Heat Mapping and Energy Masterplanning of Heat Use across Worcestershire including a 'Pre-Feasibility' Study of Geothermal Potential in Offenham

Study Report

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For Wychavon District Council

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The brief includes an assessment of the previous site usage by review of the sources identified in this report. These effectively provide snapshots of the site through time and although a consistent sequence of site usage has been deduced from these records, the possibility of some activity carried out on the site not being identified on these records cannot be excluded.

New information, changed practices or new legislation may necessitate revised interpretation of the report after the date of its submission

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1 Executive Summary

Wychavon District Council commissioned Mouchel to undertake a heat demand mapping and energy masterplanning study across Worcestershire, including a pre-feasibility study for a deep geothermal energy scheme in Offenham.

Heat demand mapping across Worcestershire included the identification of heat demand “hot spots”. These are areas with concentrated heat demand that have the potential for the development of a heat network which were then considered further as part of the energy masterplanning stage.

Prior to undertaking the detailed energy masterplanning, the identified heat demand “hot spots” were filtered to prioritise the detailed assessments. A range of available low-carbon energy sources have been assessed which could potentially supplement the currently preferred gas fired Combine Heat and Power (CHP) plants. CHP technology currently is a very common energy source for district heat schemes in the UK and is a very efficient form of generation of heat and electricity.

Additional detailed assessments were undertaken for the potential use of deep geothermal heat. The Worcester Basin, which underlies Worcestershire, is a geological structure offering significant, currently unexploited geothermal heat potential. The deep geothermal heat potential is relevant for proposed heat network schemes in southern Worcestershire, particularly for Worcestershire’s energy intense Agri-Tech sector. Numerous geothermal greenhouse schemes in the Netherlands have proved successful in using similar developments. The results of the pre-feasibility study for a geothermal scheme in Offenham show that heat network schemes are potentially viable in southern Worcestershire.

Table 1.1 summarises the identified heat demand “hot spot” areas that have the potential for the development of local heat networks. These areas are subdivided into corresponding town centre, deep geothermal (Offenham), development sites and other potential local heat networks.

Table 1.1: Identified potential Heat Network Schemes in Worcestershire

Type of site	Name	Size (annual MWh heat)	CAPEX (£M)	Payback (years)	Net Present Value £k (negative £k)	Internal rate of return (IRR)	Comments
Urban heat networks (assuming 30 years life cycle, base cases)	**Bromsgrove:** • Town Centre& NHS • Worcester Rd. • Aston Fields • Buntsford	18,200 2,100 11,100 10,800	3.1 1.7 2.8 2.3	23 7 25 22	18 3,343 (347) 347	3.5% 15.2% 2.8% 4.3%	A standalone scheme at Aston Fields is less likely to be financially viable. Worcester Rd. main looks most attractive.

Type of site	Name	Size (annual MWh heat)	CAPEX (£M)	Payback (years)	Net Present Value £k (negative £k)	Internal rate of return (IRR)	Comments
	Redditch: • Northern • NHS and Industrial	123,000 268,000	11.9 19.6	23 21	176 2,833	3.6% 4.4%	The Redditch Eastern Gateway development offers additional opportunities on the Northern network to be explored when detail becomes available. Financial performance of the NHS & Industrial main can be improved through phasing but existing waste incinerator is to be considered.
	Kidderminster: • Central; • Southern	63,000 56,000	7.9 6.5	23 21	21.3 956.4	3.5% 4.4%	Inclusion of planned and future developments (KEG) could significantly improve viability.
	City of Worcester: • Northern and Industrial • University and City Centre • Southern / NHS	30,500 30,000 22,000	5.5 6.6 4.3	20 22 21	1,268 25 509	4.8% 3.5% 4.2%	Opportunities related to linking networks to the development sites Worcester 6 and Worcester South should be considered.
Deep Geothermal (assuming 20 years life cycle)	**Offenham**	23,000	6.2	6	9,579	15.4%	Study suggests a range of different schemes could be viable: **Offenham**, **Throckmorton**, **Worcester South**, **Pershore** and **Broadway.**
Development sites	**Worcester 6**	N/A					Potential considered as part of the Worcester Northern network.
	Worcester South	N/A					Feasibility recommendations included under the deep geothermal schemes.

Type of site	Name	Size (annual MWh heat)	CAPEX (£M)	Payback (years)	Net Present Value £k (negative £k)	Internal rate of return (IRR)	Comments
	Throckmorton	N/A					Feasibility work recommended under the deep geothermal scheme recommendations.
	Hartlebury Estate	N/A					No specific feasibility work recommended but Council should encourage dialogue between Severn Waste and Wienerberger.
Other local heat networks	**Pershore Evesham, Great Malvern, Droitwich**	N/A					Potential for smaller local heat networks exists.

Table 1.1 lists a wide range of heat network projects that have the potential for future development. In order to prioritise these projects further, the Council should focus feasibility studies on schemes that meet the following criteria:

- Majority of the initial energy customers are from public sector management or ownership;
- Where key stakeholders have already shown interest to develop or join a heat network;
- The potential for phasing and expansion is identified. Particular interest should focus on development sites; and
- Where opportunities for the involvement of renewable energy sources and electricity sales (private wire) exist.

Based on the technical and financial assessments undertaken in this study and considering the overall Council objectives, the following potential urban and geothermal heat networks are of specific interest and should be considered for the first round of feasibility work (see Tables 1.2, 1.3 and following bullet points).

Table 1.2: Recommendations for potential urban heat network schemes

Network Name	Size (annual MWh heat)	Estimated CAPEX (£M)	Annual CO_2 saving (t pa)	Majority of heat demand in public sector	Private Wire potential	Phasing and development potential
Bromsgrove: (Worcester Road Industrial Estate network)	2,100	1.7	378	No	Yes	Yes
Redditch (NHS and Industrial network)	268,000	19.6	48,240	No	Yes	Yes
Worcester (Southern NHS network)	22,000	4.3	3,960	Yes	Yes	Yes
Worcester (University & City Centre) network	30,000	6.6	5,400	Yes	Yes	Yes

- Bromsgrove: The Worcester Road Industrial Estate scheme has good potential for the establishment of a local district heat network with a small energy centre. The close proximity heat demand profile promotes an ideal network arrangement. The NHS and Town Centre network has potential with good heat demand profiles however the distances between the demand clusters provides a more challenging aspect to delivering the scheme;

- Redditch: The NHS & Industrial main provides good scope for the establishment of a district heat network with the initial stage centred around the hospital targeting the new residential and employment development area close to the hospital as the catalyst to the new district heat network. Expansion to the existing industrial and commercial customers may follow post establishment. The Redditch Eastern Gateway development could offer significant opportunities to extend the proposed schemes and improve overall viability and may provide a potential location for an additional energy centre;

- Worcester:

  - The Southern district heat network has the energy centre located in the NHS Acute Hospital and around 80% of the identified heat requirement is from major public sector and school sites with the potential expansion into the mixed development area at the former

DEFRA offices. The NHS hospital has a requirement for electricity that could be provided by a private wire system from the on-site energy centre. The route does not have complex crossings of rivers or railways and follows public trackways or highways; and

- The University and City Centre district heat network is centred on the high heat demand of the St John's and Severn Campuses of the University of Worcester. The campuses also have a requirement for electricity that could be provided by a private wire system from the on-site energy centre. The proposed route uses existing crossings for the River Severn and main railway line.

Table 1.3: Recommendations for potential deep geothermal heat network schemes

Network location	Target heat customers	Particular drivers
Offenham	Greenhouses/Agri-Tech	Detailed work undertaken so far and existing high heating and cooling demands
Throckmorton	Agri-Tech/new developments	Existing nearby energy projects, future developments and available seismic data
Worcester South	New housing developments	Known geology from Kempsey borehole and potential example for other development sites and for the wider Worcester area
Pershore	Public sector	Located within area of highest deep geothermal heat potential
Broadway	Hotels/tourism	Alternative business case making use of the heat and the water itself

- Offenham: The pre-feasibility study demonstrated that significant potential for a deep geothermal scheme to supply the local Agri-Tech sector exists and stakeholder discussions have confirmed local interest. Particular advantage is the proximity of high heating and cooling demands;

- Throckmorton: The area around the Throckmorton airfield is already characterised by a diverse number of existing energy schemes (solar, anaerobic digestion, landfill gas) combined with high heat demand from large greenhouses and the potential development of the airfield itself. Detailed geological information are available from a number of deep seismic survey lines and Council ownership of landfill sites offer opportunities for an energy centre location. Throckmorton proves an ideal test area for combining (hybrid) renewable energy solutions;

- Worcester South: This large development site offers an ideal site for a detailed evaluation of a heat network scheme focusing on the comparison of a deep geothermal heat based scheme versus a conventional gas CHP scheme for a known or indicative development proposal. The historic Kempsey borehole and nearby deep seismic survey lines can be used to confirm the geological conditions in the area. A detailed feasibility study could act as an example for other future development sites in Worcestershire;

- Pershore: A high concentration of public sector heating and electricity demand was identified in Pershore town centre, centred on the Council offices and the Community NHS Hospital that could make a small local heat network viable (micro network). Similar to Worcester South, feasibility work should focus on an evaluation of competitiveness between a conventional energy source (gas CHP) and a renewable source such as deep geothermal or specific heat pump applications using shallow groundwater or sewer heat. Pershore is located within an area that has the highest deep geothermal heat potential in Worcestershire; and

- Broadway: This touristic location in the Cotswolds offers a very different deep geothermal energy opportunity. Local hotels have not only a significant heating and hot water demand but some hotels also have spa facilities, i.e. the geothermal water itself has a significant value that could make a small heat/hot water network viable. The hydro-chemical properties of the water could also be of interest, offering hotels the possibility to broaden their offers to visitors.

This project provides a high-level review of the heat network opportunities in Worcestershire and is in main parts based on assumptions. Feasibility work should focus on gaining more detailed energy data (heating, cooling and electricity) and a better understanding of the heat customer's energy systems, contractual arrangements and potential refurbishment plans. Consideration of all of these factors will significantly improve the accuracy of the technical and financial evaluations and help to prioritise developments further.

Key risks of the next stage of work relate to the ability to engage with key stakeholders to make information available, allow access to their facilities and to show interest in joining a potential scheme. Highly variable energy prices, political priorities and changes of incentive schemes pose risks and opportunities that will need to be considered throughout the development process.

2 Introduction

2.1 Background

Wychavon District Council ("the Council") has appointed Mouchel Consulting with its sub-consultant VBC Associates Limited to carry out heat mapping and masterplanning across the County of Worcestershire, including a deep geothermal energy 'pre-feasibility' study in the Offenham area.

Funding to carry out this work has been secured from the Heat Networks Delivery Unit (HNDU) with match funding provided by the Worcestershire Local Enterprise Partnership (WLEP).

The overall project aims to establish the feasibility of developing heat networks in Worcestershire through consultation with developers, businesses, Housing Associations and other stakeholders. The study also explores the potential of harnessing heat from sources including energy from waste, anaerobic digestion (Bio-Energy Technologies) and geothermal (both shallow and deep) which are all present in the County.

Figure 2-1 summarises the stages through which the HNDU supports local authorities and where this study sits therein.

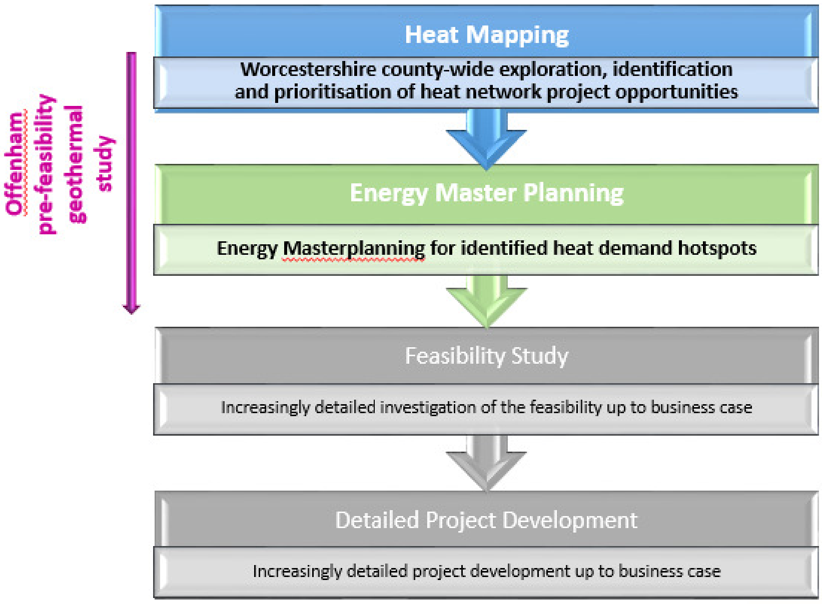

Figure 2-1 The HNDU process (*source:www.gov.uk/guidance/heat-networks-deliver-support*)

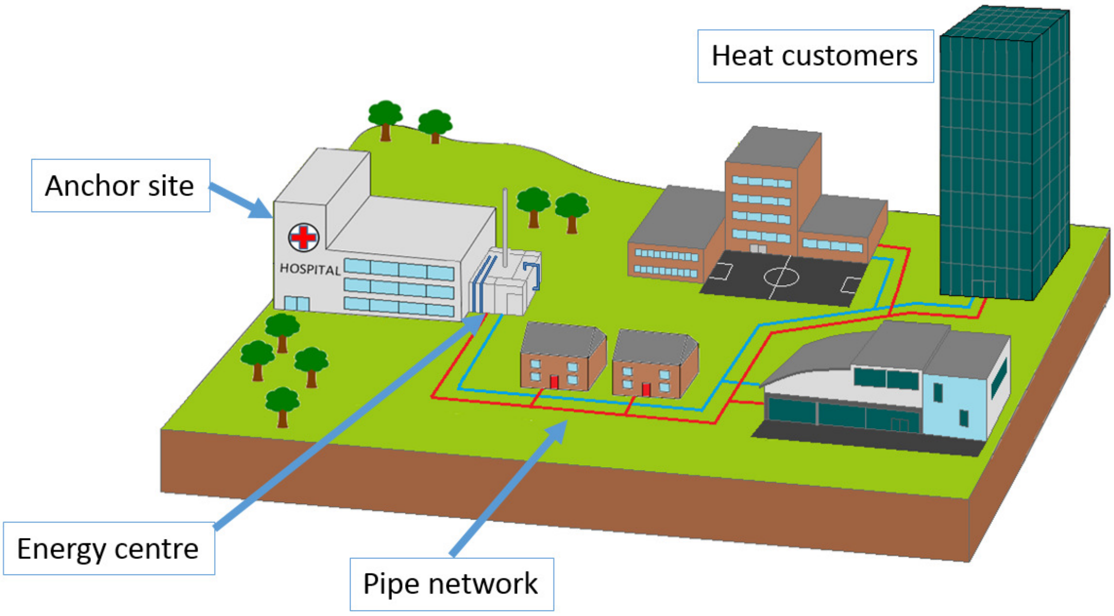

Figure 2-2: Schematic illustration of a typical district heating scheme

Figure 2-2 above is a schematic illustration of a typical district heating scheme. A district heating scheme comprises a network of insulated pipes used to deliver heat from the point of generation to an end user in an efficient manner. Networks vary in size and length, carrying heat just a few hundred metres between homes and flats, to several kilometres supplying entire communities and industrial areas.

The heat source, the energy centre, can supply heat from a range of sources such as Energy from Waste, Combined Heat and Power units, geothermal sources, waste heat from industrial sources and electric boilers.

The flow and return pipes carry hot water or steam around the network to the customers and then back to the energy centre. The customers include commercial buildings, public buildings, schools, leisure centres, and, residential customers.

Crucially, in order to make the district heating scheme viable there needs to be an anchor site, a large heat user (often, as shown on Figure 2-2, a hospital) around which the scheme could be based alone.

A heat network enables valuable energy, which is often wasted in power generation or industrial processes, to be captured and supplied to householders and businesses. Two examples of heat networks, one in the UK and one in The Netherlands are described below.

Bunhill Heat and Power is a Council owned and run inner city district heat network in Islington which was completed at the end of 2012.The network is fed by the local energy centre which produces both heat and power from a gas fired 1.9 mega-watt electric engine with a 115m^3 thermal store. There are three council estates and a new housing development connected to the network, a total of 850 homes, 2 leisure centres including a swimming pool are also connected. The resulting reduction in carbon emissions equate to approximately 1800 tonnes of CO_2 per year which is about a 60% saving in CO_2 for the housing estates and leisure centres compared to their previous heating systems. Further information can be found at *http://www.isep.org.uk/wp-content/uploads/BUNHILL-case-study-2013.pdf.*

Geothermal energy is widely used in The Netherlands where it has been developed since the 1980s and widely implemented since around 2000. As the example below illustrates, Dutch geothermal greenhouse schemes are particularly efficient as they often combine different crops to maximise the use of the heat.

The Koekoekspolder Geothermal Project in the north of the country supplies heat to 23Ha of greenhouses (equivalent to 3000 homes) via a heat network comprising 2.2km of pipes, powered by geothermal heat.

The water is abstracted from a sandstone aquifer from 1850-1950m depth which produces 72°C water. The waters are initially pumped from the heat exchanger to two greenhouses with cucumbers and one with tomatoes. When the water temperatures have dropped to 37˚C, the water is moved on to a greenhouse with strawberries and one with biological vegetable seeds (both crops need less heat). When the water temperatures fall to 20˚C, the waters are sent back to the hot water plant near the production well and get passed again through the heat exchanger, absorbing the heat from the geothermal reservoir waters until reaching 72˚C. Throughout the process, all the cooled reservoir waters are disposed of in an injection well about 1.5km away.

As of the end of 2015 there were 12 geothermal schemes in The Netherlands with a 13th scheme in the pipeline, with a typical output being about 22MW.

2.2 Overview of Worcestershire

The County of Worcestershire is administered by the County Council and six District Councils. The County is largely rural comprising undulating hills and farmland with pockets of commercial and industrial activity around the market towns. The Malvern Hills lie to the south and west of the County and extend into Herefordshire. The rural Cotswold Hills and Vale of Evesham lie to the south. The north-east of Worcestershire includes part of the industrial West Midlands. There are two major rivers flowing through Worcestershire, the Avon and the

Severn. The Severn flows through Stourpourt-on Severn and Worcester. The River Avon flows through Evesham and Pershore. Within the Vale of Evesham there is extensive fruit and herb cultivation with greenhouses being a prominent feature of the landscape. The M5 and M50 Motorways run through the County and border the City of Worcester.

Worcestershire has a local economy with a Gross Value Added (GVA) of £9bn in 2013 (source: Worcestershire Strategic Economic Plan, Worcestershire Local Enterprise Partnership, March 2014) and targets GVA growth to £11.9bn by 2025. Key sectors of the economy include: cyber security; defence; IT; advanced manufacturing; agriculture and 'Agri-tech'; visitors; education; and business services. Worcester is the largest settlement in the County of Worcestershire. Major towns in the County include Bromsgrove, Kidderminster and Redditch and there are several market towns including Evesham, Droitwich Spa, Malvern, Pershore and Stourport-on-Severn. The County comprises six administrative districts: Bromsgrove, Malvern Hills, Redditch, Worcester, Wychavon and Wyre Forest.

The 2013 carbon emissions in thousands of tonnes of carbon dioxide (kt/CO_2) for the County as reported by the National Atmospheric Emissions Inventory (NAEI) are listed in Table 2.1.

Table 2.1: Sources of Carbon Emissions in Worcestershire (2014)

Local Authority	Industry & Commercial Electricity	Industry & Commercial Gas	Industry & Commercial Other fuels	Domestic (all fuels)	Transport	Other	Total
Bromsgrove	72	28	15	214	456	6	**791**
Malvern Hills	68	16	37	174	303	25	**623**
Redditch	110	38	19	159	80	2	**408**
Wyre Forest	101	33	29	206	138	4	**511**
Wychavon	184	113	58	260	529	27	**1171**
Worcester	132	49	15	185	99	1	**481**
Total	**667**	**277**	**173**	**1198**	**1605**	**65**	**3985**

Source: *www.naei.defra.gov.uk/local-authority-co2-map, 2014*

2.3 Previous Studies

The British Geological Survey investigated the geothermal potential of the UK, including the Permo-Triassic rocks of the Worcester Basin. They demonstrated the presence of two deep basins separated by a north-south trending horst and 1500-1800m of Permo-Triassic sandstones which could potentially yield groundwater at temperatures of 40-50° C, based on information from deep boreholes.

The University of Worcester assessed the geothermal prospects within Worcestershire based on a study by the BGS of the potential for geothermal energy in the UK (Smith and Burgess, 1984) and concluded that while the temperatures across the Worcestershire Basin would be variable, it was likely that large volumes of groundwater at between 40 and 50° C were present.

We are not aware of any recent studies of district heat networks in Worcestershire but are aware of the importance that the Worcestershire Local Enterprise Partnership (LEP) and the *Worcestershire County Council Sustainability Policy and Action Plan 2015/16* attach to the contribution of geothermal heat sources and district heat networks to meeting the objectives.

2.4 Objectives and Scope

The four key aims of this study are:

- Produce detailed heat maps for Councils to identify areas of highest heat demand and the locations of existing CHP plant and energy networks;
- Identify potential areas for the development of additional viable district heat networks to support the strategic and environmental objectives of the Council, and to identify other opportunities for 'local scale' networks;
- Provide advice and master plans for a first phase development of three suitable district heat scheme with highest-level estimates of capital costing, returns and economic viability alongside carbon reduction estimates;
- Provide a pre-feasibility study for the geothermal potential of the Offenham area to provide a heat source for a district heat network in the area.

For the Offenham area in particular pre-feasibility work has been undertaken looking into the potential of using deep geothermal heat to supply heat to the local horticulture businesses.

This scope of works identified and delivered the following:

- Heat Demand Mapping
  - The output of the heat mapping phase is a geospatial analysis of the existing and future heat use in the areas designated by the Project Team, identifying the energy profile used by public and private sector non-residential clients throughout Worcestershire;
  - The top-down approach commenced with an examination of the non-residential heat use using the 2012 National Heat Map for Worcestershire prepared by the Department of Energy and Climate Change (DECC) to identify 'hot spots' for further examination (Drawing 4.1, Appendix A);

- The National heat map was qualified by the 2014 natural gas sales to non-residential users by Medium Super Output Areas sourced from DECC;
- Existing sources of heat were identified using local knowledge and planning records and included on-site CHP installations, non-residential solar photo-voltaic and solar thermal panels, energy from landfill, biomass and heat recovery from industrial processes;
- Local Authority owned sites were identified and latest annual gas, oil and power usage was identified from Display Energy Certificates (DECs) and local site invoices. The proportion of the energy used for heating was estimated using local knowledge and DECs and the load profile estimated using Automatic Metering Readings (AMR), and estimated using local knowledge, activity and occupancy;
- Private sector key sites were identified by individual Local Authorities and direct contact made by telephone and e-mail requesting annual heat and energy use. Where the annual energy consumption was not received at the time of writing the usage was estimated with CIBSE TM46 factors using the gross internal area estimated from satellite images, adjusted for activity and occupancy;
- Major industrial estates were identified by the Chamber of Commerce, Local Authority and OS maps with activity confirmed by local knowledge and annual heat demand estimated using CIBSE TM46 as above;
- Data was recorded on a master database and mapped onto OS maps using Eastings and Northing coordinates and site located with points scaled to heat demand and ownership;
- The heat mapping identified clusters of high heat demand within Worcestershire and selection criteria were agreed to identify areas and larger cluster district heat networks to take forward to masterplanning. In addition the smaller localised heat demand was identified and a number proposed as local network developments.

- Energy Masterplanning
  - The output of the heat mapping phase forms a key input for the energy masterplanning (EMP). The output of the EMP phase is the evidence base to be used to take selected district heat networks forward to full feasibility assessment;
  - The EMP stage is a high-level analysis and selection process to identify the indicative district heat network most suited to serving

each heat cluster. In this report the EMP phase was guided by the *CIBSE ADE Heat Networks: Code of Practice for the UK CP1, 2015* and, for each urban heat cluster the following parameters were considered:

- The energy requirements to meet the estimated annual demand profile for existing anchor loads and new developments and maintain a level of resilience;
- The initial interest from the potential heat users in both the public and private sectors to provide an indication for future feasibility study;
- The potential locations and technologies for the energy centres giving due consideration to technology, cost, output, environmental impact, availability of land and ownership;
- High level considerations of routes for heat mains to connect anchor customers to the energy centre including the initial review of planning constraints and cost of the dig. It is assumed that the pipework will be buried along its length and of the highest appropriate quality;
- Locations for thermal stores, pumping stations and route optimisation has been excluded at this stage and is recommended for inclusion in the detailed feasibility stage.

- Deep geothermal pre-feasibility study
  - High level geological review to describe the overall deep geothermal potential of Worcestershire with more detailed considerations for the Offenham area;
  - More detailed stakeholder discussions in Offenham to develop local interest, to compile energy data and to define requirements to progress a scheme. Develop a concept deep geothermal heat based network scheme for Offenham including initial financial evaluations;
  - Stakeholder meeting in Offenham to discuss the results of the study and to gather feedback.

3 Policy Context

3.1 International and European Policy

The *European Union Energy Efficiency Directive 2012/27/EU* establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. Under the Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain from its production to its final consumption.

The overall objective of Article 14 is to encourage the identification of cost effective potential for delivering energy efficiency, principally through the use of cogeneration, efficient district heating and district cooling, the recovery of industrial waste heat.

The *European Union Renewable Energy Directive (Directive 2009/28/EC)* sets an overall target for 20% of the energy consumed in the European Union to come from renewable sources by 2020. This overall target is divided by country, with the UK's target being 15% by 2020.

3.2 National Policy

The *Climate Change Act 2008* established the world's first legally binding climate change target to reduce the UK's greenhouse gas emissions by at least 80% (from the 1990 baseline) by 2050 with a 34% cut by 2020. (Source DECC). Moving to a more energy efficient, low-carbon economy will help to meet this target and will also help the UK become less reliant on imported fossil fuels and less exposed to higher energy prices in the future.

The *Planning and Energy Act (2008)* allows local planning authorities' policies to impose reasonable requirements for a proportion of energy used in developments to be from renewable and low carbon sources in the locality of the development.

In December 2011 the Government published the *Carbon Plan; delivering our low carbon future* that established the mechanisms to meet the UK's goal of reducing emissions by 80% by 2050 relative to a 1990 baseline and acknowledges that this is likely to mean reducing emissions from buildings to near zero by 2050, and up to a 70% reduction in emissions from industry – the majority of which are heat-related. District heat networks are acknowledged as a key mechanism to move towards a low carbon future.

To directly address the challenge of reducing the carbon emissions from heat use in the UK, the Government published the strategic framework document *The*

Future of Heating: A strategic framework for low carbon heat in the UK, 2012 that sets out a framework for solving the challenge of ensuring there is affordable, secure and low carbon heating up to 2050.

