CAMBRIDGESHIRE LOCAL AREA ENERGY PLANNING

AN EVIDENCE BASE FOR HEAT ZONING AND NETWORKS IN HUNTINGDON, ELY AND MARCH

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Glossary

Air Source Heat Pumps (ASHPs): Heat pump that uses the outside air as a heat source when in heating mode, or as a heat sink when in cooling mode using the same vapour-compression refrigeration process and same external heat exchanger with a fan as used by air conditioners.

Anchor loads: Places with high heat demand which have little variation in the amount of heat they use throughout the day, e.g. heated swimming pools.

Carbon intensity: A measure of how much CO2 is produced per unit of energy generated.

Decarbonisation: The act of removing or reducing the carbon dioxide (CO2) output of a process.

District Heating and Cooling (DHC): District heating and cooling systems move heat in urban areas. Heat and cold are generated in central supply units by heat or cold recycling, renewables, or by direct heat or cold generation. The heat and cold demands should be concentrated in order to keep low distribution costs. District heating and cooling systems substitute ordinary primary energy supply for heating and cooling. Therefore, district heating and cooling increase both energy efficiency and decarbonisation in the energy system.

Display Energy Certificate (DEC): Similar to an EPC (see below), but for public buildings. DECs are more accurate as they are based on actual energy consumption data, whereas EPCs are approximations based on building characteristics from a standard model. DECs last for one year if the floor area of the building is more than 1,000 m^2, or 10 years if the floor area is between 250-1,000 m^2.

District heating: A distribution system of insulated pipes that takes heat from a central source and delivers it to a number of domestic and/or non-domestic buildings. The term is often used interchangeably with “heat network”.

Energy centre: A centralised energy source which provides energy to a heat network.

Energy Efficiency (EE): This term has two possible meanings. Generically, it means the amount of energy required as an input to produce some desired output. In the context of the heat hierarchy, it refers to the building fabric efficiency (i.e. how well insulated a building is, or how quickly it loses heat). Energy efficiency comes first in the heat hierarchy.

Energy Performance Certificate (EPC): A certificate which describes the energy efficiency rating of buildings. EPCs have been required for all buildings (domestic and non-domestic) constructed, sold or rented since 2007. EPCs are valid for 10 years.

Gas Distribution Network (GDN): An infrastructure network that delivers natural gas to customers.

Geographic Information System (GIS): is a spatial system that creates, manages, analyzes, and maps all types of data. GIS connects data to a map, integrating location data (where things are) with all types of descriptive information (what things are like there).

Heat hierarchy: The heat hierarchy describes the steps that should be followed to reduce the cost to consumers of the heating energy transition.[1] Energy efficiency is prioritised, followed by wasted heat (heat that already exists but would otherwise be unused), followed by heat upgrading (e.g. low temperature sources of heat used for heat pumps). Direct heat, by which energy is directly input for the purpose of creating heat, comes last in the heat hierarchy: it should be avoided where possible.

Heat Interface Unit (HIU): A box that looks like a boiler. It transfers heat from a community heat network into the central heating system of a building.

Heat network: A collection of buildings or dwellings connected to a centralised heat source. The term is often used interchangeably with "district heating".

Heat pump: A technology that transfers thermal energy, typically from a warmer reservoir to a cooler reservoir, using electricity.

Heat zone: An area of land for which specific policies regarding heating are considered and/or implemented.

Heavy Duty Vehicles (HDV): Freight vehicles of more than 3.5 tonnes (trucks) or passenger transport vehicles of more than 8 seats (buses and coaches). The HDV fleet is extremely heterogeneous, including vehicles with various uses and drive cycles.

Internal Combustion Engine (ICE): An engine that generates motive power by burning petrol, oil, or other fuel.

Levelised Cost of Energy (LCOE): The levelised cost of energy, or levelised cost of electricity, is a measure of the average net present cost of electricity generation for a generating plant over its lifetime. It is used for investment planning and to compare different methods of electricity generation on a consistent basis.

Lower Layer Super Output Area (LSOA): A geographic region that contains between 1,000 and 3,000 residents comprising 400 to 1,200 households.

Middle Layer Super Output Area (MSOA): A geographic region built from groups of contiguous Lower Layer Super Output Areas. They contain a minimum of 5,000 residents.

Plug-in Hybrid Electric Vehicles (PHEVs): Vehicles run by the combined power of an electric motor and an internal combustion engine (ICE). PHEV batteries can be charged using a wall outlet or charging equipment, by the ICE, or through regenerative braking.

Social Net Present Value (SNPV): The present value of a stream of future costs and benefits to UK society (that are already in real prices) and that have been discounted over the life of a proposal by the appropriate social time preference rate.

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[1] https://www.theade.co.uk/assets/docs/resources/Heat_and_Energy_Efficiency_Zoning_A_framework_for_netzero_for_new_and_exisiting_buildings-min.pdf.

Waste heat: Heat produced as a byproduct of existing processes, including industry and commercial activities. Waste heat can also be collected from water sources like rivers and sewer systems.

