of heat network connection configurations

section covers the connection of the heat network to the consumer building; for example a heat exchange substation in the basement of a block of flats. The second section covers the connection of the consumer's heating system to the building distribution system.

In each case, these connections can be either direct or indirect. Direct connection means that there is no hydraulic separation between the heating systems, and water from one heating system is utilised in the connected heating system. Indirect connection implies that there is hydraulic separation, with a heat exchanger separating the water in the two systems.

Figure 18 discusses the advantages and disadvantages of each option. Note that a heat network may include a number of these; in fact all types may exist on the same system depending on the requirements of different consumers. For a newly designed system connecting to new developments it is preferable to adopt a common solution as there will be economies of scale in installation and reduced spares inventory savings for operation.

The advantages and disadvantages presented in figure 18 are discussed in more detail over the following two sections.

3.6.1 Building connection

This section explores the potential options for the connection between the primary heat network and the secondary heat network within a consumer building. There are two key options available with respect to the connection between the networks: direct or indirect connection.

Indirect connection

Indirect connection is the most common method in modern heat network systems. This maintains the primary heat network hydraulically separated from the secondary consumer building system.

The arrangement of heat exchanger, valves, shunt pumps and controls is termed a heat exchange substation.

Heat exchange substations are units commonly installed in a basement plant room of a building accepting heat from the supply network and distributing the purchased heat via a communal network throughout the building. One important aspect of their design is that they are constructed with two or more heat exchangers, for example a heat substation might consist of two heat exchangers each sized at 60% of the building's peak load. In the event that one of the heat exchangers is isolated for maintenance, the provision of heat service to consumers on the consumer network may continue. It is not normally necessary to size the heat exchangers based on 100% redundancy, however a design risk assessment should be undertaken which considers the implication on the consumers for a loss or reduction of service. The risk for a hospital or care home may be considerably different to that of a commercial property or residential building.



Figure 19: Typical example of a heat substation, courtesy of Danfoss

Figure 19 shows a typical example of a packaged heat substation incorporating plate heat exchangers, pumps, valves and necessary

controls monitoring system installed on steel frame. With much of the installation work being completed by the manufacturer, site installation time and cost for mechanical and electrical connection can be minimised.

If the operator of the heat network is contracted to operate and maintain this equipment, the building would need to provide the means of access for the operator to fulfil this obligation. Access rights are normally agreed at the time of contracting the service and are commonplace.

Direct connection

Direct connection allows the primary system heat network water to circulate around the secondary or consumer building system. Typically in this scenario, individual consumer heating systems will still be hydraulically separated from the primary heat network system by individual heat interface units (HIU).

Given that the HIUs are interfacing directly with primary heat network water that may operate at elevated temperatures, it is recommended that prefabricated heat exchangers should be used inside the HIUs. The HIUs should be rated to deliver the peak heat demand expected of that particular consumer for both heating and domestic hot water.

In the following section, Process and Instrument (PI) diagrams are shown for the main consumer connection options, indicating the control principle and energy metering points.

3.6.2 Consumer connections

The connection to individual consumers may be achieved through the installation of a Heat Interface Unit (HIU). HIUs are of a similar size to a domestic gas boiler and are installed in individual dwellings providing heat to meet the demands of the consumer, with the added safety benefit of not requiring gas connections.

There are several types of HIU; some provide space heating only, while other provides both space heating and domestic hot water service.



Figure 20: Typical Heat Interface Unit (HIU)

Figure 20 shows a typical example of a heat interface unit as may be installed in a consumer dwelling. It incorporates many of the same components as the heat exchange substation but on a smaller scale. As is the case with heat exchange substations, the connection may be indirect or direct. Figure 21 (on the following page) shows how HIUs could be installed in a building, interfacing between the building heat distribution system and the heating systems of the individual consumers.

Heat interface units present the most suitable solution to supply, control and meter hot water for space heating and domestic needs to each individual consumer. HIU suppliers can supply a range of solutions to connect consumers to heat networks, with the main differences being whether connection is made with (indirect) or without (direct) a plate heat exchanger (PHE)

between the two heating circuits. The most common arrangements for residential units include, but are not limited to:

- Direct connection for space heating and indirect connection (PHE) for DHW;
- Indirect connection for space heating and DHW (two separate PHEs); or
- Indirect connection for space heating with DHW cylinder.

The appropriate HIU configuration is dependent on the space heating and DHW systems in the connecting buildings. This is particularly important where a heat network is being connected to existing consumer buildings requiring retrofit of their heating and DHW systems.



Figure 21: Image of heat interface units installed in an example consumer building (courtesy of Danfoss).

Direct connection for space heating with

instantaneous production of DHW

This solution is recommended only where a central heat network substation has been installed to hydraulically separate the primary heat network mains from the secondary heating system within the building via a plate heat exchanger.

In absence of such a substation, the heat network water would flow into the consumer's heating system up to each individual radiator, introducing water quality and leak risks to the primary system in the event of faults within a building. Most crucially, health & safety standards would not allow operating temperatures and nominal pressures to exceed 90°C and 10 bar respectively. Such a configuration is therefore unlikely to be the first choice for a building connection, and would need careful analysis before being adopted.

Indirect connection for space heating with instantaneous production of DHW

This solution, although more expensive than the direct connection arrangement, provides a high degree of separation between the consumer's heating system and the primary mains, hence significantly reducing risks associated with faults within the building as well as ensuring compatibility with heat networks operating at higher temperatures and pressures. This configuration is recommended particularly where a central heat network substation has not been installed.

Indirect connection for space heating with DHW cylinder

This solution requires the installation of a hot water storage cylinder within the residential unit. It is therefore likely to be more expensive than any of the instantaneous generation systems described above, as well as requiring extra space for the cylinder.

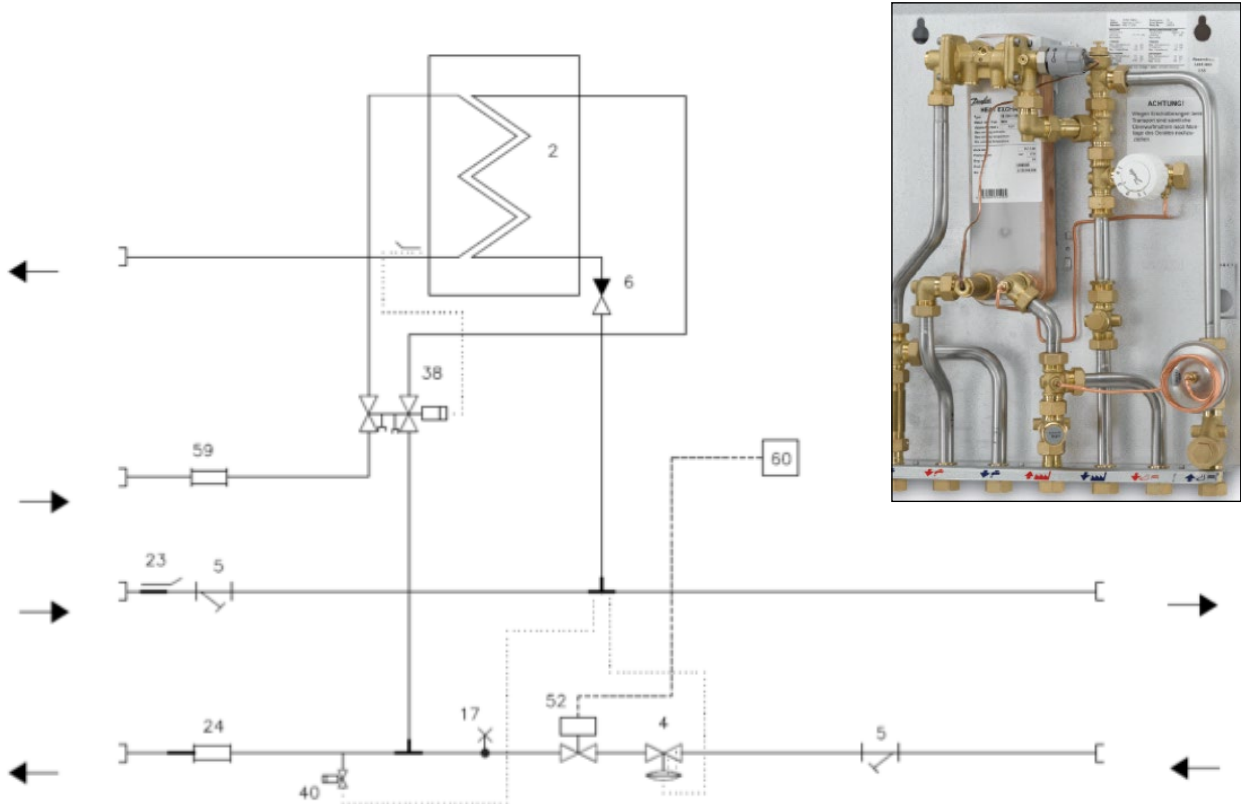


Figure 22: Domestic hot water is produced instantaneously via a plate heat exchanger

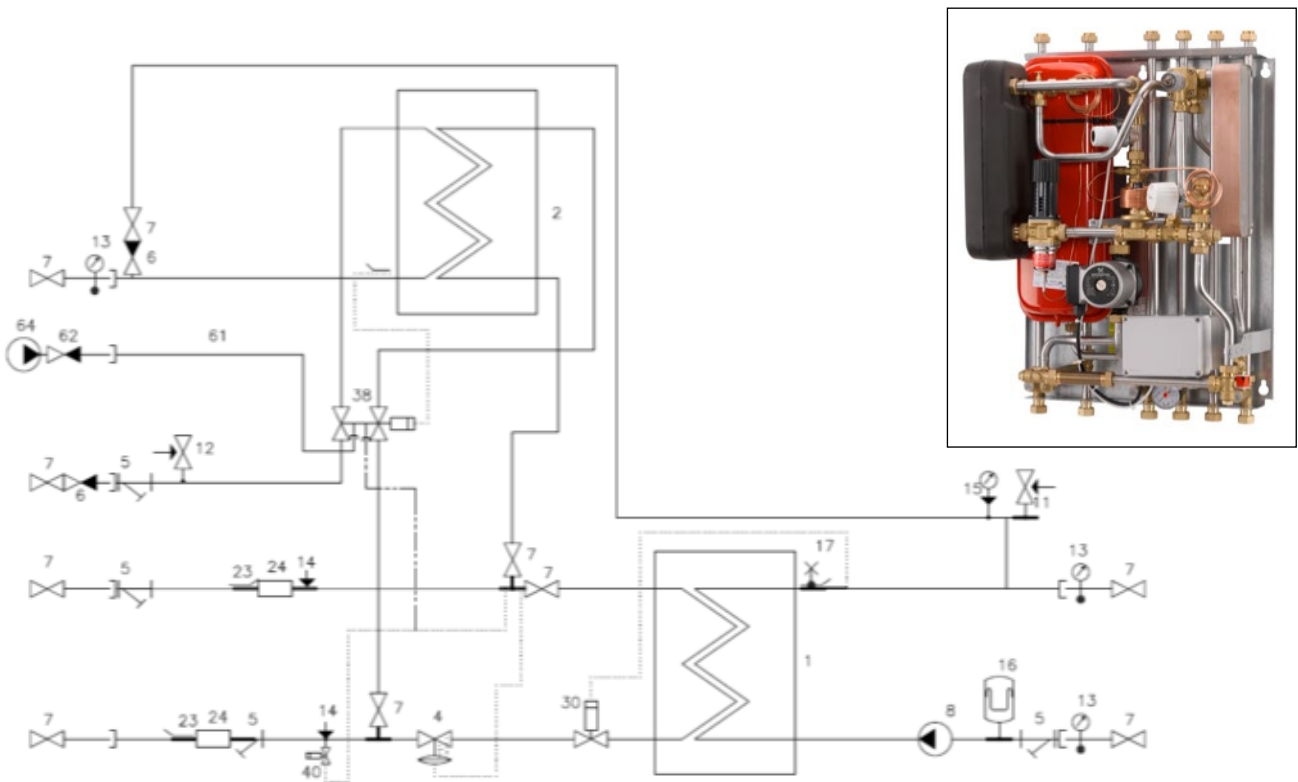


Figure 23: Both space heating and domestic hot water are produced instantaneously via a plate heat exchanger

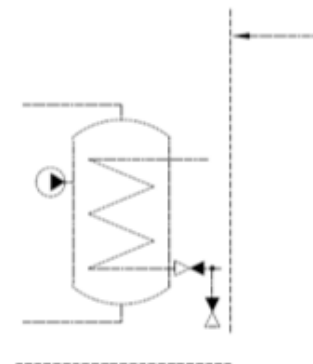
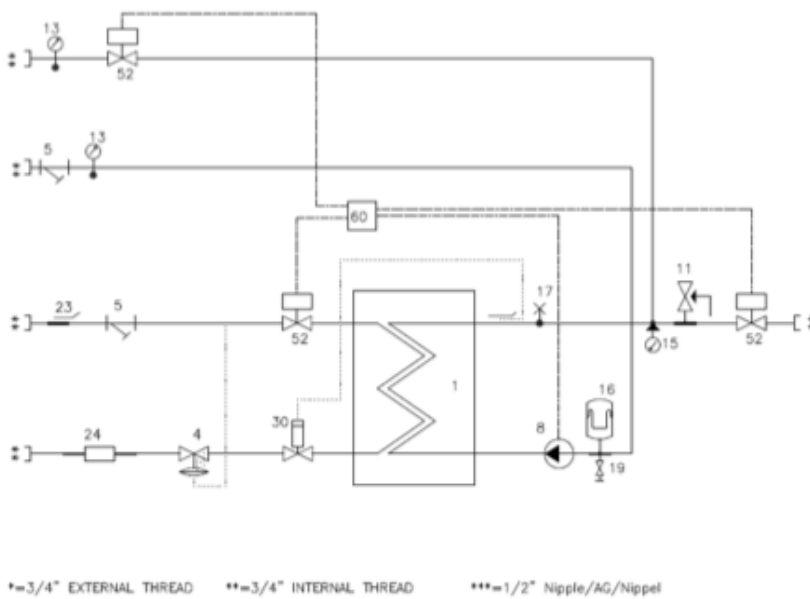


Figure 24: Indirect connection for space heating and hot water storage for domestic hot water.

Space heating is produced instantaneously via a plate heat exchanger whilst domestic hot water is brought up to the desired temperature through heat exchange in a cylinder.

This is not a typical arrangement and is normally not recommended as it results in higher supply temperature and a higher return temperature.

With this solution, particular care must be taken with the supply temperature to the hot water tank in order to avoid any risk of Legionella bacteria growth. For additional guidance on the management of Legionella see section 3.6.9.

Design Temperatures, °C	Primary side		Secondary side	
	Flow	Return	Flow	Return
Space heating • new development • renovation	110-80	55	70-80 80	40-50 60
DHW	70	max 25	55	10

Table 5: Conventional network design temperatures (assuming wet radiator systems and DHW)

3.6.3 Heat exchange design parameters

This section sets out the basic parameters to be used in the design and specification of heat exchangers.

The same basic design and dimensioning criteria can be applied to each interface type and are normally as per the following tables 5, 6 and 7.

Interfacing heat exchangers should also be designed to minimise the pressure loss through the unit to reduce pumping costs. In specifying an interfacing heat exchanger, its design maximum allowable pressure losses should be as indicated within table 6.

	Max pressure loss
Primary side	20 kPa
Secondary side	20 kPa
Domestic hot water (hot/cold)	20/30 kPa

Table 6: HIU pressure loss design parameters

It should be noted that these are allowed pressure losses for heat exchangers only. For the whole heat substation unit including piping, control valves etc. a 60 kPa pressure loss should be allowed for the primary side. This enables sufficient heat network flow when the main heat network circulation pump pressure difference control is set to maintain the min. 1 bar (100

kPa) pressure difference at a reference consumer as is normal practice.

Heat interface units are typically specified for new developments, with space allocated for their installation during the design and construction. For buildings which are designed or refurbished with a communal network, space for installation of the heat substation must be provided and table 7 provides indicative space requirements. It should be noted that the heat substation is normally provided and maintained by the heat network operator and access will be required by the operator to maintain the plant and correct any faults that occur.

3.6.4 Secondary side control

Through the application of variable volume controlled operation of heat networks the reduction in volume flow rate when heat demands are reduced has a substantial impact on reducing pumping energy costs. As a consequence, in part-load conditions when the building heat demand falls, a reduction in the mass flow rate ensures that the right amount of heat is transferred to the building without the return temperature increasing. This control philosophy is based on the adoption of variable speed pumps and it further ensures that generation assets such as CHP or low grade heat recovery systems can operate at their optimal efficiency.

Heating Capacity (space heating + ventilation) [kW]	Approximate building size [m ³]	Space required by the heating equipment [m ²]
30	1,000-1,500	2
200	10,000-15,000	4
400	20,000-30,000	5
800	40,000-60,000	6

Table 7: General indicative space requirements for heat exchange substation equipment for building plant rooms

The control of the interface between the primary and secondary sides of a district heating scheme is crucial to achieving efficient and effective operation. This section explores the control of the interface, based on a variable flow - variable temperature regime.

Two-port valves are a key component in variable flow heat networks. They provide selected return temperature by varying the flow rate, according to the demand of heat by the consumer. They are controlled by a temperature sensor installed on the return pipe and they should be used in conjunction with a differential pressure controller, to ensure that the differential pressure across the valve (dPv) is kept constant regardless of changes in flow rate. Their operation without differential pressure controllers may be compromised as detailed below.

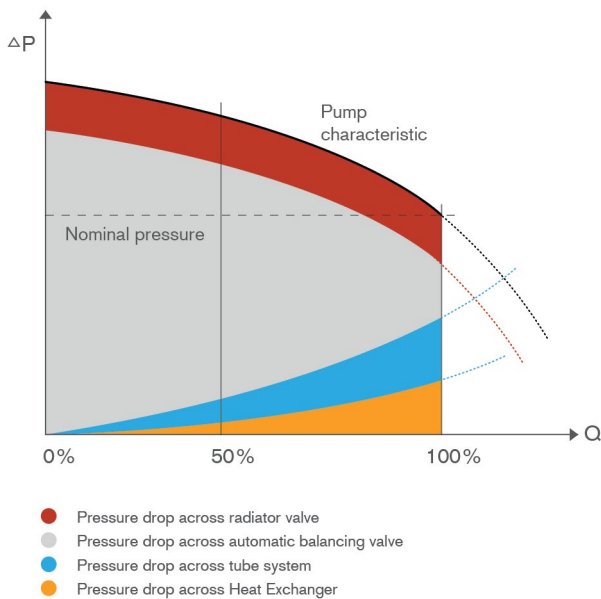


Figure 25: Pump characteristic graph

Figure 25 shows how the pressure differential across the two-port valve (red band) is maintained constant thanks to the installation of the automatic balancing valve (or differential

pressure controller, grey band), for the full range of operating flow rates (Q).

Two-port valves are classified by their share of resistance in the circuit where they are installed, also known as valve authority and expressed as a percentage. The valve authority (Va) is correlated to the pressure drop across the valve from the following formula:

$$Va = [dPv / (dPv + dPc)] \times 100$$

Where dPv is the pressure drop across the fully open valve (the minimum pressure drop) and dPc is the pressure drop across the controlled closed valve (the maximum pressure drop).

The higher the Va the higher the control performance of the valve, however the greater the pressure drop on the system. The recommended value for Va is 50% for two-port valves representing a balance between control and pressure drop.

By applying a differential pressure controller, as shown in Figure 26, the two-port control valve can be operated at increased control authority without suffering the increased pressure drop on the system, thereby reducing system operating costs.

