Low Carbon Heat Networks

How to Optimise an Existing System for Improving Performance

CBx

A CBxchange Research Project

Authors

This report was launched at the Bird&Bird offices on 3rd November, 2016. The research was conducted by the CBxchange team, and led by our participant team of industry-peers from across the industry.

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Foreword

Dr Alan Whitehead, MP for Southampton Test and Member of the Environmental Audit Committee

Heat networks are for the future. They're going to be a key component of how the UK decarbonises its heat – something we are presently failing rather badly on. Supplying efficiently produced lower carbon heat to replace industrial commercial and domestic boilers in new developments in towns and cities really will make a difference to the emission levels of the 44% of our energy that goes into heating buildings and at present stubbornly resists the decarbonisation efforts more successfully applied in other sectors. The interest shown in the recent DECC initial expressions of interest exercise – where 120 local schemes have been awarded finance to investigate development shows that at local level there is beginning to be a real appetite for such schemes, and the possibility of CHP and heating networks providing much more than the 2% of heat they presently supply.

To some, of course the fact that district heating supplies that much heat might come as a surprise. For district heat is equally of the present and the past. The digest of energy Statistics (DUKES) list over 150 existing and operating major industrial , hospital, university and neighbourhood CHP schemes all supplying heat networks in different ways. A number of schemes have been going now for thirty years or so – Southampton District Heating scheme, in which I had something of a hand in developing, has been going since the mid-eighties, as has Sheffield's District network. Some, like the Pimlico District Heating scheme have been around for much longer – starting as a network to take heat from Battersea Power Station in 1950. Other long lived schemes are in abeyance, or are only operating to a fraction of their intended potential.

This report asks a new and exciting question about all these existing networks. Should we not, while we are looking to future opportunities also look on our own doorsteps at what we've already got, and make sure we obtain, metaphorically and practically, as much steam out of the machine as possible? There is, I think great potential in this approach: either in fully utilising oversized schemes, in making networks more efficient, or in ensuring that they are used to best advantage by customers. There are not just new opportunities for low carbon heating around us already, but opportunities for money and resource saving.

This report can be a real catalyst for this work, and I warmly commend it.

Alan Whitehead MP 1.11.16.

Executive Summary

Heat networks have the potential to supply cost effective low carbon heat to households and businesses. The UK Government has pledged £320m of capital support to heat network investment in the UK. How much of this funding should be diverted to improve existing networks? This report identifies measures various stakeholders (such as housing associations, local authorities and developers) can take if they have an underperforming heat network. It draws upon real world experiences where barriers have been met and overcome, and also makes recommendations for policy changes to support this.

Policy changes to support optimisation

To support optimisation of existing heat networks, several policy interventions can be considered:

- Government funding could be prioritised for local authority schemes that link into existing, oversized networks, rather than construction of entirely new ones. Planning processes could also mandate that potential for connection to existing systems must always be evaluated
- Financial support could be made available for energy audits of underperforming networks, to identify cost-effective modifications
- Funding through innovation programmes to further explore the potential of external thermal stores and other types of energy store to buffer oversized systems
- Favourable heat tariffs could be provided to encourage dormant networks to be re-commissioned, with the additional costs provided through an uplift in the tariffs
- Data collected under part 3 of the Heat Networks (Billing and Metering) Regulations (2014) should be made available to enable the issue of heat network underperformance to be quantified reliably

Post-implementation fixes

Our findings highlight three broad areas to consider when addressing an underperforming heat network, which cover technical fixes, contractual relationships and behavioural change:

Technical

- To maximise efficiency, the heat network should be used as the lead source of heat for the buildings rather than as an auxiliary system
- Networks should be correctly sized to the development; expansion to further properties or installing extra thermal storage should be considered in the case of over-sizing
- Network fine-tuning should consider the flow and return temperatures within the pipes, and the design and setting of the Heat Interface Units, as well as issues such as boiler efficiency that also apply to conventional heating systems

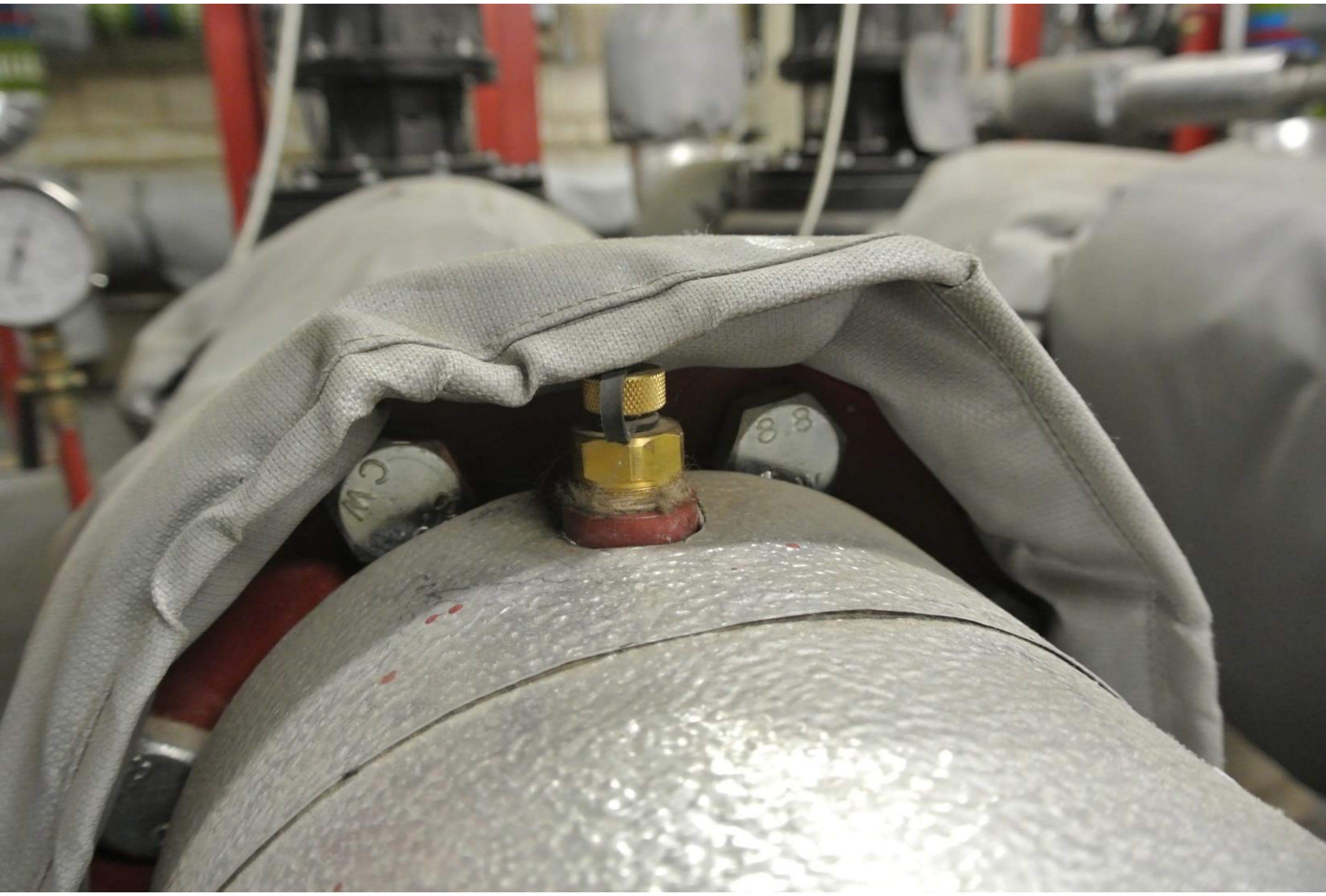
Contractual

- Different models exist for a network owner to reduce their own risk, often at the expense of a degree of control over the network and its operation
- Ensuring a reliable and affordable heat supply should be the focus of the contracts between parties installing and maintaining a heat network, supported by KPIs and incentives, and the limits of each party's responsibilities should be made clear

Behavioural

- Occupants need to adopt good energy efficiency practice. How the network operates should be explained, and key contacts provided
- Maintenance contractors should be selected based on their experience of working with heat networks, as even simple changes in individual dwellings can have ramifications further down the line

We recognise that all heat networks are unique, in terms of the technology they use, the type of buildings and customers they serve, the different parties involved in installation, maintenance and billing, and the contractual relationships between these parties. Therefore, suggestions for improving energy efficiency can only be made in general terms and we would always recommend consulting an expert to conduct an appraisal of your specific network.