The document recognises the important contribution of properly designed heat networks to meet that challenge. The framework recognises five key attributes of heat networks:

1. *Heat networks offer a way to supply heat directly to homes and businesses through a network of pipes, rather than supplying the fuel for people to generate heat on-site. Under some circumstances, heat networks can be the most effective way of supplying low carbon heat to buildings, and can offer greater convenience and reliability to consumers. Heat networks also offer flexibility over time, as a number of different heat sources can supply the same network.*

2. *Heat networks are best suited to areas with high heat demand density. They can be an excellent choice in urban areas, providing individually controlled and metered heat as reliably as gas boilers. Heat networks can also serve buildings like blocks of flats where individual gas boilers may not be an option.*

3. *Heat networks are compatible with a wide range of heat supply options and provide a way to distribute low carbon heat, which makes them easily upgradeable, creating flexibility to make the transition to low carbon heat over time with less disruption for consumers and businesses. Most of the cost and disruption occurs at the point of initial construction and installation.*

4. *Heat networks can be integrated with local authority plans for urban growth and regeneration aimed at tackling social deprivation and environmental issues such as air quality. They can also be part of an integrated low carbon system as already seen in some European cities.*

5. *Heat networks already exist in cities such as Sheffield, Birmingham and Aberdeen, helping to regenerate communities, tackle fuel poverty and provide reliable and affordable heating, often through a partnership between local authorities and the private sector.*

The framework acknowledges that the majority of heat networks start small and expand over time, potentially connecting to each other as they grow, creating larger networks that span city centres and a variety of building types. When networks are sufficiently developed, additional heat sources can be connected.

This phased approach affords time and high-profile leadership to overcome economic, environmental and stakeholder hurdles to encourage local acceptance, engagement trust and growth and is the approach adopted in this report.

The framework goes on to highlight and acknowledge the pivotal role that local authorities play in enabling the development, deployment and expansion of the heat network – noting that it is the vision and engagement that provides anchor loads through public buildings and social housing that delivers confidence for investors as well as providing the co-ordination and local knowledge to bring forward projects within their area.

In 2013 the Government published the follow-up, entitled *The Future of Heating: Meeting the challenge, March 2013***.** This document deals with four different aspects of the heat challenge: industrial heat; networked heat; heat in buildings; and grids and infrastructure. It highlights the importance of financial incentives, building regulations and zero-carbon homes and planning policy.

In these two documents the Government recognises the importance of the heat network in providing the infrastructure to transport heat from the point of generation to the point of use. It is recognised that new sustainable energy sources such as waste industrial heat, deep geothermal heat and large scale heat pumps are critical to the generation of the low carbon heat that is transported within the heat network.

This report seeks to identify the existing and future non-residential heat demand, viable and resilient district heat networks and the sustainable heat resources in the County.

National Planning Policy Framework published by the Department for Communities and Local Government (DCLG), March 2012 supports the move to a low carbon future and indicates that local planning authorities should:

- plan for new development in locations and ways which reduce greenhouse gas emissions;
- actively support energy efficiency improvements to existing buildings; and
- when setting any local requirement for a building's sustainability, do so in a way consistent with the Government's zero carbon buildings policy and adopt nationally described standards.

3.3 Regional and Local Policy

The policies surrounding the use of renewable energy infrastructure are derived from the overarching national policies and frameworks and tailored to meet the local requirements. Each District Council and key public sector stakeholders work to a carbon management strategy and action plan designed to contribute to meeting the national and local sustainability targets. Each local authority ensures that planning regulations actively promote the use of heat networks as a key part of the early growth of the networks.

The *Worcestershire Climate Change Strategy 2012-2020* aligns the Worcestershire strategy with the national policies and defines the ambitions as:

- build our low carbon economy
- hit tough but critical carbon targets
- adapt to inevitable climate change
- empower people to take action

The *Worcestershire County Council Sustainability Policy and Action Plan 2015/16* defines three themes and the actions to meet the themes:

- Promoting sustainability at a strategic level within the Authority
- Leading by example: addressing the Council's operational impacts on the community and the environment
- Promoting sustainability throughout the County

This heat network study has identified a number of clusters of heat demand that have the potential to be supplied by a viable and resilient heat network. The development of heat networks will support the objectives outlined in the 2015/16 Action Plan and will contribute to meeting the commitments by reducing CO_2 emissions from Council operations, using resources in an efficient and effective manner and contribute to the delivering against the objectives of national environmental policies and obligations.

The early adoption of the heat network will demonstrate leadership to the local communities and the private sector and promote sustainability throughout the County.

Other key policies and plans reviewed include:

- West Midlands Renewable Energy Capacity Study (March 2011)
- Worcestershire Climate Change Strategy 2012-2020
- Worcestershire County Council Sustainability Policy and Action Plan 2015/16
- Worcestershire County Council Sustainability Policy, 2015

- SWDP 27: Renewable and Low Carbon Energy,
- Bromsgrove District Plan Policies,2011-2030
- Borough of Redditch Local Plan Policies,2011-2030
- Malvern Hills Local Development Scheme 2015-2018
- Wychavon Intelligently Green Plan 2012 - 2020
- University of Worcester Carbon Management Strategy 2014-2018

4 Heat Mapping Study: Worcestershire Energy Demand and Carbon Footprint

4.1 Introduction

This report considers the options and potential of developing decentralised heat networks to supply space heating and hot water to the existing and planned heat users within Worcestershire. The brief of this heat mapping study was to identify the geographical areas of the County where concentrations of public and private sector non-residential buildings formed an area of heat demand, known as heat clusters. The brief included the assessment of known strategic developments as potential sites and a specific study into the Offenham area.

4.2 Key Site Characteristics

The key site characteristics for an early adopter of heat supplied from a district heat network was agreed with the Steering Committee as owned by the public sector or a committed private landlord, having a continuous annual heat demand, located close to other major heat users and with a simple point of connection to the district heat network.

The search for sites focussed on buildings with the following activities and ownership:

- Hospitals and care homes, NHS Acute and Community hospitals and a private sector hospital
- Central government estate
- Local government estate
- Social landlords
- Sport & leisure facilities
- HM Prisons
- Larger hotels (>150 rooms or with swimming pool)
- Educational facilities, schools, academies and further education
- Universities and colleges
- Museums & art galleries

- Other public buildings (e.g. theatres, fire stations, police stations)
- Known strategic developments and redevelopment areas
- Private sector industrial sites with estimated high heat demand
- Private sector industrial estates (including retail parks, trading estates and business parks) with expected high heat demand
- Private sector residential and mixed developments (>100 units)
- Private commercial and strategic developments (>9,999m^2)

The evaluation work was undertaken in close collaboration with Council representatives and other key stakeholders such as the commercial growers, Chamber of Commerce and the key private sector heat users on an individual basis. Other key stakeholders included local social landlords, the University of Worcester, academies, colleges and private schools.

The basic heat map template for major heat loads is summarised in Table 4.1.

Table 4.1: Core Data for Heat Mapping

Mapping Coordinates	Building Information	Heating Supply	Non Heating supply	Local Generation
OSX (Easting)	Name and address	Annual heating fuel metered	Annual non-heating fuel metered	On site heat
OSY (Northing)	Ownership	Data source	Data source	On-site power
OS Grid	Use classification	Real data or Estimate	Real data or Estimate	CO_2 emissions
Local Authority	Sub-classification	Usage pattern	Usage pattern	Available land
Object reference	Floor Area (GIA)	Load profile	Load profile	Waste Heat
Network potential	Age and status	Data confidentiality	Data confidentiality	Energy from Waste

The following section demonstrates the evidence base for the heat mapping study.

4.3 Methodology and Data Sources

The methodology is based on the guidance contained within the *CIBSE ADE Heat Networks: Code of Practice for the UK CP1, 2015*.

The Project Team identified the portfolio of sites and new strategic developments from the public and private sector and made direct telephone and e-mail contact to request the data. Where successful the data was added to the database with a confidentiality flag if required.

Where it was clear that no heat data would be forthcoming the floor area of the building was estimated and local knowledge used to identify the type of commercial activity and times of use. This information was used in conjunction with the non-residential heat demand estimates supplied in the DECC publication *Assessing the cost effectiveness of metering: Energy demand benchmarks, 2014* sourced from CIBSE TM46, 2008 to estimate the annual heat requirements and load profile.

The database of heat use was assembled and presented by the Project Team to the Steering Group and received the agreement to proceed.

The annual energy usage of 827 individual public and private buildings, an additional 119 key private sector users and 82 industrial estates across the County was collated, either through recent Display Energy Certificates, direct requests to the building occupier or by the estimating methodology described above. The method of heating, load profile and the fuel used was identified and where appropriate adjusted to reflect the fuel used for heating. Occupancy hours and load profiles were also captured or estimated.

The core data is provided separately due to its size and confidential nature.

A top-down approach to mapping the heat demand within Worcestershire was adopted, comprising:

- The initial high level view using the National Heat Map based on the National Statistics data 2012, DECC. The 2014 high-level non-residential energy consumption was sourced from DECC comprising the non-residential gas demand by Middle Layer Output Area confirmed and focussed approach (Drawing 4.2 and 4.3 in Appendix A).

- The middle level Heat Mapping Data Points Drawing 4.4 in Appendix A identifies and locates the individual sites with a reported or estimated heat demand that were included in the initial analysis and subject to the site selection criteria.

- The map shows:

    - The comprehensive dataset of 827 public and private sector buildings assembled in collaboration with representatives from the District and County Councils.

    - The 119 key private sector heat users that were identified and contacted to request heat use data. Where that data was not provided the heat use was estimated. The heat demand across 82 existing major industrial estates containing many sites was estimated using publically available data combined with local knowledge. The lower level mapping and dataset was built using a bottom-up view of the middle level datasets to identify and confirm the key clusters of heat demand.

4.4 Worcestershire Carbon Footprint

The following carbon dioxide emissions data for Worcestershire has been sourced from the National Atmospheric Emissions Inventory (NAEI), overseen by DEFRA and measured under the EU GHG Monitoring Scheme and available at *http://naei.defra.gov.uk/data/local-authority-co2-map.*

The industrial and commercial activity associated with natural gas and other heating fuels accounts for 11% of the total 2013 carbon emissions of Worcestershire, representing 450,000 tonnes of CO_2 per annum. This study focuses on the use of district heat networks to reduce the carbon emissions alongside delivering long-term commercial, infrastructure and environmental benefits aligned with the adopted strategies and to the individual users.

The highest source of CO_2 emissions within the County is the transport sector accounting for 40% of the emissions. The second highest source is the domestic sector with 30% of the total emissions, of which around half is associated with residential heating (source: Energy Saving Trust *www.energysavingtrust.org.uk*). Industrial and commercial (I&C) activity associated with electricity only accounts for around 17% or 667,000 tonnes per year of CO_2 emissions in Worcestershire.

Figure 4-1 summarises the sources of the total annual GHG emissions for 2013, measured in kt/CO_2 equivalent for Worcestershire and highlights the importance of the I&C sector in addressing the carbon reduction challenge.

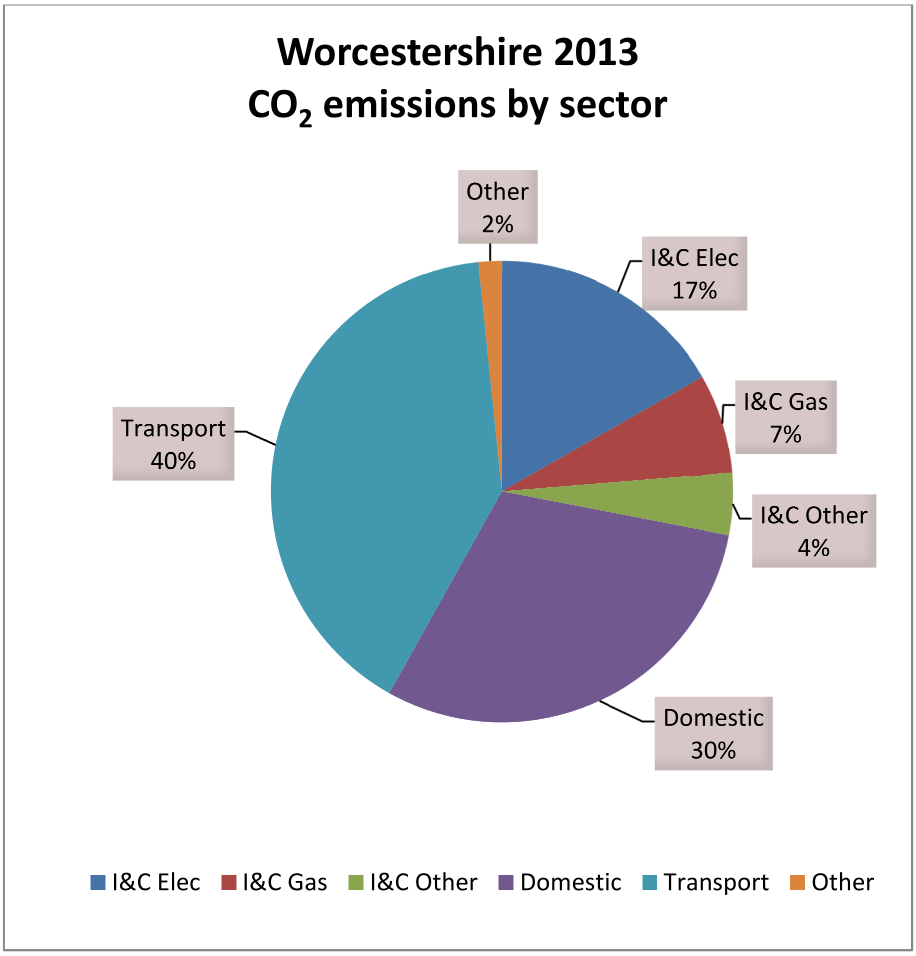

Figure 4-1: Source of total annual GHG emissions 2013 (kt/CO_2 equivalent for the County of Worcestershire) Source: National Atmospheric Emissions Inventory, 2013 http://naei.defra.gov.uk/data/local-authority-co2-map

4.5 Local Emissions Distribution

The NAEI dataset has been broken down further into emissions by local authority area as shown in Figure 4-2 and described in the following sections.

4.5.1 Carbon Emissions within local Authority areas in Worcestershire (kt/CO_2)

Within Worcestershire the annual CO_2 emissions are distributed between the sectors in broadly the same proportions as throughout each of the District Council Areas. Proposed heat networks are focussed in the clusters of industrial and commercial activity with high concentrations of heat demand which is currently met by fossil fuels.

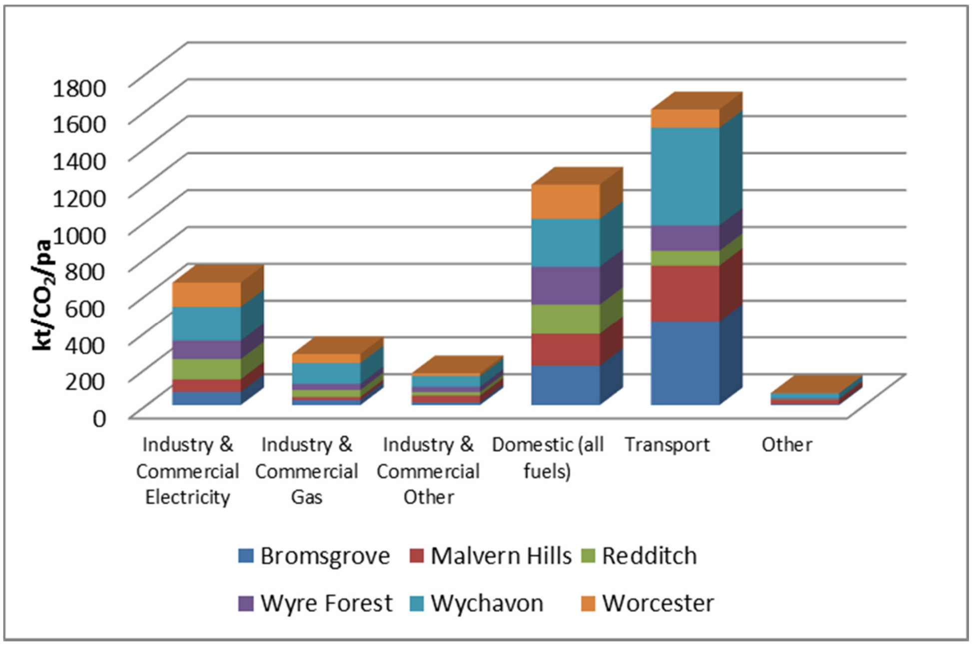

Figure 4-2: Annual CO_2 emissions by sector and authority (source http://naei.defra.gov.uk/data/2013)

4.5.2 *Map of the annual I&C gas usage GHG emissions by Local Authority*

Figure 4-3 focuses on the total annual industrial and commercial GHG emissions associated with the use of natural gas measured in kt/CO_2 equivalent for each of the local authority areas within Worcestershire.

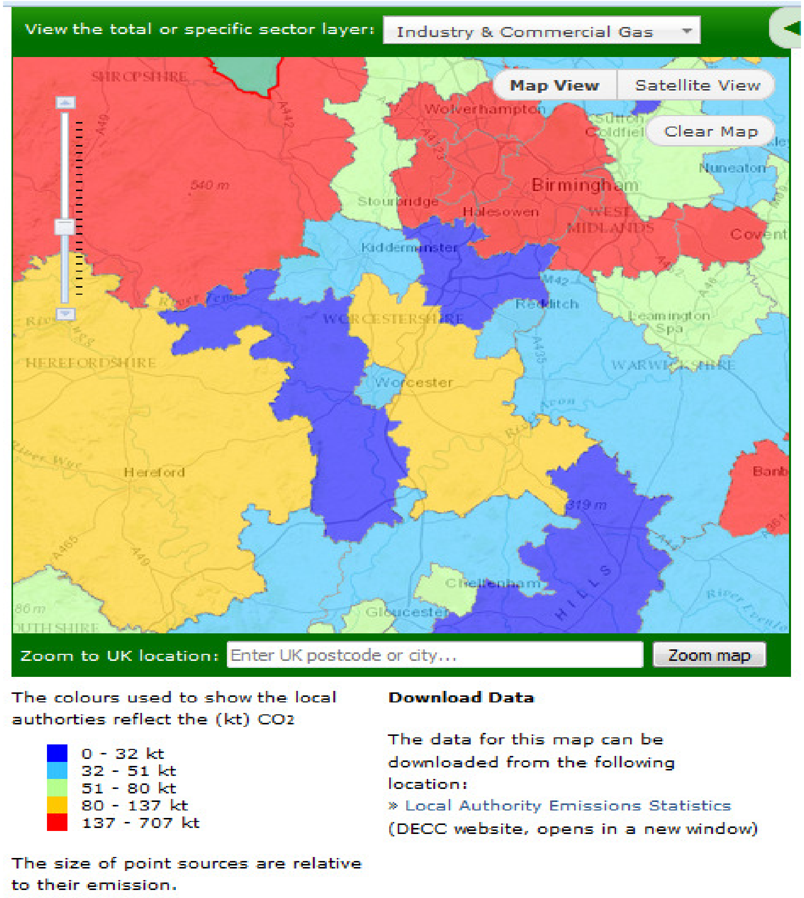

Figure 4-3: Source GHG emissions from industrial and commercial gas use by Local Authority, 2013 (source: http://naei.defra.gov.uk/data/local-authority-co2-map)

4.5.3 Annual Non-residential CO_2 Emissions by MSOA Area

Drilling further into the carbon emissions by area within the County the following map highlights the annual non-residential carbon emissions calculated from the 2013 gas consumption by the Medium Super Output Area (MSOA) using data sourced from DECC. The use of a suitable heat network is expected to have a direct effect on the gas demand used for heat.

The non-residential electricity consumption for 2013 is shown by Medium Super Output Area (MSOA) in Drawing 4.2 in Appendix A. The non-residential gas consumption data by MSOA for 2013 is shown in Drawing 4.3 in Appendix A and the very high demand areas are from using high temperature gas as part of an industrial process.

The data highlights the higher consumption in the key industrial areas close to urban settings and this study focuses on the potential for District Heat and local heat networks in the areas of highest consumption.

5 Worcestershire Heat Map Inputs and Results

5.1 Data Collection

Following the baseline heat mapping energy demand assessment described in Chapter 4 the data was mapped to identify opportunity areas in Worcestershire for district heat networks. Energy data from key buildings and industrial estates was collected and fed into a detailed mapping exercise to confirm and map areas of high heat demand using a Geographical Information System (GIS).

The heat mapping exercise was carried out in eight stages:

- Data collection of heat demand and key characteristics of buildings using the site selection criteria and methodology described in Section 4.2 and 4.3 identified areas of highest heat demand as well as the locations of any existing combined heat and power plants or other sources of heat.
- Direct contact was made with representatives of key stakeholders including the Council, the private sector, glasshouse owners; and registered social landlords were approached by telephone, e-mail and meetings to introduce the proposal, raise awareness and request the supporting heat demand and heat generation information.
- Public and private sector strategic developments were identified and the developers contacted to identify potential heat networks.
- Datasets and layers were plotted to complete the detailed mapping of heat demand onto OS maps.
- Interim workshops reviewed the outputs, identified additional data requirements and confirmed the opportunity areas for potential heat network analysis.
- Data evaluation and interim workshop were conducted to review the findings and any additional sites were identified and direct contact was made with representatives to obtain further information, clarify data already supplied, and enhance the overall quality of the data sets.
- Presentation of the findings to the key stakeholders.
- The data sets were collated into a comprehensive heat mapping matrix and formed a key input into the energy masterplanning phase.

5.2 Completion of Database in order to obtain GIS outputs

The dataset was refined into 'information layers' to describe the existing and planned heat use by the key stakeholder sites across Worcestershire. The sites and planned developments were plotted on maps and clusters of heat demand identified that have the best potential for future heat networks.

Sites where heat data was not available at the time are not included in this analysis but, depending on meeting the selection criteria could participate in later network expansion schemes. The analysis also identified opportunity areas, which although too small to be viable for a district heating network, could be linked into a smaller local network.

Heat clusters are typically developed around the existence of one or more of the following factors;

- Large heat user(s)
    - Large heat users are a critical part of any cluster development. Ideally a number of larger heat users concentrated into a small local area creates an ideal environment. Anchor loads are sought as these can provide a secure and sizeable demand or be seen as a landmark building that influences the thinking of others in the vicinity. There are a number of large heat users in Worcestershire in both public and private ownership.
- Large heat producer
    - The provision of a dedicated primary energy centre is a key requirement of any district heating network. The district heating network can provide a useful outlet to receive waste heat from existing industrial processes. In some cases the district heating network can facilitate the efficiency and commercial viability of investing in on-site electricity production for a local business. The district heating network can accept and use heat that would otherwise be wasted. Waste heat would normally be assumed to come from a source which would normally have to "dump" heat as part of the process. Waste heat can often be secured at a price less than conventional energy sources from fossil fuel, for example. Other sources of heat from conventional sources such as fossil fuel or biomass should be sought. Due to the intermittent nature of waste heat it can only be used as a subsidiary heat source to the primary district heating network heat source.

- Existing networks and/or new development(s)
    - Small heat networks, such as around a large campus site may already have been developed and maybe redeveloped or reinstated to form part of a new wider network.
    - New developments can provide an ideal platform for creating a new heat network that is able to connect to a wider area or to enhance the viability of an existing or planned district heating network by providing additional demand and a cost effective build. In this study the key strategic developments have been considered as part of the district heating network analysis. The new development can act as the anchor load and as the site of any primary energy source. This often makes the development of a wider network more viable as the initial asset provisions can be accommodated by the new development.
- Public buildings(s)
    - Connecting public buildings provides a series of potential anchor loads and carbon reduction opportunities and sends a very positive message to other building owners in the area and to the potential district heating network investors and developers. This action often provides the reassurance to encourage prospective users and private sector landlords to connect to the district heating network, either immediately or at a later stage of the development.
- Building Diversity
    - In an ideal scenario a heat network should strive to secure a variety of buildings with differing demand profiles and heat loads. This variation helps to optimise the sizing and selection of heat network equipment and the operational requirements of the primary energy centre and thermal stores. It should be noted that whilst this is desirable, it is by no means essential that this should always apply.

5.3 Identification of 'heat clusters' in existing urban areas in Worcestershire

The primary focus is to develop district heat networks in areas with existing high heat demand in existing public sector buildings (e.g. hospitals, offices, schools, leisure centres) alongside private sector industrial estates. The heat mapping data gathering identified and excluded natural gas used in other areas such as kitchens and as a part of an industrial process.

There are a number of limitations associated with the gathering of heat and cooling data as discussed below.

Estimated data is based upon a simple format using CIBSE TM46 which is based upon industry standard benchmark assumptions at the aggregate level. This data will not be sufficiently sensitive to distinguish between similarly constructed buildings with very differing operation requirements. The analysis recognises and mitigates this limitation by adjusting the results to reflect known activity and operating patterns and to apply the weather correction factor.

Actual data provided by a building user/owner may not be accurate. The scope of this type of study will not be able to determine accuracy of the data.

Metered gas consumption may include the use of gas for demands other than space heating and hot water, although it is recognised that the proportion is likely to be small. The analysis recognises and mitigates this limitation by:

- confirming with the user the details of process or non-heating gas use; and
- where no heating-specific is available the metered gas and oil use has been reduced at each site by 30% to take into account non-heating use.

Where it has been established by contact with the site that metered electricity is used to heat some parts of the building, it is often difficult to determine the proportion of consumption by heating and that by lighting and other appliances. In these cases the information is tested against local knowledge, recorded for later follow up and excluded from the energy masterplanning analysis unless there is local knowledge.

In the case of private commercial property collecting data required the identification of the most appropriate person. It was clear that many organisations adopt a ‘no name’ or ‘strict confidentiality’ policy which meant that the appropriate person was unavailable or that the data could not be released. In these cases the heat data has been benchmarked for individual sites using CIBSE TM46 using local knowledge to adjust the estimate accordingly.

The mapping highlighted 15 clusters of potential heat demand across existing industrial and commercial heat users in both the public and private sector. The predominant fossil fuel used to provide the space heating is natural gas with some older oil-fired installations in more remote areas. The clusters are shown in Drawing 4.5 and summarised in Drawing 4.6 both in Appendix A. The 15 clusters of non-residential heat demand comprise 10 clusters in existing urban areas, one major industrial concentration (Hartlebury), 3 strategic development sites (Worcester 6, Worcester South and Throckmorton) and the concentration of Agri-tech users located around Offenham: comprising some existing and potential demand from greenhouse growers as well as future potential to link in the HMPS Long Lartin site.

The clusters were filtered using the following key criteria:

- Presence of key anchor heat loads
- Diversity of users and demand
- Potential to serve new developments
- A significant heat demand from the public sector
- Physical proximity of sites
- Viable amount of annual heat demand
- The long term potential for heat sales.

The network required a location for the primary energy centre using an appropriate technology; locations were filtered by ranking against the following criteria:

- Proximity to heat demand
- Land ownership
- Planning and environmental considerations
- Heat generation technology including:
    - Energy costs and viability
    - Required temperatures and flow
    - Network resilience
    - Sustainable costs
    - Carbon impact.

The selection process and workshops refined the data and agreed the 7 heat clusters to be carried forward to energy masterplanning as shown in Drawing 4.7, Appendix A and detailed in Table 5.1.