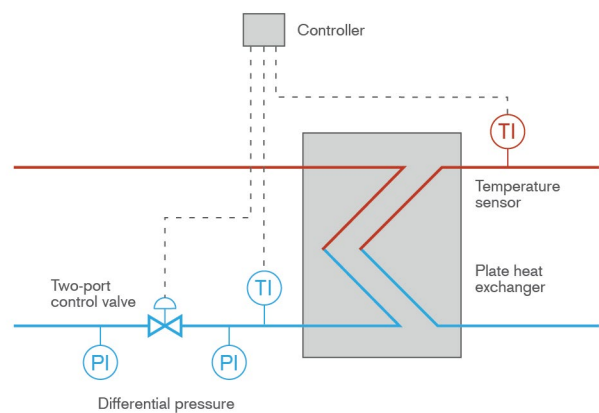


Figure 26: Arrangement of differential pressure controller for two-port valve control

3.6.5 Overheating in communal areas

The Mayor of London's Sustainable Design and Construction (SD&C) Supplementary Planning Guidance (SPG)¹⁵ highlights the London Plan policy requirement that 'Development proposals should demonstrate how the design of dwellings will avoid overheating during summer months without reliance on energy intensive mechanical cooling systems'. While this is primarily aimed at improving the comfort of building occupants there are several important considerations to take into account when designing, specifying, installing and operating any communal building heating and hot water systems, including but not limited to heat network systems.

The design and installation of communal building heating and hot water systems should be completed to an adequate standard, in order to minimise thermal loss within buildings. In many cases thermal loss from internal building pipework has been found to be significantly higher than for the heat network infrastructure installed in the streets. The loss of heat within communal areas of buildings is not only a problem for the economic operation of heat networks, driving operating costs higher to account for the additional fuel consumed, but also adds to the discomfort of building occupants, particularly on upper floors of buildings with internal risers.

When designing communal building heating and hot water systems, the issue of overheating can be reduced through a number of strategies, including:

- Increasing the thickness of insulation on pipe work;
- Ensuring that insulation is correctly installed to the specification and inspected;
- Increasing the differential between supply temperature and return temperature; this enables smaller diameter pipes to be installed reducing the rate of heat loss from pipes which is proportional to the surface area for heat transfer.

The implementation of these simple design requirements can make a significant difference to the comfort of building occupants and reduce the operating costs through reducing the heat losses on the network. For guidance on assessing the optimum economic level of thermal insulation for a system, see section 3.5.5 or review BS5422:2009 Annex G.

Where the requirements of the SPG cannot be met through minimising the heat loss from pipes, it may be necessary to apply natural or mechanical ventilation to dissipate the remaining heat; however this will increase the rate of heat transfer and therefore increase the operational cost. When assessing the economic level of insulation to specify in the communal building heating and hot water system design, this additional operational cost should be factored into the calculation as an avoided cost, thereby enabling investment in a higher grade of pipe insulation.

3.6.6 Provision for future connection

Development precedes a heat network

The economics of heat networks can mean that networks are planned for areas for a long period of time before they are installed. Where a new development commences in an area where there are plans for a future network which has yet to be installed, the new development may be required to construct or at least safeguard a route to allow its future connection. This process should ensure that the connection can be made with a minimum of disruption to building occupants.

¹⁵ <http://www.london.gov.uk/priorities/planning/consultations/draft-sustainable-design-and-construction>

Heat network precedes a development

In the event that a future connection is anticipated at a point in the heat network, with connection design fixed and a connection date known with some degree of certainty, it is normally sensible to pre-install the connection point and isolation valve. As a rule of thumb, if the new connection is more than one year into the future then the connection works should be deferred. However factors such as access to pipework may lead developers to undertake the connection earlier than this rule of thumb. The connection of the development to the heat network can be made before or after the network is operational. Connections can be made during planned maintenance works, or 'hot tapped' if the network is to continue operating during the connection.

3.6.7 Heat metering

Accurate metering is normally required at any point where heat is bought and sold. Furthermore, it is anticipated that there may be a requirement to install heat meters in existing unmetered heat networks by the end of 2016¹⁶. DECC has estimated that there are 150,000 unmetered heat network and communal heating apartments across the UK. Residents in these apartments are unable to control their heating or measure their consumption. They are unable to see how much they are using and they have no incentive to reduce their use as they pay a flat rate regardless of consumption. The Energy Efficiency Directive requires Member States to ensure that customers of heat networks are provided with individual meters where these are cost effective and technically feasible.

The metering location must be chosen to take into account heat losses, and the metering location will dictate who is financially responsible for heat losses in that part of the network. As a result heat metering is usually placed at the

consumer connection, meaning that the entity responsible for the operation of the network is financially incentivised to ensure that the network is efficiently managed and maintained.

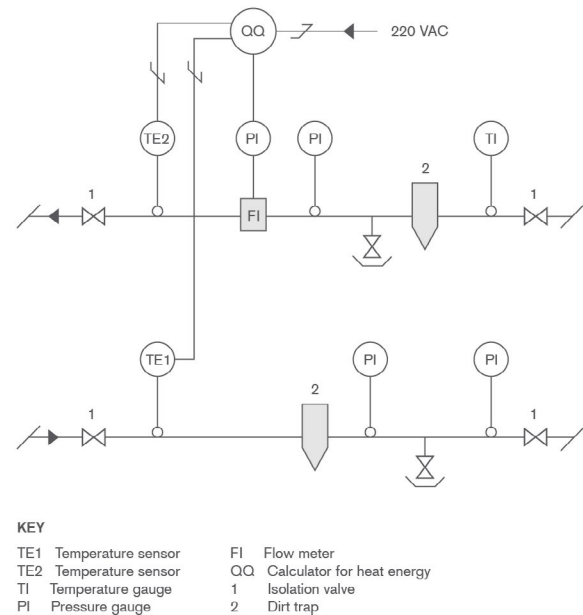


Figure 27: The general arrangement of heat metering

The components of the heat meter, as shown in figure 27 are: a flow meter, temperature sensors, and a heat calculator. The flow meter measures the volume of circulating heat network water. The temperature sensor pair constantly measures the temperatures of the water flowing into and returning from the metered space. Based on the readings of the flow meter and the temperature sensor pair, the heat calculator determines the thermal energy used by the building. The calculator automatically takes into account the water density and specific heat corresponding to the temperature.

As with electricity and gas networks, heat meters will normally be owned, installed and maintained by the heat supplier. Meter readings may be recorded by the heat purchaser and corresponding data collected manually and sent to the supplier or an automated electronic billing

¹⁶ <https://www.gov.uk/government/consultations/implementing-the-energy-efficiency-directive-metering-and-billing-of-heating-and-cooling>

system installed, depending on the heat connection arrangement and heat volume.

Automatic meter reading

The new generation of meters incorporate automatic meter reading (AMR) systems. AMRs collect data from remote metering devices and transfer the data to a central database for billing and analysis. Meters may communicate wirelessly, via a cellular mobile radio network or over optical fibre. This reduces operational costs by obviating manual meter readings and provides detailed information on consumption patterns.

Smart meters

Smart meters are the most advanced type of meters. The technology is still emerging and no industry standard has yet been established. Smart meters will provide more functions than AMR systems such as real-time or near real-time reporting, heat outage notification, and heat quality monitoring.

Although there are no standard heat meters, recommended solutions should include the following:

- Remote meter reading;
- Remote change over from credit to prepay modes and vice versa;
- In-home display conforming to Code for Sustainable Homes requirements;
- Remote diagnostics;
- Engineering transactions to be performed remotely such as change in tariff; and
- Secure electronic communication and transactions.

Given the significant potential for improved system efficiency and viability from better meter systems, heat networks should incorporate meters with AMR as a minimum. Smart meters should be

considered carefully to ensure early adoption once they are technically proven and their benefits quantified.

In selecting a meter supplier, it is important to ensure that the data is presented by the metering system in a format usable by more than one metering and billing services provider, to avoid being tied in to a particular service provider.

The security of the system is an important consideration when selecting the communications system between the meter and the central database for billing and analysis.

3.6.8 Consumer demand and behaviour

There is strong evidence to show that consumers can achieve significant energy and cost savings through the installation of heat meters and controls into existing unmetered heat network connections. As residents are provided with the ability to monitor and control their own consumption and link it directly to the amount they pay, behaviour changes and consumption reduces. However, installing individual heat meters has a significant cost and the meters have a limited life. The expected reduction in heat consumption would normally have to exceed about 15% for the retrofitting of individual heat meters to be cost effective.

3.6.9 Legionella

Legionella bacteria (*Legionella pneumophila*) can develop in wet heating systems and cause Legionnaires' disease, a pneumonia-like illness which is potentially fatal. It is therefore important to control legionella bacteria in heat networks and within communal building heating and hot water systems.

A significant amount of guidance on the control of legionella bacteria exists in the United Kingdom, including CIBSE Technical Memoranda

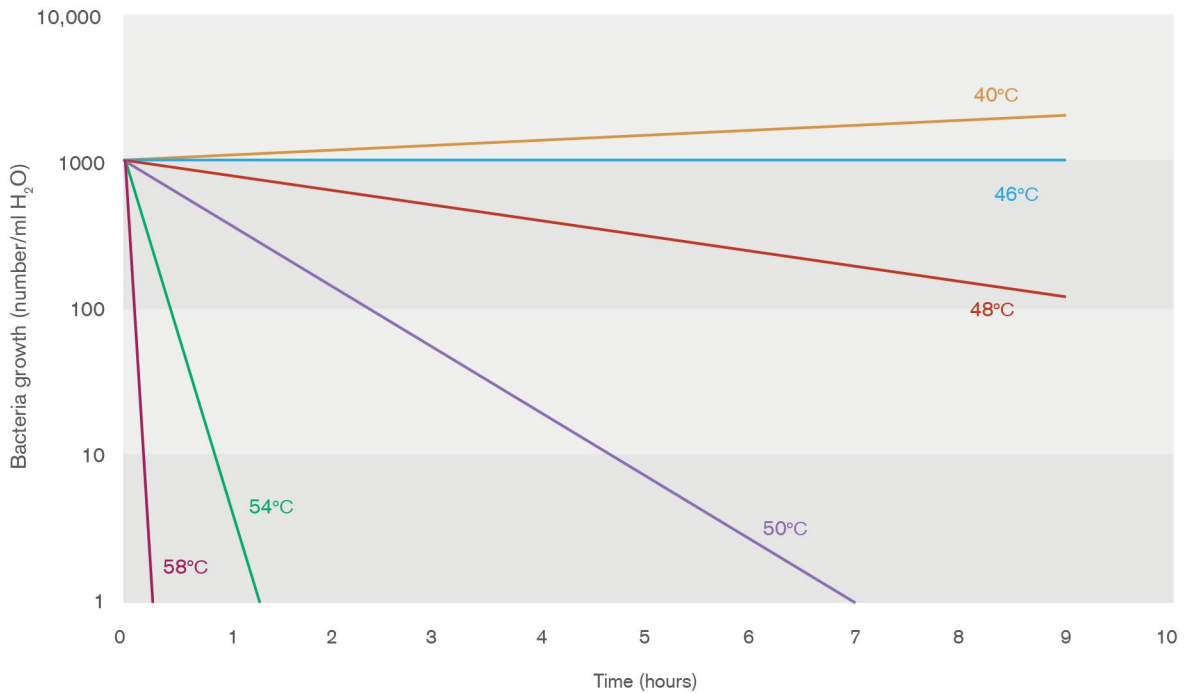


Figure 28: Legionella bacterial growth rate relationship with water temperature and time

TM13 (2013) and the Health and Safety Executive Approved Code of Practice and Guidance (ACoP) L8. Readers are referred to these documents for detailed guidance.

While the UK maintains a strong track record in relation to the control of legionella bacteria, there is no room for complacency. The risk of legionella bacteria developing in a heat network may be reduced by:

- Avoiding dead legs in the network design; that is, sections of the pipe network where water does not flow continuously. This may include runs of pipe that are shut off at an isolation valve. To avoid this, isolation valves are positioned as close to connection points as feasible; when a connection is isolated the amount of stationary water is minimised. Stationary pockets of water begin to cool slowly over time and enter the temperature band most optimal for the growth of legionella bacteria, from 20°C to 45°C.
- Operating the network above 55°C; this provides a safety margin for operation to allow for the occasional excursions from the design set point. Across Europe the preferred temperature for operation of heat networks differs slightly; the UK has historically taken a safe view. As London heat networks develop, and with the requirement for those networks to be both safe and efficient, the preferred minimum temperature for continuous operation is now recommended at 55°C, in line with Danish, Swedish and French heat networks.
- Some networks operate below 55°C; in the case of low temperature networks, these require regular pasteurisation of heat network water by raising the temperature to a minimum of 60°C for a period of time to ensure that any growth in the population of legionella bacteria within the system is halted and reversed. Figure 28 shows the impact of time and temperature on

the growth rate of legionella bacteria, at a pasteurisation temperature of 60°C or greater the population of legionella bacteria that may be present in a system can be reduced significantly within less than an hour.

3.7 Interconnecting heat networks

The strategy for transition from small community heat networks to large scale heat networks of the type envisaged by The Mayor of London's Climate Change Mitigation and Energy Strategy involves both the development of new large scale heat networks and the interconnection of existing heat networks across the capital. Heat networks may be further connected for a number of reasons, including:

- Their aggregate thermal demand allows for better operation and utilisation of low carbon or low cost heat supplies; or
- Their joining improves the heat supply resilience on one or both of the networks.

Heat networks may either be connected directly and share heat network supply water, or be hydraulically separated with a heat exchanger. Where networks are connected, the operating parameters and pipe work materials require consideration in designing the connection.

To facilitate the connection of existing or smaller networks there may be circumstances where plastic pipes have been used or may be specified on the basis of reducing installation cost. Plastic pipe materials are cheaper and easier to install than steel pipe work however their heat carrying performance is limited by their lower pressure and temperature ratings. Plastic pipe work can be sensibly used in small area networks, especially with direct consumer connections. Since plastic pipes are less commonly used for transporting bulk heat over long distances, the available pipe sizes are also typically smaller.

Plastic pipes can be physically connected to steel pipes, provided that the correct transition pieces are specified and installed. However, the consumer connections and pipes must be capable of the higher network pressures and temperatures.

Alternatively, the plastic pipe work can be hydraulically separated using a heat substation as illustrated in figure 19 in Section 3.6.1.

Development of district energy scale heat networks involves the connection of medium scale and kick-start networks. Hydraulic separation may negate some operational benefits since one of the key goals for the efficiency of large district energy scale heat networks is to receive water returned as low temperature as possible. It is recommended where possible that type 2 medium scale networks (see Table 1 in section 1.2) are design rated at 16 bar and 110°C. This will ensure that they retain the potential to connect directly (without hydraulic separation) to a larger district energy scale heat networks during the lifetime of the former and realise the full economic and operational benefits.

Design parameters for small community networks such as those associated with estates and a small number of connected buildings are likely to be hydraulically separated from the district energy heat network (existing or future). This allows for these systems to be designed on maximum efficiency and lower temperatures as pipe distances are lower and the pipe costs for larger pipes are less prohibitive.

DISTRICT HEATING STANDARDS

4

The preceding chapter set out the general principles of network design, including network configuration and selection of operational parameters. In this chapter, specific standards are provided for networks developed in London. The more consistently these standards are adhered to, the greater will be the chance of future interconnection of networks. Therefore the GLA will wherever appropriate seek to ensure these standards are applied by network designers and developers in London. These design standards have been drawn from International, European and British standards; as such they are referenced accordingly.

4.1 General design standards

Typically the heat network should be designed according to following main standards including standards for bonded pre-insulated steel service pipe systems and for plastic service pipe systems.

Standard number	Standard name
EN 253:2009	District heating pipes. Pre-insulated bonded pipe systems for directly buried hot water networks. Pipe assembly of steel service pipe, polyurethane thermal insulation and outer casing of polyethylene
EN 448:2009	District heating pipes. Pre-insulated bonded pipe systems for directly buried hot water networks. Fitting assemblies of steel service pipes, polyurethane thermal insulation and outer casing of polyethylene
EN 488:2011	District heating pipes. Pre-insulated bonded pipe systems for directly buried hot water networks. Steel valve assembly for steel service pipes, polyurethane thermal insulation and outer casing of polyethylene

Standard number	Standard name
EN 489:2009	District heating pipes. Pre-insulated bonded pipe systems for directly buried hot water networks. Joint assembly for steel service pipes, polyurethane thermal insulation and outer casing of polyethylene
EN 13941:2009	Design and installation of pre-insulated bonded pipe systems for heat networks
EN 14419:2009	District heating pipes. Pre-insulated bonded pipe systems for directly buried hot water networks. Surveillance systems
EN 15632:2009	District heating pipes - Pre-insulated flexible pipe systems
EN 15698:2009	District heating pipes – Pre-insulated bonded twin pipe systems for directly buried hot water networks
DIN 16892	Crosslinked polyethylene (PE-X) pipes - General quality requirements and testing
DIN 16893	Crosslinked polyethylene (PE-X) pipes - Dimensions
EN ISO 15875:2003	Plastics piping systems for hot and cold water installations. Crosslinked polyethylene (PE-X)
DIN 4726	Warm water surface heating systems and radiator connecting systems - Plastics piping systems and multilayer piping systems

All the specified material requirements should be understood as minimum requirements. Equipment suppliers should provide heat network pipe systems that meet the requirements of this specification.

4.2 Heat metering services

Applicable standards for heat metering on district heating networks are presented below.

Heat meters:

- EN 1434-1:2007 Part 1: General requirements
- EN 1434-2:2007 Part 2: Constructional requirements
- EN 1434-3:2008 Part 3: Data exchange and interfaces
- EN 1434-4:2007 Part 4: Pattern approval tests
- EN 1434-5:2007 Part 5: Initial verification tests
- EN 1434-6:2007 Part 6: Installation, commissioning, operational monitoring and maintenance

Communication systems for meters and remote reading of meters:

- EN 13757-1:2002 Data exchange [NB. Standard is due for review in the near future]
- EN 13757-2:2004 Physical and link layer
- EN 13757-3:2013 Dedicated application layer
- EN 13757-4:2013 Wireless meter readout (Radio meter reading for operation SRD bands)

- EN 13757-5:2008 Wireless relaying [NB. Standard is due for review in the imminent future]
- EN 13757-6:2008 Local Bus

4.3 Summary of Recommended Network Design Requirements

This section summarises the network parameters outlined in this manual for heat networks, which may form part of a small or large network of pre-insulated bonded heat network with steel service pipe. These parameters are presented in Table 9.

For plastic pipe systems the maximum operation temperature is usually limited to 95°C and pressure to 4-6 bar (depending on pipe diameter, thickness and operating temperature) as the design life is shorter at higher temperatures. In regimes where the operating conditions fall within these criteria, plastic products could be considered as an alternative to steel pipe in area wide networks.

Network parameter		London Heat Network Manual design standard	External reference
	1 Design life	Minimum of 30 years ($T_{\text{operation}} = 120^{\circ}\text{C}$) Aspiration of 50 years ($T_{\text{operation}} = 115^{\circ}\text{C}$)	IEA: District Heating and Cooling Connection Handbook, 2002 EN 253:2009 4.5.5.1
Pressures and temperatures	2 Pressures	16 bar g (maximum design gauge pressure)	HVAC TR/20, 2003
	3 Temperatures	140°C (maximum design temperature) 120°C (maximum operating temperature) 110°C (recommended operating temperature)	HVAC TR/20, 2003
	4 Temperature flow and return	110°C / 55°C but with minimum temperature difference of 50°C	
	5 External design temperature	-5°C (design air temperature) Design ground temperature variable with ground and depth.	CIBSE Guide plus -1°C margin. CIBSE AM11 and TM48 simulation of future weather patterns

Network parameter		London Heat Network Manual design standard	External reference	
Pipework	6	Pipe work material	Steel (for primary network mains, secondary network mains, branches and consumer connections) Steel quality P235TR1 for all pipe work, or alternatively P235GH for pipe work DN300 mm and above	EN 10217-1:2002 EN 253:2009
	Heat flow	7	Pressure loss guideline to be used in design (main and branch)	100 Pa/m for main lines 250 Pa/m for branches
8		Volume supply control	Variable based on pressure difference control	
9		Carbon intensity of heat supply	Maximum 0.216 kgCO ₂ e/kWh (on a Gross CV basis for Scope 1 emissions)	DECC/Defra 2013 GHG Conversion Factors for Company Reporting (www.gov.uk/measuring-and-reporting-environmental-impacts-guidance-for-businesses)
Heat transfer	10	Supply temperature	Supply temperature shall be variable following the supply temperature curve linked to outdoor temperature.	
	11	Heat metering	Recommended AMR system	BS EN 1434-1:2007
	12	Heat interface units	Space heating (new development) Primary side flow 110°C to 80°C; return 55°C. Secondary side flow 70°C to 80°C; return 40° to 50°C. Space heating (renovation) Primary side flow 110°C to 80°C; return 55°C. Secondary side flow 80°C; return 60°C. DHW Primary side flow 70°C; return max 25°C. Secondary side flow 55°C; return 10°C	
Monitoring and maintenance	13	Leakage detection and monitoring	Pipe network shall be provided with leak detection system, which can be connected to the remote monitoring system.	BS EN 14419:2009
	14	Water quality	pH 9-10 Alkalinity < 60 HCO ₃ /l (mg/l) Oxygen level < 20 µg/kg Total Fe < 0.1 mg/kg Total Chloride < 50 Cl mg/l Total hardness < 0.1 dH	BS 2486:1997
Thermal storage	15	Thermal storage	Designed to optimise utilisation of low carbon heat supplies within the constraints of heat demands, heat supplies and site requirements.	