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Introduction

Heat Networks

Heat networks have huge potential to help address fuel poverty and contribute towards the UK's Climate Change targets. Considerable Government support has been aimed at encouraging the installation of new networks through the Heat Networks Delivery Unit (HNDU). However, many existing installations, installed for planning purposes or funding requirements, remain dormant or are performing sub-optimally, with experiences of poorly-designed systems undermining networks' reputation for reliable, low carbon, cost-effective and comfortable heat.

This report looks at the contribution of heat networks, why many existing networks are not reaching their potential, and what can be done to improve the performance of an installed system.

What is a Heat Network?

Heat networks pipe hot water (or steam) from a source of heat generation directly to buildings and users. A network's infrastructure can be split into four components (see Box 1). There are various ways heat may can be generated, such as from combined heat and power (CHP), renewables and waste heat from industrial processes. Low carbon heat networks have the potential to be more efficient than conventional gas-fired boiler or electric heater systems by using a single central energy source rather than lots of small sources located within each individual property. Low carbon heat networks can also use renewable energy sources such as heat pumps, solar thermal and deep geothermal. See further benefits in the Appendix.

Box 1. Domestic Heat Network Infrastructure

A. The Energy Centre

Most heat networks have a single energy centre where an energy source is used to heat water which is then pumped through the network. N.B. Heat networks may be communal heating (serves one building with at least two final customers) or district (serves multiple buildings and at least one final customer).

B. The Primary Network

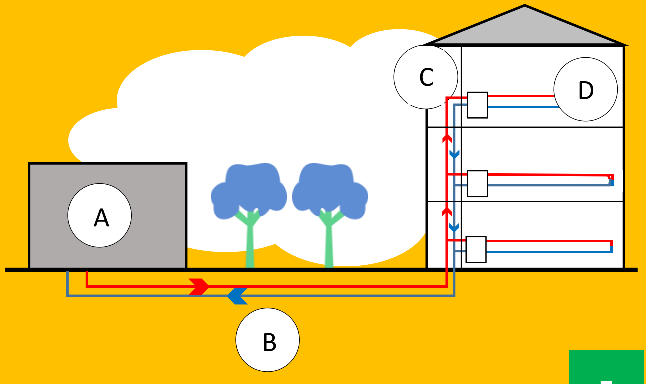
This is the pipework that connects the energy centre to the receiving building. The pipes are typically buried and insulated to reduce heat losses

C. The Secondary Network

This refers to the risers and lateral pipework that distribute heat within a building. In modern buildings, the connection between the dwelling and the primary network is a Heat Interface Unit (HIU). It may include isolation and control valves, heat exchangers, pumps and heat meters.

D. The Tertiary Network

After the HIU is the tertiary network. This is the pipework within the dwelling which distributes hot water and space heating, such as through radiators.



Why are Heat Networks Important?

The type of energy used to power our buildings, and how efficiently it is used are key areas for climate change policy. Approximately 44% of the UK's energy use is for heating buildings with 70% of this fuelled by natural gas (DECC, 2013). In domestic buildings, space heating and hot water accounts for nearly 80% of total end-use energy consumption (BEIS, 2016a).

2000

District heat networks supply

- 210,00 homes
- 1,700 commercial units

+ numerous communal networks, together they supply

~2%

of UK building heat demand

The UK Climate Change Act (2008) mandates to cut carbon emissions by 80% by 2050 relative to 1990 levels. Heat networks have the potential to contribute towards this by offering a more efficient delivery of heat than conventional sources. Furthermore, heat networks can be used in combination with renewable technology which can accelerate decarbonisation.

In 2013, the UK's 2,000 heat networks only supplied 2% of total heat demand, which is one of the lowest participation rates in Europe (DECC, 2013; Euroheat & Power, 2013). The Energy and Climate Change Committee (2016) also states that the UK is not on course to meet its 2020 renewables targets. Given the short time scale, there may be an opportunity to investigate the performance of existing networks and optimise those that have potential to improve.

The UK is not yet halfway towards its 2020 target of achieving 12% of heat from renewable energy; at the end of 2015, the UK had only reached 5.64%.

(ECC, 2016)

Government Support

It is estimated that there is potential to increase the heat demand served by heat networks to between 14% and 43% by 2050 (DECC, 2014).

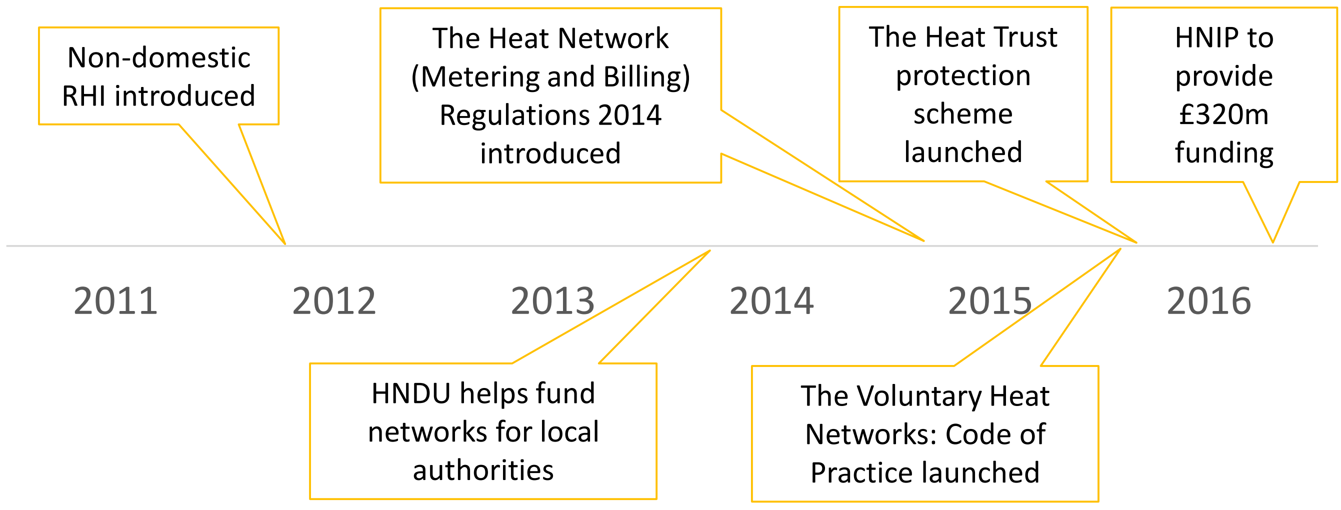
The Department for Business, Energy & Industrial Strategy (BEIS) regards heat networks as an opportunity to decarbonise the UK's energy supply and tackle fuel poverty (BEIS, 2016a). To stimulate growth, it has established the Heat Networks Investment Project (HNIP), which aims to provide £320m of capital support to heat network investment in the UK. The HNIP launched its £39m pilot project in October 2016 (HNIP, 2016).

"Well designed and operated heat networks can cut bills for households and businesses, particularly in denser urban areas where heat networks are more cost effective…Not only can heat networks enable carbon savings in the short term, they also allow us to increase these carbon reductions over time because the pipe infrastructure can utilise new lower carbon heat sources in the future."

BEIS, 2016a

There are also a number of funding initiatives already in place which support heat networks. Such polices include the Renewable Heat Incentive (RHI), Feed-in-Tariffs (FiT), and Energy Obligation Certificates (ECO). These help subsidise the implementation and running costs of heat networks.