Table 5.1: Characteristics of Heat Clusters to be carried forward to Energy Masterplanning

Heat Cluster Area	Annual Heat Requirement MWh per annum	Potential Carbon Emissions from the Heat Use (DEFRA conversion factors)	Network Characteristics
Bromsgrove	77,149	13,887	Mixed commercial and public sites
Kidderminster	127,262	22,907	Major estates and public sites
Redditch	440,616	79,311	Major estates and public sites
Worcester (North)	30,454	5,500	Major estates and strategic development
Worcester (University & Centre)	30,016	5,400	City Centre & University campus
Worcester (Southern NHS)	21,742	3,960	Major public sites
Offenham	25,000	4,812	Agri-tech
Total	**815,560**	**146,801**	

The analysis focused on delivering heat from district heat networks. Specific opportunities around combining heating and cooling requirements are discussed for the Offenham deep geothermal scheme (Chapter 8).

The following subsections with related drawings describe initial heat network routing for the town centre heat clusters developed as part of the masterplanning stage of the project. The detailed techno-economical assessments are provided in Chapter 7.

5.3.1 Bromsgrove

Within the Bromsgrove heat cluster the following four district heat networks were selected from the datasets and have the potential to link up in further phases depending on the viability and future heat demand. The non-residential users comprise both public and private sector sites. The technical and economic viability of each district heat network has been conservatively estimated and is detailed on each of the heat network drawings in Appendix A as detailed below:

- Town Centre and NHS district heat network with a primary energy centre located at the Princess of Wales Community NHS Hospital serving an identified annual heat demand estimated to be 18,246 MWh and estimated saving of approximately 3.3 kt/CO_2 per annum as described in Drawing 5.1 in Appendix A. The Hospital has an annual requirement for approximately 1.800 MWh of electricity some of which could be provided from a CHP unit located on-site, with the heat being provided to the heat network.

- Worcester Road district heat network with a primary energy centre located in the small industrial estate at Sanders Road serving an identified annual demand estimated to be 2,094 MWh and saving approximately 0.4 kt/CO_2 per annum as described in Drawing 5.2 in Appendix A. The Worcester Road Employment Site at this location is designated for redevelopment for traditional and non-traditional employment uses that support the wider regeneration aims of the nearby Town Centre.

- The Aston Fields and Buntsford district heat network proposes two primary energy centres and two networks with the potential for linking up in the future. The first network is in Aston Fields with a primary energy centre located adjacent to the swimming pool in Sherwood Road serving an identified annual heat demand estimated to be 11,090 MWh saving approximately 2.0 kt/CO_2 per annum; and the second network in Buntsford with a primary energy centre located on the land in Buntsford Drive serving an identified annual heat demand estimated to be 10,800 MWh saving approximately 2.0 kt/CO_2 per annum. The proposed development is for two separate heat networks with the potential to be linked and extended as described in Drawing 5.3 in Appendix A.

5.3.2 Kidderminster

Within the Kidderminster heat cluster the following two district heat networks were identified and have the potential to link up in further phases depending on their viability. The non-residential users comprise both public and private sector sites. The technical and economic viability of each district heat network has been conservatively estimated and is detailed on each of the heat network drawings in Appendix A as detailed below:

- Central district heat network around the town centre with a primary energy centre using gas-fired CHP located at the NHS Kidderminster Hospital serving an identified annual heat demand estimated to be 63,000 MWh saving approximately 11.6 kt/CO_2 per annum as described in Drawing 5.4 in Appendix A. The Hospital has an annual requirement for approximately 4,400 MWh of electricity some of which could be provided from a CHP unit located on-site, with the heat being provided to the heat network.

- Southern district heat network south of the town centre with a primary energy centre using gas-fired CHP located at the Hoobrook Industrial

Estate serving an identified annual demand for the full network estimated to be a total of 56,000 MWh/pa.saving approximately 10.3 kt/CO_2 per annum . The heat network development can be phased, with the initial network centred on the Hoobrook Industrial Estate and Worcester Road Retail Estate with a second phase to serve the Hoo Farm Industrial Estate as described in Drawing 5.5.

5.3.3 Redditch

Within the Redditch heat cluster the following two heat district heat networks were identified and have the potential to link up in further phases depending on the viability. The non-residential users comprise both public and private sector sites. The technical and economic viability of each district heat network has been conservatively estimated and is detailed on each of the heat network drawings in Appendix A as detailed below:

- Northern district heat network around the three Moons Moat industrial estates and potential future connection to the proposed Redditch Eastern Gateway development site with a primary energy centre using gas-fired CHP located at the East Moons Moat Industrial Estate serving an identified annual demand estimated to be 123,000 MWh saving approximately 22.6 kt/CO_2 per annum as described in Drawing 5.6 in Appendix A (numbers exclude future heat load from the Redditch Eastern Gateway site). The proposed route crosses the motorway using an existing bridge (subject to survey and consents).

- NHS and Industrial district heat network around the Lakeside and Park Farm industrial estates with a primary energy centre located at the NHS Alexandra Hospital serving an identified annual demand for the total network estimated to be 268,000 MWh saving approximately 49.3 kt/CO_2 per annum. The Hospital has an annual requirement for approximately 9,100 MWh of electricity some of which could be provided from a CHP unit located on-site, with the heat being provided to the heat network. The existing waste incinerator is to be considered as part of future assessments. The network can be developed in phases, the initial phase in red and subsequent expansions in blue as detailed in Drawing 5.7 in Appendix A.

5.3.4 Worcester

Within the Worcester heat cluster the following three heat district heat networks were identified and have the potential to link up in further phases depending on the viability. The non-residential users comprise both public and private sector sites. The technical and economic viability of each district heat network has been conservatively estimated and is detailed on each of the heat network drawings in Appendix A as detailed below:

- North Worcester district heat network around the existing industrial estates to the south of the A449 from the primary energy centre using gas-fired CHP located at the Warndon Depot adjacent to the M5 Junction 6 to the Blackpole and Elgin Industrial estates serving an identified annual demand estimated to be 30,500 MWh saving approximately 5.5 kt/CO_2 per annum. The district heat network has the potential to serve the strategic development site at Worcester 6 located to the east of the M5 at Junction 6 using existing bridge crossing of the M5. The primary energy centre is located at the Council owned depot at Wardon and the network can be developed in phases, the initial phase in red and subsequent expansions in blue as detailed in Drawing 5.8 in Appendix A.

- University and City Centre district heat network around the existing University of Worcester campuses and public sector buildings located in City Centre. The primary energy centre is proposed to be located on land at the University of Worcester's St John's and Severn Campuses serving an identified annual heat demand for the total network estimated to be 30,000 MWh/pa saving approximately 5.5 kt/CO_2 per annum. The St John's and Severn Campuses have an estimated electricity demand of approximately 4.000 MWh/pa some of which could be provided from a CHP unit located on-site, with the heat being provided to the heat network. The proposed network crosses the River Severn and Railway using existing bridges (subject to survey and consent). The network lends itself to phased development, the initial phase in red and subsequent expansions in blue as detailed in Drawing 5.9 in Appendix A.

- Southern NHS district heat network around the existing public sector buildings from the primary energy centre using gas-fired CHP located at the Worcestershire Royal NHS Hospital serving an identified annual demand estimated to be 22,000 MWh/pa and saving approximately 4.0 kt/CO_2 per annum as described in Drawing 5.10 in Appendix A. The Worcestershire Royal NHS Hospital has an estimated electricity demand of 13,800 MWh/pa electricity some of which could be provided from a CHP unit located on site, with the heat being provided to the heat network.

The process also identified the following strategic development areas as potentially suitable for new or extensions to considered district heat networks:

- Worcester 6: a strategic development site located adjacent to the M5 and the existing industrial estates along the northern boundary of Worcester. Worcester 6 is included in the Worcester North district heat network viability assessment.

- Throckmorton area: comprising little existing demand but is the subject of a supplementary planning document supporting a high-tech business park, potential future airfield development and several nearby existing energy projects and a large greenhouse complex;

- Worcester South: mixed development is located one km to the south of the Worcester South and NHS district heat network across open fields and not included in the district heat network. This is an opportunity for an extension in later phases or a stand-alone network opportunity.

6 Existing Energy Centres and Renewable Energy Constraints and Opportunities Analysis

6.1 Introduction

As part of this chapter a range of renewable energy sources is discussed to inform considerations at the masterplanning and, more importantly, at the feasibility stage of the wider project. A number of renewable energy schemes exist in Worcestershire or are at planning stage. Apart from the deep geothermal heat which is discussed in more detail in the following sections and Chapter 8 all other available renewable energy sources in Worcestershire have the potential to contribute as a heat/energy supply to a heat network scheme but are unlikely to be the main heat source for major schemes.

The following sections provide a general review of the opportunities with the future focus being on available energy sources within areas of concentrated heat demand (i.e. located within priority areas).

6.2 Solar, biomass and anaerobic digestion

There is an estimated 5.36MW microgeneration installed capacity predominantly solar PV (Ofgem, 2012). Source: Worcestershire Climate Change Strategy 2012 -2020. Each installation is predominantly small scale and restricted to generating energy for consumption on-site. Specific non-residential examples include University of Worcester installation of solar PV panels on the Woodbury and Arena buildings and solar thermal panels on the St John's Halls.

Particularly relevant for this project is one of the largest PV sites (36 acres) in Worcestershire which is located next to the former Throckmorton airfield, operated by Vale Green Energy. The site is designed for a peak electricity output of 19MW.

Numerous other solar PV schemes exist across the country but detailed mappings of these sites has not been part of this study.

Similar applies to biomass and anaerobic digestion (AD) plants. It is worthwhile mentioning the AD plants operated by Vale Green Energy around the former Throckmorton airfield (Rotherdale Farm and Springhill Farm) and AD plants installed by Severn Trent Water at their treatment works outside the major towns.

The Rotherdale Farm AD plant produces around 12,000m^3/day of bio methane feeding in the national grid and the AD plant at the Springhill Farm around

7,200m^3/day of bio methane. The produced methane at the Springhill Farm is also used to run an onsite CHP plant which supplies a large tomato greenhouse complex.

6.3 Energy from waste and landfill gas

There is an estimated 9.7MW large scale renewable energy generation capacity installed - still predominantly landfill gas (Source: Worcestershire Climate Change Strategy 2012 -2020).

The EnviRecover energy from non-recyclable waste plant is under construction at the Hartlebury Trading Estate (to the south of Kidderminster) and is scheduled to open in spring 2017. It will be operated by Severn Waste Services. The plant is designed to export 16MW electricity to the grid. Potentially up to 3MW raw heat (steam) is available for export from the plant.

The plant is expected to divert up to 200,000 tonnes of non-recyclable waste from landfill sites in Worcestershire and Herefordshire, employing 90 people on site.

Currently no significant heat demand exists at and around the Hartlebury Estate to make use of the heat from the EnviRecover site apart from the two Wienerberger sites which are used for the production of bricks and have a high gas demand for their kilns. Wienerberger imports electricity from BIFFA who generate power from landfill gas adjacent to their site at Hartlebury Estate. This covers up to 30% of their electricity demand.

Significant heat demand in Kidderminster and in Droitwich (Wiseman dairy factory) also exists but is considered too distant to be connected to the EnviRecover site. The study generally found it difficult to obtain energy data from private sector customers which shows a currently low interest in possible connections to district heat schemes. For the EnviRecover site we concluded that there is currently no commercially viable scheme to use the heat from the Energy from Waste facility. The Council and any other stakeholders may wish to arrange a meeting with the estate owner (Schroders), Severn Waste, Wienerberger and Wiseman to explore interest and opportunities to attract heat intense business to relocate to the business park to create a suitable anchor site. However, commercial barriers are likely to be significant.

Engie is currently operating a waste incinerator at the Alexandra Hospital in Redditch. Technical details and potential plans for expansion are to be obtained and assessed at feasibility stage.

Worthwhile mentioning is the power generation (6MW) from landfill gas at the landfill to the south of the former Throckmorton airfield. The site is owned by the Council and is operated by Severn Waste Services.

6.4 Shallow and deep geothermal and surface water heat extraction

The availability of shallow and deep geothermal heat and surface water heat sources in Worcestershire are controlled by the regional geology, hydrogeology and hydrology as discussed below.

6.4.1 Geology

Available Geological Information and Previous Studies

The relevant main geological features and boreholes of interest are shown on Drawing 6.1 (Appendix A).

The assessment was based on the following geological information:

- British Geological Survey Sheet 199 Worcester, Solid and Drift (1993) 1:50,000; British Geological Survey Sheet 216 Tewkesbury Solid and Drift (1988) 1:50,000; British Geological Survey Sheet 182 Droitwich, Solid and Drift (1976) 1:50,000
- The British Geological Survey's borehole record viewer - consulted to obtain all available deep borehole logs in the vicinity of the site. However almost all of the freely available logs were very shallow (<500m); deeper logs were mostly confidential;
- The Physical Properties of Major Aquifers in England and Wales (BGS, 1997);
- The UK onshore geophysical library - provided an indication of the location of nearby deep boreholes and existing seismic survey lines.

The following studies have been undertaken into the geothermal potential of the UK and the Worcester Basin; they are referred to in more detail in the geothermal section of this report but they also contain relevant geological information drawn upon here:

- I.F Smith and W.G. Burgess (1984) Investigation of the Geothermal Potential of the UK. The Permo-Triassic rocks of the Worcester Basin. British Geological Survey.
- Geothermal Prospects within Worcestershire. (University of Worcester).

Geological Setting and Structure

Most parts of Worcestershire are underlain by a geological structure known as the Worcester Basin, formed following the Hercynian Orogeny as a result of Permo-Triassic crustal extension. It is a north-south graben 30km wide, bounded by the Malvern Axis to the west and the Vale of Moreton Axis to the east. The basin gradually becomes shallower to the north and south, merging with the Birmingham/Staffordshire Basin to the north and to the south the sandstone thins and is replaced by mudstone.

The Worcester Basin is filled mainly with a thick sequence of Permo-Triassic continental sediments overlain by marine Jurassic Formations. These sediments are folded and faulted locally with these structures dividing the Worcester Basin into two roughly equal sub basins, the deeper one to the northwest centred to the east of Worcester and the other slightly shallower basin centred further southeast near Winchcombe.

Information concerning the structure of the Worcester Basin has been deduced partly from deep boreholes logs (as presented in Smith and Burgess, 1984) and seismic reflection data (also referred to in Smith and Burgess, 1984). A limited number of deep boreholes have been drilled into rocks of pre-Permian age in the Worcester Basin, the Netherton and Kempsey boreholes being the most pertinent to this study. The major structural features are indicated in Drawing 6.1 and the schematic cross-section in Drawing 6.2 in Appendix A.

The basin is bounded on its western side by a single major fault, the Malvern Fault, one of the most dominant structural features of the British Isles; to the west of which lies a band of igneous and metamorphic rocks (assigned to the Malvern Group). The eastern boundary of the basin is bounded by the Ilmington Fault Zone, beyond which are Coal Measures and Old Red Sandstone at depth.

The Worcester Basin is divided into 2 sub-basins resulting from a number of smaller north-south trending faults within the basin, divided by the centrally placed Inkberrow-Haselor Hill Axis as indicated on Drawing 6.1 in Appendix A. The deeper basin is to the west of the axis and the shallower basin to the southeast.

The greatest thicknesses of Permo-Triassic sandstone are found in the centre of each of the sub-basins, i.e. in the area to the east of Worcester and in the area around Winchcombe (in Gloucestershire). The maximum thickness of sandstone is likely to occur between the Kempsey borehole and the Inkberrow- Haselor Hill Axis as indicated on Drawing 6.2. Beneath the Cotswolds there is a marked thinning of the Permo-Triassic sediments in an easterly direction.

Stratigraphy

A schematic geological east-west cross section showing the main stratigraphical units is shown in Drawing 6.2, Appendix A and the expected stratigraphy of South Worcestershire is presented in Table 6.1.

The floor of the Worcester Basin consists of Precambrian and Palaeozoic (Cambrian to Devonian) rocks. The Precambrian Kempsey formation comprises mainly igneous and metamorphic rocks. Palaeozoic rocks (Cambrian to Devonian) bound the eastern part of the basin.

These are overlain by a thick sequence of Permo-Triassic deposits. At the base there is nearly 1000m of Permian sandstone (Bridgnorth Sandstone) overlain by up to 1000m of conglomerates and sandstone (Sherwood Sandstone Group), such thicknesses of sandstone being present in the centre of the basin in the vicinity of Worcester and Pershore. The Permo-Triassic sandstones outcrop in the northern/north-western parts of Worcestershire.

Generally the Permo-Triassic sandstones are covered by approximately 300m of Mercia Mudstone (thickest in the east of the Basin), although this is discontinuous or absent along the northern and western margins of the Worcester Basin.

Limestones, silt and clays of the Lias and Penarth Groups (Lower Jurassic/Triassic) may be present on top of the Mercia Mudstone but these are not continuous.

Table 6.1 Stratigraphy of South Worcestershire

Approximate Depth to the Top (mbgl)	Approximate Thickness	Stratigraphy			Lithology
0m	Few m	Quaternary	Superficial Deposits		Alluvial and drift deposits present along margins main rivers (Severn/Avon)
0m	Up to 100m (depending on location)	Lower Jurassic /Triassic	Lias Group, Penarth Group,		Limestone, argillaceous limestone, silt, clay
Up to 100m(depending on +/- Lias/Penarth Grp)	300m+	Triassic	Mercia Mudstone		Massive silty mudstone with occasional anhydrite and hard sandstone lenses, hard blocky siltstone or silty mudstone (skerries) also present
300m	Up to 1000m	Triassic	Sherwood Sandstone Group	Bromsgrove Sandstone	Conglomerate, pebbly sandstone and thin mudstone
				Wildmoor Sandstone	Fine grained soft sandstones with a few pebbles
				Kidderminster Sandstone	Sandstones with lenticular conglomerate bed
1200m	1000m	Permian	Bridgnorth Sandstone		Medium to coarse grained sandstones
>2000m	n/a	Precambrian	Kempsey Formation		Intrusive and extrusive igneous & metamorphic rocks

6.4.2 Hydrogeology

General Hydrogeological Conditions

Within the Worcester Basin, shallow groundwater is available in the superficial deposits and is abstracted in small quantities. The Permo-Triassic sandstones are significant aquifers (Principal Aquifer for water supply) close to their outcrop in the northern/north-western parts of Worcestershire, with the water becoming unusable for potable purposes as the depth of the sandstones and the thickness of the confining layer increases. The main water bearing units which might be suitable for open loop ground source heating or cooling purposes are summarised in Table 6.2 (sources: University of Worcester geothermal prospects study, Allen et al., 1997, Smith and Burgess, 1984).

Table 6.2 Hydrogeological Units of South Worcestershire

Stratigraphy	Principal Formations of Interest	Hydrogeological Unit and Characteristics
Quaternary	Alluvial and River Terrace Deposits	Secondary aquifers of local importance predominantly hydraulically connected to surface water bodies, contain relatively small volumes of groundwater. These aquifers are only of local importance and water availability restrictions may apply.
Triassic	Mercia Mudstone Group	Aquitard* (but includes the Arden Sandstones, potentially a secondary aquifer)
	Sherwood Sandstone Group	Bromsgrove and Wildmoor Sandstone (act as single hydrological unit): Principal Aquifer. Comprise a series of thin minor aquifers which in combination have a high transmissivity and an intergranular permeability. Individual abstraction wells may produce between 4 and 10Ml/d (dependent on local fracturing). Sand production may be an issue.
		Kidderminster Formation - Aquitard*
Permian	Bridgnorth Sandstone	Principle Aquifer, groups of boreholes may yield up to 10Ml/d.

*restricts groundwater flow

Deep boreholes indicate the top of the Sherwood Sandstone Group to be at approximately 300-600mbgl and the top of the Bridgnorth Sandstone to be at 1,300 -1,990mbgl with groundwater level being about 40mAOD in both units. Groundwater in the superficial deposits is close to the surface.

Hydrochemical Conditions

The groundwater quality in the Permo-Triassic sandstones varies from potable quality in the northern parts of Worcestershire to saline quality in the deeper parts of the Worcester Basin further south. Shallow groundwater quality is also more vulnerable to man-made pollution (industrial or agricultural sources).

Information on the chemistry of the deep groundwater in the Worcester Basin is limited, but overall the deep groundwater is too mineralised for use as drinking or irrigation water.

Information from the Kempsey borehole indicates the groundwater being mineralised but it is not so highly mineralised as to be considered a geothermal brine comparable to geothermal brines encountered in similar geological conditions (e.g. Cheshire or Wessex basins). The waters of the Wildmoor Sandstone are likely to be recharged by shallower groundwaters and show therefore a lower salinity.

The water in the deeper Bridgnorth Sandstone is more saline due to the Kidderminster Formation reducing vertical groundwater flows (aquitard), i.e. limiting effects from freshwater recharge at the margins of the basin.

Selected hydrochemical data from the Kempsey borehole obtained from the extraction of pore water from core material or collected in bulk from the drill pipe is summarised in Table 6.3.

Table 6.3 Analyses of Groundwater from the Triassic and Permian Sandstones in the Kempsey Borehole (Smith and Burgess, 1984)

Determinant (mg/l)	Triassic Wildmoor Sandstone (ca. 936mbgl)		Permian Bridgnorth Sandstone (ca 1390-1486mbgl)	
	Drill Stem	Core	Drill Stem	Core
Ca	340	500	1500	2100
Mg	90	140	290	450
Na	1800	1320	6600	8000
Cl	2840	3130	12000	16300
SO_4	820	420	1560	1580
HCO_3	n/a	2	n/a	96
Fe (total)	0.57	0.011	1.7	0.1

The hydrochemical test results in Table 6.3 indicate a much lower dissolved mineral content (i.e. lower salinity) in the Wildmoor Sandstone compared to the water samples from the deeper Bridgnorth Sandstone with the dominant mineral sources being halite (sodium chloride) and gypsum (calcium sulphate).

Highly mineralised waters (geothermal brines) can cause problems to equipment and pipe works during pumping and increases risks of low re-injection performance, therefore the relatively lower salinity of the deep groundwater in Worcester (assuming it will be confirmed) could be considered favourable compared to other locations in the UK.

6.4.3 Hydrology

Principal Surface Water Bodies

The principal rivers in Worcestershire are the River Avon, the River Severn and its tributary the Stour, and the River Teme which joins the Severn south of Worcester (also shown on Drawing 6.1 (Appendix A)).

The Staffordshire and Worcestershire canal joins the River Severn in Stourport and the Birmingham and Worcester canal joins the Severn at Worcester.

6.5 Discussion of Ground Source Heat Potential

This section describes the potential use of shallow and deep geothermal heat sources and the potential use of water source heat pumps (surface water).

6.5.1 Deep Geothermal Potential

The main deep geothermal resource in the Worcester Basin is likely to be provided by the thick Permo-Triassic sandstones present in the southern part of Worcestershire including the urban areas of Worcester, Pershore and Evesham and the wider Evesham Vale with its Agri-tech businesses.

Temperatures measured in the Kempsey and Netherton boreholes are indicated in Table 6.4.

Table 6.4: Temperatures for the Kempsey and Netherton Boreholes (based on Table 5 in Smith & Burgess, 1984)

Borehole	Base of Mercia Mudstone		Base of Permo-Triassic Sandstones	
	Depth (m)	Temp. (°C)	Depth to base (m)	Temp.(°C)
Kempsey	421	20	2305	46.8
Netherton	474	23.5	1759	54.3

Table 6.4 therefore indicates a groundwater temperature of 20-23.5°C at the base of the Mercia Mudstone Group and a temperature of about 45-55°C at the base of the Permo-Triassic Sandstone. For further assessments in this study we have assumed that groundwater temperatures of 35-45°C in the Sherwood Sandstone (Bromsgrove and Wildmoor Sandstone) and 40-50°C in the Bridgnorth Sandstone can be expected. However, significant differences are likely due to variable local

conditions (e.g. as indicated by the higher temperatures measured at shallower depth in the Netherton borehole compared to the Kempsey borehole).

The measured temperatures also from other boreholes in the Worcester Basin (Gloucestershire) confirm that temperatures are too low to consider power generation and are low for most currently used heating systems. Therefore, the use of heat pumps or combination with other energy sources will be important to make this heat source useable.

Considering the high drilling costs, heat energy output from a deep geothermal well needs to be maximised, i.e. closed loop systems within deep boreholes are not aimed for unless as an option for making use of abandoned deep wells (assumed not to be present in the study areas) or future pilot boreholes.

The geothermal potential of the southern part of the Worcester Basin is therefore considered to be good for the following reasons:

- The thick sandstone layers within the Worcester Basin (south Worcestershire) contain large volumes of hot water which due to its salinity is not useable for other purposes (e.g. drinking water, irrigation water) and therefore risks of licensing restrictions are minimal;

- Water temperature measurements from the Kempsey and Netherton boreholes indicate that tapping into the Bromsgrove or Wildmoor Sandstone may provide temperatures only slightly lower than from very deep boreholes to the base of the Bridgnorth Sandstone, i.e. there is potential to reduce drilling costs

- Geological risks are relatively low due to the overall thickness of the sandstone layers (approx. 2km in the centre of the basin);

- Additional energy sources are likely to be required to boost temperatures to required levels, i.e. risks related to the groundwater temperatures appear manageable by developing a robust technical solution;

- Layered aquifer characteristics allow to target specific formations making re-injection at a nearby location viable; and

- There is potential to use the groundwater in the sandstones for heat transfer or heat storage, in particular where geothermal heat sources can be combined with renewable cooling demands.

6.5.2 Shallow Ground Source Heat Pump Schemes

A number of shallow open loop or closed loop ground source heat pump systems have been installed in Worcestershire generally supplying heat to individual buildings rather than for larger heat networks. Full mapping of such installed systems has not been undertaken as part of this project but future feasibility work should aim to incorporate existing heat pump schemes into wider heat network developments where technically and commercially viable. Generally open loop systems produce higher heat outputs and require less space compared to closed loop systems but involve active groundwater abstraction and potentially re-injection which are both subject to licensing (>20m^3/day) and potential groundwater quality issues need to be considered.

The BGS developed the open-loop ground source heat pump (GSHP) web tool in 2012 accessible at *http://mapapps2.bgs.ac.uk/gshpnational/home.html*. The tool provides only an initial assessment of the suitability of the subsurface to support open-loop GSHP installations in England and Wales. A screen shot is shown in Figure 6-1 A Screen Shot from the Web GSHP Screening Tool.