Table 9: District heating network parameters

DISTRICT HEATING CONSTRUCTION

5

This chapter covers the physical works for the construction of a heat network. The reference network types are a large scale transmission network and a smaller scale distribution network comprising insulated steel pipe sections. The standards are directed towards the typical scenario of a buried pipe network located within the public highway.

This chapter covers:

- Installation supervision;
- Construction principles; and
- Construction standards.

Relevant variations for other typically encountered installation scenarios (e.g. soft dig, private land) are considered briefly at the end of this chapter.

This chapter also addresses appropriate space requirements for safeguarding corridors for future heat network routes.

5.1 Installation supervision

Heat networks may be well designed and quality materials specified, however, through experience it is known that the most important factor affecting the long term economic sustainability of a network is correct installation. Installations must be completed by experienced and qualified contractors under experienced and strict supervision. It is good practice during the construction and installation for inspections to be required for acceptance before the contractor is permitted to move to the next step. Example inspection points include:

- setting out
- trench construction
- sand bedding
- pipe laying
- welding/pressure and other tests (x-ray, visual, ultrasonic, etc.) on the steel pipes;
- alarm wire connection and testing;
- insulation casing joint installation and testing;
- initial back filling
- final back filling
- surface (top soil/tarmac); and
- final acceptance.

The reasons for a strict adherence to inspections are that if works are covered up before inspection and allowed to progress beyond inspection points to the stage where service is soon to be delivered then any required remedial works become very costly to implement and may involve considerable disruption and inconvenience to the system and delay to the operation of the service.

The Contractor must maintain full, detailed and accurate records of all the welding operations and the insulation casing jointing works so that all individuals' works can be monitored and measured for quality reasons.

5.2 Construction principles

The safety of construction operatives and the public must be the highest priority consideration for the installation of heat network apparatus.

The contractor responsible for installation must comply with and be cognisant of:

- current legislation, including NRSWA 1991 and attendant codes of practice;
- on site directions by authorised persons such as highway authorities, police and other statutory authorities;
- current industry standards and specifications, including National Joint Utility Group (NJUG) standards and recommendations;
- manufacturer's design, installation and commissioning requirements and recommendations;
- relevant health and safety regulations. Contractors must provide risk assessments and method statements in accordance with the requirements of the Construction (Design and Management) Regulations 2007, or subsequent replacement;
- environmental regulations, particularly in relation to the control of waste and the avoidance of local nuisance impacts including noise, dust, odour and air pollution;
- specific requirements of the highway authorities where the route runs in traffic-sensitive or congested streets;
- specific requirements of landowners where the route runs outside the public highway;
- specific requirements of statutory undertakers whose apparatus is affected by the works;
- specific requirements of transport organisations who may be affected by the works;
- specific requirements of those buildings along the route whose occupiers or users have special requirements with respect to access, noise, dust, etc.;
- any licence or other consent granted under the New Roads and Street Works Act 1991,

the Traffic Management Act 2004 and other relevant Highway legislation; and

- Building Regulations requirements and any conditions attached to planning conditions, where relevant.

Construction industry good practice principles for the set up and operation of worksites should be observed to ensure the safety of and to avoid inconvenience to businesses, residents and other members of the public affected by the works.

5.3 Construction standards

This section sets out some of the key construction standards to be applied in the construction of district heating networks. Included are typical trenching details, standards for testing and commissioning of pipe and insulation, and valves and valve chambers.

5.3.1 Typical trenching details

Figure 29 shows a typical construction detail for a heat network mains pipe trench in the public highway, using a pair of pipes for flow and return. The minimum distance from the top of the pipes to ground level is 600mm. The pipes should not be located within the road structure as defined under NRSWA. The dimensions of the excavation depth (d) and width (w) and the separation distance between pipes (a) and from the excavation edge (b) depend on the size of pipe and the highway construction. Table 10 provides the suggested relevant trench dimensions for typical pipe diameters.

An alternative arrangement is shown in Figure 30, with both the flow and return heat network pipes enclosed in the same insulation. Such arrangements can allow a narrower trench (though it may be slightly deeper), though are normally only feasible on smaller pipe sizes.

When the trench is located within the public highway the depth, surround, backfill and reinstatement of the trench must comply with the NRSWA Specification for the reinstatement of openings in roads. When backfilling, the initial surround of up to a minimum 100 mm above the heat network pipes should always be completed with specified, imported and screened sand.

The excavated trenches should be surveyed to determine high and low spots of the installed bonded pipe network. This information should be used to inform where the optimum positions for air release valves and drainage valves are to be located.

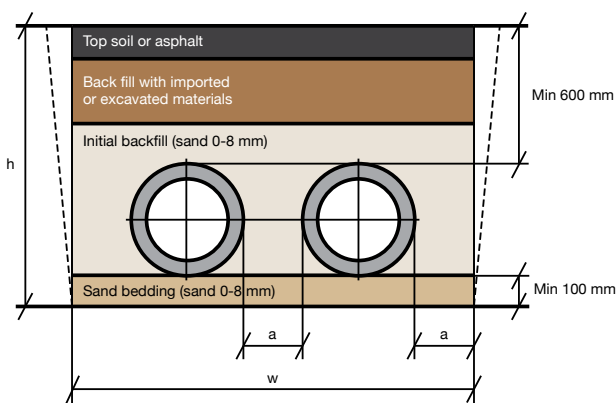


Figure 29: Typical installation arrangement for separate flow and return pipes

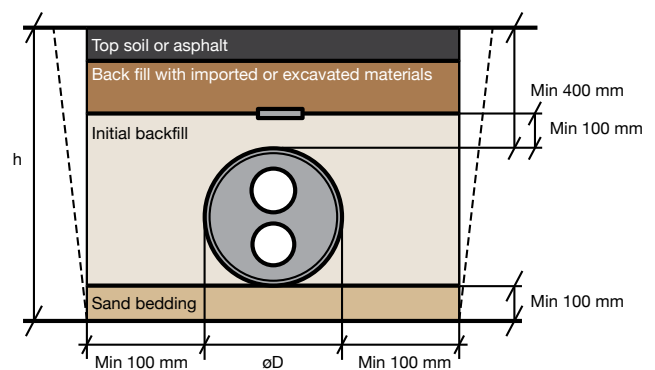


Figure 30: Typical twin-pipe installation arrangement

DN (carrier/ casing)	a (mm)	b (mm)	w (mm)	h (mm)
DN80/160	150	150	770	860
DN80/160	150	150	770	860
DN100/200	150	150	850	900
DN125/225	150	150	900	925
DN150/250	150	150	950	950
DN250/400	200	200	1400	1100
DN300/450	200	200	1500	1150
DN400/560	200	200	1720	1260
DN500/630	200	250	1910	1330
DN600/800	250	300	2400	1500
DN700/900	250	300	2600	1600

Table 9: Pipe Trench minimum dimensions (for standard side-by-side pipe installations)

It should be noted that additional space at welding points, corners, valve locations and spurs will be required.

Where a heat network is installed in proximity to other existing utility and service apparatus, the installation of the heat pipes should endeavour to comply with the principles of separation from other apparatus. Separation will depend upon the congestion of the area and consultation with owners of the existing apparatus is recommended.

Where a heat network is installed in new developments where no other apparatus exists, the installation should endeavour to comply with the principles within the National Joint Utilities Group Guidelines on the Positioning of Underground Utilities Apparatus for New Development Sites.

It is not always possible or feasible to install heat network pipe work underground. Installation can take advantage of existing tunnels or ducts, or be installed to run along outside of buildings. Crossing barriers such as railways and highways may necessitate above-ground installation. Such installations can introduce additional legal and technical details with regard to structural reinforcement, requirements for work permitting and access for operation and maintenance.

5.3.2 Testing and commissioning of pipe welding

Pipe work should be tested as detailed in EN 13941. Typical requirements which should be included in the works specification are:

- All steel pipe welding is to be undertaken by certified coded welders. Certification must be in compliance with current British and European Standards. Welders may be subjected to a welding test with at least the same acceptance criteria as the criteria for the finished work, with reference to EN 25817;
- A testing regime must be established for welded joints e.g. non-destructive testing of 10% of welds as detailed in EN 13941. Visual inspection of welds is required;
- All pipe work installations should be hydrostatically pressure tested, witnessed, and signed off by a competent engineer. All equipment used for testing should be fully calibrated and the test procedures and monitoring proposals must be agreed before the tests commence;
- Following completion of a satisfactory pressure test the site closures must be made in strict accordance with the pipe work manufacturer's specification;
- The leak detection system must be tested and certified; and
- Systems must be flushed and treated prior to being put to service.

5.3.3 Testing and Commissioning of Insulation case joint welding

Typical requirements to be included in the works specification are:

- Joint assemblies for the steel pipe systems, polyurethane thermal insulation and outer casing of polyethylene shall comply with BS EN 489. The joint assemblies shall be installed by specially trained personnel according to the instructions given by the manufacturer. Fusion welded insulation joints shall be implemented to join the pre-insulated steel pipe systems;
- All joint assemblies must be manufactured by same manufacturer as the steel pipe systems and/or approved by the steel pipes systems' manufacturer for use with their pipes;
- The joint should be pressure tested to confirm it is air tight;
- Polyethylene welders shall possess evidence of valid qualifications, which document their ability to perform reproductive welding of the quality specified.

5.3.4 Valves and valve chambers

All valves on a heat network should be pre-insulated and of the same manufacture as the pre-insulated pipe system. Where necessary spindle extensions must be provided to enable operation of the valves buried at depth or located within manholes where it is otherwise unnecessary to enter.

Where valves are housed in specific chambers then these chambers should be sized to accommodate the apparatus within them and to enable easy operation of the valves. The valve chambers and associated items must be designed to withstand the likely traffic loads applicable to their location. Valve chambers should be clearly marked such that the location and contents of the pipes are easily identifiable.

DELIVERY VEHICLES AND COMMERCIAL STRUCTURES

6

This chapter identifies the delivery vehicles and commercial structures needed to support the growth of decentralised energy systems in London at scale. In dense urban areas the development of heat networks is central to delivering the potential for decentralised energy, in linking low and zero carbon sources of heat with the locations where the heat is consumed.

London has a large number of existing networks but with limited exceptions they are small and mostly confined to single housing developments. New business models are needed to deliver the potential for heat networks in London. The delivery vehicles (often known as Special Purpose Vehicles - SPVs) and the contract structures needed to create effective commercial relationships are an important element of that. Some insight into appropriate governance structures, particularly where local authorities are participating in schemes, is also needed at an early stage in a project's development.

6.1 Why is an SPV and contract delivery structure needed?

In their simplest form heat network developments do not require a specialised delivery vehicle, for example a heat network installed in a social housing development by a local authority that owns it. The construction of the network may be integral with the housing development. It may be owned by the local authority, the heat source located on the same premises and in the same ownership and the occupiers of the housing all committed to taking their heat from the system. Under these circumstances there is barely any commercial structure called for which is separate from the construction and use of the building itself; many of these already exist.

For larger heat network schemes to develop that are not owned, financed and managed by the same party, the scheme has to be 'commercialised'. That is to say business relationships have to be formed and made legally binding to introduce investors and finance for the project, enable the installation work to be instructed and the risks associated with the establishment of the project and its subsequent management and operation to be arranged between the parties. This process will usually follow the point at which the technical and economic feasibility of the project has been established and a business plan has been developed to show how the project can be developed, financed and operated.

In the case of other than the most simple of projects, the arrangements for their commercialisation will involve an SPV to manage the construction and possibly also the initial phases of operation of the project and regulate the interests of the parties involved. A contract structure is needed to secure the construction, operation and financing of the project.

6.2 The role of local authorities in development of heat networks at scale

The role of local authorities is central to the development of heat networks at scale, since there are certain resources and capabilities available to local authorities that enable them to de-risk projects that the private sector cannot. Through their own property holdings and their ability to 'broker' the delivery of heat loads by developers and businesses, local authorities can play an important part in collecting the sources of heat demand needed. Their planning powers and their role in many instances as highway authorities facilitate heat network development, in addition to their access to cheaper capital available from public sector sources. In addition, some local authorities will see the development of heat networks as part of their climate change mitigation agenda and as supporting their agenda for relieving fuel poverty, thus providing direct policy incentives for promoting heat networks in their areas.

6.3 Structure of the Special Purpose Vehicle

In deciding upon the appropriate structures for the delivery vehicle and contract mechanisms the first step is to identify the factors which will be the major considerations in determining their design. In the case of the SPV, this step in particular involves understanding the balance of interests of the parties participating in the SPV. Identifying the commercial interests of the parties developing, delivering and operating the scheme and finding the means to distribute and reduce risks in line with the capacity of each of the parties to manage them, key object of the heat network development and operation contract structures.

Parties with direct participation in special purpose vehicles may include the project sponsor such as a local authority, the asset ownership interest which may include financial institutions, the asset operator and network operator, developers and the principal or anchor load consumers. Regulatory and governance institutions may provide rules and guidance but would not participate directly in the SPV.

6.3.1 Local authority involvement

Local authorities are likely to have a substantial influence and interest in the development of large scale heat networks in their area. Below is a list of the particular opportunities and formal and informal powers which enable local authorities to de-risk large scale heat networks:

- Local authority housing and other premises can provide the basis for initial 'satellite' networks and for securing and retaining heat loads to underwrite heat transmission infrastructure. They are also well placed to bring interested parties together to offer heat loads;
- Local authority planning powers can facilitate the development of heat networks through consenting to them expeditiously and with

- realistic conditions and by setting planning conditions on new development which require connection to an existing or planned network;
- Gaining highways consents will become a more heightened issue with larger scale networks, as a result of substantial lengths of transmission network being situated under the highways rather than, for example, confined to private land on development sites;
 - Many local authorities have an environmental or social agenda, connected with targets for carbon reduction in their area and reduction of fuel poverty;
 - Local authorities have access to cheap capital (available at public sector rates) that may be important particularly at the earlier stages of network development before the stability of heat loads and volume of income streams can attract commercial sources of finance;
 - Financial and political accountability and the deployment of the required capacity and political will within local authorities means that they need to create effective internal governance structures to manage their interest in the delivery vehicle;
 - Larger heat network systems may cross local authority boundaries, involving synchronising all these activities between different local authorities;
 - Local authorities may be motivated to ensure long term network objectives are realised, where the private sector may be less ambitious than the local authority.

6.3.2 Financing mechanisms

Financing mechanisms are likely to need to accommodate the requirements of external finance and also of private sector developers of the network. Although perhaps not initially, when funding from its public sector promoters may be the mainstay of the development of a heat network, networks developed strategically

are likely to involve sums in capital investment going beyond that which the promoters or developers of the scheme are willing or able to accept on their own balance sheets. That means the providers of such finance will need to see a structure for the delivery vehicle capable of securing the cash flows of the scheme to finance their loans; and also management structures which provide for efficient operational arrangements and the necessary degree of accountability and control to the providers of external debt and equity.

6.3.3 The 'unbundling' of networks

The role of SPVs in the development of heat networks at scale is particularly focussed at the establishment, construction management and if necessary the early operation of networks. An important consideration in the structuring and strategy of SPVs is the unbundling of networks in the medium to long term, since the continued administrative burden of the SPV may not be the most efficient means to manage the heat network once the scheme is operationally stable. London's decentralised energy prospectus 'Powering ahead'¹⁷ refers to project structures which as the projects expand, unbundle themselves into their underlying constituent businesses. This may include a heat generation company or companies, possibly in different ownership from the network itself. This is already true for example, in the case of many networks served by energy from waste plants owned by local waste authorities and waste heat taken from industrial plants. The businesses and risks associated with heat transmission or distribution or both may be separated from that of heat generation. The result is the need for a structure of control which recognises the role of these parties as contractors, but at the same time accommodates their common reliance on the network's operation and economics.

¹⁷ <https://www.london.gov.uk/priorities/environment/publications/powering-ahead-delivering-low-carbon-energy-for-london>

6.3.4 The choice of legal entity

The term ESCo (Energy Services Company) is often used for commercial entities or companies delivering heat networks. However, the acronym is used in so many contexts as to be of limited use in this context. The entity delivering the heat network need not be a company formed and incorporated under the Companies Acts; it could for example be a partnership, trust or provident society. Examples of any of these differing forms can be found although they are generally more suitable for smaller projects which are for example, community led and owned. In practice for the larger schemes described in this chapter the usual vehicle is a company limited by shares or in some instances by guarantee.

The decision to set up a SPV or to establish an ESCo is therefore not in itself a solution to the management of any of the risks and issues described above and others, because the purpose and structure of that SPV or ESCo will be driven by decisions made concerning those issues.

All four of the elements discussed above - local authority involvement, finance mechanisms, unbundling of networks and the choice of legal entity - are going to shape the structure of the delivery vehicle. It should be noted that the form and structure both of the contract arrangements and the delivery vehicle are driven by the commercial, financial and policy requirements of these schemes.

Set out in Table 11 is a summary of principal issues which will drive the structure of the delivery vehicle. Figure 32 contains a corporate structure diagram within which the commercial and policy interests involved in the development of the large scale heat network might be managed. Individual projects will not share a uniform corporate structure, but they will share important common features illustrated.