Heat Infrastructure Investment Timeline



Source: Adapted from BEIS, 2016b

Post Implementation Problems

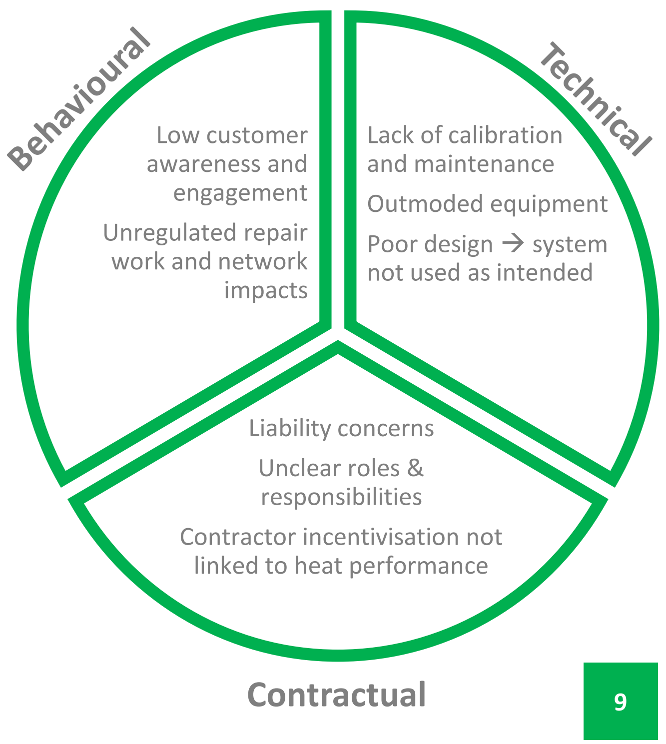
With the UK not on track to meet its renewables and decarbonisation targets, simply installing new heat networks cannot be seen as the way forward. Although there is no central database of network performance data available, the experiences of engineers, property developers, tenants, and others involved with heat networks indicate many are not operating as efficiently as they could. This can lead to higher bills for tenants and lower overall carbon savings (Citizen Advice, 2016; Which?, 2016). There are a variety of reasons why this may be the case, ranging from poor design to unanticipated changes to heat load.

Under performance can undermine the reputation of the sector as a whole. It also represents a missed opportunity; could it be more cost effective to tackle some of the existing issues, instead of (only) installing new capacity? Could this be led through Government support?

There has been substantial research on what to consider when developing a heat network strategy, but little on what to do if an already installed heat network is not performing well.

Could the Heat Network (Metering and Billing) Regulations 2014 requirement for heat meters to be fitted help close the UK's data gap on heat network performance?

Common Performance Barriers Affecting Installed Heat Networks



Chapter 2

Post Implementation Fixes

Once a network is installed, there is a limit to how far it can be optimised. Complicating the matter further is that heat networks are hugely idiosyncratic, varying in scale (one tower block or half a town?), type of end-user (residential, commercial, mixed?), heat source, whether electricity is supplied as well as heat, and so on. Whilst it may not be feasible to make major engineering changes outside the designed parameters, it is possible to fine tune a system for increased optimisation. Three themes have been identified:

Technical

From fine-tuning controls to retrofitting major equipment, current operations are reviewed and choices made during implementation are re-visited.

Contractual

With so many parties involved, the contractual side of heat networks can be as convoluted as the pipework. Responsibilities need to be defined and liabilities managed.

Behavioural

The requirement to understand how the actions of heat consumers and service/maintenance contractors may impact a heat network's operational efficiency.

Technical Fixes

Heat networks are feats of engineering capability. They have to be able to supply heat when demand is high and modulate down when demand is low. In the case of mixed-use developments, they need to meet the needs of commercial as well as residential end-users. Handling multiple pressures across the system is a delicate balancing act; one incorrect parameter could throw the network out of equilibrium and undermine performance.

Our technical fixes derive from the discussions we have held and from reviewing previous literature. This report cannot show you how to apply such fixes; every network is unique and there is no one-size-fits all approach. However, it does point to issues that can affect performance and some areas to consider for improvement.

Is it turned on?

It is perhaps surprising - but not at all unusual - that networks may ‘underperform’ simply because they are not switched on, or are used as an occasional auxiliary system. Instead of the installed low carbon technology supplying most of the heat demand, conventional systems are used instead.

This is particularly common in smaller communal systems where a lower carbon technology has been added as something of an afterthought in the design - perhaps to benefit from eco incentive schemes or to get a planning application past a carbon-focussed local council - without thought to how the system is integrated within the heating demands of the development. Issues such as low heat needs (a particular problem for CHPs, as electricity demand may outstrip heating needs), and fuel sourcing (such as fuel delivery in the case of biomass systems) also affect low carbon options. With the low carbon technology turned off, renewable income incentives (FiT, RHI, etc.) cannot be claimed and offset against the charges made to tenants, which can significantly increase bills.

Assessments of heat demand, diversity curves and heat losses can be revisited to understand how the technology can become the lead source of heat. In the case of biomass sourcing issues, a procurement exercise can be conducted to find a suitable supplier. Finally, a cost-benefit analysis can reveal the economics of running your technology against current utility and carbon tariffs e.g. current and future utility prices and carbon charges.

Technical Checklist:

- Is it turned on?
- Have you revisited the cost-benefit analysis?
- Is there room for network expansion?
- What demand side response opportunities are available?
- Does your system have thermal storage?
- Have you fine-tuned your network?
- What low cost initiatives can be implemented with a ROI of <2 years?

Case Study 1: Revisiting the Cost-Benefit Analysis for CHP

A large housing developer in London has four luxury apartment blocks running communal heating systems in each property. For each scheme, conventional boilers were serving all of the heat demand rather than the installed CHPs. The developer's energy service company (ESCo) had requested that the CHPs be switched off based on an analysis that showed the CHPs to be less efficient than the conventional boilers. This is in fact true; CHPs are less efficient than boilers for heat generation. However, the analysis failed to consider the benefits of the CHPs' electrical output, therefore skewing the analysis in favour of the gas boilers.

The developer commissioned a new cost-benefit analysis to take into account both the electrical and the heat output of the CHPs. A key part of whether a CHP is cost-effective versus conventional boiler systems is whether or not there is sufficient demand for the heat generated alongside the electricity generation, to minimise waste of energy. Heat and electricity demand profiles for the buildings were generated and compared to the installed capacity, including that of thermal stores, and the most efficient operating schedule was identified. Alongside estimates of maintenance costs and other environmental and economic considerations, the developer was satisfied that the CHPs could achieve significant cost and carbon savings and the CHPs were recommissioned.

Summary

By comparing gas and electricity prices with the costs of maintenance, it became clear that the developer would benefit by recommissioning their CHPs:

- Annual savings of 3 GWh of electricity
- Annual cost savings of £200,000
- Recommissioning costs recouped within 6 months
- Carbon savings of over 1000 tonnes per annum

System Oversizing

Having an oversized system can have negative consequences. Heating systems typically reach their highest efficiencies when operating at full output rating and for an extended period of time. An oversized system will either, a) operate at full output for short periods, or b) operate at a low output but for longer periods. Neither options are particularly ideal. System oversizing can be a result of poor planning or from external factors such as energy efficiency improvements. A system can also be deliberately oversized to meet anticipated future demand/expansion, which may then not come to pass.