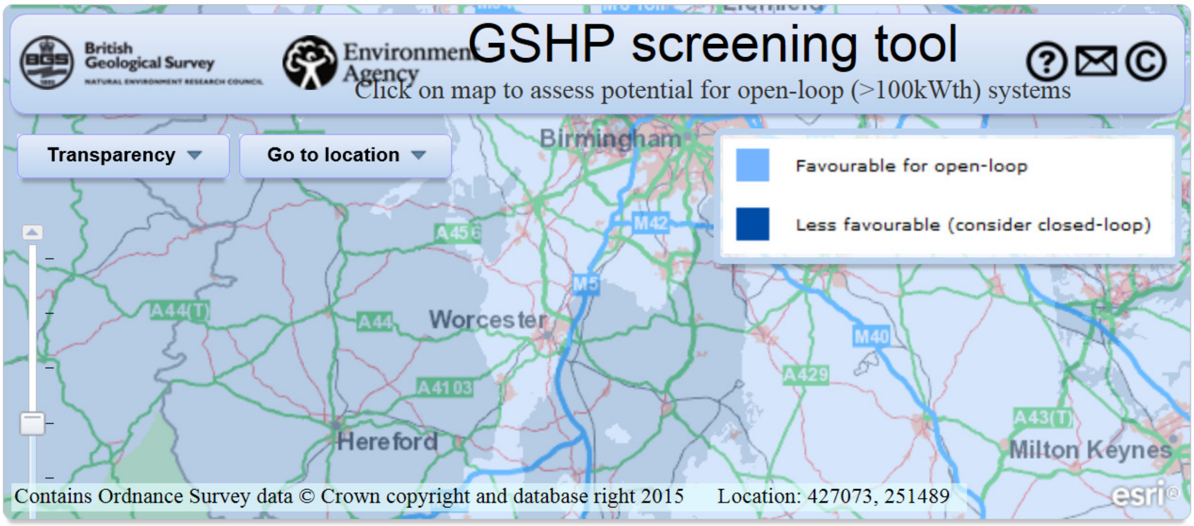

Figure 6-1 A Screen Shot from the Web GSHP Screening Tool.

The initial screening layer highlights all areas (light blue in Figure 6-1) where there is potential for the operation of open-loop GSHP systems (>100kWth). In these areas, a productive aquifer (> 1 L/s) is present within 300 m below the topographic surface.

The web tool consists of a set of data layers with different attributes, the overlaying of which produces a map indicating the prospective of the subsurface to be suitable for installation of GSHP. Depending on availability the data layers may include:

- Bedrock aquifer

- Depth to source
- Protected areas
- Existing licensed abstractions
- Groundwater chemistry, including the groundwater tendency to form calcium carbonate scaling and corrosiveness towards steel.

Details are provided in the user guide to the initial tool for West Midlands (BGS, web tool as detailed above).

The tool only considers the main hydrogeological units as providing aquifers at depth. In the area of interest this refers to the Sherwood Sandstone, generally at the margins of the Worcester Basin, i.e. in areas where the sandstone layers are relatively shallow. The favourable area expands from the west and north of Worcester all the way to Birmingham, and between Worcester and Gloucester in an approximately 10mile wide strip to the south (Figure 6-1).

Additionally, the depth to the Sherwood Sandstone is quite variable in the considered area. The most favourable areas are in the north of Worcestershire, where the bedrock aquifer is shallow and provides a good yield. To the south of Worcester, the Sherwood Sandstone is deep and in places deeper than 300m below the ground surface.

Open Loop Systems.

In open-loop systems, groundwater is abstracted at ambient temperature from the ground, passed through a heat pump before being re-injected back into the ground or discharged at the surface.

An initial assessment of the potential for a shallow open loop system was undertaken assuming a flow rate of 1,000m^3/day (41,700 l/hr) could be sustainably abstracted from a single borehole in the area. The pumped groundwater is used for heating and its temperature is reduced from 15ºC to 5ºC before it is re-injected back into the ground at a location down gradient, or alternatively used and discharged into a surface water course.

Given the following conditions:

- Initial temperature T0 = 15ºC
- Discharge temperature T = 5ºC
- Extraction/injection rate 41,700 l/hr
- Heat capacity of water 4.18kJ/kgK;

the available ground source heat is estimated as follows:

Ground Source Heat = 41,700m^3/hr * 4.18 kJ/kgK * (15-5 ºC) =
= 1,743,060 kJ/hr
= 484kW

The total heat effect is the ground source heat (GSH) and the electrical energy to run the heat pump. This can be estimated by the Coefficient of Performance (CoP):

Electrical Energy = Total Heat Effect / Coefficient of Performance,

or

Total Heat Effect = GSH + Electrical Energy = GSH/(1-1/CoP)

assuming a coefficient of performance = 3.5,

Total Heat Effect = 484kW/ (1-1/3.5) = **345kW**.

The above energy yield does not take into account the energy to run the abstraction and injection pumps and the viability of such schemes is very dependent on the achievable CoP.

Renewable Heat Incentives (RHIs) help make such schemes financially viable. However, the example above shows a relatively small heat output for a significant groundwater abstraction. This, together with generally high temperature requirements of existing heating systems makes it unlikely to be the main source of heat supply for major urban heat networks, but could be part of an energy mix feeding into a network (secondary source).

Closed Loop Systems

Closed loop systems do not require physical pumping of groundwater and do not necessarily need be in contact with groundwater overall. They involve the circulation of an antifreeze solution through the closed loop pipework in the ground. Hence they are more flexible in terms of location. These systems generally require a large number of boreholes for vertical closed loop systems or large areas (e.g. car parks) for shallow horizontal systems. Energy outputs are smaller per borehole compared to open loop systems.

With focus of this project being on the development of urban or commercial heat networks with large heat loads closed loop GSHPs are unlikely to play a significant role, unless existing schemes can be integrated into an energy mix to supply the network.

6.5.3 Water Source Heat Pumps (Surface Water)

The water source heat map published by DECC in 2014 provides an initial estimate of the potential to generate heat from many UK water bodies via water source heat pumps. A subsequent 2015 report published by DECC on the Water Source Heat Map Layer of the National Heat Map mapped the environmental constraints and designations, water resource status (CAMS), calculated the water source heat capacity and combined this with heat demand data to produce a ranked list of urban areas and their rivers based on total heat capacity and heat demand.

Within the area of this study the River Severn at Worcester (ranked 37/49) has been calculated to have a heat capacity of 307 MW and the heat demand of the city of Worcester to be medium.

Table 6.5 on the following page indicates the heat capacity of rivers within the study area and their proximity to the priority sites. No data was available regarding the River Severn navigation canal; the Birmingham canal and Shropshire Union and Staffordshire and Worcestershire canals have temperatures of about 5°C reported but very low heat capacities.

Similar to the open loop groundwater heat pump schemes, abstraction licensing and the ability to convert the low grade heat into usable heating system temperatures are the key issues. Large volumes of water will need to be abstracted as heat output per volume of abstracted water are low. Ecological constraints generally limit such schemes to low volumes/low energy outputs and would not be possible in the River Severn during summer low flow conditions. It is worthwhile considering water source heat pump schemes at feasibility stage where proposed heat network energy centres are proposed to be developed close to major water courses (rivers/canals), ideally making use of electricity produced within the energy centre (Combined Heat and Power plant).

Heat extraction from existing sewer mains may be an option in selected locations as it makes use of existing infrastructure which is generally located close to the major heat loads (urban centres). The water companies (Severn Trent Water) would be the obvious partners for such schemes as they own the relevant assets. As for other heat pump schemes the Coefficient of Performance and the ability to match required heating temperatures/profiles are the key challenges. There might be a particular advantage for smaller to medium size schemes due to low capital investment costs compared to other energy sources.

Table 6.5: Details of Rivers in the Study Area with Heat Capacities of over 6,600 KW (National Heat Map: Water source heat map layer, DECC 2015)

Name	Principle Towns/Cities intercepted within study area	Length (m)	Catchment	River Temperature (°C)	Heat Capacity (kW)	Constraints Present (fish type/ protected site)
Avon Conf. Workman Br, Evesham to Conf R. Severn	Pershore, Evesham	54,430	Avon, Warwickshire	5.602	8,026	Cyprinid
Avon Tramway BR Stratford to Workman Br Evesham	Evesham, Offenham	33,865	Avon, Warwickshire	6.16	7,720	Cyprinid
Severn – Conf R. Teme to Conf R. Avon	S. Worcester, Kempsey, Upton upon Severn	23,942	Severn Vale	5.25	73,560	Cyprinid
Teme – Cof. R. Onny to Conf. R. Severn	SW Worcester	78,702	Teme	5.867	15,984	SSSI, Salmonid
Severn – Conf. R. Stour to Conf. R. Teme	Worcester, Stourpourt-on-Severn	24,788	Severn Middle Worcestershire	6.16	88256	Cyprinid
Severn – Conf R. Worfe to Conf. R. Stour	Stourport-on-Severn	32,847	Severn Middle Worcestershire	5.54	58,772	SSSI, Cyprinid

7 Energy Masterplanning

7.1 Introduction

This part of the assignment sought to develop decentralised energy masterplanning for each urban area identified through the heatmapping stage as having potential to sustain district energy schemes.

These areas were different to those subject to the geothermal feasibility study as set out in the following chapter. For the areas in this chapter heat mapping had to start from a zero base position and be incrementally build up a picture of heat and energy demand at each location under consideration.

This study has considered eleven discrete decentralised energy network opportunities in the following geographical areas within the Worcestershire County study boundaries (introduced under Section 5.3):

a) Kidderminster

b) Redditch

c) Bromsgrove

d) City of Worcester

The aims of this decentralised energy masterplanning study have been to:

- Establish to what extent the identified decentralised energy (DE) opportunity areas are suitable for a DE network (in all or part of the opportunity area)
- Provide a DE evidence base, which can be used by the client team to further the case for DE across Worcestershire.

This chapter summarises the outputs from the assessment for each opportunity area.

7.2 Layout of Chapter

A list of the identified opportunity areas is set out in Section 7.3 providing the key areas that have been subject to energy masterplanning from across Worcestershire.

An outline methodology is described in 7.4 with an overview introduction to decentralised energy following in 7.5.

The identified heat network opportunity for each area is presented in Section 7.6, along with associated whole life costing summary evaluations and route identification considerations. Where relevant, both initial cluster networks and fully built out networks are presented.

Each of these sections is structured in a common way that firstly introduces the opportunity and discusses the identified network and energy supply opportunities. Included in these sections are summaries of connected buildings and heat demand projections for the identified developments in the opportunity areas and heat map references where these buildings along with the proposed networks and energy centre proposals.

Phasing strategy and implementation plans are then discussed briefly.

There then follows an economic appraisal of the identified opportunities, showing the key economic indicators for the projects including identified project Internal Rate of Return (IRR), Net Present Value (NPV) assuming a 3.5% discount factor and earliest year cash flow positive. These are presented over a 30-year project term for different types of energy selling arrangements. Results for both base case networks and variant networks where such cluster networks have been found to be economically viable are presented.

The results of the economic appraisal are then interpreted in relation to their implications for project procurement. A further more general discussion on project procurement is provided.

For identified viable opportunities, a high level route identification and risk appraisal is then presented. This is based on visual inspection of the identified routes and does not include reference to utility information.

Procurement issues are discussed for each of the project opportunities and an overview of the main barriers, risks and opportunities to development are considered.

Each of the identified project opportunities is based around gas fired CHP. Section 7.6 therefore deals with future supply opportunities for each of the identified projects opportunities on the basis that alternative fuel sources will need to be considered in the longer term as and when grid decarbonisation begins to displace the benefit of gas fired CHP.

The following table (Table 7.1) provides a screening of potential alternative heat energy sources for the identified heat networks for future consideration. A County wide discussion of alternative heat sources were also presented in Chapter 6.

Table 7.1: Initial screening for alternative heat sources for idendified networks

Heat source	Kidderminster		Redditch		Bromsgrove				Worcester		
Potential (no/low/medium/ high)	Central	South	North	South	Centre	Gloucester Rd.	Aston F.	Buntsford	North	University	South
Water source	high	high	low	medium	low	low	medium	medium	medium	high	no
Ground source	medium	medium	medium	medium	medium	medium	medium	medium	medium	medium	high
Mine water	no	no	no	no	no	no	no	no	no	no	no
Industrial waste heat/Energy from Waste	low	medium	medium	Medium/ high	low	low	medium	medium	medium	low	low
Comment	River Stour and could offer good potential		River Arrow and ground source heat may offer some potential, hospital waste incinerator		River Salwarpe and ground source heat may offer some potential				River Severn and the Worcetser & Brimingham Canal offer some good potential. Medium to deep geothermal could offer good potential.		

Project Conclusions, Recommendations and Next Steps are presented in Section 7.7. This includes recommendations about Client options for developing the projects along with planning policy recommendations that should be considered within Worcestershire County Core Strategy and Local Development Framework documents.

7.3 Energy Masterplanning Opportunity Study Areas

From the heat mapping activities (Section 5.3) eleven potential decentralised district energy areas have been identified within four main conurbations across Worcestershire:

- Kidderminster Town
    - a. Central Main
    - b. Southern Main

- Redditch Town
    a. Northern Main
    b. Southern Main
- Bromsgrove Town
    a. Town Centre Main
    b. Worcester Road Main
    c. Aston Fields Industrial/ Commercial Main
    d. Buntsford Industrial/ Retail Main
- City of Worcester
    a. North Worcester Industrial Main
    b. University & City Centre Main
    c. Southern NHS Main

7.4 Outline Methodology

This report has considered options for developing decentralised heat networks within each of the opportunity areas to supply space heating and domestic hot water to existing and future planned developments within the Opportunity Areas.

Project opportunities have been developed on the basis of information contained within a range of data sources

For each identified geographical area, network opportunities have been analysed in terms of their economic viability and carbon reduction potential using Internal Rate of Return (IRR)[1] and Net Present Value (NPV)[2] indicators.

Network opportunities have been assessed over a 30-year period.

Establishing a decentralised energy network requires capital investment, which can be repaid by revenues from sold heat and electricity. Projects can therefore be seen as business opportunities depending on the balance between investment and revenues.

The scale of projects depends on the size of heat demand. Heat demand projections for each of the identified existing and new developments within each of the geographical area are presented within each area in Section 7.6.

Project viability for each 'base case' network opportunity has been tested on the basis of a fully built out network comprising identified suitable existing 'anchor heat loads' as well as identified suitable private loads and planned developments.

[1] IRR is the discount rate at which the present value of all project cash flows (income and expenditure) are zero
[2] NPV is the difference of the present value of cash in and cash out over the project lifetime

The viability of ‘initial variant networks’ have also been tested for some of the geographical areas representing cases of connection of only existing ‘public’ buildings and reliable heat customers not relying on some private and future planned developments. Further modelling has been undertaken primarily to scale back initial capital requirements and to focus on higher heat density clusters. Viability has been assessed on the basis of minimum required Internal Rates of Return for fully public sector (3.5% Government Green Book) based procurement models that deliver a very competitive heat price to customers. The analysis has sought to impart benefit to customers in the form of low heat prices providing further incentive to connect and establish a base network.

Fossil fuel energy prices depend upon the source of fuel but generally speaking natural gas is used as a comparator. DECC, who are now part of the Department for Business, Energy & Industrial Strategy public quarterly energy statistics, the last published data is for the quarter ending March 2016. The data is gathered across industry users and users categorized against their usage volume. Customers using less then 278 MWh per annum are deemed very small users and then banded up to 2777 MWh as small users. The unit price differential between the two groups is about 0.2p / kWh.

Across each locality the loads are generally shown as point loads and there will be multiple users benefitting from the point load albeit that the will each currently have their choice of energy supplier leading to the conclusion that all will fall into the very small user category.

Most if not all customers will be subject to paying climate change levy against fossil fuel and have to report their annual carbon emissions through either EU Emission Trading System (EUETS) or the CRC Energy Efficiency Scheme, the former maybe replaced following Brexit. However, the UK will still be bound by the Kyoto Protocol, having signed up in 1995, requiring signatories to reduce the carbon emissions to 80% of the 1990 levels by 2050 with interim targets still to be met. EUETS will remain in place during the period 2013 – 2020. CRC is due to be phased out by 2017 leaving government to have in place a replacement scheme to measure and meet the 2020 target of 20%. EUETS currently plays a key part in meeting the 2020 target.

In the not too distant future Government will have to consider the carbon price applied to carbon emissions. The current level of £17.20 per tonne may rise to £30 and higher if it looks as if the targets beyond 2020 will be missed. Some estimates suggest that carbon taxes could account for 0.55p – 0.80 p / kWh. If targets are repeatedly missed this could rise higher. Conversely if the targets are met the figure could drop. Organizations will have to decide on their risk position.

Add the carbon price per kWh to the DECC published rates of 3.907p / kWh and include a heat efficiency conversion factor of 85%, (not untypical of older plant), the heat cost (not the gas cost) at point of use is in the order of 5.1p per kWh (3.906 ÷ 0.85 + 0.5) or higher. The actual cost is higher as plant life cycle and replacement cost would have to be considered in any cost benefit analysis of connecting to a district heat main. The modelling factors have placed a priority on producing a heat price that provides potential customers with a life cycle saving incentive to connect to the DE network i.e. a discounted energy price.

Our modelling includes inflation and we have used real IRR hurdle rates of 7.25% and 3.5% respectively for fully private sector and fully public sector based procurement models (based on inflation at 1.9%). These hurdle rates do not necessarily reflect the current market or indeed the client’s own required rates of return on investment and also do not necessarily reflect what would need to be ‘risk free’ projects to attract investment at those rates.

Our understanding of the current market is that nominal hurdle rates in the range 9-13% for the private sector and above 6% minimum for public sector are nearer reality in the current economic conditions.

Project viability for each network opportunity has been tested on the basis of a fully built out network comprising identified suitable existing ‘anchor heat loads’ as well as identified suitable phased and planned developments as reported in the planning policy documents provided by client feedback. We have tested a range of options in each case to identify suitable connections and establish which outlying buildings are not considered worth connecting for economic reasons. This has been done by comparing linear heat density indicators for the project with and without outlying buildings to identify which outliers will improve internal rates of return and which will not.

The viability of ‘initial cluster networks’ has also been tested for each of the geographical areas. These initial clusters have been assumed to comprise identified suitable existing ‘anchor heat loads’ and known developments under construction. For these modelling scenarios, internal rates of return have been assessed over a 30-year period, assuming that no future developments come forward, in order to reflect the worst case scenario to the project. It has been assumed that initial cluster projects would need to be viable in themselves (i.e. could be operated profitably regardless of any future developments connecting to the network in order to attract investment).

7.5 Decentralised Energy Networks

Decentralised Energy is a term used to describe the supply of electricity and/or heat to end users from local sources, as opposed to via the national gas and electricity grids. In the context of this report, decentralised energy refers to the use of district heating networks to distribute heat to a number of buildings from energy centres hosting combined heat and power (CHP) plants together with boilers and thermal accumulators.

Heat generated within these energy centres is distributed to local buildings through a network of pre-insulated buried underground pipes. This heat is transferred to the buildings through Hydraulic Interface Units (HIU) located within each building, beyond which the heat is distributed for the purposes of space heating and domestic hot water provision. Where larger developments are concerned, the interface with the heat network can also take place at local community level, through one or more small energy centres located within the development.

District heating serves as an alternative to the use of gas or electricity to provide heating at each building. Hydraulic Interface Units can be thought of as the equivalent of the domestic or commercial boilers that would otherwise be used to provide heat to secondary circuits, domestic hot water and heating circuits within the buildings.

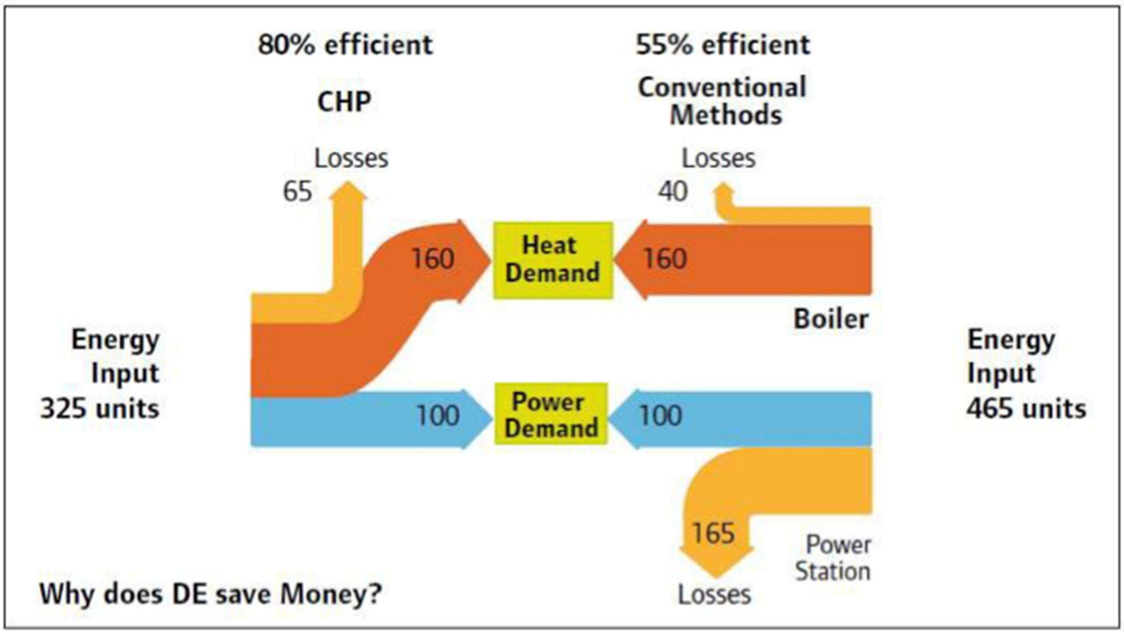

Figure 7-1: Why Decentralised Energy saves Money

The generation of heat in district heating systems is typically carried out using combined heat and power systems. Combined heat and power describes the simultaneous generation of heat and electricity in a more efficient way than if the two forms of energy were to be produced separately. There are many technologies available to produce combined heat and power, involving many scales of application and many options in relation to fuel source including energy from waste, biomass and fossil fuels. In the context of this report, the focus is on the use of internal combustion engine technology using natural gas as the primary fuel. Such applications typically involve generation capacities in the range from 500 kWe to 5 MWe and generate heat at temperatures in the region of 90°C to 95°C.

District heating systems offer many advantages over conventional alternative supply options and have a significant role to play in contributing towards the UK's CO_2 reduction targets. It is also a highly flexible and adaptable medium for capturing, transporting and storing heat energy and so has a central role to play in integrating energy from multiple sources, and thereby provide the flexibility required to deliver low cost, low carbon energy to our society in the future.

In general, a high linear density of heat demand is usually helpful in justifying the installation and economics of a district heating scheme. Linear heat density is a measure of the annual heat demand per unit length of heat network installed. The selection and sizing of district heating pipework is also critical to the economic success of a district heating scheme and, depending on the scale of the heat network, is usually the most expensive element of the scheme. Factors such as temperature difference, design and operating pressures and operating strategy all have a strong influence on scheme economics.

7.6 Technical and financial Assessments for the identified Heat Network Opportunities

7.6.1 Kidderminster Town

Kidderminster Town Centre is an area of interest in terms of future growth. The Council has identified development sites that it considers have the potential for mixed-use redevelopment within the lifetime of the Local Development Framework. The regeneration of the Kidderminster Eastern Gateway (KEG) forms a key part of the Council's ReWyre initiative and is on the back of the multi million pound transformation of the public realm in High Street, Vicar Street, Exchange Street and Oxford Street.

The existing retail, industrial and commercial areas to the south of the town centre have also shown potential for DE networks.

The scale and density of the consented and planned developments coming forward over the coming years presents an opportunity to bring forward a strategic district heating networks within Kidderminster town centre.

The identified opportunity includes an initial cluster network; the Central Main focused around a number of existing anchor heat loads within the town centre as well as a longer term fully built out network opportunity that includes existing heat loads as well as identified suitable planned development KEG. The Southern Main seeks to explore the opportunity present from the existing three industrial, commercial and retail areas south of the town centre.

The detailed network drawings showing the proposed heat network opportunities are shown in Appendix A (Figure 5.4 and 5.5). These identify the base case cluster projects as well as the extent of the variant options.

7.6.1.1 Kidderminster Town Central Main (base case)

The anchor heat loads forming the initial cluster network are shown in Table 7.2.

Table 7.2: Summary of Connected Buildings – Kidderminster Central Main Base Case

Short Name	Eastings	Northing	Type of location	Owner	Heat kWh/Ann	Elec kWh/Ann
Primary Energy Centre, Kidderminster NHS	382311	276382	Energy Centre	NHS	n/a	n/a
Kidderminster Library	383133	276471	Demand	Public	139,617	134,451
John Stretton Memorial Hall	383146	276142	Demand	Public	30,942	6,688
MCF Complex	383093	276136	Demand	Private	35,280,000	n/a
Kidderminster Town Hall	383163	276560	Demand	Public	310,602	186,405
Green Street depot	383134	275878	Demand	Public	253,899	108,269
Meadowsmill Ind Est	383215	276045	Demand	Private	16,800,000	n/a
Social Services	383241	276806	Demand	Public	20,252	1,288
Hansel & Gretel FSU	383420	277087	Demand	Public	36,310	10,382
Day Opportunities	383193	276916	Demand	Public	97,021	33,548
St. Marys CE Primary	383293	277591	Demand	School	114,171	90,535
St. Oswalds CE Primary	384187	278409	Demand	School	76,140	61,525
Comberton Primary	384803	275970	Demand	School	89,421	64,826
St. Catherines CE Primary	382137	277652	Demand	School	102,837	99,083
Baxter College	381658	276749	Demand	School	979,383	578,688
Franche Primary	381846	277659	Demand	School	411,412	312,682
Habberley Campus	381925	276948	Demand	School	51,339	87,882
Kidderminster SBU	381976	276891	Demand	Public	44,835	13,234
St. Johns CE Primary	381948	276774	Demand	School	289,117	791,623
Wyre Forest School	381947	276951	Demand	School	2,940	5,880
Sutton Park Primary	381806	275861	Demand	School	48,464	72,452
Kidderminster Hospital	382310	276381	Demand	NHS	6,754,976	4,403,646
Wyre Forest School	382468	276646	Demand	School	181,445	161,960
Kidderminster County Buildings	382539	276657	Demand	Public	423,075	24,837
Fire Station	383095	276186	Demand	Public	137,933	83,147
Wyre Forest FSU	382762	276525	Demand	Public	122,019	3,471
West Mercia Probation	382708	276851	Demand	Public	131,015	n/a
Foley Park Primary	382519	275411	Demand	School	95,059	65,324
Birchen Coppice Primary	381482	274768	Demand	School	109,803	120,681
Treetops Centre	381632	274778	Demand	Public	64,781	22,367
Wyre Forest House	381735	273589	Demand	Public	11,179	685,577
				Totals	63,209,987	8,230,451

7.6.1.2 Kidderminster Town Southern Main (base case)

The anchor heat loads forming the initial cluster network are shown in Table 7.3.

Table 7.3: Summary of Connected Sites – Kidderminster Southern Main Base Case

Southern Main - Key Sites						
Short Name	Eastings	Northing	Type of location	Owner	Heat kWh/Ann	Elec kWh/Ann
Primary Energy Centre, Hoobrook Enterprise	383168	274845	Energy Centre	Private		n/a
Hoo Farm Ind Est	383401	274278	Demand	Private	37,800,000	n/a
Hoobrook Enterprise Centre	383167	274844	Demand	Private	15,120,000	n/a
Worcester Rd Retail Est	383011	275411	Demand	Private	3,307,500	n/a
				Totals	56,227,500	

7.6.1.3 Peak demand and Annual Consumption

The diversified peak heat demand growth profile and annual consumption for the Central Main and Southern Main base case and variants are shown in Table 7.4.