Objectives / requirements	Risks	Solutions / options
Securing progressive growth of area wide network	Commercial decision making in the SPV is too short term and does not take account of long term strategic objective	Secure acceptance by the SPV of a long term business plan with milestones / thresholds for future investment stages
Delivery of competitive service provision and price despite lack of consumer choice	Network operator offers terms of heat supply that compare unfavourably to options available outside the network	Secure price transparency and adherence to available industry /consumer codes
Rights of access by heat suppliers who are not owners /managers of the network to customers connected to it	Provision of heat by multiple heat providers connected to network is discouraged through lack of access to consumers and their premises	Connection of existing and new satellite systems made conditional upon competing suppliers having access to heat consumers, subject to arrangements to support stranded assets
The SPV has efficient systems of management and control	The split interests of different shareholders in the network (notably between local authority involvement as sponsors/ facilitators / direction givers for future development and private sector investors) creates ineffective management	Shareholders' Agreement must separate commercial from political / social objectives and apportion costs to the owners of those objectives
SPV has a long term business plan adopted by shareholders sufficient to satisfy external financiers which is not abnegated by conflicting policy or political ambitions of public sector owners /controllers	Conflicting policy or political ambitions compromise agreement to or execution of business plans to the extent of making them un-bankable	Separate commercial from political and social objectives and cost separately as above
Long term agreements are reached between local authority interests and investors to ensure that revenue shortfall caused by fuel poverty programmes is made good	Revenues are compromised by heat prices charged and revenue earned being depressed by the fuel poverty objectives of individual local authorities	Fuel poverty objectives should be separately costed as above
Long term concession to a private sector party to whom the future development of the network is outsourced does not compromise SPV's control over network growth and delivery of business plan	The contacted outsourcing partner / energy company will not commit to a pre-planned chain of projects and investment.	Subcontracting to ESCo or other delivery contractor for delivery of network business plan must not commit SPV to retaining that delivery contractor outside activities for which the delivery contractor will contract to deliver from the outset.
Connections of satellite networks to the principal network can occur effectively, despite their being under different ownership	The operational and financial potential of connecting networks is frustrated by conflicting commercial or political ambitions	The SPV to adopt a network delivery plan which the owner of a satellite network must agree to prior to the connection being made

Table 11: Delivery vehicles (SPVs) matrix of principal objectives and risks

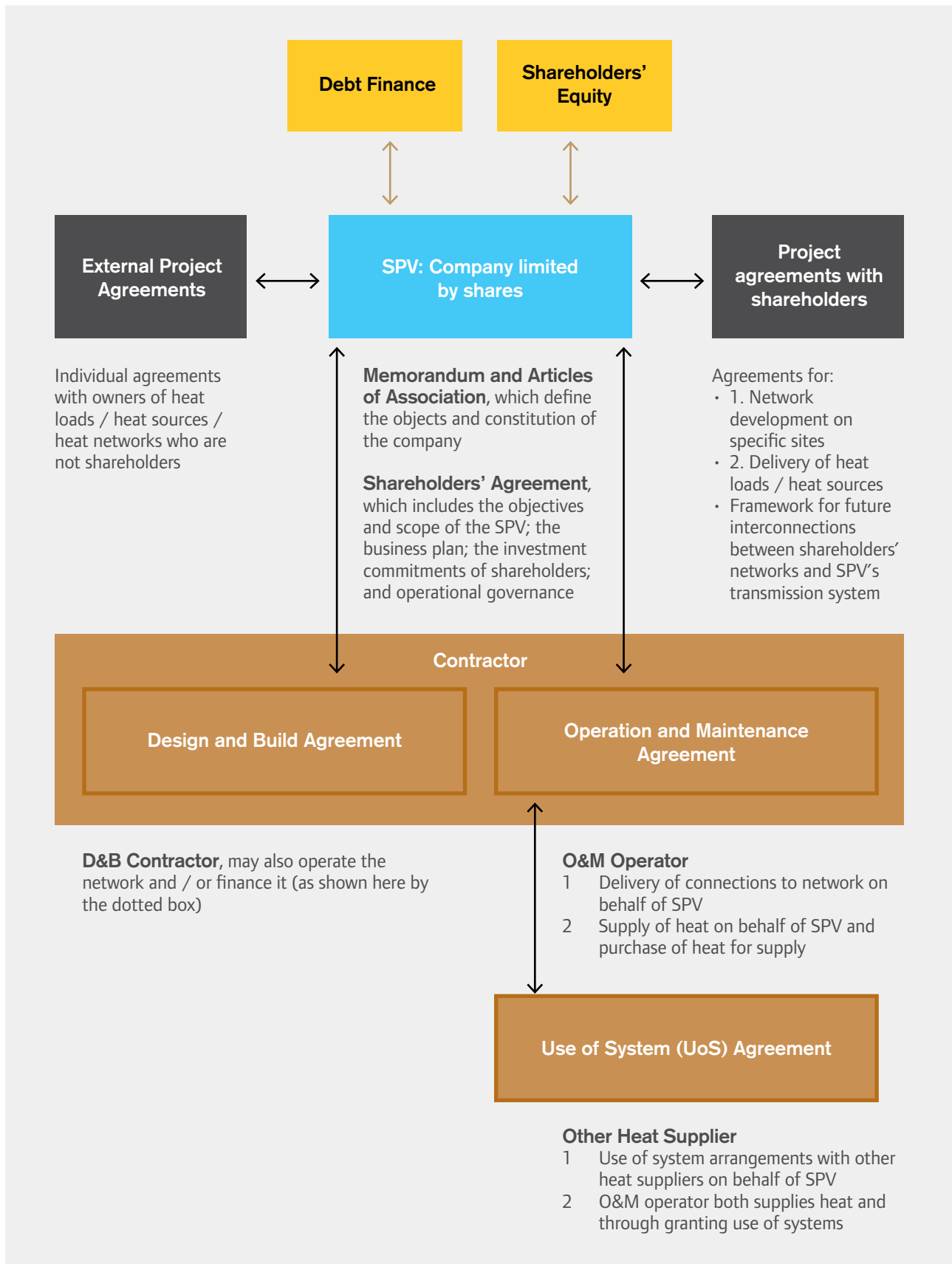


Figure 32: Special Purpose Vehicle structure

1 Taken from SPV paper prepared by Robert Tudway, GLA. This diagram shows the key agreements to be secured between the parties.

6.4 Implications for interconnection of heat networks

The strategy for transition from small community heat networks to large scale heat networks of the type envisioned by The Mayor of London's Climate Change Mitigation and Energy Strategy¹⁸ involves both the development of new large scale heat networks and the interconnection of existing heat networks across the capital.

Joining existing heat networks together means connecting schemes which may have been established upon different business models; successful integration therefore requires the structuring of a new commercial relationship to enable the networks to operate at one level as a single business and the resolution of operational difficulties at the interface between the two networks. A good example of the business modelling issues is the proposed link between the Pimlico and Whitehall district heating schemes. The need to cope with technical and operational difficulties between the two networks can also arise, for example, when introducing a link to existing private or social housing schemes.

The commercial arrangements reached between the network owners have to include managing the interface issues between interconnected networks, including:

- The possibility, particularly in the case of existing networks serving social housing, that the consumers connected to the network are not metered for the heat they use. This may restrict those consumers from being supplied directly by other commercially financed heat sources connected to a wider network, since such consumers cannot be invoiced for the heat they actually use. In these circumstances the existing network owner (for example a

housing association) may need to buy and be invoiced for the heat in bulk and themselves continue to supply the tenants;

- Some interconnection arrangements may include a change of heat supplier, particularly if the distribution of the heat is separated out from its supply, as the network grows with more heat sources. For that to happen, the consumer agreements for the supply of heat need to be assignable;
- The credit rating of some of the heat users in a scheme to be connected to a wider network may not be satisfactory to the prospective providers of heat in an expanded network;
- There may be differences in the temperature at which the heat is produced, delivered or returned within a scheme to be connected to a wider network which may reduce thermal efficiency or involve capital cost.

Some of, or these entire interface issues may arise in making connections between systems and will need to be factored into the connection terms between networks. The circumstances of the connection opportunity may differ widely. In some cases, the connection is between networks where the existing network owners remain responsible for the distribution and sale of the heat to their customers. In other cases, the interconnection may be part of a process of merging the networks, heat consumers joining the same supply arrangements, perhaps not only with the network with which the connection takes place but perhaps also with other networks to which it becomes indirectly connected.

¹⁸ <https://www.london.gov.uk/priorities/environment/publications/delivering-londons-energy-future-the-mayors-climate-change-mitigation-and-energy-strategy>

6.5 Shaping the design of the contract structure

The following development requirements will shape the contract structures required to deliver large scale heat networks:

- Infrastructure may be installed at the outset which includes 'future proofing' capacity planned for use following the initial network build out, thus ensuring that the network is capable of future extension in line with a known future strategy;
- Connection of the large scale heat network to satellite networks, whether existing or developed as part of the strategy, and involving the interconnection issues and commercial relationships referred to in paragraphs above;
- Investment in heat transmission infrastructure to link networks, the transmission infrastructure carrying risk of heat loads not materialising when planned or at all or disappearing, particularly if relying substantially on retrofitted connections;
- In the case of many planned large scale heat networks, a significant proportion (if not the main proportion) of the heat load being derived from retrofitted connections to existing premises. Retrofitting connections carries different risks, because occupiers of existing buildings tend to retain a choice between buying heat from a network or using their existing source of heat supply;
- A requirement in the future, if not initially, for arrangements between the owners of the assets and operators of the network to accommodate 'unbundling';
- The size of capital investment involved in building out the large scale heat network and the demands it places on the introduction of commercial debt or equity;

- Greater need for access to installation space under highways, space occupied by other public utilities, including railways and canals and private land, on account of the reach of the transmission network between sites; and/or
- Ensuring a transition to stable and competitive long term heat sources that will reflect expectations of declining carbon content in the heat. It will be expected that the heat transmission assets have a long life (say 50 years and may be amortised over around half that period).

Established contract structures exist for the development of heat networks at smaller scale and there are a number of publications containing forms of contract and structures for delivery vehicles. These are important both to support the replication of smaller projects and also as building blocks for large scale heat network projects. However, because of the different characteristics of these smaller projects, their development contracts and delivery vehicle structures will need to be adapted or fit within a broader framework, since they tend to reflect the commercial arrangements associated with networks more typical of 'satellite' networks.

Set out in Table 12 is a matrix of principal objectives and risks applicable to the development of large scale heat networks. Table 13 contains a summary of some of the existing contract structures and illustrates how they might inter-relate to form a contract structure for an area wide network. Further detail regarding existing forms of contract is provided in Chapter 7, which provides guidance for the structure of less complex satellite and community energy networks

Objectives / requirements	Risks	Solutions / options
Heat sources <ul style="list-style-type: none"> • availability long term • low / zero carbon • cost of heat compatible with market 	<ul style="list-style-type: none"> • single sources of heat disappear • no access to low / zero carbon heat • alternative sources of heat may not track gas prices 	<ul style="list-style-type: none"> • add heat sources to deliver security of supply • new heat sources include low/zero carbon fuels /waste heat • diversity of heat supply
Heat loads <ul style="list-style-type: none"> • critical mass of heat load secured • risk of loss of heat load within acceptable margin 	<ul style="list-style-type: none"> • owners of heat loads may lack incentive to commit long term • over long payback period of heat networks future of heat loads unpredictable 	<ul style="list-style-type: none"> • identify demand clusters or satellites with diverse heat loads • secure anchor loads / interconnections to expand range of heat loads
Installation of heat networks <ul style="list-style-type: none"> • adequate access to private land and highways • supply chain costs economic 	<ul style="list-style-type: none"> • access denied or delayed • construction /supply chain costs over budget 	<ul style="list-style-type: none"> • secure access in contract terms with owners of land and premises served by network / early arrangements with highways authority • pass construction cost risks to contractors best able to take it
Interconnection with other networks <ul style="list-style-type: none"> • technical compatibility of networks • certainty of heat loads and heat sources available from connected networks • consumers on connected network are metered • heat supply agreements are assignable • connected network's heat source is capable of required control and efficiency 	<ul style="list-style-type: none"> • different temperatures / physical compatibility of connection interfaces • small network may be open to loss through redevelopment of site / lack of income to finance cyclical refurbishment • consumers are not metered and do not pay for heat actually used • no clear option for connecting network to supply or permit supply by others than the existing satellite network owner /operator • the connected network operates inefficiently and cannot synchronise heat production / heat supply with larger network requirements 	<ul style="list-style-type: none"> • early master planning to identify / secure compatibility of networks • retain and grow connections to satellite networks and multiple heat loads • retain consumer interface with existing network operator and supply operator bulk • secure option as a condition of interconnection with the network, retaining if need be the existing operator as the consumer interface as above • a management structure put in place for all the interconnected networks so that they are managed as a single operation
Electricity – prevailing market rates expected to be obtainable from sales of electricity from CHP units operated to supply heat.	The small packets of power exportable by the CHP scheme do not attract competitive offers from the market	Explore potential of 'licence lite'
Government financial support for other heat and local electricity production technologies do not create a competitive disadvantage	RHI / FiTs / ROCs available for other forms of heat and electricity production without the infrastructure costs of pipe systems make the heat provision uneconomic relative to supported competitors	Influence government policy and investigate sources of zero carbon heat which attract support

Table 12: Development requirements, matrix of principal objectives and risks

There are already some commonly used types of contact structures for the development of heat networks at a smaller scale which can form important building blocks for larger scale area wide projects. The following is a representation of how such structures might inter-relate in the development of larger networks.

Description	Characteristics	Contracts used
Single site schemes	An energy services company (ESCo) undertakes to supply heat to customers and for that purpose to build and operate a heat network system. This is set up with a defined set of consumer buildings within a single site (either new development or existing)	<ul style="list-style-type: none"> • Master and Connection Agreement between ESCo and developer/ landowner/landlord • Heat supply contracts with occupiers • Service level agreement to enforce standards • Property leases to grant ESCo asset ownership subject to terms
Multi- site schemes (mixed-use)	Developers of a number (usually adjacent) sites contract with an ESCo to build and operate a heat network to serve the new developments and possibly also retrofitting some existing buildings with heat connections	<ul style="list-style-type: none"> • Design and Build Contract • Connection Agreements to premises • Operation and Maintenance Contract (possibly with same contractor) • Heat Supply Agreements between O&M ESCo and heat consumers • Service Level Agreement between O&M ESCo and developer • Property leases granted (possibly for a fixed concession period to D&B contractor if also operating the network)
Large scale heat networks	A special purpose vehicle (SPV) promotes and secures the construction of an area wide heat transmission system, built out over time as heat loads justify it, extending through connecting with existing smaller scale networks (such as the networks described above), new developments and retrofitting connections to existing buildings, either operating the network itself or subcontracting to an ESCo	<ul style="list-style-type: none"> • SPV enters into design build and operate contract • ESCo/contractor design and build only • SPV or appointed ESCo operates the network and manages connections with other networks • SPV secures additional heat generation connections • SPV offers use of systems contracts to heat generators / suppliers to deliver heat to individual customers

Table 13: Contract structures

6.6 Bridging the gap – delivering a bankable proposition

Securing funding sources for large scale heat networks presents a major challenge to deployment of decentralised energy infrastructure across London and this section of the Manual focusses on the underlying issues and presents some guidance on potential strategies to bridge the gap.

6.6.1 Financial indicators

A common method of measuring the viability and potential of a project to attract finance is through the related concepts of net present value (NPV) and internal rate of return (IRR).

NPV is frequently used for long term projects to calculate the prospective return on a project over its life, allowing for the time difference between the time when the investment is made and cash flows are received in relation to it. The NPV calculation discounts the projected cash flows to allow for the time delay in receiving them, at the required rate of return on the investment. The required rate of return is usually the cost that is incurred to acquire money to fund the project (the cost of capital) plus a risk adjustment (for example, to allow for appraisal optimism). If the NPV is zero, it means that the project will repay its original investment plus the required rate of return and, if the NPV is positive, better than that. An NPV calculation takes no account of risk, although that can be factored into the required rate of return and therefore the discount rate applied to the NPV calculation.

IRR is used to measure the return that can be made from alternative investments. The higher a project's IRR, the greater the rate of return or profit the project may offer. A project may be considered an acceptable investment if its IRR is greater than an established minimum acceptable rate set by the institution making it, although its

limitations are that it indicates the rate but not the magnitude of return. Where alternative projects (or alternative variants of the same project) differ in risk profile, an additional risk adjustment needs to be made to the IRRs, for example by applying a discount to future revenues or a premium to costs.

In the case of large scale heat networks, as detailed throughout this chapter, projects are strongly influenced by the need to reduce risk. The key project risk may lie, for example, in the magnitude and type of heat loads that are available to provide the planned cash flow, the continued availability of heat at an economic price and uncertainties that may arise in the construction of the network itself, including ground conditions and project delays. All of these risks, unless reduced to acceptable levels and adequately managed, may create a barrier to investors.

6.6.2 The challenge for heat network development

Establishing an adequate financial return and reducing risk levels to an acceptable level are challenges for heat network projects, notably in their earlier years of development. Ascertaining these requirements begins at the energy master planning process and is developed through subsequent technical and economic assessment. The challenge for these networks as they are developed to their full potential is that through the development:

- The heat loads increase in number and diversity;
- Long term heat sources are established, of which there may be several, spreading heat cost risks in some cases through gaining diversity of heat source; and
- Economies of scale are achieved, through the assets being used more intensively.

These factors and others mean that as a large scale heat network develops its business model may change, with the potential for progressive improvements in IRR and progressive reduction of risk. A private sector investor or provider of loan capital may be looking for a project that has an IRR of at least 10 -12 per cent to ensure a return on capital or repayment of loans within an acceptable period. Since an IRR at that level is not regarded as good by most sources of external funding, the investor or lender may also be expecting a low level of risk, perhaps akin to that normally associated with utility investments such as gas or electricity distribution undertakings. Many large scale heat networks may expect to attain that level of bankability in time through the advantages of scale, but how do they get there?

6.6.3 Bridging the gap

The principal challenge in funding heat network development is therefore bridging the gap between the earlier stages of network development which may have lower rates of return and higher levels of risk and the middle and later stages when the network attains scale and diversity of heat load and with it, the features of a stable, profitable utility business. If, as in the case of other utility infrastructure businesses, the risks are low and the revenues and returns assured by a stable market for the heat, then heat networks have the potential to take on the features of investments attractive to institutions such as pension funds looking for stability rather than higher returns. One key to bridging that gap is to plan the growth of a heat network incrementally. Another is to plan for re-financing. As heat networks develop, different sources of funding will be most efficient, at the outset relatively small levels of funding but available at lower rates and tolerant of higher risk; at later stages of development larger scale funding, at higher rates and less tolerant of risk. The former is hardly a commercial proposition, the latter is.

6.6.4 Funding sources

The sources of funding for decentralised energy projects may be both from public sector sources and private sector debt and equity funding. Some examples include grant funding or 'free', such as revenue from Renewables Obligation Certificates, Feed-in Tariffs and the Renewable Heat Incentive or proposed funding from 'Allowable Solutions'. Others are public sector debt or equity that may be available in acceptance of low initial returns and made available as part of a local authority's policy package for the development of a heat network in its area, perhaps fully or partially funded through borrowing from the Public Works Loan Board. It may be expected that developing large scale heat networks will tend to be reliant substantially upon such public sector sources of funding in the earlier years.

6.6.5 Designing the delivery vehicle to accommodate the funding mechanisms

The contract and corporate structures for delivering large scale heat network projects have to be designed around not only the ambitions of their promoters and developers (including and in particular local authority promoters) but also the requirements of the providers of finance to secure their investment or lending. What those requirements are will evolve as the network develops and the delivery vehicle for the project must be flexible enough to accommodate change.

CONTRACT STRUCTURE AND MANAGEMENT

7

This chapter considers the forms of contract under which heat networks are procured, constructed and operated, and shows how the selection of a particular contract structure should reflect the particular circumstances of the project and its sponsor, including the size and type of network being developed, the type of organisation responsible for its delivery and type of consumers.

The objective of the Mayor under the Decentralised Energy for London programme is to support the development, growth and interconnection of large scale low carbon networks, leading to the creation of a London-wide decentralised energy network. Sponsors will be expected to take account of that policy objective alongside their project-specific drivers for contract structure and terms. This includes ensuring that contracts facilitate and, where possible, incentivise:

- network expansion and new customer connections;
- interconnection with other networks; and
- connection of new low-carbon energy supplies.

The development of heat networks in London at the scale and in the volume envisaged in the Mayor's strategy for decentralised energy means that the retrofitting of premises and localities for compatibility with heat networks will become mainstream, rather than as at present the basis of new network development being more biased towards new property development.

Clarity about the project-specific drivers and wider policy objectives, and the associated forms of contract to be used is essential if the costs of procurement are to be contained.

7.1 Contract structures

Which contract structure is most appropriate for a particular heat network project depends in part on the main contractual elements – works, services and property rights:

Works elements

- Design
- Construction of energy centre and heat network
- Connection of premises

Services elements

- Energy purchase (supply and off-take)
- Generation of heat and electricity
- Operation and maintenance
- Metering and billing
- Connection of new customers
- Supply of heat or heat and electricity to connected customers
- Customer services

Property agreements

- Sale or lease of operational land and buildings
- Easements, rights of way and access arrangements on private land and buildings
- Street works licence

Heat networks can be procured, constructed and operated in a variety of ways. The spectrum of possible structures runs from individual contracts for each of the elements listed above to a bundle of services and works procured under a comprehensive agreement. However, in practice only a few contract structures are commonly used. These are summarised in Table 14 and developed further in the sections which follow.