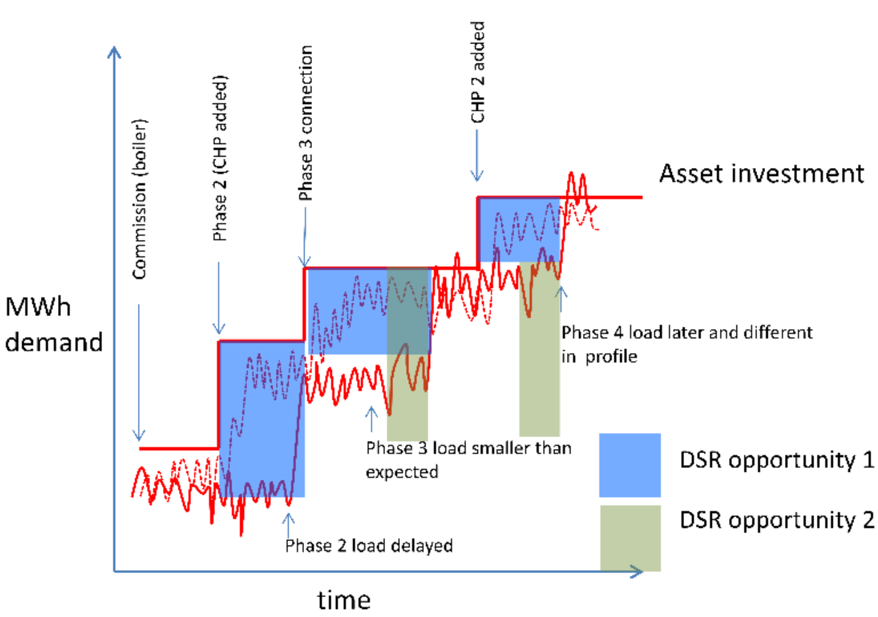
There are options that can be considered if system capacity is oversized. The operation of a system can be scaled back to run at a lower capacity and follow the load. This does have drawbacks as heat networks are less efficient when modulated down. Additionally, there is an increased risk of a diminished asset life as reoccurring cycling can increase maintenance costs. This can be an option for the short term if planning to expand in the near future.

Another option is to capitalise on the electricity market. This is applicable for CHP systems. As a rule of thumb, CHPs should be designed to follow the heat load and any electricity produced is a bonus. An oversized CHP will produce too much heat especially at times when demand is low which may see it turned off during the summer. If this wasn't factored into the initial financial model it can result in the operation becoming too expensive (this cost is often then passed on to the network's customers).

In the short term, the scheme can be reviewed and scaled so that it is financially viable to operate. There may be opportunities to maximise income from electricity sales if operating a CHP. Demand Side Response (DSR) opportunities can be taken advantage of. DSR is where consumers sign up to special tariffs to supply electricity back to the grid when peak electricity demand is expected (e.g. winter evenings). There are a number of schemes available such as Triad, STOR, Project Falcon and Capacity Market. These opportunities must be balanced with system operation. A financial model must be performed to understand this additional operation. For example, running a CHP at full capacity to capitalise on electricity markets will result in heat being wasted. However, this may be the trade-off if it is the only option to keep the scheme financially viable. It may be better to run at a high capacity for a certain amount of time a year and waste heat rather than to lose the scheme altogether.

A long term option for oversized systems is to plan for new connections. Understanding local developments and/or refurbishments can help identify future opportunity for expansion. A full feasibility study should be completed before new connections are made to understand the technical and financial costs.

An Example of Planning with Oversizing



Unplanned circumstances may lead to a system being oversized. This graph shows an example of how future planning can work. Once the CHP is commissioned during Phase 2, the anticipated load is delayed, resulting in the system being oversized. To keep the network financially viable and operational, a DSR opportunity was undertaken until the anticipated Phase 2 load developed. As in this example, this may happen multiple times over a network's life so forward planning is crucial.

Graph Source: Thameswey Ltd. (2016)

Consider Storage

An oversized system will result in the heat load being met at a faster rate than it can be used which results in systems shutting down prematurely. Such 'short cycling' is considered improper operation. Short cycling can be costly in the long term and can lead to premature control failures, lockouts, service calls and frustrated customers. Furthermore, short cycling impedes the realisation of greater fuel efficiencies which are achieved when low carbon technology operates over sustained periods.

Short cycling can be prevented by ensuring heat demand matches heat output. It's important that a system is not oversized to begin with (without planning for future expansion). But it is also important that the system can cope with variation in heat demand, for example when heat is called for at an unusual time, such as late at night. This can also be a common occurrence in commercial buildings that employ zoning techniques.

To overcome this problem, additional mass (water) needs to be added to the system. If calculated correctly, increasing the volume of water will increase the time required to heat the system which results in longer operation hours and stops the short cycling. This added mass is known as a buffer tank.

Buffer tanks act as a thermal store, helping smooth the heat demand profile, reducing the need for boilers to be switched on at peak times, and, in the case of CHP, allowing electricity production to be maximised in the daytime. They can be retrofitted to existing developments where oversizing is known and short cycling common. Where internal space is an issue, there may be future opportunities for storage to be located outside (see box 2).

When considering additional storage, equipment and installation costs should be compared against the life of the system, the cost of energy, and the efficiency gains from longer operational periods.

Box 2: External Thermal Stores

Plant rooms are spaces within a building that house mechanical and electrical equipment. Space is often limited and there are few opportunities for installing additional equipment that is bulky and unplanned for, such as thermal storage. To overcome this, researchers are exploring the opportunities for situating thermal storage outdoors, where space is more plentiful.

Innovations in thermal insulation and special charging/discharging have made this possible (Gerschitzka et al, 2015). External stores are not commercially available yet but could be in the near future.

Case Study 2: Retrofitting a Thermal Store

South Acton Estate in West London is managed by Catalyst Housing and is comprised of over 2,600 dwellings. The estate expanded to include 254 new homes along with a new energy centre housing a biomass boiler, a gas CHP and gas backup boilers. This was installed to meet the requirements for a 25% improvement on building regulations minimum standards and a 10% reduction in carbon emissions through the use of renewable technologies. It was understood that a biomass boiler and CHP would meet these stipulations. However, issues soon emerged with the biomass boiler regarding reliability, emissions, fuel transport and consistency of fuel quality. The CHP was of a size that required a relatively large base thermal and electrical load if it was to operate for the longest period (more efficient). For the development, this load was not available which meant the CHP would have to operate for shorter periods if no action was taken (less efficient). To improve the situation, a thermal store was retrofitted post-occupation which meant the CHP could operate for longer periods and during periods of relatively low demand.

Unfortunately, the biomass boiler is not likely to be operated on a scale that would deem it cost effective to run. However, it can serve as a backup in the event of a loss of gas supply (providing a store of fuel is available and the boiler in serviceable condition). There is also potential for future expansion if there is any additional heat demand from neighbouring developments/refurbishments that could connect to the network.

Catalyst Housing have gained some valuable learning through this project which they can now apply to new schemes. Key lessons include:

- Increase organisational knowledge through training, and support scheme-specific knowledge transfer
- Develop in-house expertise on communal heating systems from planning and design right through to billing and maintenance
- Understand the importance of outsourcing to an ESCo or special purpose vehicle from the outset
- Conduct a comprehensive feasibility study at an early stage

Network Fine Tuning and Optimisation

Often, once a heat network is installed and commissioned, the project team disband and head to their next job. In the commercial sector, new buildings may take a ‘soft landings’ approach where the systems are fine tuned over a year to account for occupant behaviours and iron out any flaws. This does not always happen with heat networks. Once commissioned, a heat network may receive no further commissioning and operates ‘as built’ for the rest of its life. This is poor practice because many variables, such as seasonal temperatures and occupancy, can change during a heat network’s life.

Many of the principles behind optimising a heat network are the same as for any other heating system (insulation, controls, boiler efficiency, etc.). But heat networks have many components working together so to understand what performance tweaks can be made, operational data is crucial.

Flow and return temperatures

One of the most important aspects of an efficient heat network is the temperature of the water returning to the energy centre. Contrary to conventional boilers, where flow is supplied at a temperature as high as possible to meet the output of the radiators, heat networks require a more balanced flow so that enough heat is extracted before returning it. The temperature difference between the flow/return is the Delta T (ΔT). The recommended ΔT for heat networks is typically between 30 and 40°C (CIBSE, 2015). If a network is not operating at this range, it is possible to fine tune so it does. Additionally, varying the flow rate to match seasonal variation is a low cost option and typically achievable on most schemes.