1. Introduction

In 2016, the generation and supply of heat produced 37% of the UK's total greenhouse gas emissions[2]. Heating is therefore responsible for a larger proportion of emissions than transport, agriculture or power generation. As laid out by the government's recent Heat and Buildings Strategy[3], in order to reach net zero carbon goals by 2050 across the UK, virtually all heat supply will need to become carbon neutral.

The objective of this project is to consolidate currently available data and provide updated strategic evidence to inform the development of low and zero-carbon space heating and hot water policies in Cambridgeshire, using Huntingdon, March and Ely as demonstrator examples. Cambridgeshire aims to reach net zero well before its official 2045 target. Reaching that objective will depend on:

- Understanding the current energy demand and supply for space heating and hot water;
- Understanding how low carbon and renewable energy will be integrated into the UK's existing energy infrastructure in various future scenarios;
- Assessing the potential for further deployment of low carbon space heating and hot water technologies.

Heat networks connect multiple buildings or dwellings to a central energy source. Their benefits are wide-ranging: they can provide far more energy efficiency than individual heat supply, they can take advantage of renewable and low-carbon sources, and they can reduce heating bills for consumers.

There are already over 14,000 heat networks in the UK — however, many of these networks are small-scale and rely on combined heat and power (CHP) generators. Although CHP generators are more efficient than individual gas boilers, they tend to be natural gas fired[4]. In this report, we investigate the evidence base for installing heat networks in Huntingdon, Ely and March, focusing on technologies that would instead be supplied by a low-carbon or zero-carbon source.

To do this we:

1. Investigate two methodologies. The first, Local Area Energy Planning (LAEP), is a broad methodology in which heat zoning can feature as one of many components. The second, the BEIS heat zoning methodology, is specific to heat zoning.
2. Summarise the different technologies which can be used in the energy centre of a heat network.
3. Use the National Grid's Future Energy Scenarios to assess the future energy landscape across the UK.
4. Review a range of case studies from across the UK which plan to install or have installed a heat network.
5. Identify priority zones for the development of heat networks in Huntingdon, Ely and March, based on the distribution of current heat demand.

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[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf

[3] https://www.gov.uk/government/publications/heat-and-buildings-strategy

[4] https://post.parliament.uk/research-briefings/post-pn-0523/

Cambridgeshire has the potential to become a leader in low-carbon heating[5]. It should capitalize on the promise offered by heat networks and become part of the growing landscape of low-carbon energy solutions in the UK.

2. Heat Zoning Methodologies

The Cambridgeshire County Council identified Local Area Energy Planning and the BEIS heat zoning methodology as frameworks that could be used to facilitate the planning of heat networks and/or the decarbonisation of heating. This Section will outline the key components of these methods and explain how they relate to our research.

Local Area Energy Planning

"All places are different – the people, housing stock, energy networks and opportunities for change are all unique to an individual local area – there will be no 'one size fits all' solution."[6]

At present, there is no formally structured planning process to help local governments transition to low-carbon energy systems. Current planning processes for infrastructure in the UK are not delivering the scale of intervention necessary to meet the UK's legally binding carbon goals. Local Area Energy Planning is a system which has been designed to provide a long-term framework to decarbonise energy systems in the UK, and to provide an opportunity for dialogue between local governments, energy network operators, consumers, and other stakeholders.

What is LAEP?

The Local Area Energy Planning (LAEP) process, developed by Energy Systems Catapult (ESC) and the Energy Technologies Institute[7], uses a whole-system analysis to identify cost-effective and low-regret solutions to aid the decarbonisation of buildings. LAEP explores a range of possible future energy scenarios and investigates options for heat networks in the local area, while incorporating an inclusive and comprehensive stakeholder engagement process which reflects the unique nature of each region. One of the main underlying premises of LAEP is that the decarbonisation of buildings cannot be a "one size fits all" solution; different places will require tailored, individual plans to reach the best possible low-carbon outcome.

LAEP can facilitate the local decarbonisation of buildings by:

- Identifying cost-effective options for heat decarbonisation in a whole-system context;
- Identifying clear pathways to reach local and national decarbonisation objectives;

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[5] CUSPE report 2019: Net Zero by 2050 in Cambridgeshire, https://data.cambridgeshireinsight.org.uk/sites/default/files/2019%20CUSPE%20Policy%20Challenge%20-%20Net%20Zero%20Cambridgeshire.pdf

[6] https://es.catapult.org.uk/case-study/local-area-energy-planning/

[7] https://esc-non-prod.s3.eu-west-2.amazonaws.com/2018/12/Local-Area-Energy-Planning-Guidance-for-local-authorities-and-energy-providers.pdf

- Supporting dialogue among members of the community and increasing awareness of the energy transition;
- Providing an evidence base to increase investment in energy networks;
- Generating local plans which can aid accountability, governance, and performance management of the system against climate goals;
- Addressing fuel poverty and air quality, and supporting local job creation.

LAEP implements a whole-system approach in its analysis. This means that different aspects of the energy system will be considered together; for example, the role of electricity in aiding the decarbonisation of heat will be considered alongside its role in powering electric vehicles. The effects of improving the energy efficiency of buildings and the effects of implementing local heat networks will be considered side-by-side.