Type	Description	Contracts required
Energy supply (ESCo)	An energy services company (ESCo) undertakes to supply heat to the customers, and for that purpose to build and operate the heat network. This could be set up with a defined set of consumer buildings to be connected, or to provide the service to developments within a defined area.	<ul style="list-style-type: none"> • Master agreement • Connection contract • Heat supply contract • Service level agreement (SLA) • Property leases
Wholesale supply of energy	A sponsor appoints a single contractor to design, build, own, operate and supply wholesale heat and electricity. The sponsor sells the energy retail to consumers, and may be a consumer itself. ESCOs often prefer wholesale supply to multi-occupant commercial buildings.	<ul style="list-style-type: none"> • Master agreement or design, build, operate (DBO) Contract • Wholesale heat supply contract with SLA • Connection contract • Property leases
Network delivery and operation (DBO)	A sponsor (such as an owner of tenanted properties) appoints one or more contractors to design, build, operate and maintain a heat network but the sponsor remains the asset owner and contracts to supply heat and electricity to consumers. The sponsor may also purchase the fuel required.	<ul style="list-style-type: none"> • DBO contract or a combination of D&B contract and O&M contract with SLA • (Metering and billing contract) • (Connection contract)
Network operation (O&M)	An operator is contracted to run a heat network that has already been constructed, for example under a main building contract. The operator may also be contracted to undertake metering and billing and customers services, if the landlord wishes to outsource these activities.	<ul style="list-style-type: none"> • O&M contract with SLA • (Metering and billing contract)

Table 14. Commonly used types of contract for heat network schemes

7.2 Choosing the main contract structure

The following notes provide guidance on the main considerations to help a project sponsor decide which contract arrangement is most likely to be suitable. They are intended for guidance only; a detailed assessment of objectives and options should be undertaken prior to a decision being made. Each of the common contract arrangements set out in Table 14 is explored.

7.2.1 ESCo

Master agreement or concession

The master agreement with an ESCo has to be long term to enable it to remunerate the investment it agrees to make. If the ESCo is expected to finance the construction of the heat network, then provision of a demand guarantee, or other means of moderating demand risk, is essential if the cost of capital is to be contained.

If future demand is unpredictable, or the sponsor is unable to give a comprehensive demand guarantee, the master agreement may take the form of a concession. The concession may provide for exclusivity within a defined area and/or period of time. Concessions are mainly associated with new developments where the sponsor can provide exclusivity or a demand guarantee. The ESCo would then normally expect to own part or all of the assets comprising the heat network scheme, albeit the assets may revert to the sponsor upon termination of the agreement. The ESCo would take responsibility for design and construction of the assets as well, enabling a complete transfer of project risks from the sponsor.

Several variants on the concession contract can be envisaged, as alternatives to the demand guarantee or exclusivity methods of keeping the cost of capital down. The project sponsor may advance some of the initial funding required, either as advance connection charges, as a loan

or loan guarantee or as an outright grant or capital contribution. Which of these options is used will depend on the perceived risks of the scheme and the relative cost of capital to the project sponsor and the ESCo.

Where the project sponsor is a developer, it might take on part of the construction activity itself and then transfer the assets to the ESCo for an agreed fee (which may not exactly match the cost incurred). The installation of HIUs and secondary networks is commonly undertaken by the developer, but this approach has on occasion been extended to include the heat sub-stations, the pipe work that connects premises to the heat network and the energy centre building.

Where more than one developer or house builder is to connect to the heat network, the terms of connection would typically be specified in a template connection contract, which the ESCo would be obliged to adhere to. In principle, the template connection contract ensures that the terms agreed between the sponsor and the ESCo are reflected in the terms the ESCo agrees with developers and house builders. The connection contract effectively recapitulates the key provisions of the master agreement, and in addition sets out in detail the connection process and cost. As the ESCo has a commercial advantage within the concession area or timeframe, the charge for connection should be controlled through the template contract.

Where the connection is to existing premises and no property developer or house builder is involved, the ESCo's freedom to offer its own terms will depend upon the requirements contained in the Master Agreement, the counterparty party usually being a local or public authority.

Template heat supply contracts for residential and commercial customers would be drawn up as part of the master agreement. These would

specify the prices that could be charged and define the quality of service, so that the customers could in future deal direct with the ESCo and not need to involve the sponsor in disputes. The form and content of heat supply contracts are examined in more detail in Section 6.4. The supply agreements would also define the procedures for customer complaints and the penalties that apply in the event of failure to deliver the promised level of service. Both prices and customer services differ as between residential and commercial customers, so it is normal to draw up separate agreements for each group. Any supply agreement between landlord and tenant will need to comply with landlord and tenant legislation.

The service level agreement (SLA) works at several levels to assure a sound alignment of commercial incentives as between the project sponsor, ESCo, developers and customers. At the highest level, the sponsor and the ESCo would agree how the network as a whole is to be built and operated, including carbon performance, flow and return temperatures, reliability and downtime. At the next level, developers and the ESCo would agree about the manner in which connection is to be achieved, including lead times and compensation in the event of delay. Finally, customers and the ESCo would contract for utility-standard levels of service quality, with equivalent levels of compensation in the event of non-performance. The levels of compensation would differ significantly as between commercial and residential customers.

All these SLA provisions can be included in the master agreement or be distributed amongst the master agreement, connection contract and heat supply contracts. The advantages of a single SLA document are that consistency of performance standards can more easily be assured and that all interested parties then have

access to an overview of the standards to which the heat network is to be operated. In any event, residential customers would usually need to have a plain language summary of key performance standards and their rights to compensation if these are not met.

In addition to the service level requirements, the master agreement may provide for the sponsor or a management company to have step-in rights in the event of a fundamental failure by the ESCo. Early termination may involve compensation of the ESCo for loss of profit opportunity.

Property leases

Property agreements are normally separate contracts, even when the parties are the same as in the main contract. A standard arrangement is for the buildings or spaces housing the energy centre and other equipment to be leased long term to the ESCo at nominal rents. The ESCo may also need easements and rights of access. The lease, easements and other such rights would normally be coterminous with the master agreement.

7.2.2 Wholesale heat supply

Wholesale heat supply is more appropriate where the landlord wishes to retain a direct relationship with customers. It can be implemented either under a concession or through a DBO contractor, the essential difference being that the DBO contractor would not normally own the energy assets, though it may have the obligation to pay for asset repair or replacement. The operator would typically supply heat wholesale to the point of entry to each building, while the developer or landlord would be responsible for selling it retail to customers. In this way, the project risks are distributed: risks associated with the provision of heat are with the operator, demand and credit risk with the landlord.

The D&B and O&M aspects of a wholesale heat supply contract would normally be considered together, in order to ensure optimal life-time costs. For the same reason, the contract would normally be for at least fifteen years. At the end of the contract, the assets would normally be handed over to the sponsor.

The wholesale heat supply agreement would set out the basis for setting the price at which heat is supplied by the operator. The price would reflect any financing that the operator has provided and its share of the risks of the project. The pricing formula would also need to take into account the price of fuel and, usually, the revenues to be secured from the sale of electricity produced by CHP. Responsibility for the supply of fuel or the sale of electricity would be assigned to whichever party can secure best value. For a long term agreement, there should also be provision for periodic re-basing of the pricing formula to ensure that it does not get out of line with market comparators. A common error is to index-link prices over the long term without making due allowance for productivity improvements that accumulate over time and with increasing scale.

The operator would normally be responsible for connecting customers to the scheme, although the connection contract may be between the sponsor and the occupier or developer of the premises to be connected.

7.2.3 Network delivery and operation (DBO)

Network delivery and operations contracts would be appropriate where demand is dominated by a limited number of customer types, such as council-owned buildings, or social housing, or a shopping centre. The project sponsor (typically the landlord) would be responsible for pricing of heat and for the customer interface, and would normally pay for and own the assets.

In this arrangement the owner takes the majority of operating risk of the service (i.e. absorbs any losses consequential to the non-availability of the heat supply). The owner might also retain responsibility for new connections and the expansion of the network, though these functions could also be assigned to the contractor. Risk associated with appropriate design and operation of the system is carried by the supplier.

One of the strengths of this approach is that it can make the best use of a sponsor's access either to lower cost fuel supplies or lower cost capital where that is available. It also ensures the sponsor retains control over prices at which energy is sold to customers.

The contract will likely include some provision to ensure efficient operation of plant (as well as just maintenance). There are a wide range of options for the design of performance guarantees to ensure this, such as an incentive to maximise electricity output from the CHP.

While service reliability can usually be assured through a DBO contract structure, the incentive to minimise the total cost of ownership only exists at the point where the DBO contractor is selected. Thereafter, the contractor is likely to seek opportunities to increase the D&B cost through variations, and the O&M cost through early replacement of assets and a range of other techniques. In short, getting good value through a DBO contract depends critically on the quality of contract documentation, including SLA, at the

time of contract award. Procurement and getting to contract is therefore likely to take considerable time and effort.

The D&B contract and the O&M contract components should be considered separately, because the form of the contract would be different in each case, but may be awarded together, as performance risk will be mitigated by assigning responsibility for the design, build and operations to one contractor. The D&B and O&M contracts will outline the requirements the sponsor has of the supplier, and outlines that relationship.

The D&B and O&M specifications for this contract type usually require a greater level of specificity than with concessions or wholesale heat supply because most of the risk associated with the scheme is being borne by the sponsor. The D&B contractor may lack the incentive to provide a design consistent with sponsors' drivers. Supplier can be expected to design to meet the wording of the D&B specification and to maximise O&M fees.

Methods that can be used to mitigate this risk include requiring the design proposals of D&B bidders to be more clearly outlined, appointing the O&M contractor in time for it to be able to approve the design or be involved in commissioning the network and requiring extensive warranties from the D&B contractor for the operational efficiency of the plant installed.

In relation to O&M, one way of limiting the tendency for charges to creep up is to limit the term of the O&M contract to, say, five years and to use the opportunity to re-bid the O&M contract periodically to ensure contractors have appropriate incentives.

Connection and supply contracts, as discussed in the preceding section, will also need to be in place between the sponsor and all energy customers.

7.2.4 Operation & Maintenance

A network operation and maintenance (O&M) contract may be appropriate where an existing heat network is being upgraded, or where a new heat network is to be installed by the main building contractor. Note that in this case, the O&M contract is likely to leave virtually all risks with the asset owner, and should be of relatively short duration to retain the incentive to run the scheme efficiently.

An O&M contractor typically lacks the incentive to maximise revenues. This can be an issue where a heat network includes CHP. The merits of CHP are that it produces additional revenues from electricity sales, and secures improved carbon performance by comparison with simple boilers. From an O&M perspective, however, running CHP involves considerable additional cost and complexity. Careful attention to incentives is essential to ensure optimal running of a CHP system under an O&M contract.

Whereas an ESCo and a DBO contractor can be penalised for poor performance, an O&M contractor will not normally be willing to accept contracts with penalty clauses. The contract value is usually too small for the risk of being penalised to be covered by prospective revenues under the contract, and the assignment of responsibility for service failure is likely to be disputed.

7.3 Common contractual issues

7.3.1 Metering and billing

Unless an ESCo contract is adopted, additional contract decisions will have to be made on how to manage metering and billing, including the customer interface. A typical arrangement for local authorities or landlords is for them to retain metering and billing, revenue collection and customer services, as they are already engaged with the heat network's customers to collect rent or service charges. Several specialist firms exist who provide these services, other than accepting credit risk, typically under short term contracts; however, their charges vary widely. Metering and billing contracts are examined in more detail in Section 7.5.

7.3.2 New connections

The terms on which new connections are made will be set out in the connection contract, and these terms can be reflected in the master agreement, DBO or O&M contract. New connections can require complex contract negotiations and involve disruption to operations, putting performance standards at risk. These issues can be addressed either by sponsors retaining the new connections role for themselves or through the inclusion of new connection performance targets within the relevant contract.

However, for local authorities and other network developers or owners there is a strong policy driver to ensure the steady growth of networks once they are up and running. The extension of networks can often reduce risk associated both with heat loads and sources of heat supply and introduce economies of scale. Yet DBO and O&M contractors only have weak incentives to extend the network, and even ESCos may be reluctant or unable to commit the financial resources required to extend a network in advance of firm orders for connection that would fully remunerate the investment.

Methods of overcoming the poor incentives to extend a heat network include:

- Requiring through planning conditions that new developments connect to an existing heat network if within a defined distance of the development. The net effect of this rule is to increase the density of the heat load served by the heat network;
- Imposing an obligation on the operator to connect new customers on standard terms where the premises to be connected are within a defined distance of the existing scheme. The net effect of this rule is to spread any additional cost of new connections over all connected customers;
- Providing refundable finance for the cost of a new connection.

Where the heat network is in separate ownership from the energy supplier, (the prevailing model in the UK and in Danish urban heat networks), rules are required to determine the allocation of the costs of new connection.

The underlying logic of network extension in a UK context can be most clearly illustrated in relation to the rules governing gas connections. To connect a building to existing gas infrastructure, a developer would hire the services of a UIP (utility infrastructure provider) which would charge the full cost of making the connection.

If the nearest gas infrastructure were some distance away, the developer would seek out an IGT (independent gas transporter), which would invest in the necessary infrastructure and be remunerated in part by the developer and in part through future charges for gas transported over the infrastructure. With gas, the balance between these two sources of funding for network extension is determined through competitive tendering among IGTs. With heat networks, that opportunity does not exist and so will need to be determined on the basis of rules. The current

absence of formal regulation of city-scale heat networks means that the rules are required to be written into the relevant contracts each time.

7.3.3 Contract boundaries

Whatever the contract structure, it will be necessary to define the point of connection between the heat network and the customer's own heating system.

A typical arrangement with an ESCo serving residential premises would be for the ESCo to own and be responsible for the entire network up to and including the HIU, and especially the meter within it. The ESCo has the incentive to make sure that the network equipment is working properly, and has a direct contractual relationship with customers, and so logically should be responsible for maintenance, repair and replacement of all equipment used to provide service. The point of connection would then be at a valve on the customer's side of the HIU.

Alternatively, the developer may decide to own the secondary network in order to have control over all building services. The point of connection would then be at a valve on the building side of the substation serving it. The developer may still prefer the ESCo to be responsible for the HIU and heat meter, which require specialist maintenance.

DBO and O&M contractors do not have the same incentives as an ESCo and it might be more appropriate in these contracts for responsibility for HIU maintenance to belong with building management, especially if the building management also accepted responsibility for distribution of heat within the building. If that is done, then the DBO or O&M contractors would not need to be given rights of access to customers' premises.

For commercial premises, the point of connection to a heat network would normally be

at a substation in the basement of the premises. Responsibility for the distribution of heat around the building would then rest with the building management. This arrangement is usually more convenient for property managers, who are responsible for building services. The point of connection to the heat network would then be at a valve on the building side of the substation.

Other contract boundaries may be more straightforward to define, but in all cases the sponsor must consider interface risks, where they should reside and how best they can be mitigated. Typically, with DBO and O&M contractors, the client will retain all interface risks between its contractors unless expressly handed over, since the contractors will not normally have a direct contractual relationship with each other.

7.3.4 Aligning contract incentives

In general, an ESCo agreement can more easily achieve a sound alignment of incentives, as the operator is then responsible for all aspects of the delivery of heat to customers. The transfer of roles, responsibilities and risks to an ESCo also enables the terms and conditions of the contract for the heat network to be focussed on outputs – the quality of service to be provided and the prices to be charged – and so avoid specifying the details of design or of operating standards. The regulation of prices of quality of service will still be necessary, as the ESCo will effectively have a monopoly position in relation to served premises. Pricing principles are examined in Chapter 8.

If the ESCo owns the assets as well as the revenues from customers, its commercial incentives should be appropriate. The ESCo is sometimes permitted only to lease the assets for the period of the concession, with an obligation to hand them back in good condition at the end of the concession. This approach can work well, at least until the termination date approaches (given the long payback period on investment in heat networks, the ESCo's incentive to invest in

expanding the network disappears once there are fewer than about ten years left on a contract). Typically, this incentive problem is resolved by renewing the concession well before its expiry date.

Strong incentive effects can be secured by drafting and then enforcing well-defined termination clauses in the master agreement. To avoid the sponsor of the heat network having to take over the running of the system and to procure a new ESCo at relatively short notice, the termination clauses would need to contain detailed transition arrangements.

It would be feasible to set up an ESCo arrangement in which ownership of the assets was retained throughout by the landlord. However, in such a case, the ESCo's incentives are likely to be distorted: it could make more money if the assets were replaced more frequently, or if maintenance was skimped. In such a case, therefore, the ESCo contract will need to contain:

- A detailed asset register with expected asset lives, linked to the SLA (i.e. penalties for early replacement of critical assets);
- Detailed provisions about O&M standards and procedures;
- Strict record keeping requirements, and a periodic inspection regime.

Alternatively, the remuneration of the ESCo could include profit sharing; however, few heat networks are sufficiently profitable (or their operation profitable soon enough) for this to be a practical option.

Similar incentive issues arise with DBO and O&M contracts. The problem is more acute with DBO, as these are typically long term (in order to incentivise good design and build). The mitigation measures in this case are as above.

While having detailed provisions on standards and procedures, and periodic inspection, O&M contracts are usually short term (e.g. 5 years). The regular market-testing of O&M performance, with the credible threat of termination, helps to mitigate the adverse effects of these incentive issues.

7.4 Heat supply agreements

Table 15 on the following page provides an outline of standard terms to be included in an agreement where heat is supplied directly by an operator ('ESCo') to a residential customer.

Examples of completed heat supply agreements are in the public domain. Gas and electricity supply agreements can also be referred to as a guide to the detailed provisions.

Supply agreement heading	Outline of contents
The served premises	Identification of the address to be supplied and contact details of the customer
Supply dates	Date of the agreement; date of first supply, if different; duration of the agreement.
Charges for heat	Fixed charge; variable charge; other charges that may be applied e.g. in the event of temporary disconnection.
Annual price review procedure	Description of the procedure the ESCo will follow each year to revise the charges. This will typically be a formula linked to the prevailing rate of price inflation and/or gas price inflation, and the price of a comparable boiler maintenance contract with equivalent terms (e.g. no excess).
Reading the meter	Frequency and method of meter reading; customer access to the meter and to consumption data; what to do if the meter reading is disputed, or the meter fails.
Billing procedure	Frequency of billing (not necessarily the same as for meter reading); content and format of the bill; methods of payment; time to pay; penalty for late payment; what to do if the amount owed is disputed. Where credit risk is a concern, it is important to provide some means of pre-payment, either through a pre-payment meter or a method of keeping an account in credit. The agreement would specify the conditions which would trigger a switch from payment in arrears to an in-credit arrangement. In general, pre-payment should not result in a higher charge.
Data protection	What the ESCo may do with the consumption data, with the customer's payments and with contact details.
Standards of service	The temperature of the heat to be supplied and permitted variation; permitted downtime and notification process; other performance standards; method of reporting performance; penalties for non-compliance. It is usual for standards of service and penalties for non-compliance to be set out in a separate document which can be updated without requiring all supply agreements to be revised. It is also good practice to make this information available in plain language for residential customers.
Changes to the service	Procedure for the ESCo to notify changes in the service to be provided (other than a price change). Procedure for the customer to request a change to the service to be provided, and the method for calculating any charges that may apply.
Moving house	Procedure for the customer to follow when leaving the premises and handing over the agreement to another person.
Access	Procedure for the ESCo wishing to gain access to the served premises (if necessary).

Table 11. Typical contents of heat supply agreements to residential customers

Liabilities	Listing of the liabilities of the ESCo and the customer (e.g. for death or injury, for damage to property, etc) and any limits on liability.
Suspension and termination	The reasons and procedure for suspending the agreement (e.g. due to absence from the property or failure to pay bills). The reasons and procedure for terminating the agreement (e.g. ESCo's failure to perform). Protection for vulnerable customer groups.
Annex 1 The District Energy System	Description of the district energy system and of the connection of the premises to it (e.g. capacity)
Annex 2 Residential HIU	Whether the HIU will be located inside or outside flats and houses. Whether the ESCo, the landlord or the customer will be responsible for the maintenance, repair and replacement of the HIU. Arrangements for inspection, repair and replacement of the heat meter if attached to the HIU.
Annex 3 Quality of service	<ul style="list-style-type: none"> • Supply temperature of heat; • Supply interruptions; • Response time to reports of supply failure; • Aspects of billing performance.