Reducing the flow rate and maximising the time useful heat can be extracted from the network will improve efficiency. Less pumping power is used and thus maximising the latent heat extracted. Selecting suitable radiators and control valves can also help bring temperatures within the optimal range. This can be considered during the next upgrade cycle.

Case study 3: Data Analysis for Network Optimisation

Elizabeth House, a 13-storey apartment block completed in 2013, uses a gas-fired heat network for hot water and heating. Energy costs for heat generation and pumping exceeded expectations, and overheating was reported in corridors and flats. Metering was already in place throughout the network. Web-based analytics software, Guru Pinpoint, developed as part of a project funded by the Department of Energy and Climate Change, was used to examine the data. Information on the amount of gas used by the energy centre, the power used by the pumps, flow rates and temperatures, and the heat demand of each flat was analysed to form recommendations targeting the energy centre’s efficiency and network losses.

Savings achieved:

- 68% lower network heat losses
- 80% lower pumping energy costs
- Energy tariff for residents reduced from 7.7p to 3.8p per kWh

Source: GURU, 2016

Boiler efficiency

Typical reasons for boiler inefficiency include simple on/off rather than modulating controls, insufficient casing insulation and lack of regular tuning to optimise excess combustion air (RE:NEW, 2016). If the heat network has a configuration using a series of boilers of different ages and efficiencies, ensuring the firing order has the most efficient model first will lead to better optimisation.

HIUs and user controls

Heat Interface Units (HIU) and their meters can be checked for functionality, especially those with plate heat exchangers. A HIU's internal components are often sourced from various manufacturers and may not necessarily work well together. Consider reviewing the designed package and the working envelope of the installed HIUs and see if they are still suitable for their original purpose. Consideration should be made of the temperature profiles, flow rates, size of envelope, its location and level of appropriate insulation.

Seasonal commissioning

It is not unusual to find a heat network that has been left on its original commissioned setting. As the name suggests, seasonal commissioning involves recommissioning the system in the winter and again in the summer in order to maximise performance. This can be taken a step further with continuous commissioning where the system is fine tuned month by month. It involves all of the network's systems being continuously monitored to provide optimum performance. These actions can be rolled up into a performance contract and set as a KPI (see page 25).

Measures with typical Return on Investment of less than 2 years

Measure	Description
Pipe insulation	Heat losses through poorly insulated pipes decrease efficiency but also reduce comfort, with 'stuffy' public areas a particular criticism of older heat networks. The secondary network is often the most accessible for extra lagging, since the primary network is often partially buried and the tertiary network is in occupied premises.
Fixed to variable speed pumps	Variable speed pumps allow a lower pumping rate to be selected during periods of moderate heat demand, such as spring and autumn, supporting seasonal commissioning. Saving pumping power and reducing wear and tear on the motor, such retrofits can often keep the existing motor and just change the controls.
Hot water cylinder insulation	If the heat network is configured with hot water tanks in individual dwellings, these should be insulated.

Source: RE:NEW (2016)

Contractual Considerations

Through operating a heat network, a property developer, housing association or local authority may suddenly find itself playing the role of an energy provider which can include metering and billing residents directly. Heat networks can generally be considered as monopolies - the resident has very little choice over their energy provider. If the quasi energy manager lacks the experience and resources to fulfil the role, residents may become dissatisfied and find that they can't switch to someone else.

The feasibility of the technical solution will have to be considered alongside factors such as the network owner's access to funds, the ownership of the network, and the desire to generate revenue, improve security of supply and maximise performance. The types of contracts and nature of contractual relationships will flow from this.

A network owner which has access to funding, is comfortable implementing the technical solution and has a healthy appetite for operational and income risk may want to retain as much control as possible over the installation and/or operation of the system. Subcontractors may be appointed on a short-term basis to fill any gaps in expertise, including design, installation, operation, maintenance, metering, billing and fuel procurement on a "fee for service" basis.

However, a more risk-adverse owner which is not in the business of providing supplies (such as a residential landlord, local authority or registered provider) may prefer to outsource some or all responsibilities to an energy services company (ESCo) via a long-term concession arrangement. We have outlined below some of the questions which may help shape such a decision.

What is the size and type of the network?

The site location, heat demand profile and types of customer will influence the commercial drivers and whether an ESCo is involved. For example, a public or private landlord will focus more on the customer service needs (including heat supplies) of the residential and non-residential tenants, whereas an industrial or commercial customer (such as a factory, school or hospital) will primarily be concerned about continuity of supply for its own needs.

Many ESCos will only consider investing in district heating projects large enough to offer sufficient heat demand and therefore a revenue stream to justify any upfront capital expenditure. Smaller communal systems will not attract an ESCo and owners may have to outsource the operation, maintenance, metering, billing and fuel procurement on a fee for service basis.

Contractual Checklist:

- What is the right compromise between risk exposure and strategic control for your situation?
- Have you defined the roles and responsibilities for everyone involved in the network?
- Remember to use appropriate KPIs that incentivise optimum heat performance.

Who will own the energy centre and network?

There will be commercial and legal drivers around ownership of the energy centre and network once they have been installed or upgraded. An operation and maintenance consultant appointed on a short-term basis will need access rights but not require a legal interest. In contrast, an ESCo will likely require some kind of legal interest (which may not necessarily extend to legal title as outlined below) over the energy centre and primary network, and rights of access over the secondary network. This may be a requirement of the ESCo's funder, its corporate policy or its ability to access financial incentives.

If an ESCo requires a legal interest in the energy centre plant and network, this is often via the grant of a lease and access rights, rather than transferring title outright. Upon termination of the ESCo's appointment or upon its insolvency, the ability to terminate a lease and automatically revert ownership back to the landowner helps guard against the risk of any disruption to the heat supplies.

Granting property rights to the ESCo may be complex where the land and buildings across the network are owned by different parties. If an ESCo is not involved, the network owner must ensure that it has sufficient ownership or access rights across all parts of the network in order for it and any of its contractors to operate and maintain it.

Is there access to upfront and cyclical capital expenditure?

The network owner may be in a position to fund the network upgrades, extension and/or the installation of new technologies. Alternatively, an ESCo may offer to fund all or part of the capital required and recover its costs via the exclusive right to charge customers for heat over the long term of the concession. In certain circumstances, there may be public sector and private sector funding options available. An ESCo would also take the risk and cost of cyclical plant replacement once the initial plant has reached its useful life. If there is no ESCo in place, the network owner would need to ensure that sufficient costs are recovered from customers to build up a sinking fund to cover these future costs.

An example of responsibilities within a Heat Network

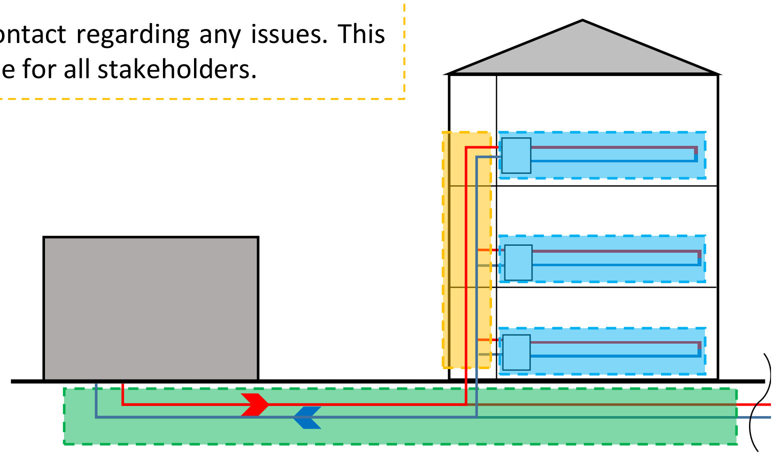
A heat network can be complicated in terms of ownership and where responsibilities may lie. Different parts of land may be owned by different parties but one party may have rights over all parts of land. The example below shows how this may happen in a network. For example:

Entity 1 could be owned by the network owner;
Entity 2 could be owned by the building owner; and
Entity 3 could be owned by the property owner or tenant.