Table 7.4: Sumary of Peak Demand and Annual Consumption - Kidderminster

Kidderminster Town	Heat Peak Demand	Annual Heat Consumption
	MW	MWh
Southern Main	12	56,000
Southern Main (Variant 1)	4.2	18,000
Central Main	14	63,000
Central Main (Variant 1)	6	26,000

There is a degree of uncertainty around the feasibility and future timescales of some of the connection opportunities. Initial enquiries with stakeholders have returned some information, as have assessments of energy statements for recently developed opportunities.

Known buildings with incompatible heating systems have been excluded from the analysis and the remaining buildings have been assumed to be compatible on the basis that they contain wet heat systems[3] fed through gas boilers. This is considered to be a realistic assumption at this stage, although further assessment is clearly required at the next stage, particularly where direct engagement has not been possible with larger consumers.

Of the potential connections listed in Table 7.2 and 7.3, the presumption has therefore been made that connection would be feasible at the point of

[3] typically operating at 82°C / 71°C

development of the heat network. The technical viability and cost implications of connecting these buildings has not been carried out at this stage and individual plantroom surveys have not been undertaken. This is normally carried out at feasibility stage. However, in our experience neither physical space or design compatibility of existing wet heating systems are unlikely to present insurmountable barriers to connection and are therefore not considered to be critical factors at this stage.

The MCF Complex presents a significant opportunity in view of its size and location. At the time of carrying out the analysis we were unable to establish contact with MCF Complex. Therefore based on our experience of similar shopping centre developments we identified that, as a minimum there is likely to be an opportunity to supply the communal spaces being fed through AHU's[4]. In the absence of information from the MCF Complex, we therefore applied a benchmarking approach to estimate the scale of this opportunity. The variant has been modelled without the inclusion of the MCF Complex.

The Southern Main base case includes the connection of commercial and industrial businesses at three designated industrial areas. The variant excludes connection of the Hoo Farm Industrial Estate.

7.6.1.4 Energy Centre Locations

Two options for locating the energy centre within the Central Main and one option within the Southern Main have been identified (Table 7.5). The basis for selecting these sites has included consideration of a number of factors including land ownership and land asset value considerations. The sites are:

1) Adjacent to existing plant room: a car park area on the Kidderminster Hospital site which is currently NHS owned land and not necessarily intended for redevelopment.

2) Green Street Council Depot, assumed to be council owned land, currently containing employment units and the transport depot.

3) On land within the Meadowsmill Industrial Estate, privately owned land, currently containing a mixture of industrial units, employment units and business units and intended for possible redevelopment as part of the Hoobrook Linkroad project.

In principle any of these sites could be used for location of the energy centre. A summary of the advantages and disadvantages of each site opportunity is

[4] either by displacing heating coils currently being supplied through gas boilers or by retrofitting heating coils if these are currently directly gas fired. It is noted that cost associated with this has not been factored into the analysis at this stage

presented in the table below. Grid connection and gas supply connection issues have not been considered, since utility route information has not been provided.

Table 7.5: Energy Centre Location Options - Kidderminster

Advantages	Disadvantages
Kidderminster Hospital (car park adjacent Plant Room)	
Hospital has an existing flue stack and operating energy centre Ample space for energy centre development. Energy centre location reasonably close to centre of gravity of anchor heat demands. Reduces costof network and development risk if stakeholder uptake isdispersed. Location away from town centre implies lower land value and fewer nuisances to local business and general public during construction. Utility infrastructure already installed (subject to sizing application)	Stack likely to be required for new EC or additional plant. Car parking spaces needed for EC Site is located off major road. Access for construction and maintenance is likely to cause possible traffic disruption. Less suited to biomass, since ongoing fuel deliveries will also cause traffic disruption. Highest pipework cost associated with maintaining greater pipe sizes to serve remote demands implies increased development risk and reduced IRR relative to other options. Land is owned by the NHS. This will require negotiation with the landowner and presents an additional development risk to the project.
Green Street Depot	
Site is adjacent to major road. Suggests that noise and air quality impact will be lower impact than for other options. Energy centre can be located to the west of the site. Opportunity for shared access thereby reducing traffic impact during construction and operation (for example if biomass deliveries are proposed). Land is owned by Council, therefore reduces development risk. Location away from city centre implies lower land value and less nuisance to local business and general public during construction and during operation.	Energy Centre stack requirement could limit use of site. Energy centre location is remote from centre of gravity of anchor heat demands. Adds to cost of network and increases development risk if stakeholder uptake is dispersed. Challenge to find space for energy centre development.

Advantages	Disadvantages
Land on Meadowsmill Ind Est	
Energy centre location is close to centre of gravity of anchor heat demands. Reduces cost of network and minimised development risk if stakeholder uptake is dispersed. Land owned by Council. Reduces development risk. Access off A442 reduces disruption and traffic management issues. Central location benefits this financial case. Location away from city centre implies less nuisance to local business and general public during construction and during operation	Energy Centre stack requirement could limit use of site. Exact possible land allocation to be confirmed. Space is very limited. May require two storey energy centre, increasing cost and visual impact. Biomass option less likely to be viable, taking into account access requirements and fuel storage requirements. Likely to be harder to implement due to local air quality concentrations. Land value relatively high implies higher project costs. Visual impact likely to be an issue in relation to the required stack height.

Modelling of the options has identified that the configuration involving an energy centre at Kidderminster Hospital for the Central Main and Meadowsmill Ind. Est. for the Southern Main provides the highest IRR of the three options. The Hospital and Meadowsmill are therefore taken forward as the basis of the heat network opportunity for the remainder of this report and all identified costs and economic indicators presented in this report reflect this assumption. Based on our initial assessment, these locations are considered to be feasible for an energy centre. However, it is recognised that the available space is tight and may require a two storey energy centre to be constructed with an elevation of up to 10 m from ground level (excluding stack height) or a buried basement which may increase construction costs. Further work will also be necessary to further establish the feasibility of the opportunity in relation to air quality[5]impact, noise and visual impact.

7.6.1.5 Phasing Strategy and Implementation Plan

At this stage a single gas engine is proposed at the start of the project. The network should be installed in a modular fashion in order to minimise capital

[5] i.e. the required stack heights for flue dispersion purposes and any costs associated with achieving required NO_X emission levels which will also be dependent on existing NO_X levels at the proposed energy centre location.

outlay and under-utilisation in the early years and allow capital expenditure to be matched more closely to revenues from heat and electricity sales.

7.6.1.6 Economic Modelling

Economic modelling has been carried out for both the base case and the variant options for each Kidderminster cluster. The key economic indicators for the project are presented in Table 7.6, for the base case option as a function of electricity selling arrangements and assuming a project term of 30 years.

For this project, an Electricity Sell and Buy Back[6] arrangement has been considered, since a private wire network is unlikely to be cost effective, unless one or two large-scale users could be connected[7].

Table 7.6: Kidderminster Central and Southern Main Base Case – Key Economic Indicators

Base case		Central Main	Southern Main
Total Investment CAPEX	[£ K]	7,900	6,536
Energy Centre CAPEX	[£ K]	2,986	2,472
Length of Heat Network	[m]	6,100	3,600
Cost of Heat Network	[£ K]	2,543	2,104
Connection CAPEX	[£ K]	1,459	1,207
Project Development Costs	[£ K]	909	751
Annual Operating Costs	[£ K]	1,300	1,076
Annual Revenues from Heat Sales	[£ K]	2,800	2,530

The required capital investment for the Central Main base case cluster would be around £7.9m. For the variant option the capital figure is discounted to approximately £4.3m.

The discounted heat sell price to connected customers for the base case and variant options is included at 4.08p/kWh and 4.54p/kWh respectively with the gas input price set at 2.8p/kWh

The calculated IRRs for the Central Main base case and variant option would be around 3.5% and 3.9% over 30 years, based on an electricity buy and sell arrangement. The corresponding NPV would be £21k and £321k at a 3.5%

[6] The electricity producer can arrange with a local electricity license holder to net off, for a fee, consumption against production

[7] The possibility of this arrangement could be explored at the next stage if the project is taken forward, although it is noted that this approach would also carry significant risk to the project, since the customer(s) would not enter into long term agreements for this electricity and would be free to change supplier at any time under current electricity supply laws

discount factor with both models achieving positive cash flow in year 23. The NPV describes today's value of the project due to expected future cash flow[8].

Table 7.7: Key Financial Modelling Outputs – Kidderminster Central Main

Kidderminster		Northern Main District Heating Network		
		Basecase		Variant
Estimated Scheme Data	***Units***			
Heat Sales Revenues	£m	£2.8M	Y5	£1.65m
Energy Centre Capacity	MW	14		6
Forecast Annual Heat Supply	MWh	62,000		26,000
Total Route Length of Pipework	km	6.1		5.83
Capital Cost	£m	£7.9m		£4.325m
IRR	%	3.50%		3.90%
NPV	£	£21,268		£320,658
Heat Sell Price	p/kWh	4.08		4.54
Year Cashflow Positive	Year	23		23

One of the most important variables (i.e. high impact) for the financial performance is the initial realised value of the electricity produced. The modelling undertaken has taken a prudent view of the electricity-selling rate with this price set at 5.125p/kWh. This benchmark is provided for all projects. Other electricity trading models can be explored during the feasibility phase. Often improved electricity value can have a significant impact on financial performance.

The required capital investment for the Southern Main base case cluster would be around £6.5m. For the variant option the capital figure is discounted to circa £3.9m.

The calculated IRRs for the Southern Mainbase case and variant option would be around 4.4% and 2.4% over 30 years, based on an electricity buy and sell arrangement. The corresponding NPV would be £321k and -£697k at a 3.5% discount factor with the models achieving positive cash flow in years 21 and 25 respectively.

[8] A positive NPV indicates a positive project value in present terms, whilst a negative NPV indicates an overall cost in present terms. A positive NPV suggests a project is financially viable for public sector investment with an IRR > 3.5%

Table 7.8: Key Financial Modelling Outputs – Kidderminster Southern Main

Kidderminster		Southern Main District Heating Network		
		Basecase		Variant
Estimated Scheme Data	***Units***			
Heat Sales Revenues	£m	£2.53m	Y5	£1.25m
Energy Centre Capacity	MW	12		4.2
Forecast Annual Heat Supply	MWh	56,000		18,000
Total Route Length of Pipework	km	3.6		1.36
Capital Cost	£m	£6.536m		£3.954m
IRR	%	4.40%		2.40%
NPV	£	£956,390		-£696,846
Heat Sell Price	p/kWh	4.08		4.54
Year Cashflow Positive	Year	21		25

7.6.2 Redditch Town

Heat mapping in Redditch also produced additional DE potential to that originally listed by the Client. The analysis of heat loads and potential heat load clusters showed that opportunity centred around two distinct areas of the town.

The identified opportunity includes an initial cluster network; the Northern Main in the northeast sector centred on the Moons Moat industrial and commercial areas and the Southern Main centred on a number of existing anchor heat loads within the central part of Redditch moving northwards from the Hospital site (see Drawings 5.6 and 5.7 in Appendix A). Following initial modelling a variant option for the Southern Main has been considered.

7.6.2.1 Redditch Town Northern Main

The anchor heat loads forming the potential DE network are shown in Table 7.9.

7.6.2.2 Redditch Town Southern Main (NHS & Industrial)

Table 7.9: Summary of Connected Buildings – Redditch Northern Main

Redditch Northern Main						
Short Name	**Eastings**	**Northing**	**Type of location**	**Owner**	**Heat kWh/Ann**	**Elec kWh/Ann**
Primary Energy Centre			Generation			
South Moons Moat	406810	267894	Delivery	Private	28,800,000	not available
Marubeni-Komatsu	406810	267894	Delivery	Private	Included	not available
East Moons Moat	407400	267946	Delivery	Private	8,208,000	not available
Blue Earth	407405	267951	Delivery	Private	Included	not available
SP Group	407972	268531	Delivery	Private	Included	not available
Lear Corp	407974	268533	Delivery	Private	Included	not available
Magna Intier	407411	268262	Delivery	Private	Included	not available
UK-NSI	407416	268267	Delivery	Private	Included	not available
FW Thorpe	407333	268637	Delivery	Private	Included	not available
Moon Moat North	407430	268625	Delivery	Private	86,400,000	not available
Master magnets	407432	268621	Delivery	Private	Included	not available
				Totals	123,408,000	

The anchor loads forming the initial cluster network are shown in Table 7.10.

Table 7.10: Summary of Connected Sites – Redditch NHS and Industrial Main

Redditch NHS and Industrial Main						
Short Name	**Eastings**	**Northing**	**Type of location**	**Owner**	**Heat kWh/Ann**	**Elec kWh/Ann**
Primary Energy Centre	406090	264627	Generation			
Enterprise Centre	407271	265365	Delivery	Public	231,004	52,803
Rockline Industies	407251	265571	Delivery	Private	0	not available
Gardner Denver	407413	265433	Delivery	Private	0	not available
Valeo Service U	407693	265876	Delivery	Private	0	not available
Arrow Vale Academy	406970	266484	Delivery	School	686,440	596,904
Washford Ind Est	407566	265645	Delivery	Private	40,320,000	not available
Park Farm Ind Est South	406048	265948	Delivery	Private	90,100,000	not available
Vsmpo Tirus	406048	265948	Delivery	Private	0	not available
Greenlands Bus Centre Main	405684	266110	Delivery	Public	168,325	27,262
Greenlands Bus Centre 4	405694	266117	Delivery	Public	0	2,012
Greenlands Bus Centre 5	405715	266077	Delivery	Public	0	1,013
Park Farm Ind Est North	405712	266078	Delivery	Private	28,560,000	not available
Langdons	405927	265671	Delivery	Private	0	not available
Lucet Meadow Development	405673	265867	Delivery	Private	1,545,900	not available
Tesco	404405	265589	Delivery	Private	420,000	not available
Woodrow Centre 74 - 76	405869	265469	Delivery	Public	0	4,838
Woodrow Centre 44 - 46	405878	265473	Delivery	Public	0	2,958
Woodrow Library	405869	265469	Delivery	Public	33,555	15,366
Woodrow Office	405851	265479	Delivery	Public	41,117	36,503
Woodrow Centre	405869	265469	Delivery	Public	0	not available
Crossgate Depot	406195	265401	Delivery	Public	474,514	246,220
Profin Protective Finishing	406224	265313	Delivery	Private	0	not available
Woodrow Youth	405216	265240	Delivery	Public	0	9,018
Linread Northridge	406018	265566	Delivery	Private	0	not available
New development	406046	264739	Delivery	NHS	2,061,200	not available
NHS Alexandra Hospital	406092	264629	Delivery	NHS	6,215,360	9,111,870
Kingsley Sports	406305	264879	Delivery	Public	0	226,698
School Tudor Grange	406231	264878	Delivery	School	1,111,418	433,603
School Woodrow First	405711	265170	Delivery	School	281,836	132,070
Lakeside Ind Est, Victor	405379	267084	Delivery	Private	38,880,000	not available
Lakeside Ind Est, Charles Martin	405268	267798	Delivery	Private	3,600,000	not available
Lakeside Ind Est, Arrow	405553	267053	Delivery	Private	5,440,000	not available
Lakeside Ind Est, Broadground	406444	268443	Delivery	Private	51,840,000	not available
				Totals	272,010,668	10,899,138

7.6.2.3 Peak Demand and Annual Consumption

The diversified peak heat demand growth profile and annual consumption for the Northern Main and the NHS & Industrial Main base case and variant are shown in Table 7.11.

Table 7.11: Sumary of Peak Demand and Annual Consumption - Redditch

Redditch Town	Heat Peak Demand	Annual Heat Consumption
	MW	MWh
Northern Main	28	123,408
NHS & Industrial Main	60	268,128
NHS & Industrial Main (Variant 1)	38	168,368

There is a degree of uncertainty around the feasibility and future timescales of some of the connection opportunities. Initial enquiries with stakeholders have returned some information, as have assessments of energy statements however the level of granularity achieved in the energy profile is not ideal and would need to be targeted further during feasibility stage.

Of the potential connections listed in Table 7.9 and Table 7.10, the assumption has therefore been made that connection would be feasible at the point of development of the heat network. The technical viability and cost implications of connecting these buildings has not been undertaken at this stage and individual plantroom surveys have not been carried out. This is normally carried out at feasibility stage. We do not expect any matters arising from this aspect.

7.6.2.4 Energy Centre Locations

Two options for locating the energy centre within the Northern Main and one option within the NHS and Industrial Main have been identified. The basis for selecting these sites has included consideration of a number of factors such as land ownership and land asset value considerations. The sites are: -

1) Site 1 – Land directly between Padgets Lane and the western side of Winyates Way at rear of existing industrial units.

2) Site 2 – Development land directly opposite Territorial Army offices on Winyates Way within the Moons Moat North Industrial Estate, privately owned land, currently containing shrubs, flora and fauna.

3) Adjacent to existing plant room: a car park area on the Alexandra Hospital site which is currently NHS owned land and not necessarily intended for redevelopment.

In principle sites 1 and 3 could be used for the location of the energy centre on the Northern Main and Southern Main respectively. A summary of the advantages and disadvantages of each site opportunity is presented in Table 7.12. Grid connection and gas supply connection issues have not been considered, since utility route information has not been provided.

Potential opportunities for an energy centre location at the Redditch Eastern Gateway development site (Northern Main) should be considered at feasibility stage. The utilisation and development of the existing waste incinerator at the Alexandra Hospital creates additional risks and opportunities which require assessment at feasibility stage.

Table 7.12: Energy Centre Location Options - Redditch

Advantages	Disadvantages
Alexandra Hospital (car park adjacent Plant Room)	
Hospital has an existing flue stack and operating energy centre (Engie waste incinerator). Ample space for energy centre development. Energy centre location reasonably close to centre of gravity of anchor heat demands. Reduces cost of network and development risk if stakeholder uptake is dispersed. Location away from town centre implies lower land value and fewer nuisances to local business and general public during construction. Utility infrastructure already installed (subject to sizing application)	Stack likely to be required for new EC or additional plant. Car parking spaces needed for EC Site is located off major road. Access for construction and maintenance is likely to cause possible traffic disruption. Less suited to biomass, since ongoing fuel deliveries will also cause traffic disruption. Highest pipework cost associated with maintaining greater pipe sizes to serve remote demands implies increased development risk and reduced IRR relative to other options. Land is owned by the NHS. This will require negotiation with the landowner and presents an additional development risk to the project.

Advantages	Disadvantages
Site 2 – Winyates Way opposite TA Depot, Moons Moat North Ind Est	
Site is adjacent to major road. Suggests that noise and air quality impact will be lower impact than for other options. Energy centre can be located to the west of the site. Opportunity for shared access thereby reducing traffic impact during construction and operation (for example if biomass deliveries are proposed). Biomass option easier to adopt (for reasons identified above). Location away from city centre implies lower land value and less nuisance to local business and general public during construction and during operation if biomass adopted.	Land is subject to a planning application and is therefore unavailable for use.
Site 1 – Land directly between Padgets Lane and the western side of Winyates Way at rear of existing industrial units	
Energy centre location is close to centre of gravity of anchor heat demands. Reduces cost of network and minimised development risk if stakeholder uptake is dispersed. Central location relative to planned network benefits the financial case. Location away from city centre implies less nuisance to local business and general public during construction and during operation	Energy Centre stack requirement could limit use of site. Land ownership unknown, enquiries needed to ascertain possible use. Increased development risk Exact possible land allocation to be confirmed. Space is very limited. May require two-storey energy centre, increasing cost and visual impact. Biomass option less likely to be viable, taking into account access requirements and fuel storage requirements. Likely to be harder to implement due to local air quality concentrations. Land value relatively high implies higher project costs. Visual impact likely to be an issue in relation to the required stack height.

Modelling the options has identified that locating an energy centre at Alexandra Hospital for the Southern Main provides reasonable IRR against the economic methodology.

Locating a suitable site for an energy centre location for the Northern Main proved to be a more difficult task. Site 1 was selected based on a small piece of development land opposite the Territorial Army depot on Winyates Way however during the energy masterplanning task the Council informed us that the same piece of land was subject to a planning application thus excluding its possible use. With no obvious alternative location clearly available Site 2 was selected for its close proximity to Site 1 and its central position within the district heating network.

The Hospital and Site 2 are therefore taken forward as the basis of the heat network opportunity for this report and all identified costs and economic indicators presented in this report reflect this assumption.

A viable energy centre location would need further investigation as part of the feasibility stage.

7.6.2.5 Phasing Strategy and Implementation Plan

A single gas engine is proposed at the start of the project. The network should be installed in a modular fashion in order to minimise capital outlay and under-utilisation in the early years and allow capital expenditure to be matched more closely to revenues from heat and electricity sales.

7.6.2.6 Economic Modelling

Economic modelling has been carried out for both the base case and the variant options for the NHS Main. The key economic indicators for the scheme are presented in Table 7.13 below, for the base case option as a function of electricity selling arrangements and assuming a project term of 30 years.

For this project, an Electricity Sell and Buy Back[9] arrangement has been considered, since a private wire network is unlikely to be a cost effective, unless one or two large-scale users could be connected[10]. Refer to Technical Appendices for definitions of electricity selling arrangement opportunities.

[9] The electricity producer can arrange with a local electricity license holder to net off, for a fee, consumption against production

[10] The possibility of this arrangement could be explored at the next stage if the project is taken forward, although it is noted that this approach would also carry significant risk to the project, since the customer(s) would not enter into long term agreements for this electricity and would be free to change supplier at any time under current electricity supply laws

Table 7.13: Redditch Northern Main and NHS & Industrial Main – Key Economic Indicators

Base case		Northern Main	NHS & Industrial Main
Total Investment CAPEX	[£ K]	11,900	19,580
Energy Centre CAPEX	[£ K]	4,502	7,407
Length of Heat Network	[m]	5,265	10,916
Cost of Heat Network	[£ K]	3,832	6,304
Connection CAPEX	[£ K]	2,199	3,618
Project Development Costs	[£ K]	1,369	2,252
Annual Operating Costs	[£ K]	1,959	3,224
Annual Revenues from Heat Sales	[£ K]	5,440	11,650

The capital investment requirement for the Northern Main totals £11.9m with no variant option considered. The discounted heat price for customer of the Northern Main calculated to 3.995 p/kWh with same gas purchase price at 2.8p/kWh. The calculated IRR over a 30-year term is 3.60% with a corresponding NPV at £176k with the first year of positive cash flow at year 23.

Table 7.14: Key Financial Modelling Outputs – Redditch Northern Main

Redditch		Northern District Heating Network
		Basecase
Estimated Scheme Data	***Units***	
Heat Sales Revenues	£m	£5.44m
Energy Centre Capacity	MW	28
Forecast Annual Heat Supply	MWh	123,408
Total Route Length of Pipework	km	5,265
Capital Cost	£m	£11.90m
IRR	%	3.60%
NPV	£	£0.176m
Heat Sell Price	p/kWh	4.00
Year Cashflow Positive	Year	23

The required capital investment to design and install the NHS & Industrial Main base case network would be approximately £19.6m. The high Capex requirement through discussion with the Client became the catalyst for a variant option in which the requirement capital investment was scaled back, mainly from the reduction in pipework length to £9.4m. Pipework costs have been saved from disconnecting the industrial areas furthest north from the hospital. The following industrial areas have been disconnected from the base case as part of the variant option:

- Charles Martin Business Park
- Lakeside Industrial Estate
- Victor Business Centre
- Arrow Business Park
- Washford Industrial Estate

With forecast annual heat supply at full build out of circa 268,000 MWh and a heat peak demand of 60 MW the base case modelling presented a 4.4% IRR and £2.9m NPV performance with a heat-selling price of 3.955p/kWh.

Table 7.15: Key Financial Modelling Outputs – Redditch Southern Main and NHS & Industrial Main

Redditch		Southern Main (NHS and Industrial Main)		
		Basecase		Variant
Estimated Scheme Data	***Units***			
Heat Sales Revenues	£m	£11.65m	Y5	£7.42m
Energy Centre Capacity	MW	60		38
Forecast Annual Heat Supply	MWh	268,128		168,368
Total Route Length of Pipework	km	10916		5616
Capital Cost	£m	£19.58m		£9.427m
IRR	%	4.40%		3.50%
NPV	£	£2.833m		£60,110
Heat Sell Price	p/kWh	3.955		4.00
Year Cashflow Positive	Year	21		23

The variant returned economic figures that suggested its performance would not necessarily improve with a significant reduction in capital cost less plant in the energy centre and less network alongside a corresponding reduction in the level of heat demand. The modelling outputs showed a 1% drop in IRR performance to 3.5% and a £60k NPV based on a 4p/kWh heat sell price.

Positive cash flow for the base case and variant was evident in years 21 and 23 respectively.

7.6.3 Bromsgrove Town

Bromsgrove Town is located within an area to which the client assigned a high priority in terms of future growth and intensification of development in Worcestershire. The client is keen to encourage Bromsgrove to build on its strategic role as a retail and leisure destination, realise opportunities for mixed-use intensification (including a substantial proportion of housing) and improve its public realm.

The Client has identified a number of local sites that it considers have the potential for re-development within the lifetime of the emerging plan 2011-2030. These sites are in variety of public/private sector ownership and include: -

- Sites within and around the town centre that have been allocated for development; and
- Other opportunity sites that were identified by the Client as having potential to contribute to the delivery of the Council's objectives for a sustainability agenda in Bromsgrove.

The scale and density of the planned developments coming forward over the coming decade presents a possible opportunity to establish strategic district heating networks within Bromsgrove.

The network drawings showing the proposed heat network opportunities are shown in Appendix A (Drawings 5.1, 5.2 and 5.3). From the heat mapping activity we were able to identify 4 network opportunities of varying size and heat connection composition.

a. Bromsgrove Town Centre & NHS Main
b. Worcester Road Main
c. Aston Fields Industrial / Commercial Main
d. Buntsford Industrial / Retail Main

7.6.3.1 Bromsgrove Town Centre & NHS Main

The Town Centre & NHS Main as the title suggests provides a DE network that starts north-east of the town centre at the Hospital and drops into the town centre picking up a various number of heat connections on route.

The anchor loads forming the initial cluster network are shown in Table 7.16.