Table 15: Example standard terms for an ESCo heat supply agreement

7.5 Metering and billing contracts

The costs of metering and billing exhibit economies of scale. With small heat networks, it is usually worth considering using specialist providers of metering and billing services that can offer to share the benefits of the scale they have already achieved on other schemes. Gas and electricity suppliers that also operate heat networks can normally integrate their billing systems and customer services, to the benefit of the heat networks that they operate.

The charges for metering and billing heat are likely to be higher than with gas and electricity supply, since the customer base is much smaller and also because heat meters are not to be standardised and to have a shorter life.

With an ESCo, it would normally be responsible for selecting the metering and billing system to be used. Even in this case, it is important to ensure that data is presented by the metering system in a format usable by more than one metering and billing services provider, in order to facilitate transfer on termination. Where a DBO or O&M contract structure is used, the requirement to avoid being tied in to a particular

service provider is even more important (see section 3.6.7 for further information on meters). Where meter procurement is the responsibility of the building contractor, these considerations should be incorporated into the specification of the building contract.

Metering and billing service contracts need not be as long as ESCo concession or DBO contracts. However, minimum contract duration of five years is recommended, both to reduce the transaction costs of procurement and to allow the metering provider to spread its initial set-up costs related to the scheme.

Specialist metering and billing service providers will not normally accept credit risk, but contract performance standards can be used to mitigate the risk for the client. For example, follow-up phone calls can be helpful in identifying payment problems early. This must be done with care to avoid incentivising aggressive or insensitive debt recovery practices, leading to negative customer perception. Dealing with vulnerable populations in particular will require the balancing of revenue protection and customer satisfaction objectives.

7.6 Customer service

Heat network services are not currently subject to national regulation, nor are there existing recognised standards of service for heat providers. This means that consumer protection must be built into the specific contract under which heat is supplied to consumers. The consumer protection measures have to cover all aspects of customer service: charges for service, the quality of service provided and complaints procedures.

In practice, the way in which electricity, gas and water services are provided in this country offers a practical reference point for determining what should be required of heat providers. Most ESCos publish standardised customer charters, usually based on utility standards of service, which can be referenced for a new heat network. The benefit of this approach is that it assures that the standards of service for heat supply will be regularly updated in line with the generally applicable utility standards of service.

The agreed standards for customer services can be attached to the supply agreement or can form a separate contractual commitment to the project sponsor (see SLA discussion in Section 7.2.1). Other, more aspirational standards of performance, behaviour of ESCo staff and treatment of customers, tend to take the form of a customer charter, although the two types of document can overlap to an extent.

Independent Heat Customer Protection scheme

In the absence of national regulation, an independent scheme developed by heat network industry and consumer groups together with government support is currently under development. Under the proposed scheme, where a new network operator is being procured, project sponsors may require that heat suppliers register their network with a customer protection scheme endorsed by the Government. The scheme, expected to launch later in 2014, aims to establish a common standard in the quality and level of protection for household customers and micro-businesses connected to heat networks and provide independent adjudication; a dispute resolution service at no cost to heat consumers, once the heat supplier's complaint procedure is exhausted.

CHARGES FOR HEAT AND REVENUE MANAGEMENT

8

This chapter covers the revenue side of network operation, including the types and formulations of charges paid to the operator and the typical arrangements for metering and billing. As with the preceding chapter on contracts, this is provided as information and guidance to assist the development of well-managed, viable networks.

8.1 Types of charge

The charges levied by the heat provider typically comprise:

- Connection charge: an initial charge for connecting to the heat network, which may be paid by the developer or landlord, but is not usually payable by customers;
- Standing charge: the fixed component of the heat supply charge, normally paid by the customer but by the landlord of rented residential premises;
- Unit charge: the price per unit of heat supplied, normally paid by the customer.

These charges can be set in several ways:

- Initially by the heat provider through competitive tender and then index-linked;
- Set expressly to recover construction and operating costs (cost-based pricing);
- Set to match the opportunity cost of using the heat network (avoided cost).

Each of these methods come with potential benefits and pitfalls. The avoided cost approach is normally best for ESCo contracts, as it best ensures that the heat network will continue to provide good value for customers in the long term. Index-linking prices is liable to result in heat supply becoming uncompetitive in the longer term, as a price index such as RPI does not expressly take into account productivity

improvements. Cost-based pricing, as is well known, tends to reduce the operator's incentives to be efficient.

Basing the charges for connection to a heat network on avoided cost is also helpful in assuring developers that they will not incur greater costs than with a conventional heating solution. However, calculating the avoided cost of connection can be complex and not entirely objective.

8.1.1 Connection charges

Connection charges can contribute significantly to the commercial viability of heat networks. The developer of new premises to be served by the heat network would normally be willing to pay a connection fee that did not exceed the cost to provide a gas supply, inclusive of the cost of a gas boiler (for flats the cost of a central heating system), plus the cost of achieving an equivalent level of carbon reduction. As the heat network will contribute to reducing carbon emissions, the connection fee should take account of the cost of the most economical alternative method of achieving the same reduction in carbon emissions. Taken together these constitute the 'avoided cost'. The higher the carbon reduction standard to be achieved, the higher the avoided cost.

For a development that is to be built over an extended period, it may be possible to formalise the avoided cost into a formula or schedule, and then index-link or benchmark the connection fee based on this formula. Such a formula can provide both ESCo and developers with certainty, which is helpful in determining capital contribution (the ESCo's main concern) and land value (the developer's concern). Alternatively, it would be possible to re-calculate the avoided cost every few years, since the carbon performance required of new buildings is rising while cost of achieving a given level of carbon performance through adjustments in the building fabric is falling, in real terms.

8.1.2 Connection of local networks to city-wide networks

Once a local heat network is operational, then there are several reasons for connecting it to a larger network:

- to reduce further the cost of provision of heat;
- to improve the utilisation of existing heat generating plant;
- to avoid replacement of heat generating plant and maximise network diversity benefits; or
- to spread demand risk.

The cost of connection can be compared in NPV terms with the savings in heat costs. In this case some price guarantee may be advantageous. Where the connection cost is substantial, for example a long pipe run, the cost of financing the connection may also need to be taken into account.

The calculation of the avoided cost of generation plant replacement will depend on the location of the scheme and the type of property to be connected. Where local generation plant is underutilised, it may be able to contribute heat to the larger network via the connection. That is, a replacement plant would be dimensioned in relation to the heat export opportunity presented by connection to the larger network. Alternatively it may be sensible to close it down completely. In that case, the property value that can be realised may be a significant factor.

In any event, it is likely to be impractical to standardise the charges for connection of a smaller heat network to a larger network.

8.1.3 Heat charges

The pricing approach to be followed should be specified in the procurement process of any heat network.

For the reasons given in section 8.1.1, prices charged for heat supplied by heat networks are normally set by reference to the equivalent cost of gas-fired central heating (the 'avoided cost' or 'gas comparator'). For most residential customers, gas-fired central heating is the most cost-effective alternative form of heating and hot water. For high-rise and 'green' developments, this may not be the case and an alternative benchmark may be used.

Even where the initial set of charges for heat has been derived through a competitive tender process or on the basis of costs, the annual adjustment of prices is typically made by reference to a gas comparator.

So the first step in developing a tariff for heat is to establish the gas comparator. There is no specified process for making this comparison, as gas suppliers offer a multitude of tariffs, the take up of which is not publicly known. Gas suppliers are required to quote for an average level of consumption, specified each year by Ofgem. Almost certainly, the customers to be served by the heat network will consume less than this average. The level of consumption can be estimated though it cannot be known with certainty in advance.

It should be borne in mind that energy suppliers and the gas tariffs they offer are constantly changing and for a long running contract the reference energy price should be expressed generally. For instance, the gas comparator could be stated as 'the average gas price calculated from the cheapest gas tariffs available locally on a dual fuel basis from each of the six largest gas suppliers for a consumption of 7000 kWh per year'.

To determine the equivalent heat price, a conversion factor has to be applied to the gas price. With modern gas boilers, a 85% or 90% efficiency should be assumed.

An alternative method of calculating a gas comparator is to use the wholesale price of gas with a mark-up. The benefits of this approach are that it is more easily calculated each year and the wholesale price more closely corresponds to the actual costs of the heat provider (in the case that the heat source for the heat network is gas-fired). Data on wholesale gas prices are published regularly by ICIS Heren¹⁹. For example, the year ahead, NBP price of gas at the end of 2013 was 2.3p per kWh. So a mark-up of about 100% on the wholesale price would match a price derived from a retail gas comparator.

The advantages of reference to the wholesale price of gas are, firstly, that it is a single, published point of reference whereas the retail price of gas can only be determined through calculation and there is room for argument as to the data to be used in such calculation and, secondly, the wholesale price of gas is a key component of the heat provider's costs, so the ESCo may consider it a less risky approach. Conversely, because the wholesale and retail prices of gas may move in different ways, in any year there is a risk that consumers experience heat prices that are too high by comparison with retail gas. In recent years, the gap between wholesale and retail gas prices has widened so this risk has not materialised.

The heat provider typically maintains the energy system as well as supplying heat, so the price for heat should also take into account the value of this service. The value of a boiler maintenance contract can be determined by obtaining quotes. For example, in September 2011 the British Gas Homecare 100 with no excess (considered to offer a comparable service to that of heat providers) was priced for London customers at £156 a year including insurance tax.

The pricing approach to be followed should be specified in the procurement process. Where the heat provider has been selected by competitive

tender, the prices offered in its tender can be reconciled with the gas comparator approach by means of just such an adjustment to the discount or mark-up.

It is not advisable to revise prices for heat simply by linking the tender heat price to an inflation index. By doing so, there is a high probability that heat prices will quickly get out of line with customers' expectations, which are based mainly on current energy prices.

It is also not advisable to base annual revisions to charges for heat directly on the actual costs of the heat network as to do so risks removing the heat provider's incentive to be efficient and, perhaps more important, provides no assurance to customers that they will continue to receive good value for money in future.

It is important that the tariff based on a gas comparator includes all charges to residential customers. As well as the fixed charge and the unit cost, heat providers may charge for late payment, for disconnection and re-connection, and for transfers when a dwelling changes hands; they may also offer a discount for paying by direct debit. All these extras should be taken into account. Tariffs should be reviewed regularly. Residential consumers dislike the frequent tariff changes to which they are exposed by gas and electricity suppliers. With heat networks, there is the opportunity to limit price changes to one a year. Further certainty can be provided by basing the annual tariff adjustment on a formula that is made clear to consumers (for example, by its inclusion in the heat supply contract).

In the short term the gas price may be the best comparator for a heat tariff. However, this may change in the future to reflect changes in the general nature of heat production in the UK. So the contracts should allow for a review every, say, five years to see whether the gas comparator remains appropriate.

¹⁹ ICIS HEREN energy price reporting, available online at www.icis.com.

8.1.4 Fixed charge

Heat networks typically use a tariff that comprises a fixed component and a variable component, with the fixed charge for heat being significantly larger than for gas. The main commercial reason for their preference for high fixed charges is that heat demand is highly variable over the year and a fixed charge stabilises cash flow. Also, a high proportion of the operating costs of a heat network are fixed in the short term.

In principle the fixed element should cover regularly recurring operational and maintenance costs and the variable element should cover energy use. For residential rental tenants, the maintenance costs must be charged to the landlord and so it is particularly convenient if the fixed charge exactly matches the relevant O&M costs.

8.1.5 Variable charge

Given an overall limit on what can be charged to the customer, set by reference to a relevant external benchmark, such as retail or wholesale gas prices, then the higher the fixed charge, the lower the unit cost of consuming heat. In general, a low unit cost is not desirable as it reduces the incentive for customers to economise on heat consumption. A balance needs to be struck between the interest of the operator in a steady cash flow and preserving incentives for consumers.

For heat networks that serve existing dwellings with a higher heat demand, it may be necessary to set more than one variable charge for heat in order to ensure that all customers benefit from the system.

8.1.6 Commercial tariffs

The same tariff principles can be applied to commercial developments. Prices for heat chargeable to commercial customers are generally lower than for residential, reflecting their much higher levels of consumption via a single connection and their reduced requirements for customer services.

The market for gas supplies to businesses is more fragmented than the retail domestic market. Many private sector firms have national agreements for gas supply and many public sector organisations participate in the 'Government Procurement Service Framework Agreement for the Supply of Natural Gas, Ancillary and Associated Services' run by Buying Solutions, or participate in the procurement service offered to local authorities by Laser Energy. These various agreements may provide a suitable benchmark for the avoided cost of gas supply.

Where reference to such agreements is not feasible, a 'gas comparator' for commercial developments can be obtained by reference to DUKES, which publishes data on prices paid by industrial companies for gas.

For commercial customers, the avoided cost of maintenance can be determined by reference to quotations from specialist firms for the maintenance of central heating systems, taking care to compare like-with-like.

Similarly, the connection fee payable in respect of commercial buildings can be based on a calculation of the avoided cost of connection to gas plus the avoided cost of carbon reduction.

8.1.7 Wholesale heat tariffs

Wholesale heat tariffs will be needed where a DBO contractor is paid for heat supplied via a heat network to the local authority or landlord

who retails it to customers, or where a local network is supplied with heat by means of a connection to a larger network.

Wholesale heat tariffs can be developed following the same principles as for commercial customers, set out above. As the scale on which heat is to be supplied wholesale is likely to be significantly higher, the avoided cost calculation is likely to produce a lower total price.

How the total wholesale price for heat is divided between fixed and variable components will depend on the capacity of the connection, and the expected total demand for heat, as this affects the commitment that the heat provider must make at the energy centre. The fixed element of the charge for heat may be constructed on a 'take-or-pay' basis.

8.2 Revenue management

As with other utilities, billing consists of reading the heat meters and collating the data into a database. Heat meters can be read in person or remotely, depending on the type of meter. Once the consumption data is collected and validated, a bill is prepared and issued to the customer. Bills can provide additional information for customers, including cumulative and average consumption and equivalent carbon emissions or carbon savings as compared with a standard benchmark for that consumer type.

The normal position for a customer with a good credit history is to bill in arrears, and not to place a deposit into the billing system. If the customer's credit rating is poor, or drops due to persistent non-payment, the billing system can be kept in credit or a deposit held while still allowing payment in arrears. Fixed monthly direct debit arrangements can be used to spread payments evenly over the course of the year (since demand will normally be high in the winter and low in the summer).

Alternatively, a formal pre-payment system can be used. Pre-payment is generally run by hardware in the HIU, and thus has a cost. However, with smart meters, pre-payment can now be achieved solely through billing system software.

8.3 Debt management and credit risk

Accurate metering and billing is essential to minimise the quantity of bad debts. A well-managed heat network should be able to limit bad debts to about 1% of revenues, which is the typical level for electricity and gas suppliers. If so, no specific allowance for bad debt need be made, since the benchmark tariffs will already include an adequate allowance for bad debt.

Debt management is achieved primarily through an escalation procedure that combines formal reminders of amounts due, telephone contact to identify specific issues, referral to Citizens Advice or other bodies to help those with financial difficulties and, finally, suspension of service. These stages of escalation will be documented within the customer charter and, because of the potential risk to the health of the customers, suspension is only permitted as a last resort and in accordance with specified procedures (e.g. during summer). Where a heat network is being operated under contract (such as under concession or on behalf of a local authority), the contract will set out the conditions under which suspension may be made.

Pre-payment or requiring accounts to be kept in credit can be used in case of persistent payment problems. Pre-payment and credit customers should normally be charged the same prices as other customers, as arranging pre-payment does not normally entail additional costs of revenue management.

PLANNING GUIDANCE FOR DEVELOPERS

9

This chapter covers the planning policy and development control issues which are likely to arise in connection with new development which could or does connect to a heat network, and development of heat networks themselves.

Developers should always take planning advice or check with their local planning authority at an early stage in the project to ensure that they have an up-to-date understanding of relevant planning policy and statute.

9.1 Planning policy framework

There is considerable policy support for the implementation of decentralised energy. Decentralised energy promotion is a key policy theme in the National Planning Policy Framework, which requires local authorities to identify and plan for opportunities, including heat networks.

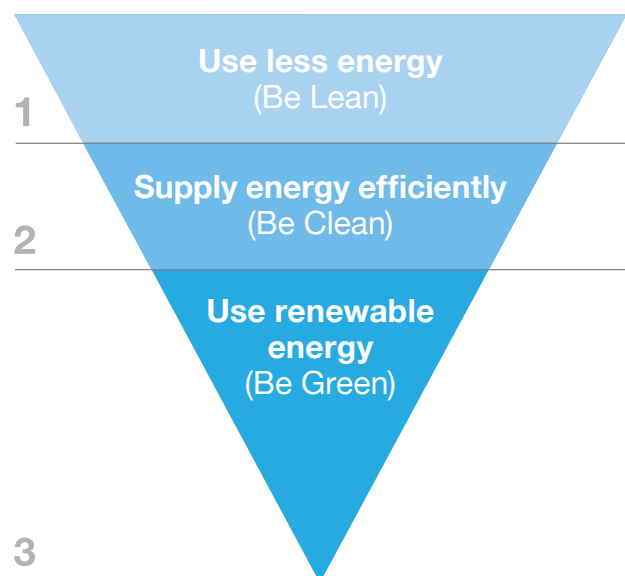
9.1.1 Policy summary

At the regional scale, the London Plan²⁰ (2011) requires that all major developments seek to achieve demanding carbon reduction targets through the application of the Energy Hierarchy (see Figure 33) to the design of the scheme. Decentralised energy networks provide the primary means of ‘supplying energy efficiently’ (Tier 2). Even where a potential heat network connection would not provide very significant carbon savings against a stand-alone solution, the potential of heat networks to improve their savings through future low or zero carbon heat supplies means that it may still be appropriate for a development to connect to a heat network. The draft Further Alterations to the London Plan (2014) do not change these principles but place more emphasis on the transition from gas CHP-based systems to those powered by energy

from waste and lower temperature secondary heat sources.

Extensive guidance is provided by the GLA through its guidance for developers on preparing energy assessments²¹ and the Sustainable Design and Construction Supplementary Planning Guidance²². In addition, the GLA has worked with its borough partners to establish a standard of good practice for borough-level policies and development management practices to ensure widespread compliance with London Plan policy. The GLA and boroughs also hold extensive information on potential, planned and existing networks across the capital. Much of this information is shown on the London Heat Map, but other schemes may not yet have been published. Given the typical lead times for network development and connection, these policies, guidance documents and local knowledge should be referred to at an early point in the development of a project to ensure that potential opportunities to connect are maximised.

The sub-sections of this chapter identify some key policy issues related to heat networks and connections.



²⁰ <http://www.london.gov.uk/priorities/planning/london-plan>

²¹ <http://www.london.gov.uk/priorities/planning/strategic-planning-applications/preplanning-application-meeting-service/energy-planning-gla-guidance-on-preparing-energy-assessments>

²² <http://www.london.gov.uk/priorities/planning/consultations/draft-sustainable-design-and-construction>

9.1.2 Requirements to connect

Where there is an existing heat network, policies may require new developments to connect to the network unless it would not be feasible or viable to do so (see section 9.4.3 for further details).

Such policies may set a distance threshold or designate an area within which developments are expected to connect. The requirement to connect will typically include the provision of the means to connect to that network and a requirement to bear the cost of connection.

9.1.3 Relationship with other policy requirements

In addition to specific requirements to connect to heat networks, local planning policy may require a certain level of energy performance on site, for example a requirement to achieve a certain reduction in carbon dioxide emissions in accordance with Building Regulations Part L²³. In some instances there may also be specific targets for the percentage of the energy demand to come from decentralised and renewable or low-carbon energy sources.

It will be for the applicant to determine the best method to achieve the target for each particular development. Connecting to a heat network is likely to make a significant contribution to on-site carbon reduction and hence the achievement of other policy targets.