The key is in understanding which party to contact regarding any issues. This information should be made clear and available for all stakeholders.

Companies Responsible for Maintenance:

- Primary Network – Entity 1
- Secondary Network – Entity 2
- Tertiary Network – Entity 3 or homeowner



Key Contractual Considerations

The elements of a contract will depend on whether the network owner has retained control of the network and subcontracted various duties (common for small communal systems) or appointed an ESCo to take all risks (common for larger district heating schemes). In order to decide which model is appropriate, the following questions should be asked:

Who will rectify heat supply failures?

A network owner making supplies to customers will take the risk of supply failures unless it can delegate responsibility. It is unlikely that a subcontracted operations and maintenance contractor would fully accept this risk or the cost of mobilising to provide temporary supplies (unless a supply failure is due to their breach). If an ESCo is appointed then the owner would consider the ESCo to be best placed to mobilise temporary supplies (regardless of the supply failure cause) with the cost of mobilising such temporary supplies sitting with the party responsible for the supply failure.

What fiscal measures could apply?

Depending on the technology and the generating capacity, the owner or operator of the heat network may be subject to certain fiscal measures, which may impact on how the deal is structured. At the time of writing, these may include:

- Renewable Heat Incentive payments;
- Renewable Obligation Certificates or Contracts for Difference;
- Feed-in Tariffs;
- Climate Change Levy exemptions;
- Business rating exemptions;
- Enhanced Capital Allowances, and;
- Carbon Price Support tax exemptions and EU ETS.

How is income recovered and customer debt risk managed?

An owner retaining responsibility for the network will have ultimate control over setting its heat prices and standing charges and could delegate the administration to a metering and billing provider, but the provider will not take the risk that the prices charged are sufficient to meet the cyclical maintenance costs. An ESCo would take this risk with limited recourse to the owner or customer for further funds.

Where an ESCo is not appointed, a network owner who is also a landlord is likely to recover costs through lease service charges. It may subcontract metering and billing duties but will ultimately take the risk of customers not paying. An ESCo would enter into Supply Agreements with each customer, bill directly and take the risk of non-payment. A landlord considering whether to recover costs through a lease or Supply Agreement should check what the existing leases permit and whether it would still be responsible for heat supplies as a landlord under the lease, regardless of whether an ESCo is in place.

Monitoring and maximising network output performance

Either a subcontracted operations and maintenance contractor or an ESCo could be obliged to comply with a clear set of network operating parameters and output targets, and each should be monitored and incentivised through key performance indicators.

Case Study 4: Importance of Performance KPIs

A housing developer sought a maintenance contractor to ensure that interruptions to the heat and electricity supply were minimised for their CHP operation. Performance KPIs were included in the tender and subsequent contracts, such as:

- an overall system availability of at least 92% over a year
- a CHP Quality Assurance programme (CHPQA) score greater than 100

Since the CHPs had not been operational for over a year, the maintenance contractor was taking on greater risk. To compensate for this, an initial 12-month contract was negotiated with performance monitoring to validate the operation of the units. After this period, sufficient information would be available to provide a minimum guarantee of performance and introduce energy efficiency KPIs into a longer-term contract.

Behavioural Changes

A heat network is intrinsically different to conventional heating systems. As such, it cannot be operated in the same way as an individual combi boiler. When something changes with a combi boiler central heating system, whether a valve change or the bleeding of a radiator, the knock-on effects are too small to have a significant impact on the system. In a heat network, small changes may be multiplied by thousands given the scale some networks operate on. Therefore, it is important to advise and inform those using or working on a network that their actions can have consequences that affect overall performance.

This section covers the behavioural changes that can improve heat network operation. Key heat network stakeholders whose behaviour can affect performance are the occupant and maintenance providers.

Behavioural Checklist:

- Ensure users understand system and controls
- Consider standardising equipment
- Perform a post-occupancy evaluation of controls
- Engage with heat customers
- Use experienced maintenance contractors

Consumer Behaviour

Tenants told that they have access to cheap, low carbon, and unlimited heat may abandon the energy-saving habits they would have applied when using a conventional heating system. A common issue found is when space heating inside dwellings is left on for long periods when not being used. For example, in unmetered dwellings where heat charges are shared, windows may be left open during the winter while the heating is on. These actions can result in more fuel being used which in turn creates higher bills and poor overall efficiency.

There are several things that can be done to help tenants understand how their actions have an impact on a communal level. This research has found that engagement can lower bills by promoting energy efficient behaviour. Consider setting up a network forum where tenants can voice their concerns and receive updates such as planned downtime.

Energy efficient occupant behaviour is supported by clear user interface controls. At one extreme, removing controls altogether, such as replacing regular manual radiator valves with thermostatic valves (TRVs) will reduce human error. On the other end of the scale, having simple controls with complex programming can deter end users from setting their 'ideal' heat. Good controls are rarely requested or specified because they can be expensive. Heat networks are often designed to be built for a low cost and as such, are exposed to value engineering. As a result, 'soft' components such as user controls may not be the highest quality or the most user-friendly.

It may be feasible to change the user interfaces if the network is small and the problem widespread. If that is not cost effective, then spending time explaining controls and running workshops could improve user confidence. The benefits of this would be lower bills for the users thus improving network satisfaction.

Key Information for Occupants *You will need to explain:*

1. The energy bill

- Be transparent with static (maintenance) and variable (metered usage, if applicable) charges
- How metering works (if applicable)
- Who the bill is received from (e.g. ESCo)
- Why bills will not vary seasonally as much as they do with conventional heating systems (due to the static maintenance fee)

2. Key Contacts

- Who to contact in the event of interrupted supply
- Who to speak to about improvements of heating systems within dwellings
- Who to speak to about queries on the energy bill

3. Network Operations

- Key information such as times when heat is available
- How heat is generated and why it is different to conventional systems
- If possible, consider providing tours of the energy centre if interest is expressed

4. Impacts of Customer Behaviour

- How to use interface controls
- The importance of being energy conscious e.g. closing windows, turning the heating off when leaving the home, etc.

Maintenance of the Tertiary and Secondary Network

Another issue that was uncovered during the research was the affect that maintenance contractors may have on a network. Without a good set of KPIs within contracts, contractors have little incentive or drive to improve efficiency. Because a network is linked, one small change can have a butterfly effect for the rest of the network. Multiply these small changes by a hundred and the network is no longer 'as built' and operating at designed specifications. Typically, maintenance of a network is managed up to the tertiary network. After that, it is the occupier's responsibility to maintain their system (if privately owned).

Anyone working on any part of the network should be made aware that their actions can have cascading impacts. One example encountered during this research was where a network's calorifiers were due be replaced and upgraded. It was recognised that replacing the calorifiers with a more efficient model would make available some spare capacity, thus resulting in the network becoming oversized. This presented an opportunity for network expansion. Engaging with contractors and realising potential future issues can help mitigate performance losses.

New contractors should be introduced to the network through an induction manual or training event. New contractors should also be vetted based on their familiarity with heat networks and low carbon technology. It can be challenging to tell residents who they should hire to fix the heating within their own home. For the tertiary network, consider providing residents with a list of approved contractors. Communicate the benefits of selecting from the list and incentivise them to do so. This could be achieved by arranging preferential rates with contractors for tenants who use their services (e.g. 5% off). This way, the owner is assured that work is completed to a standard that is suitable for their network, the tenants receive a discount and the contractor has a steady supply of work.

Consideration should also be made of the components used during repair work. A set of standards could be set on what can be installed/replaced, e.g. all valves are selected from the same manufacturer. This ensures consistent quality across the network in areas that are controllable, i.e. the energy centre and secondary network. An additional measure is to keep common replacement items in stock which will minimise network downtime and instil customer confidence.

Even simple changes can be employed to reduce costs. For example, numbering electrical cables and heat meters can reduce the time it takes to diagnose malfunctions within complex networks. Whilst this does not improve performance per se, it does mean that contractors spend less time on site thereby reducing overall maintenance costs.