Table 7.16: Summary of Connected Sites – Bromsgrove Town Centre and NSH Main – Base Case

Town Centre and NHS Main - Key Sites						
Short Name	**Eastings**	**Northing**	**Type of location**	**Owner**	**Heat kWh/Ann**	**Elec kWh/Ann**
Primary Energy Centre, NHS	382310	276381	Energy Centre	Public		n/a
Princess of Wales Hospital	382310	276381	Demand	Public	2,100,452	1,815,205
Council House	396677	271376	Demand	Public	665,393	732,046
BDHT Alvechurch	396711	271362	Demand	RSL	274,909	n/a
BDHT Birlingham	396715	271401	Demand	RSL	274,909	n/a
BDHT Clent	396729	271376	Demand	RSL	274,909	n/a
BDHT Cropthorne	396682	271335	Demand	RSL	274,909	n/a
BDHT Dodford	396690	271310	Demand	RSL	274,909	n/a
BDHT Evesham	396715	271312	Demand	RSL	274,909	n/a
BDHT Fairfield	396696	271364	Demand	RSL	274,909	n/a
BDHT Feckenham	396664	271369	Demand	RSL	274,909	n/a
BDHT Grafton	396691	271406	Demand	RSL	274,909	n/a
BDHT Hagley	396719	271385	Demand	RSL	274,909	n/a
BDHT Tardebigge	396723	271374	Demand	RSL	274,909	n/a
School North Bromsgrove	396512	271021	Demand	School	414,357	531,195
Dolphin Centre	396224	270980	Demand	Public	0	175,000
Bromsgrove sports and leisure centre development	396224	270980	Demand	Public	1,951,090	766,500
School Blackwell First	399032	272534	Demand	School	40,581	32,851
BDHT Cedar	396512	271142	Demand	RSL	210,000	n/a
Blue Light Centre	396651	271289	Demand	Public	261,627	235,865
BDHT Maple	396458	271118	Demand	RSL	210,000	n/a
BDHT Shenstone	396529	271354	Demand	RSL	210,000	n/a
Artrix Theatre	396592	271177	Demand	Public	7,147	166,275
HoW College	396592	271177	Demand	School	1,189,410	704,318
Windsor Road	396101	270816	Demand	Public	0	n/a
Windsor Gardens	396060	270685	Demand	Public	2,772,000	n/a
School Parkside Middle	396051	271460	Demand	School	263,990	364,344
Council Buildings	396099	271445	Demand	Public	540,811	n/a
School Meadows First	396040	271466	Demand	School	185,087	374,783
School Parkside	396048	271459	Demand	School	234,606	n/a
POWCH Main	396321	271766	Demand	NHS	2,100,452	1,815,205
POWCH Newhaven	396196	271740	Demand	NHS	286,165	353,290
Iceland	396016	270906	Demand	Private	35,000	n/a
ASDA	396062	271136	Demand	Private	504,000	n/a
Birmingham Road Retail Park			Demand	Private	957,100	n/a
Padstone Day Services	395880	271094	Demand	Public	82,734	1,386

7.6.3.2 Bromsgrove Worcester Road Main

This network is centred on the Sanders Road Industrial estate with a network distributed from there to schools and business in that locality.

The anchor loads forming the initial cluster network are shown in Table 7.17.

Table 7.17: Summary of Connected Sites – Bromsgrove Worcester Road Main – Base Case

Worcester Road Main						
Short Name	**Eastings**	**Northing**	**Type of location**	**Owner**	**Heat kWh/Ann**	**Elec kWh/Ann**
Primary Energy Centre	395507	270299	Energy Centre	Private		n/a
Bromsgrove Prep	395949	270019	Demand	School	incl	n/a
Bromsgrove School	395957	270426	Demand	School	350,000	n/a
Worcester Road Trading Estate	395506	270298	Demand	Public	1,339,480	n/a
Millfields First School	395060	270010	Demand	School	94,918	60,698
St Johns CE Middle School	395490	270376	Demand	School	219,475	197,314
St Peters RC School	395343	269824	Demand	School	90,128	80,544
				Totals	2,094,000	338,556

7.6.3.3 Bromsgrove Aston Fields Industrial & Commercial Main

To the southern part of Bromsgrove there are two good-sized industrial & commercial areas with a good mix of businesses, Aston Fields is one that has been highlighted as a potential DE network opportunity.

The key loads forming the initial cluster network are shown in Table 7.18.

Table 7.18: Summary of Connected Sites – Bromsgrove Aston Fields Industrial Main

Aston Fields Industrial & Commercial Main						
Short Name	**Eastings**	**Northing**	**Type of location**	**Owner**	**Heat kWh/Ann**	**Elec kWh/Ann**
Primary Energy Centre, Adjacent to Homebase			Energy Centre	Private		n/a
ALDI	396100	269019	Demand	Private	52,500	not available
Aston Fields Area 1	396086	269107	Demand	Private	2,585,925	not available
Aston Fields Area 2	395730	268489	Demand	Private	5,400,000	not available
Bromsgrove Technology Park	396182	268654	Demand	Private	2,025,000	not available
Council Depot	396040	268760	Demand	Public	235,062	not available
Aston Yard	395958	268710	Demand	Public	282,945	not available
School Charlford First	395967	269332	Demand	School	130,440	not available
School South Bromsgrove High	395929	269657	Demand	School	228,374	not available
Homebase			Demand	Private	149,755	not available
				Totals	11,090,001	0

7.6.3.4 Bromsgrove Buntsford Industrial & Retail Main

Adjacent to Aston Fields is the Buntsford Industrial area, this also showed potential for a DE network with a number of commercial, industrial and some retail heat customers.

The key loads forming the initial cluster network are shown in Table 7.19.

Table 7.19: Summary of Connected Sites – Bromsgrove Buntsford Industrial Main

Buntsford Industrial & Retail Main						
Short Name	**Eastings**	**Northing**	**Type of location**	**Owner**	**Heat kWh/Ann**	**Elec kWh/Ann**
Primary Energy Centre, Buntsford			Energy Centre	Private		n/a
Buntsford Ind Est	395730	268489	Demand	Private	10,800,000	not available
BDHT HQ			Demand	Public	Included	not available
Duferco UK	395730	268489	Demand	Private	Included	not available
Morrison			Demand	Private	Included	not available
				Totals	10,800,000	0

7.6.3.5 Peak Demand and Annual Consumption

The diversified peak heat demand growth profile and annual consumption for the Bromsgrove Mains are shown in Table 7.20.

Table 7.20: Summary of Peak Demand and Annual Consumption Bromsgrove

Bromsgrove Town	**Heat Peak Demand**	**Annual Heat Consumption**
	MW	MWh
Town Centre & NHS Main	4.0	18,246
Town Centre & NHS Main (Variant 1)	2.8	12,177
Worcester Road Main	0.6	2,094
Aston Fields Industrial & Commercial Main	2.5	11,090
Aston Fields Industrial & Commercial Main (Variant 1)	1.5	6,695
Buntsford Industrial & Retail Main	3	10,800

As with the other potential opportunities there is a degree of uncertainty around the feasibility and future timescales of some of the connection opportunities. Initial enquiries with stakeholders have returned some information, as have assessments of energy statements however the level of granularity achieved in the energy profile is not ideal and would need to be targeted further during feasibility.

Of the potential connections listed in Table 7.16 to Table 7.19, the assumption has therefore been made that connection would be feasible at the point of development of the heat network. The technical viability and cost implications of connecting these buildings has not been undertaken at this stage and individual plantroom surveys have not been carried out. This is normally carried out at feasibility stage. We do not expect any matters arising from this aspect.

7.6.3.6 Energy Centre Locations

Energy centre locations in Bromsgrove were considered for each of the potential networks based on land that appeared to have potential for EC development (Table 7.21). Each potential site has not been addressed with the relevant stakeholder. We would expect each site to be confirmed and developed further as part of any feasibility study.

Table 7.21: Energy Centre Location Options - Bromsgrove

Advantages	Disadvantages
Town Centre & NHS Main – Princess of Wales Hospital (car park adjacent Plant Room)	
Hospital has an existing flue stack and is operating energy centre Possible space for energy centre development. Location away from town centre implies lower land value and fewer nuisances to local business and general public during construction. Utility infrastructure already installed (subject to sizing application) Site is located off major roads. Access for construction and maintenance is unlikely to cause possible traffic disruption.	Stack likely to be required for new EC or additional plant. Car parking spaces needed for EC Energy centre location is not close to centre of gravity of new anchor heat demands. Increases cost of network and development risk if stakeholder uptake is dispersed. Highest pipework cost associated with maintaining greater pipe sizes to serve remote demands implies increased development risk and reduced IRR relative to other options. Land is owned by the NHS. This will require negotiation with the landowner and presents an additional development risk to the project.
Site 2 – Town Centre & NHS Main – New Leisure Centre, School Drive	
Site is a new development close to the centre of gravity of the new anchor heat demands. New development includes a new Energy Centre for its own purposes. Additional space for plant may be available. Energy centre location reasonably close to centre of gravity of new anchor heat demands. Reduces cost of network and development risk if stakeholder uptake is dispersed Land is owned by Council, therefore reduces development risk.	Site is not adjacent to a major road. Suggests that noise and air quality impact will be a higher impact than for other options. Footprint for new development is defined under planning permission. To achieve additional plant space could be challenging and may encroach on leisure space. Location near the town centre implies higher land value and more nuisance to local business and general public during construction and during operation.

Advantages	Disadvantages
Worcester Road Main – Land northern most part of Sander Road Ind Est adjacent to existing industrial units	
Energy centre location is close to centre of gravity of anchor heat demands. Reduces cost of network and minimised development risk if stakeholder uptake is dispersed. Central location relative to planned network benefits the financial case. Location away from town centre implies less nuisance to local business and general public during construction and during operation Land value relatively low implies lower project costs.	Energy Centre stack requirement could limit use of site. Land ownership unknown, enquiries needed to ascertain possible use. Increased development risk. Possible land allocation to be confirmed. Space is very limited. May require two-storey energy centre, increasing cost and visual impact. Biomass option less likely to be viable, taking into account access requirements and fuel storage requirements. Visual impact likely to be an issue in relation to the required stack height.
Aston Fields Industrial Estate Main – Land at the rear of Homebase adjacent to the overflow car park adjacent to Sugarbrook.	
Energy centre location reasonably close to centre of gravity of new anchor heat demands. Reduces cost of network and development risk if stakeholder uptake is dispersed Location away from town centre implies less nuisance to local business and general public during construction and during operation Land value relatively low implies lower project costs. Site is adjacent to major road. Suggests that noise and air quality impact will be lower impact than for other options.	Energy Centre stack requirement could limit use of site. Land ownership unknown, enquiries needed to ascertain possible use. Increased development risk. Possible land allocation to be confirmed. Space is very limited. May require two-storey energy centre, increasing cost and visual impact. Visual impact likely to be an issue in relation to the required stack height.

Advantages	Disadvantages
Buntsford Industrial Estate Main – On development land at the rear of Car Dealerships on Buntsford Road	
Energy centre location reasonably close to centre of gravity of new anchor heat demands. Reduces cost of network and development risk if stakeholder uptake is dispersed. Site is adjacent to major road. Suggests that noise and air quality impact will be lower impact than for other options. Location away from town centre implies less nuisance to local business and general public during construction and during operation.	Energy Centre stack requirement could limit use of site. Land ownership unknown, enquiries needed to ascertain possible use. Increased development risk. Possible land allocation to be confirmed. Visual impact likely to be an issue in relation to the required stack height.

Modelling of the opportunities has identified that the configuration involving an Energy Centre at the Princess of Wales Hospital for the Town Centre & NHS Main, on the Sanders Industrial Estate for the Worcester Road Main, on land at the rear of Homebase for the Aston Fields Industrial Main and on development land off Buntsford Road for the Buntsford Industrial Main provides a suitable datum from which to undertaken energy master planning modelling. The listed energy centre options are therefore taken forward as the basis of the heat network opportunity for the reminder of the Bromsgrove analysis and all identified costs and economic indicators presented in this section reflect this assumption.

Based on our initial assessments, these locations are considered to be feasible for an energy centre. However, it is recognised that in some cases the available space or consented space is likely to be tight and may require a two storey energy centre to be constructed with an evaluation of up to 10m from ground level (excluding stack height) or a buried basement which may increase construction costs.

Likewise further modifications or significant changes to the networks may render the location of the energy centre as less appropriate.

7.6.3.7 Phasing Strategy and Implementation Plan

A single gas engine is proposed at the start of the project. The network should be installed in a modular fashion in order to minimise capital outlay and under-utilisation in the early years and allow capital expenditure to be matched more closely to revenues from heat and electricity sales.

7.6.3.8 Economic Modelling

Economic modelling has been carried out for each option and the variant options within Bromsgrove. The key economic indicators for the scheme are presented in Table 7.22, for the base case option as a function of electricity selling arrangements and assuming a project term of 30 years.

For this project, an Electricity Sell and Buy Back[11] arrangement has been considered, since a private wire network is unlikely to be a cost effective, unless one or two large-scale users could be connected[12]. Refer to Technical Appendices for definitions of electricity selling arrangement opportunities

Table 7.22: Bromsgrove Heat Clusters – Key Economic Indicators

Heat Cluster Name		Bromsgrove District Heating Network			
		Town Centre & NHS Main	Worcester Road Main	Aston Fields Industrial/ Commercial Main	Buntsford Industrial/ Retail Main
Total Investment CAPEX	[£ K]	3,111	1,725	2,785	2,274
Energy Centre CAPEX	[£ K]	1,177	696	1,012	917
Length of Heat Network	[m]	3.8	1.9	2.0	0.8
Cost of Heat Network	[£ K]	1,002	512	966	766
Connection CAPEX	[£ K]	575	319	487	329
Project Development Costs	[£ K]	358	198	320	262
Annual Operating Costs	[£ K]	512	284	459	375
Annual Revenues from Heat Sales	[£ K]	861	80	567	547

Across each of the Bromsgrove DE clusters the gas cost is set at 2.8p/kWh and the discounted heat price offered to initial heat customers is 4.60p/kWh.

The capital investment requirement for the Town Centre & NHS Main totals £3.1m with annual heat sales at full build out totalling £861,000.

[11] The electricity producer can arrange with a local electricity license holder to net off, for a fee, consumption against production

[12] The possibility of this arrangement could be explored at the next stage if the project is taken forward, although it is noted that this approach would also carry significant risk to the project, since the customer(s) would not enter into long term agreements for this electricity and would be free to change supplier at any time under current electricity supply laws

For the smaller Worcester Road Main the capital investment is £1.7m with heat revenues at full build out of £80,000 p.a.

For the Aston Fields Industrial Main capital costs outturn at £1.0m with annual revenues from heat sales at full build out of £567,000.

The Buntsford Retail Main shows heat revenues of £547,000 with a capital cost of £0.9m.

7.6.3.9 Town Centre & NHS Main

Table 7.23 shows the financial modelling summary outputs of the Town Centre & NHS Main base case and variant options. For the variant option a number of heat connections that were on the periphery of the base case network was omitted from the corresponding modelling of the variant.

The variant option excludes the following key connections;

- Asda
- Iceland
- The re-development of the County building & fire station in Windsor Road
- The Birmingham Road Retail Area

Table 7.23: Key Financial Modelling Outputs – Bromsgrove Town Centre and NHS Main

Heat Cluster Name		Town Centre & NHS Main	
Bromsgrove District Heating		Basecase	Variant
Estimated Scheme Data	***Units***		
Heat Sales Revenues	Y5	£0.861m	£0.62m
Energy Centre Capacity	MW	4.0	2.8
Forecast Annual Heat Supply	MWh	18,246	12,177
Total Route Length of Pipework	kM	3.8	3.8
Capital Cost	£	£3.111m	£2.955m
IRR	%	3.50%	3.50%
NPV	£	£18,173	(£15,325)
Year Cashflow Positive	Y	23	23

The base case provides an IRR at 3.5% over a 30-year term with an assumed inflation rate of 1.95% with a £18,173 NPV value and cash flow positive in year 23.

The variant option provides very similar financial figures albeit with a negative NPV of -£15,325.

7.6.3.10 Worcester Road & Buntsford Retail Mains

Table 7.24 below shows the financial modelling outputs for the Worcester Road and Buntsford Retail Mains. Variant options have not been developed for either of these clusters.

Table 7.24: Ley Financial Modelling Outputs – Bromsgrove Worcester Road and Buntsford Retail Mains

Heat Cluster Name		Worcester Road Main	Buntsford Industrial/ Retail Main
Bromsgrove District Heating Network		Basecase	Basecase
Estimated Scheme Data	***Units***		
Heat Sales Revenues	Y5	£0.08m	£0.547m
Energy Centre Capacity	MW	0.6	2.5
Forecast Annual Heat Supply	MWh	2,094	10,800
Total Route Length of Pipework	kM	1.9	0.8
Capital Cost	£	£1.725m	£2.274m
IRR	%	15.20%	4.30%
NPV	£	£3.343m	£346,766
Year Cashflow Positive	Y	7	22

The Buntsford Retail Main provides a 4.3% IRR with a positive £347,000 NPV with a positive cash flow occurring in year 22 of the 30-year term.

Worcester Road shows a 15.2% IRR with a positive £3.3m NPV with positive cash flow occurring in year 7.

7.6.3.11 Aston Fields Industrial Main

Table 7.25 demonstrates the financial summary outputs for the Aston Fields cluster including the variant option that was also considered. The variant has been modelled without the Bromsgrove Technology Park.

The base case and variant results show 2.8% and 2.6% IRR with negative £347,000 and £249,000 NPV figures with positive cash flow showing in year 25.

Table 7.25: Key Financial Modelling Outputs – Bromsgrove Aston Fields

Heat Cluster Name		**Aston Fields Industrial/ Commercial Main**	
Bromsgrove District Heating Network		**Basecase**	**Variant**
Estimated Scheme Data	***Units***		
Heat Sales Revenues	Y5	£0.567m	£0.34m
Energy Centre Capacity	MW	2.5	1.5
Forecast Annual Heat Supply	MWh	11,090	6,695
Total Route Length of Pipework	kM	2.0	2.0
Capital Cost	£	£2.785m	£1.172m
IRR	%	2.80%	2.60%
NPV	£	(£346,502)	(£249,333)
Year Cashflow Positive	Y	25	25

7.6.4 City of Worcester

The heat mapping exercise in Worcester highlighted some strong areas of heat demand with a mix of heat use including proposed new developments.

For the City of Worcester three network clusters have been identified:

1. North Worcester Industrial Main,
2. University & City Centre Main,
3. Southern NHS Main.

The network drawings showing the proposed heat network opportunities are provided in Appendix A (Drawings 5.8, 5.9 and 5.10).

7.6.4.1 North Worcester Industrial Main

The anchor heat loads forming the initial network opportunity are shown in Table 7.26.

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Table 7.26: Summary of Connected Sites – North Worcester Industrial Main

North Worcester Industrial Main - Key Sites						
Short Name	**Eastings**	**Northing**	**Type of location**	**Owner**	**Heat kWh/Ann**	**Elec kWh/Ann**
Primary Energy Centre	389127	257320	Energy Centre	Public		n/a
School Tudor Grange	386082	257207	Demand	School	678,888	876,390
Blackpole Retail Park	386581	257465	Demand	Private	1,770,064	n/a
Blackpole Trading Park	386723	257786	Demand	Private	6,391,665	
Warndon Depot	389127	257320	Demand	Public	72,000	318,904
Worcester 6	389341	256964	Demand	Private	421,045	n/a
Worcester 6	389341	256964	Demand	Private	2,087,463	n/a
Cranham Centre	386979	257367	Demand	Public	10,591	2,139
School Cranham Prim	386974	257373	Demand	School	117,553	132,123
School Oasis Academ	387419	256884	Demand	School	195,815	168,011
School St. Josephs	387581	257042	Demand	School	125,719	88,198
School Gorse Hill	386388	255885	Demand	School	133,168	91,501
Bridgewater Road	387634	257481	Demand	Private	395,843	n/a
Berkeley, Apex & Wainwright Business Parks	388197	257339	Demand	Private	6,976,384	n/a
Brindley Road	387954	257463	Demand	Private	1,842,750	n/a
Ebrington Drive	387537	257589	Demand	Private	1,978,121	n/a
Badgeworth Drive	387274	257558	Demand	Private	2,315,250	n/a
Buckhold Drive	386951	257597	Demand	Private	1,325,914	n/a
Homestead Ave	387840	257030	Transit Node	Private	0	n/a
Warriors Stadium	388970	257482	Demand	Private	0	n/a
David Lloyd	389092	257564	Demand	Private	3,616,000	n/a
				Totals	30,454,232	1,677,266

7.6.4.2 Worcester - University and City Centre Main

The key anchor heat loads forming the initial network opportunity are shown in Table 7.27.

Table 7.27: Summary of Key Sites – University of Worcester and City Centre Main

Worcester - University and City Centre Main						
Short Name	**Eastings**	**Northing**	**Type of location**	**Owner**	**Heat kWh/Ann**	**Elec kWh/Ann**
Primary Energy Centre	383480	255500	Energy Centre	University		n/a
Museum & Gallery	384909	255383	Demand	Public	162,572	178,160
Shrub Hill Retail	385311	255198	Demand	Private	2,362,500	n/a
UoW Jenny Lind	384833	255132	Demand	University	62,287	n/a
UoW City Campus	384696	255200	Demand	University	846,532	874,780
Library	384645	255083	Demand	Public	40,895	1,080,304
School Our Lady	383945	254372	Demand	School	70,384	50,082
St. John's Sport Centre	384006	254213	Demand	Public	123,406	278,703
St. Johns Library	383969	254527	Demand	Public	42,935	47,870
Fortis Living	384216	254552	Demand	RSL	0	50,601
Fortis Living	384216	254552	Demand	RSL	0	43,375
Fortis Living	384216	254552	Demand	RSL	0	24,243
Fortis Living	384127	254657	Demand	RSL	293,171	62,670
Everoak I/E	383256	254386	Demand	Private	5,355,000	n/a
UoW Riverside	384259	255051	Demand	University	49,196	130,633
UoW The Arena	384259	254966	Demand	University	217,633	416,353
Hylton Road I/E	384108	255084	Demand	Private	2,037,000	n/a
UoW Garage	384077	255147	Demand	University	51,671	37,588
School Oldbury Pk	383700	255342	Demand	School	203,013	91,460
School Manor Park	383856	255421	Demand	School	0	n/a
UoW Fern Court	383335	255798	Demand	University	75,482	13,255
UoW Porters	383454	383454	Demand	University	0	926
UoW Sheila Scott	383816	255460	Demand	University	51,671	109,171
UoW St Johns Campus	383485	255508	Demand	University	4,901,531	3,990,290
UoW Stores	383834	255507	Demand	University	15,020	37,642
Fortis Living	383473	255870	Demand	RSL	575,962	102,278
Heenans Ct	385185	255256	Demand	Private	99,488	n/a
RGS School	384590	255672	Demand	School	360,000	n/a
West Mercia Police	384712	255410	Demand	Public	992,264	1,368,452
Magistrates Court	384772	255431	Demand	Public	173,999	467,460
Combined Court	384931	255436	Demand	Public	444,756	463,164
ASDA	385285	255109	Demand	Private	588,000	n/a
Whitehead College	384156	254234	Demand	Private	918,876	440,227
Venture Bus Pk	384263	253063	Demand	Private	2,040,120	
Amdac	384263	253063	Demand	Private	0	
Citizen's Pool	384265	253065	Demand	Public	678,000	

7.6.4.3 Worcester - Southern NHS Main

The key anchor heat loads forming the initial network opportunity are shown in Table 7.28.

Table 7.28: Summary of Connected Sites – Worcester Southern NHS Main

Worcester - Southern NHS Main Key Sites						
Short Name	Eastings	Northing	Type of location	Owner	Heat kWh/Ann	Elec kWh/Ann
Primary Energy Centre	387698	254793	Energy Centre	NHS		n/a
Royal NHS CHEC	387695	254795	Demand	NHS	59,115	253,350
Royal NHS MAIN	387698	254793	Demand	NHS	12,829,468	13,562,533
Fire Station	387857	254838	Demand	Public	33,023	621,600
School Nunnery Primary	386829	254148	Demand	School	77,879	62,055
Wildwood Way Offices	387798	254333	Demand	Public	400,569	634,550
School Nunnery High	387109	253992	Demand	School	693,445	593,486
6th Form Secondary	387327	253986	Demand	School	308,700	206,074
6th Form Main	387327	253986	Demand	School	1,056,304	493,600
County Hall Complex	387617	254161	Demand	Public	1,065,428	3,012,961
County Hall Secondary	387562	254156	Demand	Public	0	37,578
Worcs Mental Health Trust	387553	255015	Demand	Public	3,220,980	0
Kings Court Bus Pk	387853	254872	Demand	Private	420,000	0
Perry Manor Care	388015	254890	Demand	Private	1,008,000	0
RNIB New College	387158	253470	Demand	Private	569,321	317,055
				Totals	21,742,230	19,794,842

7.6.4.4 Peak Demand and Annual Consumption

The diversified peak heat demand growth profile and annual consumption at full build out for each of the three Worcester cluster opportunities is shown in Table 7.29.

Table 7.29: Peak Heat Demand and Annual Consumption at full Build out for Worcester Clusters

City of Worcester	Heat Peak Demand	Annual Heat Consumption
	MW	MWh
North Worcester Industrial Main,	7.0	30,490
University & City Centre Main,	7.0	30,016
Southern NHS Main	5.0	21,742

7.6.4.5 Energy Centre Locations

Single energy centre locations have been identified for each of the Worcester opportunity clusters.

Table 7.30: Energy Centre Locations – Advantages and Disadvantages

Advantages	Disadvantages
North Worcester Industrial Main - Development Land in the locality of Worcester Warriors	
Possible space for energy centre development. Location away from town centre implies lower land value and fewer nuisances to local business and general public during construction. Site is located off major roads. Access for construction and maintenance is unlikely to cause possible traffic disruption.	Stack likely to be required for new EC or additional plant. Spaces needed for EC Energy centre location is not close to centre of gravity of new anchor heat demands. Increases cost of network and development risk if stakeholder uptake is dispersed. Highest pipework cost associated with maintaining greater pipe sizes to serve remote demands implies increased development risk and reduced IRR relative to other options. Land is not owned by the Council. This will require negotiation with the private landowner and presents an additional development risk to the project.

Advantages	Disadvantages
Worcester - University and City Centre Main – University of Worcester St John's and Severn Campuses Energy Centre	
UoW has an existing flue stack and operating energy centre Ample space for energy centre development. Energy centre location reasonably close to centre of gravity of anchor heat demands. Reduces cost of network and development risk if stakeholder uptake is dispersed. Location away from town centre implies lower land value and fewer nuisances to local business and general public during construction. Utility infrastructure already installed (subject to sizing application)	Stack likely to be required for new EC or additional plant. Car parking spaces needed for EC Site is located off major road. Access for construction and maintenance is likely to cause possible traffic disruption. Less suited to biomass, since ongoing fuel deliveries will also cause traffic disruption. Highest pipework cost associated with maintaining greater pipe sizes to serve remote demands implies increased development risk and reduced IRR relative to other options. Land is owned by the NHS. This will require negotiation with the landowner and presents an additional development risk to the project.
Worcester - Southern NHS Main – Worcester Royal NHS Acute Hospital Energy Centre	
Hospital has an existing flue stack and operating energy centre Ample space for energy centre development. Energy centre location reasonably close to centre of gravity of anchor heat demands. Reduces cost of network and development risk if stakeholder uptake is dispersed. Location away from town centre implies lower land value and fewer nuisances to local business and general public during construction. Utility infrastructure already installed (subject to sizing application)	Stack likely to be required for new EC or additional plant. Car parking spaces needed for EC Site is located off major road. Access for construction and maintenance is likely to cause possible traffic disruption. Less suited to biomass, since ongoing fuel deliveries will also cause traffic disruption. Highest pipework cost associated with maintaining greater pipe sizes to serve remote demands implies increased development risk and reduced IRR relative to other options. Land is owned by the NHS. This will require negotiation with the landowner and presents an additional development risk to the project.

7.6.4.6 Phasing Strategy and Implementation Plan

A single gas engine is proposed at the start of the project. The network should be installed in a modular fashion in order to minimise capital outlay and under-utilisation in the early years and allow capital expenditure to be matched more closely to revenues from heat and electricity sales.