Where such a policy target exists, the carbon dioxide reductions anticipated from connection will need to be assessed and agreed by the local planning authority. It may be appropriate in this context to secure as part of a connection agreement a commitment from the heat network operator to a maximum carbon dioxide emissions factor for the heat supplied by the network. Other measures proposed to contribute to the relevant carbon dioxide reduction target should be complementary with network connection technologies in order to achieve maximum reasonable carbon dioxide reductions.

9.1.4 Technical specification

Local planning authorities may wish to take into account the design standards set out in the Manual when specifying connections or future proofing measures and in assessing planning applications. In some cases local authorities may choose to adopt the specifications contained in this guidance as a supplementary planning document.

²³ <https://www.planningportal.gov.uk/buildingregulations/approveddocuments/part/>

9.2 Planning of network development

One of the key challenges of developing a new heat network is the timing between the delivery of the new network and the completion of new developments which would be connected to the network. If the network is delivered early, viability may be affected by delays to consumer connections. If it is delivered late, new developments may need to secure contingency supplies of heat, or they may have to commit to alternative heat supply solutions. This section provides some guidance of how to address this issue through planning.

There are essentially three cases to consider assuming that a new building development falls within an Energy Master Plan (EMP) that proposes a heat network. These are identified below and commentary provided on options for the new development.

Case A: Where an EMP identifies the feasibility of an area-wide heat network but no firm plans exist as to who will build the network or by when:

The development should 'future-proof' a connection assuming it has a single energy centre for the site (or plant room if a single building development) producing heat for space heating and domestic hot water. Future-proofing involves providing 'tees' and isolation valves in the hot water headers to facilitate the connection of an interfacing heat exchanger at a later date.

- A space reservation could be provided for the heat exchanger, or it could be planned that the heat exchanger replaces a heat-only boiler at time of making the connection to the heat network.
- Provision should be made in the building fabric to facilitate future heat network connections;

- External buried pipe work routes should be safeguarded to a nearby road way or similar location where connection to the main heat network would be made.

Case B: Where there is a heat network being delivered but there is no programme to connect the development due to its distance from the network and the lack of plans for intervening sites:

- The development should be designed on the basis of its own heat solution, and 'future-proofed' according to the guidelines given above;
- Allowance could be made to defer installation of more costly heating plant (such as lower carbon CHP engines or heat pumps) for, say, five years to allow time for the heat network to be constructed and connected to the network. Once the network connection is made, the requirement to install such plant falls away.
- If the heat network connection is not made within the deferral period and there is no reasonable prospect of doing so, then the development should be required to install the lower carbon generation system. A planning obligation could be employed from the outset to ensure the installation is carried out.
- During the deferral period, the development would be supplied with heat from its own simpler system (e.g. heat-only boilers); it should be noted that this will affect the carbon emissions from the development during this period.
- The developer could be given a planning condition allowing any 'freed-up' plant space resulting from the heat network connection to be used for more profitable purposes (e.g. an extra parking space).

Case C: Where there are firm plans to connect a development to the heat network, but the network build-out will not reach the new development until some years after the development is complete:

- The development should design for a heat network connection from the outset, taking account of the flow and return temperature specification of the heat network.
- Heat should be provided by temporary on-site generation plant, which could be provided by the entity responsible for the heat network as part of the supply agreement.

9.3 Do heat networks require planning permission?

The construction and installation of heat networks would normally fall under the definition of ‘development’ under the Town and Country Planning Act 1990²⁴. Therefore such works would normally need planning permission. This is true of all utility network installations, but unlike electricity, gas and water networks, heat networks are unregulated utilities and therefore do not benefit from the permitted development rights which are enjoyed by the regulated statutory undertakers. However, there are a number of routes by which planning permission for heat networks can be secured. These routes include:

- Permission as part of a wider development;
- Local authority Part 12 permitted development rights;
- Electricity Undertaker permitted development rights;
- De minimis treatment of heat network works; and
- Adoption of a Local Development Order.

The guidance provided below on each of these routes is of a general nature; specific planning advice should be sought at an early stage in a project to ensure that all legal and policy requirements are correctly identified.

9.3.1 Permission as part of a wider development

Where a development proposes to provide an on-site heat network or to connect to a heat network, the works within the planning application boundary for the heat infrastructure including heat source, pipe, heat interface units, would normally be implicitly included in the overall permission for the development, in the same way as would apply to other utility infrastructure. If the energy centre is located on

²⁴ <http://www.legislation.gov.uk/ukpga/1990/8/contents>

the site then the energy centre building (if separate) would need to be explicitly included as part of the proposed development and shown on the submitted drawing, including details of any flue or stack. Emissions from heat generation plant would also need to be reflected in any air quality assessment which was required for the development.

Where a new pipe connection is required between an existing network and the development site, it may be most convenient to include this connection route into the development's planning application.

9.3.2 Local Authority Permitted Development Rights

Where a network is brought forward by a local authority on land belonging or maintained by them, the network may be able to be delivered using Permitted Development Rights afforded to the Local Authority in Part 12 of the Town and Country Planning (General Permitted Development) Order 1995 (as amended)²⁵. Such powers are subject to maximum thresholds which state that buildings must be no more than 4m in height and the total volume of development (i.e. buildings and pipe work) must be no more than 200m³. In addition, the rights would be limited to development which does not require an Environmental Impact Assessment, see the Town and Country Planning (Environmental Impact Assessment) Regulations 2011²⁶.

9.3.3 De minimis treatment of heat network works

In some cases the scale of heat works may be deemed to be of such a minor nature as to be insignificant. In such cases the local authority may agree with a developer that planning permission does not need to be sought. This might apply to a short heat network connection between the edge of a development site and a nearby network.

9.3.4 Adoption of a Local Development Order

One alternative to conventional planning permission would be for the local planning authority to use a Local Development Order (LDO) to secure a 'class-based' planning permission for the development of heat networks. LDOs can be adopted by local authorities to grant permission for a class or type of development across a whole or part of a local authority area. A development which met the description contained within the LDO would be able to commence as soon as any conditions set out in the LDO were satisfied. The London Borough of Newham was the first authority in the country to use this approach for its planning London Thames Gateway Heat Network²⁷.

²⁵ <http://www.legislation.gov.uk/uksi/1995/418/contents/made>
²⁶ <http://www.legislation.gov.uk/uksi/2011/1824/contents/made>

²⁷ http://www.newham.gov.uk/Documents/Environment%20and%20planning/District%20Heat%20Network%20LDO_adopted_20%203%2013.pdf

9.4 The planning application process

This section provides guidance for developers in relation to the connection of new development to a heat network.

9.4.1 Pre application discussions

Each development site will have a unique set of circumstances and opportunities which will affect the ability to provide or connect to a heat network. It is therefore vital that discussions regarding heat network connection are commenced with the local planning authority as soon as possible. Such discussions can be combined with discussions on the development more generally; however it is essential that the relevant carbon/energy officer from the local authority is in attendance.

The following topics in respect of the provision of heat networks might be discussed at the pre-application meeting:

- Potential of the development for heat networks;
- Local policy requirements;
- Planning application boundary (should be drawn so as to include all local supply pipe work required for the connection);
- Specification of heat network connection/apparatus;
- The expected location and timing of connection to the heat network; and
- Information to be submitted with the application.

9.4.2 Information to be submitted

In preparing a planning application, the local authority's validation list should be referred to. This list, which can usually be found on the authority's website, sets out the information the local planning authority expects to be submitted with various types of application.

A heat network connection is not likely to increase significantly the amount of information to be submitted as part of the planning application and is unlikely to trigger the need for additional assessments to be undertaken. Where a planning application is supported by other assessments, such as a Utility Strategy, Archaeological Assessment or Flood Risk Assessment, the heat network connection or future proofing apparatus should be assessed in the same way as the rest of the development.

In respect of applications for developments which include a heat network connection or future proofing measures, the following information might reasonably be expected in addition to that already required for the development:

- Plan showing the pipe route and connection point to the wider network;
- High level technical specification;
- Date of implementation and connection;
- Details of financial contributions;
- Feasibility and viability assessment; and
- Energy statement demonstrating carbon and energy savings.

9.4.3 Feasibility and viability assessments

Policy requirements to connect to heat networks or include future proofing measures will normally be subject to evidence whether it is feasible and viable to do so. Most local authorities will require applications to be accompanied by a feasibility and viability assessment which will be scrutinised by their officers in order to determine whether connection is reasonably practicable.

In assessing viability (cost and financial implications) and feasibility (engineering and practical constraints) local planning authorities are likely to consider the following:

- The size of the development, and the heat load and energy demands;
- The distance of the development to an existing or planning heat network;
- The presence of physical barriers such as major roads or railway lines
- The cost of connection and the impact this has on financial viability;
- What efforts the applicant has made to secure agreements to create a new network through connection of nearby buildings or estates. This will be an increasingly important part of driving the development industry to take ownership of planning and developing networks;
- The proximity of any public sector estates and buildings with communal heating systems, especially uses such as swimming pools, hospitals and large housing estates;
- Land use mix of proposed development;
- Land use mix and density of surrounding built environment

The developer should agree the scope of a feasibility and viability assessment with the local authority early on. The local authority, or relevant heat network operator, may be able to provide relevant information to inform the assessment, including for example the approximate cost of connection.

9.4.4 Other consents

In addition to securing planning permission there may be other consents which must be in place before work can commence. These include the need for permits under the Environmental Permitting Regulations (EPRs) should these be required. Any works undertaken in Air Quality Management Areas may also require additional approval under the Clean Air Act 1993. In order to implement elements of a scheme that fall within the highway, it may also be necessary to secure a Street Works Licence under Section 50 of the New Roads and Street Works Act (NRSWA) 1991. Before an application can be submitted all statutory undertakers, including utilities operators, must have been consulted and confirm that they are satisfied with the proposal in respect of the protection or diversion of their apparatus. In order to determine the Street Works Licence application the local authority will also need to be satisfied that the proposed operator and contractor would meet their requirements i.e. that the operator will undertake the works in the highway in an acceptable way. Section 81 of NRSWA sets out the 'duty to maintain apparatus'; the organisation undertaking the work must demonstrate that it will be able to maintain the apparatus once it is installed. Therefore, this process will also satisfy the local authority that an operator who can demonstrate the relevant credentials will be installing and maintaining the apparatus.

9.4.5 Planning conditions and obligations

Where connection to an existing or future heat network is feasible and viable, a commitment to connection may be secured via a legal agreement; this may include provision for a financial payment to the local authority to enable connection (although a connection charge may instead be paid directly to the heat network operator). Planning conditions may also be used to ensure the connection is implemented.

Where it has been agreed that the development will connect to an existing heat network, a planning condition might be used to prohibit the development being occupied until a physical connection to the network has been installed and commissioned.

Where it has been agreed that a development will connect in the future, a legal agreement may be used to require a development to connect at any economically viable opportunity. Such an obligation is likely to state that the developer should use all reasonable endeavours to connect and should also recognise that the most suitable opportunity may arise at some point in the future, for example at the end of the economic life of a stand-alone CHP plant. Within the legal agreement a cut-off point will be defined, which will be the latest point at which a decision can be made in relation to network connection. If at this time it is not possible to agree connection to a network, due to the network being incomplete, the alternative energy strategy submitted with the planning application should be implemented (or submitted for agreement and then implemented).

9.4.6 Financial contributions

Increasingly local authorities in London are seeking to secure financial contributions to fund off site infrastructure which might include heat networks. There are two main routes to securing such contributions; Section 106 Agreements and the Community Infrastructure Levy (CIL).

The introduction of the CIL significantly reformed regulations governing the use of financial contributions. It is likely that the majority of local authorities will adopt a CIL Charging Schedule in the future. Once a Schedule is adopted all new development will be charged at a flat rate per square metre basis, and this payment should be taken into account in viability modelling from the offset. Local authorities may choose to fund heat network infrastructure using receipts from the Levy which potentially means there is a new funding stream available to deliver heat networks. These contributions, whether through a S106 agreement or CIL, would be separate and additional to the connection charge which would be made by the heat network operator to cover the reasonable cost of connection itself.

INNOVATION AND THE FUTURE OF DISTRICT ENERGY IN LONDON

10

This section looks to the future direction of the decentralised energy industry, in particular with regard to 'fourth generation' heat networks.

10.1 Lowering operating temperatures of networks

Whether for an existing or a new heat network, heat is transferred from the heat source and distributed through the network to a building's heating system. It is assumed that in modern systems or existing systems undergoing refurbishment that the heat network and building heating systems are hydraulically separated by a heat exchange substation and/or heat interface unit (HIU). The heat network supply temperature must be a lower temperature than the heat generation source (heat generating plant or another heat network supply temperature) and a higher temperature than the building's heating system supply temperature in order to ensure heat transfer in the right direction. The inverse relationship is true of the return temperatures. This means that the lowest practical temperatures for a system are dictated by the performance of buildings connected to the heat network.

Designing heat network temperatures to meet the requirements of the buildings, as opposed to that of the heat generators, produces lower operating temperatures in the heat network. Lower heat network operating temperatures allows more heat to be extracted from heat generators (e.g. gas boilers becoming condensing) and a variety of plant (e.g. CHP engines and heat pumps) to operate more efficiently. Even if plant is not changed on an existing heat network after lowering the operating temperature the ability to do so allows far greater flexibility in the future.

Lower heat network operating temperatures also create a smaller temperature difference between the heat network pipes and the ground (or air) that they are routed through. This leads to a

reduction in heat loss and saves in heat generation required and allowing heat to be provided at lower cost.

Monitoring and control of the return temperature of the heat network from a building can be used to address unacceptably high return temperatures. Heat exchange substation and building heating systems should be oversized for operation during mild weather and could potentially be oversized at design winter conditions. This will allow the ability to reduce the heat network supply temperature, but attention should be paid to what provisions have been assured by the heat network operator. The design of the building internal heating system has a key role to play in the reduction of operating temperatures. Radiators can be oversized or designed to operate at low temperatures, the operating temperatures of the building could be lowered. This in turn would reduce the heat network supply temperature required at the heat exchange substation.

Unless precisely designed, it is usual to find that existing building heating systems have been designed to accommodate margins of flexibility in operation and demand. This leads to a tendency for space heating systems to have a supply temperature far higher than the required room temperature. It is typical for a 21°C room to be heated by 80°C water.

Similarly a domestic hot water system has to balance a variety of priorities compounded by the need to minimize the risk of legionella. It is typical for domestic hot water to be stored at 60°C, heated by 80°C water.

To allow the heat network to operate at reduced temperatures buildings need to reduce their heating systems supply temperatures. This is beyond the control of the heat network operator; however it is within their control to efficiently operate the network. Modulating the volume flow

rate by variable volume flow control of the main circulating pumps will allow better control of return water temperature arriving back at energy centres and ensure that both thermal plant and the heat network is operated efficiently. The following key points are characteristics of variable volume design of heat networks:

- Heat network main variable speed drive (VSD) pump motor inverter control;
- Heat network main differential pressure measurement at low system pressure point providing VSD control signal; and
- Consumer connection primary heat network two-port motorised control valve for new installations or as replacement of three-port or bypass existing arrangements. Two-port control valves are actuated on building temperature and domestic hot water demand.

There may be opportunity to change the operating characteristics of older buildings connected to the network in order to reduce their required supply temperature. Retrofitting insulation will reduce overall heating demand, and may allow a reduction in flow temperature. Where air handling units (AHUs) are utilised, a constant supply temperature at the design supply temperature is likely to be required. In such a case, two substations may be able to be utilised for heating – one to provide a constant temperature to the AHU and a second to provide a variable temperature to the remaining heating demands.

Many existing buildings currently operate on a fixed volume regime. A change to variable volume flow would allow the internal system to be controlled based on a return temperature set-point, resulting in a reduced and more reliable return temperature on the heat network side of the heat exchange substation. In addition, existing hot water storage systems could also be switched to instantaneous systems to help reduce the return temperature of the system.

In order to avoid these changes in the future, new developments could be specified to have low temperature heating and instantaneous domestic hot water at the master planning stage.

10.2 Heat storage and smaller pipes

Heat networks with a higher differential temperature require lower flow rates to deliver heat, thereby saving on heat transfer losses and pumping requirements. Pipe diameters can be reduced by lowering heat demand through good practice energy efficiency measures. Localised hot water storage in individual buildings or buffer tanks on the primary side of the heat exchanger could be used to flatten the demand profile.

10.3 Developments in electricity market

10.3.1 License lite

Following consultations with a working group of decentralised energy stakeholders in February 2009 Ofgem published proposed changes to the standard conditions for electricity supply licences to include a new condition, enabling licence applicants to be granted an electricity supply licence without becoming parties to the Balancing and Settlement Code, the Master Registration Agreement and other industry codes, providing certain conditions were met. The purpose is to enable smaller electricity generators/suppliers to be able to supply electricity retail, without the constraints of private wire (see below). The main condition the applicant has to comply with is the requirement to ensure that it can obtain a range of market interface services from a fully licensed electricity supplier. Ofgem has published guidance on the services that are involved.

Although Ofgem's proposals laid out the principles and a regulatory route forward, translating the proposals into an actual 'junior' electricity supply business involves a range of complex issues of implementation. However, on those being resolved, the effect will be that small players can enter the electricity supply market and supply their electricity retail to any premises connected to the public electricity distribution system, thus gaining the prospect of earning higher returns on the electricity they export. The effect should be to enable schemes to earn greater over-all returns on their energy generation; enabling more CHP decentralised energy schemes to become viable and capable of attracting investment.

The Greater London Authority has led a project to secure the implementation of the Ofgem proposals and is currently taking steps to apply for a 'licence lite' itself. This will enable retail supply to be made by London boroughs and other public sector bodies in London owning electricity generating capacity.

10.3.2 Private wire

It may be worthwhile for a decentralised energy scheme to supply locally-generated electricity to customers over a private network, thereby avoiding costs and losses arising in the public transmission and distribution system. Electricity supply made in compliance with the Electricity Class Exemption Order does not have to be licensed and the regulatory burden of licensed supply does not apply.

Connecting customers to a private electrical network may entail some alteration to existing wiring, the installation of additional meters and possibly a switchboard. If a new cable has to be run down a street, it may be difficult to secure permission, since access to the public domain is normally limited to organisations serving the public interest. However, the electrical cable would normally be able to follow the same route as the heat network.

To cover the capital costs associated with a private wire solution, it will normally be necessary to enter into a long term contract with the intended customers. The price at which electricity is to be supplied will also normally be benchmarked, to ensure customers obtain good value for money.

The private wire option is not as useful as used to be thought. First, under the Exemption Orders, there are limits on the size of private wire scheme which can be used to supply electricity to domestic consumers. In practice

that limit is 1 MW per site or set of private wires. Since heat networks are getting bigger, that size limit will become more and more of a constraint and it is very unlikely that the Government will increase the allowable licence exempt scope for domestic consumers, for fear of eroding the competitive market. Second, the 'Citiworks' case of 2009 has caused changes to be made to the licence exempt arrangements for electricity supply that give all parties (domestic and commercial) who are connected to private wire systems, the right to ask for a supply through those wires from a third party supplier. The effect is that the private wire owner has lost the ability to make an exclusive supply to those connected to its wires. Such rights of third party access are currently difficult to implement but it can be predicted that they will become easier. Third, electricity from CHP cannot normally be the basis of a 'firm supply' offer, so that either the supplier or the customer would incur additional costs in arranging a top-up supply.

It is partly because of the constraints on private wire described above that the 'licence lite' alternative, having no constraints on scale and far more flexibility, is attracting increasing interest.

10.3.3 Netting off

Netting off is an option available to large energy consumers that also operate energy generation plant as a means to obtain a retail price for the energy they produce. Under this arrangement an energy supplier will reduce the total bill of the large consumer by an amount equal to the energy that the large consumer can export to the grid.

This option is available only to large energy consumers who operate generation plant since the incentive for the supplier is to secure the contract to provide the remainder of their energy by effectively offering a discount to the consumer.