Case Study 5 – A Designer's Point of View

Clydes Biomass project is a district heating scheme commissioned by Leeds City Council and designed and built by Willmott Dixon. This is a retrofit scheme which replaced the old electrical heating with district heating. The scheme comprises of two tower blocks with 99 flats in each block and 32 low rise shelter homes. The dwellings are supplied by a single purpose-built energy centre that houses one biomass boiler of 201 kW capacity and three gas backup boilers of 560 kW capacity. The biomass boiler is designed to take the majority of the heat load (targeted at 65% of total annual load).

The project did not come without its challenges. Being a retrofit scheme, the project relied on access to occupied dwellings to remove existing electrical heat appliances and install HIUs. This itself posed a number of challenges with legal and access issues. To ease this process, a local resident liaison officer was appointed to act as the first point of call for residents' concerns. The result of this was to achieve connectivity to 221 of the 230 dwellings. Those that could not be accessed have had the pipework laid and capped off, ready for connecting the dwelling when it is most appropriate.

As with other heat networks, understanding the profile of the heat consumer is important. The heat demand profile of heat users can vary vastly and is often influenced by a number of socio-economic factors such as age, employment status and type, economic status, etc. In hindsight, a more thorough upfront analysis of resident profile may have provided further opportunity for optimisation and expansion.

As such, Willmott Dixon now suggest at least a three-month monitoring period during the pre-specification stages of a heat network. This includes a detailed building assessment which would look at factors such as internal temperatures and relative humidity, in-situ U-values, co-heating, air tightness, occupancy behaviour and sensitivity analysis. This information would then be used to inform the design team so that the scheme is optimised for the project and potential for future expansion is identified.

"Specifying the project correctly from the beginning and asking for the right things is fundamental"

Dr Zachary Gill, Willmott Dixon

Case Study 6 – Lessons from a Long Standing System

Pimlico District Heating Undertaking (PDHU) is a large district heating scheme located in West London. The scheme has been in existence since 1950 and originally utilised waste heat from Battersea Power Station to supply heating for homes. This reduced the requirement for coal fires thus reducing London's smog. Today, it supplies heat to around 3,256 homes, 50 commercial units and three schools in the area. The heat is supplied by two 1.55MW CHP engines and three 8MW boilers, all fuelled by natural gas. Working in conjunction with the boilers is a 2.5 million litre thermal store, the largest in the UK.

PDHU is an example of how a heat network can provide sustainable heat over decades of operation. Key factors for its longevity are:

• **Engagement** – PDHU set up a heat network 'User Forum' that serves as a communication forum for residents. Residents can raise issues such as heat charges and financial accounting. With heat charges, discussions are held to ensure charges never adversely impact the residents. The focal point of PDHU is to address fuel poverty so keeping charges to a minimum is paramount. With regards to accounting, the forum provides financial transparency and scrutiny of how PDHU operates.

• **Experience** – PDHU has had the time to mature its controls systems and learn from its mistakes so that today it can offer low carbon heat to thousands of end users. Contractors are chosen based on their experience of heat networks. New contractors are expected to understand a heat network from a holistic stand point and how their actions may influence performance elsewhere.

• **Equipment** – PDHU only sources quality equipment that they know works well and their contractors understand. They have compiled a standardised list of over 100 parts that should be used in their network. When upgrading ageing equipment, they consider the implications that it will have on the network and always look to future-proof their system.

PDHU have had the opportunity to mould and develop their heat network into a robust system that still stands strong today. They are able to supply reliable, affordable and low carbon heat to their residents and are a positive asset to the local community.

Chapter 3

Key Performance Indicators

KPIs can be a tool to help incentivise parties involved in the installation and maintenance of heat networks to prioritise heat performance and efficiency. KPIs may reference operating and annual energy production to provide consistent quality across the heat network. Identifying KPIs as early as the initial feasibility study is preferable as it gives an indication of how the network should operate.

This section outlines some KPIs that should be considered. The list is comprehensive but not exhaustive as certain KPIs may be scheme specific. They are here as a guide and offer support for those who may not have been previously exposed to heat networks.

KPI	Requirement	Rationale
Δ T	ΔT to be maintained between 30 and 40°C	A wide ΔT is desirable in line with industry best practice
Seasonal management	The network is operated to take into account lower demand in summer and higher demand in winter	Seasonal commissioning ensures heat is not being generated when it is not needed
Seasonal and annual efficiency	Seasonal efficiency should be within [XX[% of specification Annual efficiency should be within [XX[% of specification	To ensure that the overall efficiency of the system is maintained as per specification
System availability	System availability should be no less than [X]% over a year	Ensures that customers have a reliable supply of heat
Customer response	Respond to single customer report of loss of heat supply within [X] hours	Ensures a prompt response to customer needs

KPI	Requirement	Rationale
Customer response multiple	Respond to multiple customer loss of heat within [X] hours	Ensures a prompt response to customer needs
Heat supply failure	Heat supply fully restored within [X] hours of initial report/loss	Support reliability of heat supply
Heat supply agreement	100% HSAs signed by customer within [X] month[s] of occupation	To ensure that customer is aware of their rights and what service levels can be expected
Notification of interruption	A minimum of [X] days' notice of planned interruption	Customers are given adequate time to plan and prepare for interruption as well as respond to the notice
Performance	Minutes lost per customer, per annum should be no more than [X] minutes	More nuanced KPI on availability that takes account of scheme size
Efficiencies	CHP system achieves: • October-April: [X]% • May-June: [X]% • June-September: [X]%	To take account of seasonal fluctuations in efficiency due to differing demand during the year
Tarff review	Tariff reviews to take place twice a year with full methodology	To take account of changes in cost of fuel
Tariff and standing charge changes	No more than one tariff change per year	Gives customers confidence in the scheme
Reporting	Performance report to be submitted to client on a bi monthly basis for all KPIs	To ensure that there are clear reporting relationships between client and supplier, and that fluctuations in performance can be identified and addressed quickly
Environmental Monitoring	CO_2, NO_x and PM are all kept within legal requirements and that noise and vibration are acceptable levels	Ensure client meets planning
Customer reporting	Individual customer reads supplied on a monthly basis to client	To highlight high users and target advice and/or debt management

Chapter 4

Next Steps

CBx agrees that the UK needs to increase the number of its heat networks to help decarbonise the heat supply. However, there are still opportunities to improve networks that are already installed rather than a focus on building new capacity. This could be a cost effective approach to help the UK Government reach its climate change targets.

The following is a summary of the issues to consider if a heat network is underperforming, and some policy recommendations which could help support this optimisation.

Technical

- If installed technology lies dormant, assess current market conditions to understand if it is cost effective to recommission
- Examine the costs of installing a thermal store in comparison with the whole life cycle costs of the network
- Fine tune the network, considering efficiencies such as insulation, variable speed pumps, seasonal commissioning, flow and return temperatures, and user controls
- Meter and monitor energy centre and heat equipment to determine losses in the system
- Consider remedial works to address malfunctioning and unsuitable equipment
- If you have an oversized CHP, consider Demand-Side Response opportunities to maximise income
- If the system is oversized, is there capacity to expand the network to neighbouring buildings?