7.6.4.7 Economic Modelling

Economic modelling has been undertaken for each of the three Worcester DE base case opportunities. The key economic indicators for each scheme are shown in Table 7.31, for the base case options as a function of electricity selling arrangements and assuming a project term of 30 years.

As with the other clusters, an Electricity Sell and Buy Back arrangement has been considered, since a private wire network is unlikely to be cost effective, unless one or two large-scale users located close to each energy centre could be connected.

Table 7.31: Worcester City Base Case Options – Key Economic Indicators

Heat Cluster Name		Worcester District Heating Network		
		North Worcester Industrial Main	University & City Centre Main	Southern NHS Main
Total Investment CAPEX	[£ K]	5,500	6,640	4,322
Energy Centre CAPEX	[£ K]	2,081	2,412	1,743
Length of Heat Network	[m]	5,000	5,800	3,500
Cost of Heat Network	[£ K]	1,771	2,304	1,457
Connection CAPEX	[£ K]	1,016	1,160	625
Project Development Costs	[£ K]	633	764	497
Annual Operating Costs	[£ K]	906	1,094	712
Annual Revenues from Heat Sales	[£ K]	1,530	1,510	1,090

Across each of the Worcester City DE clusters the gas cost is set at 2.8p/kWh and the discounted heat price offered to initial heat customers is 4.555p/kWh.

The capital investment requirements for the North Worcester Industrial Main totals £5.5m with annual heat sales at full build out totalling £1.53m.

For the larger University & City Centre Main the capital investment is £5.8m with heat revenues at full build out of £1.51m p.a.

For the Southern and NHS Main capital costs outturn at £4.32m with annual revenues from heat sales at full build out of £1.09m.

The discounted heat sell price to connected customers for each base case is 4.555pkWh with the gas input price set at 2.8p/kWh.

Table 7.32: Key Finacial Modelling Outputs – Worcester City

Heat Cluster Name		City of Worcester District Heating Network		
		North Worcester Industrial Main	University & City Centre Main	Southern NHS Main
Estimated Scheme Data	***Units***			
Heat Sales Revenues	Y5	£1.53m	£1.51m	£1.09m
Energy Centre Capacity	MW	7.0	7.0	5.0
Forecast Annual Heat Supply	MWh	30,490	30,016	21,742
Total Route Length of Pipework	kM	5.0	5.8	3.5
Capital Cost	£	£5.5m	£6.64m	£4.322m
IRR	%	4.80%	3.50%	4.20%
NPV	£	£1.268m	£25,554	£509,032
Year Cashflow Positive	Y	20	22	21

Over a 30 year period the modelling shows that the North Worcester Industrial Main delivers a 4.8% IRR, a positive £1.268m NPV with a positive cashflow in year 20.

The University and City Centre Main provides 3.5% IRR, a marginal £25,554 NPV with a positive cashflow in year 22.

The Southern NHS Main provides 4.2% IRR, a positive £0.509m NPV with positive cashflow in year 21.

7.7 Conclusion and Recommendations

Summary of findings for project opportunities are as follows.

7.7.1 Kidderminster Central and Southern Mains

Overall Recommendation

It is recommended that the Local Authority should carry forward these project opportunities at some stage in the future. The development timescales for the project are such that a fully built out project opportunity would not materialise until around 2025 and it is unlikely that the private sector will step in to develop a Project in the interim period.

On this basis, Local Authority should consider establishing an initial cluster project to catalyse the opportunity and lay the foundation for any future involvement by the private sector. This may be best initiated with an energy centre within the town centre.

In order for the initial cluster project to be more economically attractive it is likely to require an electricity model that provides an improvement on the Sell and Buy Back Arrangement i.e. a private wire connection to large users close by.

Key Considerations Going Forward

The long development timescales present a significant development risk to the project. Future expansion of the project will depend on whether the future development proposals materialise. The large number of stakeholders involved in the initial cluster phase of the project presents a risk in relation to developing a secure bankable customer base for the project.

The costs and differing timescales associated with refurbishment of existing internal heating systems in the numerous existing buildings making up the cluster project makes the availability and phasing of future revenues from these buildings difficult to predict. There remains uncertainty about the technical suitability of many of the identified commercial and private existing buildings.

Future developments in government policy around building regulations, zero carbon homes policy, financial and policy support mechanisms to gas CHP and alternative technologies that might be adopted in lieu of CHP with a heat network affect viability. Similarly uncertainty around future grid decarbonisation will have an impact on the future role for gas CHP.

7.7.2 Redditch Town – Northern Main

Overall Recommendation

It is recommended that the Local Authority should carry forward this project opportunity at some stage in the future. The development timescales for the project are such that a fully built out project opportunity would not materialise until around 2030 and it is unlikely that the private sector will step in to develop a Project in the interim period.

On this basis, Local Authority should consider establishing an initial cluster project to catalyse the opportunity and lay the foundation for any future involvement by the private sector. In order for the initial cluster project to be more economically attractive it is likely to require an electricity model that provides an improvement on the Sell and Buy Back Arrangement i.e. a private wire connection to large users close by.

Key Considerations Going Forward

Validating a location for the Energy Centre in the locality of the position modelled is a key success factor. The long development timescales present a significant development risk to the project. Future expansion of the project will depend on whether the future development proposals materialize (REG).

The large number of stakeholders involved in the initial cluster phase of the project presents a risk in relation to developing a secure bankable customer base for the project.

The costs and differing timescales associated with refurbishment of existing internal heating systems in the numerous existing buildings making up the cluster project makes the availability and phasing of future revenues from these buildings difficult to predict. There remains uncertainty about the technical suitability of many of the identified commercial and private existing buildings.

Future developments in government policy around building regulations, zero carbon homes policy, financial and policy support mechanisms to gas CHP and alternative technologies that might be adopted in lieu of CHP with a heat network affect viability. Similarly uncertainty around future grid decarbonisation will have an impact on the future role for gas CHP.

7.7.3 Redditch Town – NHS and Industrial Main

Overall Recommendation

There appears to be a viable project opportunity for the NHS and industrial Main, based on the existing energy centre assets at Royal Alexandra Hospital. It is recommended that the project opportunity is considered further by the Local Authority. The development timescales for the project are such that a fully built out project opportunity would not materialise until around 2030 and it is unlikely that the private sector will step in to develop a Project in the interim period.

On this basis, the stakeholders should consider establishing an initial cluster project centre close to the hospital to catalyse the opportunity and lay the foundation for any future involvement by the private sector.

The Local Authority are likely to have little interest or incentive to become directly involved in the project, since the scope for reducing local authority carbon emissions and future fuel costs would be limited and the opportunity to extend the project beyond the immediate vicinity appear to be very low. The Local Authority's role in this project should be to act as a facilitator for the project bringing together key stakeholders including any developments to safeguard for connection to the project if taken forward.

Key Considerations Going Forward

A key barrier to this project opportunity is the timescales for the development proposals. Engie, the current owner/operator of the hospital energy centre may have a short to medium term objective to address around the future of its existing energy centre asset (waste incinerator) but the wider development opportunities may not come forward for some years. It is therefore important to liaise with Engie to get a detailed understanding of their plans and priorities and to discuss scope for a potential district heat network feasibility study.

Future expansion of the project will depend on whether the future development proposals materialize and commercial and private heat demand can be secured. There is uncertainty around the cost and technical viability of retrofitting heating systems to the proposed commercial areas.

There is uncertainty around the viability and costs to Engie associated with modifying its existing energy centre to operate a district system.

7.7.4 Bromsgrove Town – Town Centre and NHS Main

Overall Recommendation

There appears to be a viable project opportunity for the Town Centre Main, around the existing energy centre at the Princess of Wales Hospital. It is recommended that the Local Authority should carry forward this project opportunity at some stage in the future. The development timescales for the project are such that a fully built out project opportunity would not materialise until around 2030 and it is unlikely that the private sector will step in to develop a Project in the interim period.

On this basis, the stakeholders should consider establishing an initial cluster project centre close to the hospital to catalyse the opportunity and lay the foundation for any future involvement by the private sector. The possibility of locating an energy centre within the town centre cluster to improve initial capital costs in the form of less pipework should be considered.

The Local Authority is likely to have an interest or incentive to become directly involved in the project, since the scope for reducing local authority carbon emissions and future fuel costs would be attractive. The Local Authority's role in this project should be to act as a lead for the project bringing together key stakeholders including any developments to safeguard for connection to the project if taken forward.

Key Considerations Going Forward

A key barrier to this project opportunity is the timescales for the development proposals. The Trust may have a short to medium term objective to address around the future of its existing energy centre asset but the wider development opportunities may not come forward for some years. The proposed network opportunity may not therefore be in the Trust's best economic interests. A more detailed assessment of alternative energy centre locations (or a combination of smaller energy centres), taking into account the relocated Council offices, may offer significant opportunities to improve viability and should therefore be included at feasibility stage.

Future expansion of the project will depend on whether commercial and private heat demand can be secured. There is uncertainty around the cost and technical viability of retrofitting heating systems to the proposed commercial and residential areas. There is uncertainty around the viability and costs to the Trust associated with modifying its existing systems to operate a district system.

7.7.5 Bromsgrove Town – Worcester Road Main

Overall Recommendation

It is recommended that the Local Authority should carry forward this project opportunity. The development timescales for the project are such that a fully built out project opportunity would not materialise until around 2025 and it is unlikely that the private sector will step in to develop a Project in the interim period.

On this basis, Local Authority should consider establishing an initial cluster project to catalyse the opportunity and lay the foundation for any future involvement by the private sector. This may be best initiated with securing firm data and knowledge on the heating requirements of the proposed key heat customers. In order for the initial cluster project to be more economically attractive to it is likely to require an electricity model that provides an improvement on the Sell and Buy Back Arrangement i.e. a private wire connection to large users close by.

Key Considerations Going Forward

The long development timescales present a significant development risk to the project. Future expansion of the project will depend on whether the future local customers materialise.

The large number of stakeholders involved in the project presents a risk in relation to developing a secure bankable customer base for the project. The seasonal cycling of the demand profiles for the educational connections need due consideration.

The costs and differing timescales associated with refurbishment of existing internal heating systems in the existing buildings making up the project makes the availability and phasing of future revenues from these buildings difficult to predict. There remains uncertainty about the technical suitability of many of the identified non-public existing buildings. Validating a location for the Energy Centre in the locality of the position modelled is a key success factor.

Future developments in government policy around building regulations, zero carbon homes policy, financial and policy support mechanisms to gas CHP and alternative technologies that might be adopted in lieu of CHP with a heat network affect viability. Similarly uncertainty around future grid decarbonisation will have an impact on the future role for gas CHP.

7.7.6 Bromsgrove Town – Aston Fields Industrial / Commercial Main

Overall Recommendation

There is insufficient anchor heat load to support an economically viable heat network in the Aston Fields Industrial Estate.

The calculated economic indicators for the Aston Fields corridor project would be of no interest to a private sector ESCo and equally would offer only a barely acceptable return to a public body over 30 years, assuming an Electricity Sell and Buy Back arrangement.

The recommendation is therefore for this opportunity not to be taken forward as a stand-alone project in isolation of other heat network opportunities.

7.7.7 Bromsgrove Town – Buntsford Industrial / Retail Main

Overall Recommendation

It is recommended that the Local Authority should carry forward this project opportunity at some stage in the future. The development timescales for the project are such that a fully built out project opportunity would not materialise until around 2030 and it is unlikely that the private sector will step in to develop a Project in the interim period.

On this basis, the Local Authority should consider establishing an initial cluster project to catalyse the opportunity and lay the foundation for any future involvement by the private sector. This may be best initiated with securing firm data and knowledge on the heating requirements of the proposed key heat customers. In order for the initial cluster project to be more economically attractive to it is likely to require an electricity model that provides an improvement on the Sell and Buy Back Arrangement i.e. a private wire connection to large users close by.

Key Considerations Going Forward

The long development timescales present a significant development risk to the project. Future expansion of the project will depend on whether the future local customers materialise. The large number of stakeholders involved in the project presents a risk in relation to developing a secure bankable customer base for the project.

The costs and differing timescales associated with refurbishment of existing internal heating systems in the existing buildings making up the project makes the availability and phasing of future revenues from these buildings difficult to predict. There remains uncertainty about the technical suitability of many of the identified non-public existing buildings. Validating a location for the Energy Centre in the locality of the position modelled is a key success factor.

Future developments in government policy around building regulations, zero carbon homes policy, financial and policy support mechanisms to gas CHP and alternative technologies that might be adopted in lieu of CHP with a heat network affect viability. Similarly uncertainty around future grid decarbonisation will have an impact on the future role for gas CHP.

7.7.8 Worcester City – North Worcester Industrial Main

Overall Recommendation

It is recommended that the Local Authority should carry forward this project opportunity at some stage in the future. The development timescales for the project are such that a fully built out project opportunity would not materialise until around 2030 and it is unlikely that the private sector will step in to develop a Project in the interim period.

On this basis, Local Authority should consider establishing an initial cluster project to catalyse the opportunity and lay the foundation for any future involvement by the private sector. In order for the initial cluster project to be more economically attractive to it is likely to require an electricity model that provides an improvement on the Sell and Buy Back Arrangement i.e. a private wire connection to large users close by.

Key Considerations Going Forward

Validating a location for the Energy Centre in the locality of the position modelled is a key success factor. The long development timescales present a significant development risk to the project. Future expansion of the project will depend on whether the future development proposals materialize (Worcester 6).

The large number of stakeholders involved in the initial cluster phase of the project presents a risk in relation to developing a secure bankable customer base for the project.

The costs and differing timescales associated with refurbishment of existing internal heating systems in the numerous existing buildings making up the cluster project makes the availability and phasing of future revenues from these buildings difficult to predict. There remains uncertainty about the technical suitability of many of the identified commercial and private existing buildings.

Future developments in government policy around building regulations, zero carbon homes policy, financial and policy support mechanisms to gas CHP and alternative technologies that might be adopted in lieu of CHP with a heat network affect viability. Similarly uncertainty around future grid decarbonisation will have an impact on the future role for gas CHP.

7.7.9 Worcester City – University & City Centre Main

Overall Recommendation

It is recommended that the Local Authority should carry forward this project opportunity. The development timescales for the project are such that a fully built out project opportunity would not materialise until around 2030 and it is unlikely that the private sector will step in to develop a Project in the interim period.

On this basis, Local Authority should consider establishing an initial cluster project to catalyse the opportunity and lay the foundation for any future involvement by the private sector.

In order for the initial cluster project to be more economically attractive it is likely to require an electricity model that provides an improvement on the Sell and Buy Back Arrangement i.e. a private wire connection to large users close by such as the university.

Key Considerations Going Forward

The long development timescales present a significant development risk to the project. Future expansion of the project will depend on whether the future development proposals materialize.

The large number of stakeholders involved in the initial cluster phase of the project presents a risk in relation to developing a secure bankable customer base for the project. The costs and differing timescales associated with refurbishment of existing internal heating systems in the numerous existing buildings making up the cluster project makes the availability and phasing of future revenues from these buildings difficult to predict. There remains uncertainty about the technical suitability of many of the identified commercial and private existing buildings.

Future developments in government policy around building regulations, zero carbon homes policy, financial and policy support mechanisms to gas CHP and alternative technologies that might be adopted in lieu of CHP with a heat network affect viability. Similarly uncertainty around future grid decarbonisation will have an impact on the future role for gas CHP.

7.7.10 Worcester City - Southern NHS Main

Overall Recommendation

There appears to be a viable project opportunity for the Southern NHS Main, based on a CHP at the Worcester Royal Hospital. It is recommended that the Local Authority consider the project opportunity further. The development timescales for the project are such that a fully built out project opportunity would not materialise until around 2030 and it is unlikely that the private sector will step in to develop a Project in the interim period.

The Local Authority is likely to have an interest or incentive to become directly involved in the project, since the scope for reducing local authority carbon emissions and future fuel costs would be attractive. The Local Authority’s role in this project should be to act as a lead for the project bringing together key stakeholders including any developments to safeguard for connection to the project if taken forward.

Key Considerations Going Forward

A key barrier to this project opportunity is the timescales for the development proposals. The Trust may have a short to medium term objective to address around the future of its existing energy centre asset but the wider development opportunities may not come forward for some years. The proposed network opportunity may not therefore be in the Trust’s best economic interests.

Future expansion of the project will depend on whether commercial and private heat demand can be secured and whether the future development proposals materialize (Whittington Rd).

There is uncertainty around the cost and technical viability of retrofitting heating systems to the proposed commercial and residential areas. There is uncertainty around the viability and costs to the Trust associated with modifying its existing systems to operate a district system.

8 Geothermal Pre-feasibility study for Offenham

8.1 Introduction

Offenham is the centre of the Agri-Tech sector in Worcestershire. It includes a number of heated and unheated glass houses, poly tunnels and open fields for fruit and vegetable production. Food processing and packaging facilities are also present near Offenham, in particular Kanes Foods at Middle Littleton. Agri-Tech is one of the County's priority economic sectors and it is a key LEP aspiration to support the sector to retain and advance its competitiveness. Energy demands for greenhouse heating and vegetable processing are significant and influence local companies in their ability to increase their turnover. As part of this project a pre-feasibility study was included aiming to undertake a pre-evaluation of the potential exploitation of geothermal heat sources in Offenham.

8.2 Overview of Offenham

Offenham is located three miles north east of the town of Evesham in the Vale of Evesham. The village is situated on the River Avon at an elevation of approximately 25mOD adjacent to the river with the topography rising gently around the village to surrounding hills at approximately 50mOD.

The principal land use in the area is farming, specifically market gardening with the principal growers (comprising nurseries and glass houses) being Vale Fresco, Westland Nurseries, R.&L. Holt, Evesham Vale Growers, Avoncross Ornamentals Nurseries and Zenith Nurseries. Fruit/vegetable packing and distribution is undertaken at Kanes Foods Ltd and Bannister Distribution and Logistics. HMPS Long Lartin Prison is located approximately 2km to the east of Offenham.

8.3 Geology, hydrogeology and hydrology

Offenham is located within the Worcester Basin, a geological structure which offers significant deep geothermal low grade heat potential with two specific target formations, the Sherwood Sandstone and the Bridgnorth Sandstone, the geological and hydrogeological properties of which are summarised in Table 8.1.The overall regional geological and hydrogeological setting and geothermal energy potential is described in Chapter 6 Sections 6.4 and 6.5.

Table 8.1: Geological and Hydrogeological Conditions of the Offenham Area

Formation	Approximate Depth/Thickness	Hydrogeology	Estimated Water Level	Estimated Groundwater Temperature
Sherwood Sandstone	350mbgl / up to 1000m	Bromsgrove and Wildmoor Sandstone: Aquifer Wide ranging permeability (of the order of 0.5m/d)* (Kidderminster Formation: Aquitard)	40mAOD	30-45°C
Bridgnorth Sandstone	1200mbgl /ca.700-800m	Aquifer, permeability up to 0.17m/d**	40mAOD	40-50°C

*measured close to outcrop. Likely to be less but still significant at depth

**measured at depth in Kempsey borehole

No deep borehole and no deep geophysical survey information are available for the Offenham area which would allow confirmation of the exact depth of the target strata and expected groundwater temperatures; the closest deep borehole information is from the Netherton borehole which is located approximately 8km to the southwest.

Based on the regional information, the thicknesses of the sandstone layers are expected to be significant, groundwater salinities are expected to be brackish to saline and temperatures in the order of 40ºC. The deep groundwater is currently not in use and is not classed by the Environment Agency in their Catchment Abstraction Management Strategy documents.

The locally present shallow groundwater also represents a local geothermal resource but with much lower temperatures, lower volumes and strict regulation due to its value for drinking water and farm water supply.

Surface water from the River Avon is also considered a potential source for heat pump applications but is located relatively distant from the main heat demand in and around Offenham. Ecological constraints could also limit its potential.

8.4 Summary of heat mapping and masterplanning considerations

More effort was put into understanding the energy demand in the Offenham area compared to the Worcestershire wide study. After consultation with WDC, farmers and local businesses with known significant energy demands were approached. Communication was undertaken via phone, email and face to face meetings, mainly during October and November 2015. Businesses and residential users with expected minor heating demands were not specifically approached during the heat mapping stage but are invited to join a local heat network scheme in the future if technically and economically viable.

The heating demand in Offenham is dominated by glass house heating requirements for the local horticulture businesses. These are generally small to medium size, family owned businesses. Heating demand profiles, requirements for cooling and CO_2 and currently available energy centres vary significantly from business to business. Considering the combined gas consumption for heating purposes of the Sandylands Nurseries, Westlands Nurseries, Valefresco, Evesham Vale Growers and Kanes Foods alone adds currently to a heat demand of approximately 25,000 – 30,000MWhours per year. Discussions with farmers in Offenham confirm a strong interest in investigating the potential of a local heat network as this could allow them to extend growing periods, and together with business expansion plans, this could result in a significant overall increase of local productions.

There is also potential to include the Blackminster Middle School and the Long Lartin Prison into a wider district heat scheme in and around Offenham.

At Kanes Foods in Middle Littleton cooling requirements are dominating the overall energy demand, mainly using electric chillers. Being the biggest energy consumer in and around Offenham it appears sensible to involve Kanes Foods into a local heat network scheme, if technically and commercially viable.

Detailed technical evaluations and stakeholder discussions are required to confirm the local interest, to confirm technical and commercial viability and to develop a detailed business case for a local heat network. In terms of potential energy sources for a heat network a basic options appraisal is provided in Table 8.2.

Table 8.2 Potential heat network energy sources - options appraisal

Energy sources	Advantages	Disadvantages
Gas – CHP at central location	Currently the most cost effective way of meeting the farmers heating, electricity and CO_2 demands.	The farmers' requirements differ significantly, i.e. individual CHPs designed to meet individual requirements are preferred. Sensitivity to gas price variation.
Individual CHPs feeding into the network	Allows the farmers to generate their own heat, electricity and CO_2 and create extra revenue via heat sales. An overall network provides more flexibility (resilience).	There are practicality and commercial issues as energy supply is not their business and meeting the balance between offer and demand is seen as very challenging considering the seasonal nature of some of the demands. Long term commitments to provide/take heat are unlikely to be achievable. Low energy prices make heat sales less attractive. Existing CHPs are optimised for the site specific requirements.
Open loop deep geothermal (direct heating – low grade heat)	It is renewable heat, being available over the long term at low operational cost. Negligible sensitivity to variable energy market prices. Direct heating optimises the payback and RHIs. Temperatures can be boosted locally by the farmers to meet their specific requirements.	Raw water temperatures are expected around 40ºC, whereas current greenhouse heating systems in Offenham use higher temperatures. It doesn't provide CO_2 or electricity for lighting. High CAPEX for borehole drilling. Expected salinity of the water requires re-injection of the water (i.e. a second borehole).
Open loop deep geothermal with additional heat source at a central location to allow a higher network temperature (60-80ºC)	It is renewable heat, being available over the long term at low operational cost. Low sensitivity to variable energy market prices. Modern heat pump solutions offer ability to boost temperatures and include simultaneous cooling option. Additional heat sources can provide CO_2.	Considering the different requirements (heating/cooling profiles) management and design of the heat network become more complex. CO_2 will be available at the energy centre which potentially requires extra pipework to make it useable to the farmers. High CAPEX for borehole drilling. Expected salinity of the water requires re-injection of the water (i.e. second borehole).
Open loop shallow geothermal	Much lower CAPEX due to lower borehole drilling costs.	Shallow groundwater temperatures are low, i.e. high volumes may need to be pumped to achieve a significant energy output.

Energy sources	Advantages	Disadvantages
	Water could be used for other purposes.	Heat pumps would be required to boost temperatures. The water quality is unknown. Water availability will be limited and requires a license from the Environment Agency. Existing farm wells may be affected. There might be opportunities for individual users but unlikely to act as a main source for a heat network.
Closed loop deep geothermal	A single borehole scheme could be considered allowing to confirm the geology, water temperatures and quality. No need for dealing with the saline groundwater; no need for re-injection.	Energy output from a closed loop system is much lower compared to open loop systems, i.e. unlikely to be enough to justify the high drilling costs. Groundwater flow in the deep aquifer is likely to be low to stagnant (less heat exchange). CAPEX for a single borehole scheme is lower compared to the open loop solutions but high mobilisation costs of the drilling rig make it more expensive if a second borehole is to be drilled later on.
Water source heat pump (River Avon)	No borehole drilling required, i.e. relatively low CAPEX.	The River Avon is relatively distant to the main heat demands in Offenham (i.e. significant pipework would be required). In order to achieve significant heat outputs high volumes would need to be pumped and heat pumps being used to boost temperatures (relatively high operational costs). Might offer opportunities for individual businesses/premises but unlikely to be enough for a wider network. Ecological constraints will need to be considered.

Considering the current energy prices, specific energy requirements of the individual businesses, available energy sources and feedback from the stakeholders it becomes apparent that a heat network based on conventional energy sources is unlikely to feasible in Offenham. That is different for the potential use of the deep geothermal resources as it would address two key concerns which all businesses have in common:

1. Sensitivity to highly variable energy prices is a risk to their businesses; and

2. Pressure to reduce CO_2 emissions and to increase use of renewable energy sources.

RHIs for deep geothermal heat (currently at 5p/kWh) incentivise such schemes but there are no project examples in the UK and there is a lack of geological data to improve investor and stakeholder confidence. Examples from other countries (in particular from The Netherlands) have demonstrated feasibility and made businesses there more competitive.

A concept for a heat network project in Offenham based on deep geothermal heat sources has been developed and was presented to the local businesses on 28 January 2016. Details are provided in the following sections.

A fundamental aim of the concept was to develop a simple embryonic scheme forming the basis for discussions and for development of a scope for further stages of technical and commercial evaluations.

8.5 Technical and financial Considerations

8.5.1 Scheme description

The scheme concept that was presented to the stakeholders and which was used for the pre-feasibility assessments is shown on Drawing 8.1 and 8.2 (Appendix A). It comprises two deep boreholes, an abstraction and a re-injection well, both drilled into the Bromsgrove Sandstone (700m and 800m depth and 12 and 14inch drilling diameter respectively). The injection borehole is slightly deeper and wider in diameter compared to the abstraction well. The abstraction well is placed close to the main heating demand in east Offenham whereas the re-injection borehole is located approximately 2km to the northeast and uphill near Kanes Foods in Middle Littleton. The borehole locations are indicative only to allow preliminary costing of a possible scheme. Groundwater pressures in the abstraction borehole are expected to be around/slightly above ground level and slightly below ground level at the injection location. It is assumed that the groundwater temperature is around 40ºC.

Due to the salinity of the groundwater a heat exchanger will be required at the abstraction location (proposed energy centre) to transfer the heat from the groundwater to the heating network (secondary, closed loop). A heat network flow temperature of 40ºC is assumed, which allows use for some direct heating and use for frost protection purposes but most of it will need to be boosted to higher temperatures (e.g. via heat pumps) to meet the requirements of the individual user. Costs for extra pipework in the greenhouses or for boosting to higher temperatures would be with the heat customer. A heat network with higher temperatures might be more useable for the heat consumers, being more compatible with the existing heating systems. However, for the purpose of this project stage and from a heat network point of view the proposed concept is much simpler and gives more flexibility to the end user. This also includes the potential use of CO_2 from gas fired heat pumps or other energy sources which might be of interest to the farmers but would require extra infrastructure to distribute CO_2 from a central location (the energy centre). An options appraisal for a central versus a decentralised energy centre(s) to boost temperatures will need to be undertaken as part of the feasibility study.