10.4 District cooling

District cooling operates on similar principles as heat networks, whereby chilled water is produced centrally and distributed through a network of insulated pipes. This removes the requirement for energy intensive local cooling in buildings, thereby potentially reducing the city's carbon output.

District cooling has been successfully incorporated into heat networks in Helsinki and Copenhagen as a complementary system, making a tri-generation scheme as outlined in the diagram below, showing how the system provides electricity, heating and cooling. The installation of a heat network may be the ideal time to install district cooling when the major ground works are taking place to install the pipe work.

Copenhagen's scheme uses cold seawater as a source of free cooling and uses surplus heat from the heat network to drive absorption chillers to provide cooling when cold seawater cannot meet peak demand during the summer. This scheme has allowed Copenhagen to reduce the carbon dioxide emissions by 67% when compared to traditional cooling. The carbon performance of absorption cooling is dependent on the nature of the surplus heat from the heat network. Modern high performing electric chillers frequently demonstrate superior carbon reduction performance.

District cooling schemes are most attractive when there is a large heat sink locally, such as the sea which can act as a free source of cooling. In direct comparison with electrical chillers, the coefficient of performance of an absorption chiller is poor. As the grid decarbonises, it is important to consider both options for cooling.

APPENDIX 1

Example of Technical Standards to enable future connection

Islington Council have developed technical standards to enable future connection to heat networks as part of their Environmental Design Planning Guidance: Tackling fuel poverty,

enhancing quality of life and environment for all. The following extract is taken from this supplementary planning guidance document and reproduced here with kind permission of Islington Council and acknowledging PB and AECOM as providing technical support for its development.

-
- 1.0.1** This section provides guidance on how the secondary heat network and systems contained within a new development should be designed to allow efficient future connection to a decentralised energy network. The council already secures details of design for future connection via planning condition for major developments; by setting out clear standards in this guidance we seek to provide clarity about our requirements for all stakeholders.
- 1.0.2** Secondary systems shall be designed based on constant operating temperatures and variable flow rate criteria to ensure full compatibility with primary supply systems.
- 1.0.3** Differential temperatures (difference between flow and return temperature) in the secondary distribution networks must be kept as large as possible to minimise pipe size, enable the supply of decentralised energy network heat from various heat sources and optimise any CHP output. To ensure that low grade waste heat, and other heat sources, can be utilised by decentralised energy network the secondary design must focus on low return temperatures. The temperature differential at the primary / secondary interface will depend on the design of the internal building services. Therefore, all internal systems must ensure compatible designs that maintain optimum differential temperature and low secondary return temperature at the interface during all demand scenarios.
- 1.0.4** Key considerations for the design of building internal systems are as follows:
- The selection of low temperature operating systems such as under floor heating systems to significantly reduce return temperature.
 - Low flow rate radiator circuits for buildings, complete with thermostatic control.
 - Where used radiator circuits should be designed to operate satisfactorily at low temperatures with a maximum 70°C / 50-40°C flow and return (as opposed to the traditional 82°C / 71°C) without compromising the ability of the system to deliver the required level of heat. Return temperatures should be minimised and systems capable of operating at very low flow and return temperatures should be considered.
 - The use of direct instantaneous hot water generation should be considered. This removes the need for hot water storage, reducing energy consumption and heat losses, reduces pipework, space and pumping costs and more importantly secures low return
-

temperatures by adopting a heat exchanger arrangement that uses the heat network return water to pre-heat the cold water makeup.

- Ensure minimum return temperature from hot water service connections, whether storage or instantaneous.
- Taking advantage of unique opportunities, like heat sinks such as swimming pools, to optimise return temperatures.
- The primary circuit will be sized for a nominal maximum pressure of 16 bar (PN16). Therefore the head loss at the primary circuit connections within the building and the plant room will be a target of 1.5 bar.

- 1.0.5** Shunt Pump and Low Loss Header: This is a common inclusion in heating systems but should not be used on a heat network. This arrangement will only serve to return supply temperature water back to the heat exchanger as demand reduces on the main building sub-circuits.
- 1.0.6** Two-port Control Valves and Variable Speed Pumping: The use of two port control valves in constant temperature system applications is fundamental in ensuring that the unnecessary return of supply water temperature back to the heat exchanger is avoided. The use of variable speed pumps, in conjunction with differential pressure control valves for system balance should be considered as it provides an efficient method of delivering only the energy that is needed and when combined with the parallel pumping, provides the required turn down of the system to maintain optimum return temperatures throughout the annual demand profiles.
- 1.0.7** Circuit Mixing: Wherever possible, water returning from one heating circuit at a high temperature should be used in a second circuit. This is not always possible since one circuit may demand energy at a different time to another.
- 1.0.8** Metering: Energy meters measure volume flow rates and supply and return temperatures to provide an accurate record of energy usage. The preferred choice in a modern system is an ultrasonic device. Metering shall be installed to record flow volumes and energy delivered on the primary circuit. For residential connections, meters will also be installed on the secondary circuit where individual dwelling billing is required. The energy metering system must include a flow meter, two temperature sensors and a stand-alone integrator unit complete with battery back-up.
- 1.0.9** Route onto and through site: It is a requirement that there is space on site for piping connecting the point at which primary piping come onto onsite with the on-site heat exchanger/ plant room/ energy centre. If the proposed site for the heat exchanger and the point at which heat network piping comes onto site are separated by an obstacle such as deep water feature, it may not be possible to connect them. Therefore proposals must demonstrate a plausible route for heat piping and demonstrate that suitable access could be gained to the piping at short notice and that the route is protected throughout all planned phases of development.

- 1.0.10** Plant Layout: New developments where the detailed connection arrangement to a decentralised energy network is unknown will require physical space to be allotted for installation of heat exchangers and any other equipment required to allow connection. The table below indicates the space required as dictated by the site heat demand.

Item	Heat exchange substation details						
Output (kW)	250	500	800	1000	1500	2000	3000
Number of heat exchangers	1	1	1	2	2	2	2
Length (mm)	1500	2250	2250	2750	2750	3000	3000
Width (mm)	500	750	750	1500	1500	1500	1500
Height (mm)	2000	2500	2500	2500	2500	2500	2500
Approximate dry weight (kg)	750	1050	1300	1725	1800	1925	2000

Table A1.1 Space requirements for heat exchange substations

- 1.0.11** The figures indicated in the table above are the packaged skid dimensions only. The sizes listed are indicative and space requirements should be considered on an individual site and system design basis. Additional space allowance for access and maintenance requirements must be considered (an allowance of at least 1m should be incorporated all around the skid to facilitate access and maintenance).
- 1.0.12** If the development has a plant room/energy centre it should include provision for the following requirements to ensure it can accommodate a connection to an off-site area wide heat network:

Item	Specification Requirements
Room Illumination	Minimum light level: 150 lux
Electrical Connection	III 380V to earth / 32 A (See Note 1 below)
Electrical Supply	220 V AC (+/- 5%), 50 Hz (+/- 3%) Thermo-magnetic protection recommended 16 A curve C (the box incorporates a thermomagnetic protection of 10 A curve C in the supply)
Water Supply	DN 25
Water Discharge	Provide wastewater discharge line in the plant room and a sump to collect condensation from heat exchangers
Concrete Bases	Provide concrete bases for heat exchangers and pumps (if present)
Ventilation	Mechanical and continuous, with a minimum of three air changes per hour
Health & Safety	Plan showing evacuation route in case of fire, located in a visible place. The plant room should not have elements of risk to health and safety (sharp metallic objects, holes in roof or floor without protection,...)
Layout & Dimensions	As described for the relevant packaged substation unit

Table A1.2 Plant room requirements

APPENDIX 2

Case Study: Danish approach

This case study is provided courtesy of Ramboll Energy

Historical context

When studying the layout principles used in Danish heat networks it should be noted that there is no single Danish approach. Depending on the technical conditions, each network has had its own individual characteristics, but over the years a best practice has become generally accepted. In particular the large city-wide systems like the Copenhagen system have realised the benefits of this technical approach.

The design concept of the Copenhagen heat network is based around a transmission heat network supplying heat from the city's Combined Heat and Power plants and waste to energy to a number of both existing and new distribution heat networks serving local communities via hydraulic interface stations. Historically, this concept evolved as a result of the Danish Heat Laws introduced in the 1980's when it became mandatory to recover heat from the power stations.

The approach taken was to develop a transmission network hydraulically separated from the distribution networks that it served. In terms of system pressure, the transmission network was designed according to an average head concept and was sized for the transport of the base load capacity delivered from the main heat production facilities. This enabled it to connect many heat production units that were geographically separated over large distances across the city. It also provided sufficient flexibility to allow the future connection of new heat production facilities without impacting on design or operation of the existing system.

The local heat networks were connected to the transmission network through hydraulic interface stations, which created a hydraulic separation. Minimising construction costs was a

major driver in the design as was the requirement to interconnect many existing local networks in a seamless way. In many cases these existing networks had been designed according to different thermal and hydraulic parameters and could not therefore be integrated through a direct connection to the transmission network.

As the heat network was extended to new parts of the city, new distribution networks were connected through additional hydraulic interface stations. Local peaking plants were also constructed to meet peak demand events. These were embedded within the distribution networks as an alternative to placing them at the main heat production facilities. This approach allowed the transmission network to be designed and optimised around a higher operating pressure/high velocity concept which in turn enabled the use of low diameter pipe work. At the same time, the distribution networks could be optimised for local conditions without having to meet the design requirements of the transmission network. The overall impact was a low construction cost relative to the alternative design options.

The high velocity concept was achievable in design terms due to the long, straight sections of the transmission network. However, it did increase the potential risk of damage due to pressure surges. The risk was manageable through an 'average head' hydraulic concept in which the static pressure of the network was maintained at a fixed level under all flow conditions.

Design Considerations

When a number of distribution networks are established they can be connected to one or more large central production plants through a transmission network. These distribution networks are hydraulically separated from the transmission network.

Transmission networks are in general characterised by distributing a large amount of heat over a relative long distance and thereby

having high velocities in the heat network pipes. The high velocities allow pipe sizes to be minimised, thereby minimising investment but do increase the risk of water hammering in case of pump trips.

In order to minimise the risk of water hammer, a fixed average head principle is used, where the static pressure is kept at a fixed average pressure level. The principle of the average head system is illustrated in Figure A2.1, where a transmission line connecting two production plants is indicated.

The pressure is fixed at the cold header (e.g. the inlet of the heat network return water to the condensers located in the energy production facility) of one the plants supplying heat to the transmission network. The concept requires heat network flow pumps as well as return pumps, which are regulated in order to maintain a symmetrical pressure profile around the level of the average head. Figure A2.1 illustrates this with pressure head in both supply and returns from the plant on the right are shown both for maximum and minimum load.

The heat network pumps (both flow and return) are controlled in order to maintain an average

head level in the network as well as the differential pressure in the network. Both the flow pump and the return pump may contribute to the differential pressure regulation and the average head regulation.

Figure A2.1 indicates a simple controller concept consisting of a differential pressure (ΔP) regulator and an average head regulator. The average head regulator adjusts the ratio between the speed of the supply and return pump in order to maintain the average head level.

Figure A2.2 shows the result from a simple model of this controller concept. The consumption in the network is increased by increasing the KV_ value of a valve (red line), representing the opening of a control valve to allow additional flow of hot water to the consumer. This will at first decrease the differential pressure in the network (dp_{cons}) but this will in turn lead to an immediate increase of the speed of the supply and return pumps (dotted lines) to compensate and maintain the constant pressure differential set point. It is seen that the average head level (blue line) is maintained in the process.

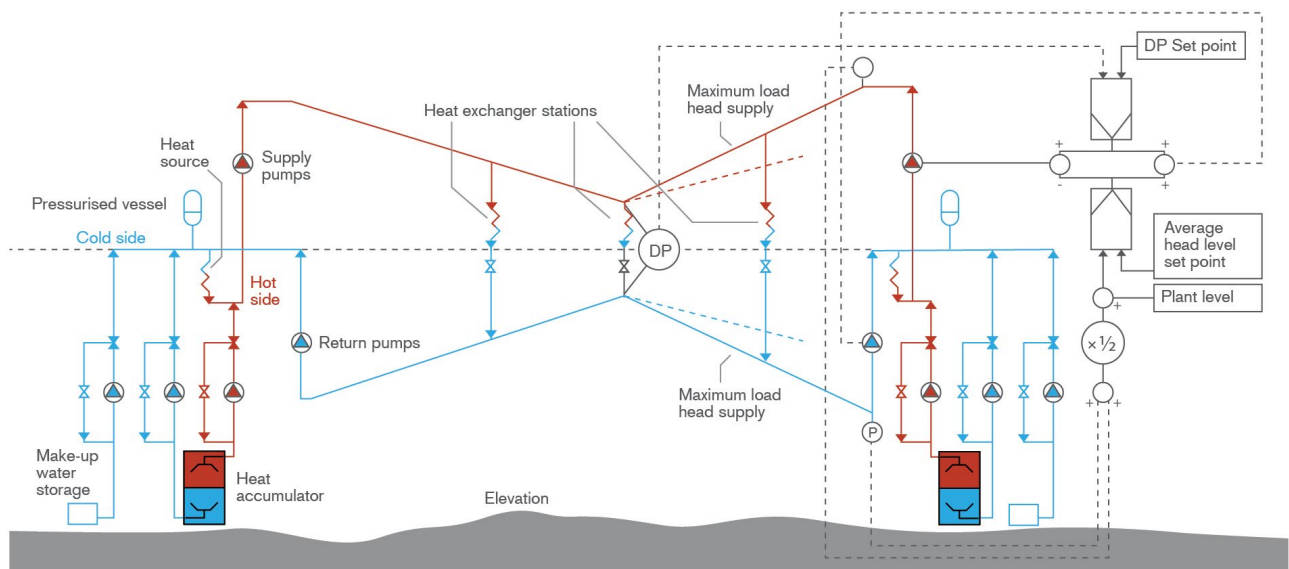


Figure A2.1: Principle of the fixed average head system

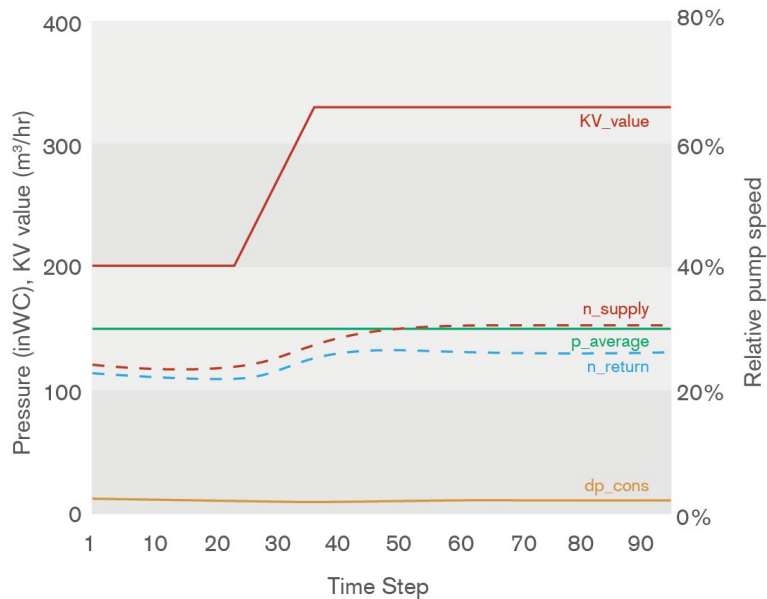


Figure A2.2: Illustration of results from a model of the controller concept

One of the main advantages of the average head level concept is that pressure may be kept within acceptable limits during a pump trip, provided that the supply pumps are tripped if the return pumps are tripped and vice versa. After a pump trip the head in the supply and return pipes of the heat network transmission system will simply settle at the average head level and thereby maintain a stable situation where the pressure is within acceptable limits all over in the network.

Furthermore, the fixed average head increases the possibilities for connection of production units along the transmission line. The average head system makes it much easier to achieve favourable pressure conditions in the network regardless of the load or the production situation. Figure A2.3 illustrates an example of a low load situation of a system where the pressure is maintained in the return leg (in this example by a heat accumulator tank). Further down the line another production unit, for example a waste-to-energy plant, is indicated, and it is seen with this pressurisation concept the minimum pressure may be unacceptably low

and can set a limit of how much of the available heat production from the second production unit can actually be utilised. This problem can be avoided by implementing the fixed average head system where it is easier to achieve favourable pressure conditions in the network regardless of load or the production situation.

All in all, networks with fixed average head are in general very safe to operate and very flexible to future expansion and connection of new production plants connected to the network.

Implications for London

The average head system used in Copenhagen follows one of a number of principles that can be used to develop wide area heat networks. Other types of system usually focus on the principle of maintaining pressure in the return leg and to have one large distribution network. There are advantages and disadvantages to each approach, depending on the context of the heat network concept being developed.

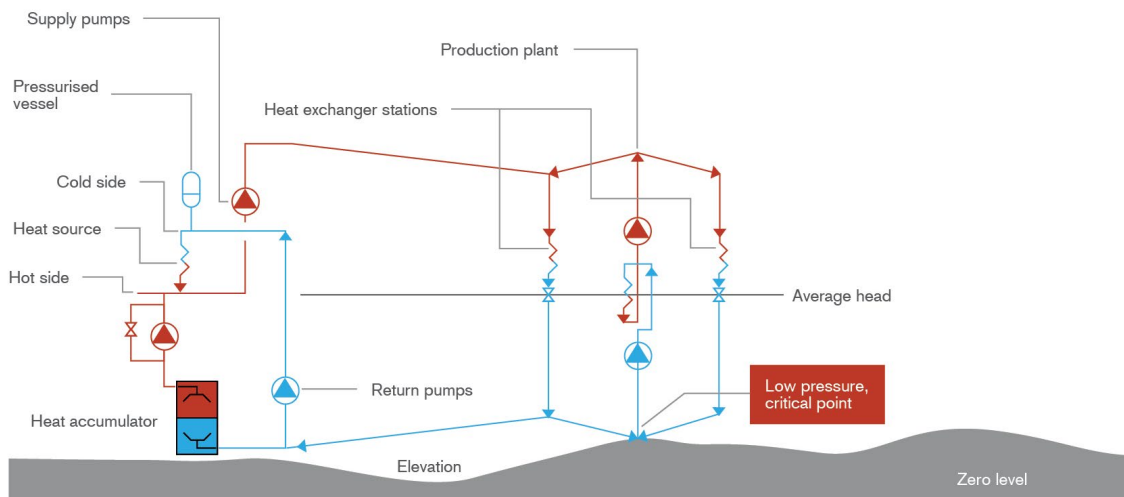


Figure A2.3: Illustration of a low load situation of a system where pressure is maintained in the return leg

However, the approach taken in Copenhagen has several possible benefits in large systems and certainly in the context of London's ambitions for District Energy scale heat networks. Heat networks in London are expected to develop around a series of cluster networks over the short to medium term and where the longer term aspiration is to interconnect many of these to form a wider strategic heat network connecting multiple waste to energy and/or combined heat and power stations at various locations across London. In this context it offers the following potential benefits for London:

- Design to 25 bar reduces network diameters and reduces the need for booster pumping stations
- Allows transmission main to be sized for the base load, with peaking plant embedded at distribution level. Hydraulic isolation of distribution networks allows them to be optimised around local conditions thereby allowing them to be designed to local pressure requirements

- Relatively low complexity of control in operation, even with multiple energy production facilities connected over large distances;
- Ease of integration of future energy production facilities of all scales and at any location with no adverse impact on existing transmission network design or operation;
- Safe transient and dynamic operation in all conditions;
- Flexibility in interim design of cluster networks so that each can be optimised around local requirements;
- Well suited to commercial model appropriate for wide area heat networks involving a heat network operator.

It is noted that the approach requires hydraulic interface stations to be constructed at distribution level. This requires land and adds cost. However, energy centres constructed to serve cluster networks can become the location for these hydraulic interface stations, since they would need to be developed in any case. It

should also be observed that in a large distribution network without hydraulic interface stations there is still a requirement for facilities to absorb pressure transients and there are extra costs embedded in this solution for this reason.