Contractual

- Understand what types of contracts are available for managing risk and incentivising energy performance improvement
- Incentivise the operator to keep performance and efficiencies high
- Understand network roles and responsibilities. Different parts of the network may be controlled by different parties, who need to work together
- Contracts should include KPIs and incentives linked to heat performance
- Remember to include the costs of maintenance when budgeting

Behavioural

- Explain the features of the energy bill, such as fixed and variable costs, and lower seasonal variation in energy cost
- Create a user group forum where residents can communicate suggestions and announcements can be made
- Raise customer awareness of the impact of their actions on the efficiency of the network, and promote energy efficient behaviours
- Provide contact details for queries on maintenance, billing, and other heat network services
- Review user controls and consider upgrading if they are not easy to understand
- Standardise maintenance parts and keep a small stock of common replacement items
- Ensure maintenance teams are aware of the implications of their actions
- Label parts of the network so maintenance time can be reduced

Policy Recommendations

- Data on the scale of heat network underperformance is lacking in the UK. Data collected under part 3 of the Heat Networks (Billing and Metering) Regulations (2014) should be made available to enable the issue to be quantified
- Over 120 local authorities have been awarded funding for exploring heat network opportunities. Local authorities should be encouraged to connect properties to existing networks that are oversized. Priority funding should be given to local authorities to explore these options compared to installing entirely new capacity
- Planning processes for new developments should also consider if there are any networks with spare capacity in the local vicinity and provide incentivises to connect to and improve the network
- Underperforming networks should be given support to carry out initial energy audits to identify areas for improvement
- The uptake of the RHI has been low and cuts to tariffs can lead to a lower deployment of renewable heat (Committee on Climate Change, 2016). A separate tariff could encourage the optimisation of underperforming heat networks allowing an underperforming network to investigate options for improvement
- Setting up a national information service for network operators and customers would help with engagement on a local level and encourage further deployment
- Funding should be made available through innovation programmes for further research on external thermal stores and other types of energy storage.

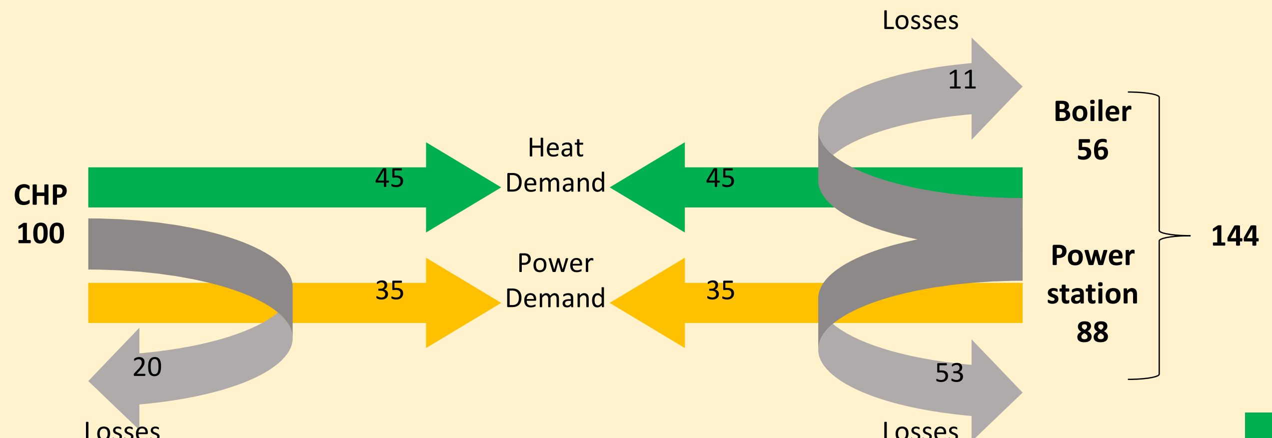
Appendix

The following shows some of the advantages of heat networks. These can be considered as a heat network's objectives; a network that reaches its designed optimal performance should be able to check all of these boxes off.

Benefit	Advantages
Environmental	Decentralised energy generation technology can incorporate low carbon technologies such as heat pumps, biomass, solar thermal, geothermal and CHP. Individual boilers must be sized to meet peak heat demand. With a heat network, peak demand is aggregated which results in a lower overall output per person.
	Higher efficiencies result in less CO_2 per kWh generated. Therefore, heat networks are capable of reducing green house gasses (GHG) expelled into the atmosphere thus having a lower contribution to climate change.
	When heat networks are combined with power generation (CHP) the overall efficiency is even greater. Typically, conventional electricity generation is less than 50% efficient (when accounting for transmission losses). In a heat network, not only are power transmission losses significantly reduced, but the heat from the engine is also utilised. See **Box 3** for a an energy flow diagram of a CHP engine.
Economic	Efficiently transporting heat through a network enables more heat to be generated from a unit of fuel than conventional forms. This means less fuel is needed, keeping costs low.
	Maintenance of the energy centre, primary and secondary networks is typically bundled together in the standing charges, therefore replacing the need for individual boiler maintenance costs.
Social	Heat networks can be used to address fuel poverty by making heat more accessible and cheaper. Greater fuel flexibility is also enabled which means heat networks are less likely to be affected by fuel price hikes.

Box 3

Sankey diagram showing how CHP is more energy efficient that conventional sources of heat and power. This is because heat is better utilised and not wasted as seen in power stations, which are typically around 40% efficient.



Source: Adapted from Carbon Trust, 2004

Bibliography

BEIS. (2016a). *Energy Consumption in the UK*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/541163/ECUK_2016.pdf

BEIS. (2016b). *RHI deployment data: July 2016*. Retrieved from https://www.gov.uk/government/statistics/rhi-deployment-data-july-2016

BISRIA. (2015). *Heat Interface Units (BG62/2015)*

Carbon Trust. (2004). *GPG 388 Combined Heat and Power for Buildings.*

CIBSE. (2013). *AM12: Combined Heat and Power in Buildings*.

CIBSE. (2015). *Heat Networks: Code of Practice for the UK*.

Citizens Advice. (2016). *District Heat Networks*. Retrieved from https://www.citizensadvice.org.uk/Global/CitizensAdvice/Energy/District%20Heating%20Information%20Request%20-%20January%202016.pdf

Committee on Climate Change. (2016). *Next Steps for UK Heat Policy*. Retrieved from https://www.theccc.org.uk/wp-content/uploads/2016/10/Next-steps-for-UK-heat-policy-Committee-on-Climate-Change-October-2016.pdf

DECC. (2010). *National Renewable Energy Action Plan for the United Kingdom*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/47871/25-nat-ren-energy-action-plan.pdf

DECC. (2013). *The Future of Heating: Meeting the Challenge*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04- DECCThe_Future_of_Heating_Accessible-10.pdf

DECC. (2014). *£2m awarded for local authority low carbon heat networks*. Retrieved from https://www.gov.uk/government/news/2m-awarded-for-local-authority-low-carbon-heat-networks

DECC. (2016). *Heat Networks Deliver Unit Round 6: Overview*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/513884/HNDU_overview_round6_April2016.pdf

DUKES. (2016). *Digest of United Kingdom Statistics 2016*. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/552060/DUKES_2016_FINAL.pdf

ECC. (2016). *The 2020 targets*. Retrieved from http://www.publications.parliament.uk/pa/cm201617/cmselect/cmenergy/173/17305.htm

Euroheat & Power. (2013). Retrieved from https://www.euroheat.org/

GURU. (2016). *Heat Networks: Make a date with data*. Retrieved from http://www.gurusystems.com/wpcontent/uploads/2016/06/Guru_PinPoint_21April16_SlidePack-optimised.pdf

Gerschitzka, M., Lang, S., Bauer, D., Drück, H.: *Development of a high-efficient long-term thermal energy store for outdoor installation*. IRES 2015, 9th International Renewable Energy Storage Conference, Düsseldorf, Germany, 2015.

HNIP. (2016). *Consultation on the Heat Networks Investment Project (HNIP)*. Retrieved from https://www.gov.uk/government/consultations/consultation-on-the-heat-networks-investment-project-hnip

RE:NEW. (2016). Retrieved from www.london.gov.uk/renew

Thameswey Ltd. (2015). *Demand Side Response: The District Energy Supplier's Perspective*., (p. 11).

The Heat Network (Metering and Billing) Regulations. (2014). Retrieved from http://www.legislation.gov.uk/uksi/2014/3120/pdfs/uksi_20143120_en.pdf

Which? (2015). *Turning up the heat: Getting a fair deal for District Heating users*. Retrieved from http://www.staticwhich.co.uk/documents/pdf/turning-up-the-heat-getting-a-fair-deal-for-district-heating-users---which-report-99546.pdf

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