For initial costing purposes 2km of insulated pipework and 3km of uninsulated pipework have been allowed for as part of the network. After heat exchange it is proposed to pump the raw water to the re-injection site via an uninsulated pipe, at temperatures of around 10ºC. There is significant cooling demand at the Kanes Foods site (process water and space cooling) which is currently delivered by electric chillers. There is a potential opportunity to use the water for cooling purposes via heat pumps and there is a potential for absorbing waste heat from the site which would result in the water temperatures to be raised again prior to re-injection. It has been assumed that the original groundwater will be re-injected at temperatures of around 20ºC. Waste heat recovery or combination with cooling would improve the efficiency of the scheme but are not essential. A pure geothermal heating scheme would probably have a different borehole layout targeting different depths (i.e. a deeper abstraction borehole and a shallow injection borehole).

A number of technical solutions for heat network schemes appear to be viable and should be investigated at feasibility stage. As an example, modern and innovative heat pump solution can achieve simultaneous heating and cooling outputs, maximise the thermal output of the available water and provide flexibility in terms of heating profiles. Thermal stores are also likely to improve efficiencies.

Kanes Foods have previously investigated the idea of exporting their waste heat but found that this would not be financially attractive or viable. Combining the heating and cooling demands in one network scheme offers the opportunity to maximise the carbon reductions to the benefit of all involved stakeholders. The conditions in Offenham with greenhouse heating demands close to food processing sites with cooling demands are representative of a number of other sites in the Evesham area, Worcestershire and other parts of the UK. Using deep groundwater as a conduit for heat transfer or for heat storage offers new opportunities which should be investigated. The proposed concept offers a novel, self-contained solution which minimises geological risks (e.g. back circulation of cold water to the abstraction location) and allows development of similar schemes nearby with low risk of interference.

8.5.2 Cost model

Capital and operational costs (CAPEX/OPEX) were estimated for 2 scenarios:

a. Renewable heat output of 1.5MW at 75% utilisation; and

b. Renewable heat output of 3.5MW at 75% utilisation.

A breakdown of estimated scheme costs and the financial models are provided in Appendix C and a summary is provided in Table 8.3. Potential financial benefits from cooling outputs are not considered in the financial model.

Table 8.3 Financial modelling results

	1.5MW Scenario	3.5MW Scenario
Total annual renewable heat output (kWhrs per year)	9.87million	23million
Deep geothermal heat incentives	5p/kWhr	5p/kWhr
Heat energy sales price (constant)	1.6p/kWhr	1.6p/kWhr
Estimated scheme cost (CAPEX)	£6.03million	£6.24million
Internal Rate of Return (IRR)	0.2%	15.4%
Payback period	20 years	6 years
Net Present Value	£2.3million	£9.58million

The results of the financial modelling provide a good feel for likely scheme costs and required size of the scheme. Developing a 3.5MW scheme is likely to be of interest for financial investors, a 1.5MW is unlikely to be of interest. 23million kWhrs per year (3.5MW Scenario) compares to approximately 25-30million kWhrs of current heating demand identified as part of the heat mapping for the Offenham area (not including proposed developments). The estimated borehole costs account for approximately £3.6million (including well M&E) and represent the most significant cost item.

It should be noted that cost estimates and the financial modelling results are precise enough for this stage of work but due to the range of heat profile and other requirements and opportunities (e.g. CO_2 or combination with cooling) a number of technical solutions are possible which can influence the viability and profitability of the scheme. The financial projections should be updated as the project progresses through the feasibility stage.

8.5.3 *Potential business model*

During the heat mapping stage potential heat demand customers have been consulted about their preference for how a potential heat network should be operated and by whom. Different feedback has been received but general preference seems to be for a community run scheme. An Energy Service Company (ESCO) might provide a suitable vehicle to develop and operate the heat network scheme. This could involve some private investment from local stakeholders or financial investors.

A purely private investment proposition may also be feasible considering the potentially very attractive financial returns. The private investor would need to be able to evaluate risks to justify the high upfront costs to develop the scheme. Long term agreements with heat customers to purchase heat from the network would also be essential.

Liaison with the Department of Energy and Climate Change (DECC) and their Heat Networks Delivery Unit (HNDU) should continue. DECC/Ofgem consider the provision of a Renewable Heat Incentive (RHI) guarantee prior to commissioning of the scheme which is a vital condition for investors. DECC also consider direct investment to enable the development of heat network schemes. In addition, negotiations about eligibility of RHIs for renewable cooling should continue as this could contribute significantly to carbon reductions and improved viability of the proposed scheme.

DECC is currently in the process of setting up the Heat Network Investment Programme (HNIP) which will allow DECC to invest directly into schemes. This may be particularly relevant for deep geothermal schemes using HNIP to de-risk some of the up-front investments (i.e. borehole costs) helping to generate more confidence into development of this new energy source.

8.5.4 *Initial stakeholder feedback*

The proposed Offenham scheme concept and the results of the financial modelling were presented to a range of local stakeholders and representatives of the National Farmers Union on 28 January 2016. The objective of the meeting was to gather initial technical feedback and feedback on the potential interest to join such a scheme.

The farmers and Kanes Foods confirmed their interest in the development of a geothermal scheme in Offenham and suggested that feasibility work is undertaken to allow them to assess the costs and benefits to their businesses. Key items that should be addressed as a next stage are:

1. How can the geological risks been managed, i.e. what if the groundwater temperature or flows are lower than expected?

2. A higher network temperature would be better and more useable than the 40ºC, also reducing required investment in changes of their current heating system.

3. The management of different heating profiles and requirements for the provision of CO_2 have to be considered.

4. Heat supply costs need to be competitive compared to currently cheap outputs from Combined Heat and Power (CHP) plants.

5. More technical details of the heating and cooling outputs are required for Kanes Foods to evaluate opportunities to generate renewable cooling effects to the benefit of their site.

8.6 Wider Opportunity

As described in the geological sections of this report, a significant part of Worcestershire is underlain by hundreds of metres thick deep sandstone layers which contain large volumes of hot, brackish to saline groundwater. Due to the salinity and the depth of the water these large volumes of water are currently of no use and require innovative technical design to transform the water into a valuable asset.

The deep groundwater is colder but also shallower than groundwater in comparable geological structures in the UK (e.g. the Wessex Basin or the Cheshire Basin). It is also characterised by a lower salinity improving the chances of successful re-injection.

Significant heating demand from the horticulture sector in Worcestershire and proposed new housing or mixed use developments offer an ideal application for a low grade heat source such as the geothermal energy sources. Heat pump solutions or other energy sources can be used to boost temperatures.

A characteristic of the energy demands in Worcestershire is that horticulture businesses are often located close to food processing facilities with significant cooling demands. This offers additional opportunities for combining heating and cooling networks including waste heat recovery and the use of the deep groundwater as a conduit or store for thermal energy. Such a combination of heating and cooling purposes maximises carbon reductions, increases the financial feasibility and allows a number of schemes to be developed in close proximity to each other with reduced risk of interferences.

Key to the development of the geothermal heating scheme in Offenham or other nearby locations is the public sector support to develop feasibility and to create an example scheme which generates additional geological data and grows confidence for private investment.

A simple (2 borehole) geothermal scheme as described above has the potential to generate 3-5MW renewable heat output with the potential bonus of a cooling output providing:

- A long term, sustainable, cheap, local energy source to the benefit of local businesses with potential involvement of publicly owned buildings such as schools or leisure centres;

- A potential low carbon heat source for new housing or mixed use developments with low infrastructure requirements and no significant impact on traffic burden.

Considering that a number of such schemes could be developed in Worcestershire indicates the size of the overall opportunity. Using the geothermal heat would not only reduce the requirements for burning fossil fuels or implementation of traffic intense biomass based solutions, it would also allow growers to increase the local vegetable production creating additional jobs, economic growth and reducing the requirements for importing vegetables from abroad (reducing the carbon footprint for long distance transport).

Once an initial scheme is successfully developed private investor confidence is expected to increase significantly due to better geological and hydrogeological information, the performance of the network can be optimised and heating systems for new greenhouse developments can incorporate an optimised use of the geothermal resources into the design (e.g. underfloor heating).

8.7 Conclusions and Proposed Actions

8.7.1 Conclusions

The geothermal pre-feasibility study confirms the significant potential of geothermal low grade heat sources in significant parts of Worcestershire. The focus of the evaluation was on Offenham with the high density of glass houses businesses but the conclusions are transferable to the wider Evesham area and the area to the west (Throckmorton, Pershore and Worcester). The Worcester Basin is expected to get shallower towards the north, hence providing much lower geothermal potential in the northern parts of the County.

8.7.2 Proposed Actions

The technical and financial evaluations together with the consultation of the principal stakeholders in Offenham confirmed that feasibility work should be undertaken to develop the concept of a geothermal heat based heating network in Offenham further. Geothermal energy specific actions are recommended to be undertaken as part of the feasibility stage or, preferably, prior to the feasibility stage as the results may affect the scope of the feasibility stage. These specific actions are:

I. Re-process and re-interpret available deep seismic data to confirm the depth and thickness of the target geological layers;

II. Develop a concept heat pump layout which maximises the thermal output from the raw water and combines a heating and cooling function providing technical details such as flow/return temperatures, size and approximate costs; and

III. Explore opportunities with stakeholders, universities and farmers associations to develop a Research and Development project for an optimised greenhouse type with a heating system that maximises the use of the available geothermal heat.

The details and justifications for the recommended actions are provided below:

Re-process and re-interpret available deep seismic data

Information from only two deep boreholes (Kempsey and Netherton) which were drilled in the 1970's are available for the southern part of Worcestershire. Work undertaken by the British Geological Survey (BGS) including the geological maps and cross sections confirms the presence of a regional structure (i.e. the Worcester Basin) with substantial thicknesses of deep sandstones. Deep seismic surveys were undertaken in the 1970's for oil exploration purposes. The data are privately owned but can be purchased and re-processed under a specific license agreement. The interpretation of geophysical data is more conclusive where it can be tied in with geophysical data from a borehole with known geology. Figure 8.1 provides a screenshot from the UK Online Geophysical Library website showing two specific areas of available survey data tying in the deep borehole locations (Kempsey and Netherton, shown as pink dots). A number of detailed survey lines (green lines) are available from the southern County boundary to the west of Evesham and to the north of the Throckmorton area. Another set of survey lines is available in approximate east-west direction to the southeast of Worcester.

With modern technology the re-processing of the seismic data provides much clearer outputs and allows re-interpretation of the dimensions of the target layers.

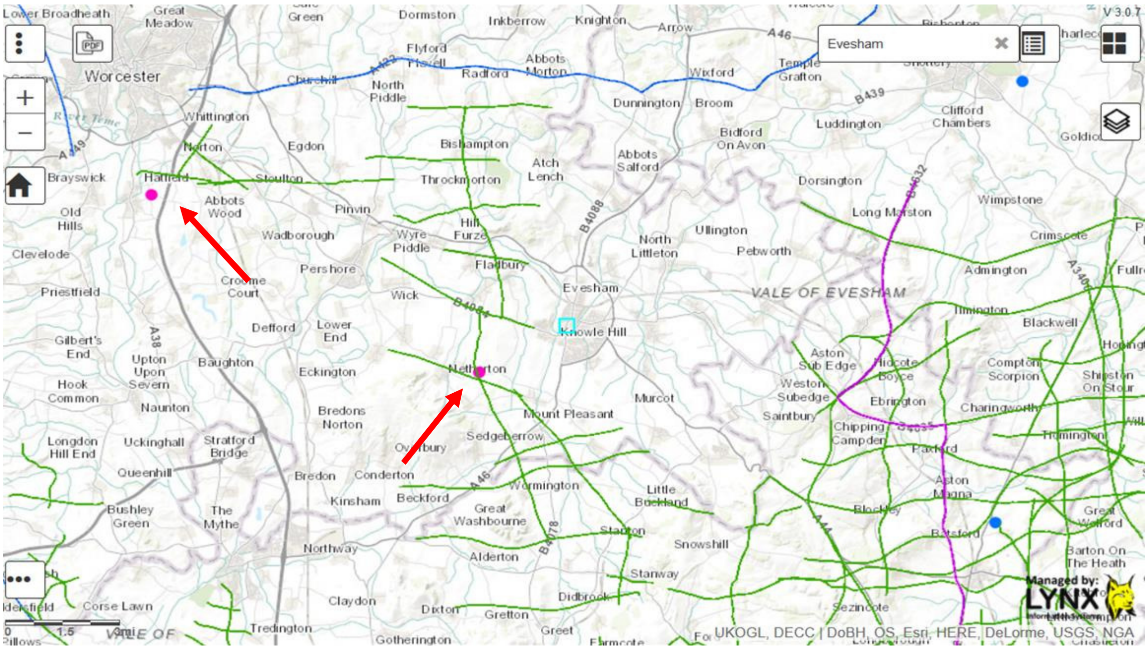

Figure 8-1 Available deep seismic Survey Data (*source: UK Onshore Geophysical Library website*)

It is recommended to re-process and to re-interpret the available deep seismic data for the two areas indicated above (i.e. approximately 90km of survey lines)to:

- Confirm the top and the base of the Bromsgrove/Wildmoor and the Bridgnorth Formations. This provides information for required drilling depths and the available thickness of the formations.

- Confirm presence of major and local faulting of the rock formations in the survey areas.

The assessment of the deep seismic data provides an economical way of generating more information about the deep geological conditions. Alternatives are new geophysical surveys and consideration of drilling and testing of a pilot borehole. Both options are very expensive.

The available deep seismic data do not cover all of the southern part of Worcestershire and there is no survey line through Offenham. However, considering that the thicknesses of the sandstone layers are expected to be several hundreds of meters and being part of a regional geological basin, reasonable indications of the likely geological conditions for sites that are located some kilometres away from the survey lines (e.g. Offenham) might also be obtainable from such a study.

Deep seismic data assessments do not confirm groundwater temperatures and flow conditions but have the ability to confirm the depth and thickness of the target strata.

Development of a concept heat pump layout

Equally important to the confirmation of geological conditions is the development of a concept on how the low grade heat of the groundwater can be transformed into a heat source that is most attractive for the heat users in Offenham and providing more technical details for future discussions with the stakeholders.Heat pump applications seem to provide the most suitable technical options but other energy sources are not excluded and may be considered during the feasibility work. Heat pumps generally boost temperatures but modern systems also allow simultaneous heating and cooling outputs with the potential of achieving even higher efficiencies.

The heat pump concept shall maximise the thermal output from the groundwater creating a 60-70ºC heat main flow temperature and a maximum 5ºC cooling main temperature. The concept is vital for the discussions with the stakeholders during the feasibility stage to provide basic technical details (e.g. flow/return temperatures, efficiency), to demonstrate technical viability and ability to generate the required heating loads, to estimate costs, specify requirements (e.g. space) and to influence the discussion about a potential involvement of a cooling main to include Kanes Foods in the network. The concept is not the outline design for the scheme energy centre as this would require detailed considerations of the individual heat profiles and confirmation of which heat customer joins the scheme.

Such a heat pump concept together with the geological information form the starting point for any other geothermal scheme in Worcestershire independent from being used for greenhouse heating or for residential heating on future development sites.

Explore opportunities for an R&D project

Local heat networks are generally easier to implement on development sites thanin developed areas as the design of an energy centre that provides heat which fits all existing heating systems and heat demand profiles can be challenging, may require investment in the existing heating infrastructure and potentially reduces the efficiency. For the greenhouse sites other requirements such as CO_2 or electricity demand may need to be considered.

Offenham or the wider Vale of Evesham may offer the opportunity to develop an innovative greenhouse design which optimises the use of the available low grade geothermal heat. Examples for greenhouse projects which use lower heating temperatures or use groundwater heat sources in combination with underfloor heating systems exist. Tomato glass houses are seen as the ideal anchor sites for heat networks due to the high, relatively constant heating demand over the year. Optimisation of the greenhouse designs in combination with the available geothermal resources and innovative heat pump applications may allow production of other vegetables at competitive costs compared to products from the Netherlands or Mediterranean countries.

We recommend that consultation with stakeholders, farmer associations, specialist consultants and research institution is undertaken to explore the opportunities for an R&D project in Offenham. Research funding from the European Union or via Innovate UK might be available to support such a scheme. If the consultation and networking indicates a significant stakeholder interest and potential to develop such a scheme detailed evaluations should be incorporated in the feasibility stage. This could potentially involve a new greenhouse development site which could ultimately act as an anchor site for the network scheme.

Overall feasibility stage

In addition to the geothermal energy specific tasks described above it is recommended to progress the project to feasibility stage in line with the HNDU process.

Offenham is the obvious location for such a scheme considering the assessments undertaken so far. However, it is recommended to consider feasibility work also for other potential sites. These sites could be:

- Throckmorton;
- Pershore;
- Worcester South; and potentially
- Broadway.

Throckmorton provides particular opportunities due to the potential airfield development in the future (including space for trial glass house sites), the area being well covered by previous deep seismic survey lines, the Council owning land (landfill), existing landfill gas and other energy source schemes (solar, anaerobic digestion) and presence of a large greenhouse site (Fladbury). There is no significant cooling demand there at the moment so the scheme would be different from Offenham. Feasibility work would need to focus on stakeholder negotiations and the development of a scheme concept, including evaluations of borehole locations and optimisation of heating demands. This could well evolve into an innovations centre for renewable energies comprising both the landfill site (with surrounding areas) and the airfield site. Opportunities for innovation funding for particular developments should be considered at feasibility stage (e.g. for a pilot borehole).

The development area of Worcester South is located close to the Kempsey borehole and close to the centre of the Worcester Basin, i.e. in an area with the highest potential for deep geothermal heat extraction. Detailed discussions should be held with the developer to enable creation of a heat network proposal which can be assesses financially and from a commercial point of view. This will form a start point for discussions between the Council and the developer about the viability and potential further work to develop such a network. The scope should involve an options appraisal considering other energy sources from conventional gas CHP to other innovative sources such as sewer heat recovery or combinations of available energy sources. The Worcester South development area extends beyond the Wychavon District into the Malvern Hills District and the Worcester District and there might be an opportunity to link it with an urban network (Worcester NHS) at a later stage.

The town of Pershore has been discussed as one of the initial priority sites during the heat mapping stage. The heat demand is relatively low compared to other identified urban areas but the proximity of the Council buildings, the hospital and the leisure centre may offer an opportunity for a smaller local heat network led by the public sector, which could later expand to private customers (e.g. to businesses to the north of the town centre). A separate feasibility study, specifically addressing the public sector priorities should aim to collect more detailed information on the current heating requirements (i.e. technical details of the existing heating systems). Pershore could then become a potential standalone project using conventional, deep geothermal heat or other innovative heat sources or could be considered as a future target for extension of a potential scheme in Throckmorton which is only a few kilometres away. Based on the previous geological reviews Pershore is located within the centre of the north-western sub-basin of the Worcester Basin, i.e. in an area considered to have the highest deep geothermal heat potential in Worcestershire.

The village of Broadway is a leading Cotswold tourist destination with major hotels being present and highly visible to the public. Broadway has not been discussed as a heat demand hot spot in this project but the concentrated location of hotels with their heating, spas and hot water demands offers potentially a particular and very different opportunity. In addition to the heat energy of the water also the mineralised water itself has a value (for swimming pools, spas) whichcould form part of a business case for a local heat network. The deep seismic survey lines provide geological information to an area very close to

Broadway which could help estimating drilling costs for geothermal wells. Feasibility work should focus on initial stakeholder engagement, with further data collection and the development of an outline business case. This should involve heating costs, hot water generation and potential spa water/swimming pool water demands.

Detailed Technical Feasibility

This will involve more detailed technical assessment and optimisation of the recommended scheme option(s). Vital for feasibility work will be a successful stakeholder engagement to allow that more technical details about the existing heating systems can be obtained from target heat customers. Such information will allow a much more detailed review of potential energy centre locations, pipework routes and subsequent financial modelling. Access to data may involve signing of confidentiality agreements to protect commercially sensitive information.

9 Conclusions and Recommendations

9.1 Conclusions

This study concludes that there is significant potential for commercially viable urban district heat networks serving four existing urban areas:

- **Worcester:** 3 separate district heat networks have been assessed;
- **Bromsgrove**: 4 separate district heat networks have been assessed;
- **Redditch**: 2 separate district heat networks have been assessed;
- **Kidderminster**: 2 district heat networks have been assessed.

Out of the 11 assessed urban heat networks the following schemes appear to be the most promising and should be prioritised at feasibility stage:

- **Bromsgrove**: The Worcester Road Industrial Estate scheme has good potential for the establishment of local district heat network with a small energy centre. The close proximity heat demand profile promotes an ideal network arrangement.
- **Redditch**: The NHS & Industrial main provides good scope for the establishment of a district heat network with the initial stage centred around the hospital targeting the new residential development close to the hospital as the catalyst to the new district heat network. Expansion to the more industrial and commercial customers to follow post establishment. Key to this scheme is to explore this opportunity with Engie, the operator of the hospital waste incinerator. The Redditch Eastern Gateway development site offers additional opportunities which were not included in the assessments but could significantly improve the results of the techno-economic analysis.
- **Worcester**:
    - The Southern NHS district heat network has the energy centre located in the NHS Acute Hospital and around 80% of the identified heat requirement is from major public sector and school sites with the potential expansion into the mixed development area at the former DEFRA offices. The NHS hospital has a requirement for electricity that could be provided by a private wire system from the on-site energy centre. The route does not have complex crossings of rivers or railways and follows public trackways or highways.

- The University and City Centre district heat network is centred on the high heat demand of the St John's and Severn Campuses of the University of Worcester. The campuses also have a requirement for electricity that could be provided by a private wire system from the on-site energy centre.

The following table summarises estimated parameters for these schemes.

Table 9.1: Details for prioritised urban heat network schemes

Network Name	Size (annual MWh heat)	Estimated CAPEX (£M)	Annual CO_2 saving (t pa)	Majority of heat demand in public sector	Private Wire potential	Phasing and development potential
Bromsgrove: (Worcester Road Industrial Estate network)	2,100	1.7	378	No	Yes	Yes
Redditch (NHS and Industrial network)	268,000	19.6	48,240	No	Yes	Yes
Worcester (Southern NHS network)	22,000	4.3	3,960	Yes	Yes	Yes
Worcester (University & City Centre network)	30,000	6.6	5,400	Yes	Yes	Yes

Other urban areas (e.g. Malvern, Evesham, Pershore) and large development sites (Worcester South, Hartlebury Estate and potentially the Throckmorton airfield area) also offer potential for smaller networks.

The Offenham deep geothermal pre-feasibility study confirmed a significant deep geothermal heat potential across southern Worcestershire. A deep geothermal heat driven concept for a heat network in Offenham has been developed and assessed financially. Renewable Heat Incentives for deep geothermal heat extraction make investments in such schemes financially attractive. Additional opportunities relate to options of combining the heat network with cooling requirements of nearby food processing facilities. Offenham, together with Throckmorton, Pershore, Worcester South and Broadway are recommended to be considered for detailed feasibility work.

9.2 Recommendations

It is recommended that:

- Feasibility studies are undertaken for the prioritised schemes using the guidance in the ADE/CIBSE Code of Practice CP1 Heat Networks in the UK to confirm the detailed design and benefits of the heat networks including the identification of land and consents for the primary energy centres;
- A strategic committee of the key stakeholders and influencers in the public and private sector to lead the development of district heat networks across Worcestershire is created;
- Local policy is reviewed to promote the district heat networks as a potential source of heat and electricity to serve strategic and local developments;
- A communications strategy is prepared to encourage early adoption and acceptance of district heat mains and communicate the economic and environmental benefits to key stakeholders and the wider public
- A policy and planning review is undertaken to incorporate and promote the benefits of district heat networks to interested parties
- Early stage engagement with potential funding parties to communicate the potential of the district heat networks and identify potential governance and investment models

The study identified smaller heat clusters that have the potential to form smaller local heat networks with a limited number of public sector and local authority clients.

These smaller local heat clusters are high profile and can serve as leadership networks. The design and objectives of these clusters will differ from the larger district heat networks.

It is recommended that the smaller local heat networks are subject to a separate feasibility study.

The study identified the potential for deep geothermal as a heat source for the Agri-tech sector and potentially for new housing developments. In addition to routine feasibility work, specific deep geothermal heat related recommendation are provided with focus on:

- Re-processing and interpretation of existing deep seismic data to confirm geological conditions;

- Development of concept heat pump layout aiming to generate more confidence in the ability to use deep geothermal heat sources and to provide more technical details on achievable heating and cooling effects; and

- Initial considerations for the development of a potential Research and Development project aiming to optimise greenhouse heating designs and to consider selection or combination of different crops.

Undertaking these three particular tasks is likely to significantly increase the chances of developing a deep geothermal scheme increasing stakeholder confidence and providing additional technical details to demonstrate viability.

References

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Allen et al., 1997: The physical properties of major aquifers in England and Wales. British Geological Survey Technical Report WD/97/34. Environment Agency R&D Publication 8.

Appendix A Drawings

Drawing 4.1 Worcestershire Heat Demand Hot Spot (sourced from *http://tools.decc.gov.uk/nationalheatmap/)*

Drawing 4.2: Electricity Consumption MSOA Area sourced from *https://www.gov.uk/government/collections/sub-national-electricity-consumption-data*

Drawing 4.3: Gas Consumption MSOA Area (sourced from https://www.gov.uk/government/collections/sub-national-gas-consumption-data)

Drawing 4.4: Heat Mapping Data Points

Drawing 4.5: Heat Mapping Data Points and Initial Cluster Identification

Drawing 4.6: Identified Potential Heat Clusters

Drawing 4.7: Heat Clusters Taken Forward for Detailed Masterplanning

Drawing 5.1: Proposed Town Centre and NHS District Heat Network, Bromsgrove

Drawing 5.2: Proposed Worcester Road District Heat Network, Bromsgrove

Drawing 5.3: Proposed Aston Fields and Buntsford District Heat Network, Bromsgrove

Drawing 5.4: Proposed Central District Heat Network, Kidderminster

Drawing 5.5: Proposed Southern District Heat Network, Kidderminster

Drawing 5.6: Proposed Northern District Heat Network, Redditch

Drawing 5.7: Proposed NHS and Industrial District Heat Network, Redditch

Drawing 5.8: Proposed North Worcester District Heat Network, Worcester

Drawing 5.9: Proposed University and City Centre District Heat Network, Worcester

Drawing 5.10: Proposed Southern District Heat Network, Worcester

Drawing 6.1: Main Geological Features and Boreholes of Interest

Drawing 6.2: Schematic Geological Cross Section through Southern Worcestershire

Drawing 8.1: Offenham Geothermal Scheme Concept - Schematic

Drawing 8.2: Offenham Heat Network Concept

Appendix B Heat Mapping (confidential information)

Appendix C Offenham Financial Information