The aims of LAEP

As described by ESC[8], Local Area Energy Planning has three goals:

1. To create a clear plan for local energy systems in line with local decarbonisation targets;
2. To inform an optimum investment strategy for network operators, large-scale heat producers, and heat consumers, which will align the consumers' interests with those of the network companies;
3. To enable resources to be deployed where they will have the greatest impact and value for money — for example, where they can make a lasting impact in tackling fuel poverty.

Key elements of LAEP

As laid out by Energy Systems Catapult and the Centre for Sustainable Energy[9], Local Area Energy Planning should be guided by four principles:

1. Robust technical evidence should consider the whole energy system and make use of all accessible data;
2. Wider non-technical factors, such as the social impact on residents, should be comprehensively assessed;
3. A well-designed and inclusive social process should engage all appropriate stakeholders and manage all vested interests, ensuring that plans represents local intent;
4. All plans should be delivered through a sustained and well-planned set of governance structures.

These four elements are shown in Figure 1.

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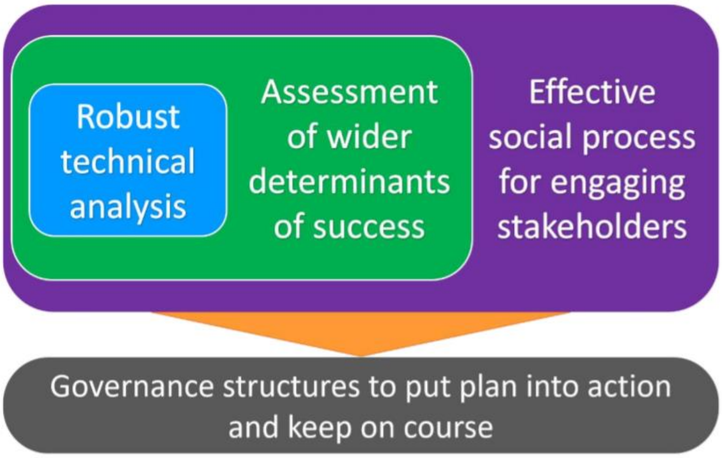
[8] https://es.catapult.org.uk/report/local-area-energy-planning/

[9] https://es.catapult.org.uk/report/local-area-energy-planning-the-method/

Element 1: Technical Analysis

The purpose of this element of Local Area Energy Planning is to gain a detailed understanding of the changes to local energy systems — and the associated investment — that would be required to achieve certain decarbonisation goals. The question guiding this aspect of LAEP is:


Robust technical analysis

Assessment of wider determinants of success

Effective social process for engaging stakeholders

Governance structures to put plan into action and keep on course

Figure 1: The four key elements of Local Area Energy Planning, as taken from Local Area Energy Planning: The Method (CSE & ESC).

“What is the preferred combination of technological and system changes we can make to the local energy system to decarbonise heat and local transport and realise opportunities for local renewable energy production?”

Various factors inform the answer to this question — including, for example, how much of the area’s heat demand could be provided by district heat networks, how many existing buildings could be retrofitted with carbon-friendly technologies, and what standards should be imposed on new buildings. The costs and benefits of possible changes, across all levels of society and throughout time, should be considered as part of the analysis.

Element 2: Wider Determinants of Success

A successful Local Area Energy Plan should assess a range of non-technical factors that will determine whether the options suggested by the technical analysis can be realised in practice. Two methodological tools are well-placed to support this assessment: PESTLE analysis and Participatory Systems Mapping. PESTLE analysis considers the political, economic, social, technological, legal and environmental context of a system. Participatory Systems Mapping identifies, maps, and analyses the range of factors that can influence a system and lead to different outcomes.

This element of the LAEP process is critical for determining the timescale needed to realise the options laid out in the technical analysis. It should support the production of a timetable which includes targets for actions required from non-local stakeholders (like national government or energy regulators), local stakeholders, and the interactions between the two.

Element 3: Social Process

The LAEP process should involve a wide range of stakeholders to ensure that the plan it prescribes has been shaped by local perspectives. In particular any suggested plan needs to be adopted by the relevant local council and endorsed by a wide range of local stakeholders.

First, the stakeholders need to be identified and mapped. Discussions with critical stakeholders should then help to determine existing or emerging local priorities. Once a plan has been identified, further discussions should ensure that stakeholders are committed to implementing the agreed upon steps.

Element 4: Deliverability and Ongoing Governance

The plan established by a LEAP process must have ongoing governance arrangements and realistic delivery commitments from all stakeholders. It must be grounded and realistic in its assessment of the current and future agency of the stakeholders to deliver at the pace necessary to reach local decarbonisation goals. It should also be a “living plan”, which can adapt according to changes in local or national guidance.

These four elements can be captured by a 7-step LAEP process, as illustrated in Figure 2.

The Local Area Energy Planning Process

Figure 2: The 7 stages of LAEP, from Local Area Energy Planning: Guidance for local authorities and energy providers[10].

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[10] https://es.catapult.org.uk/brochure/local-area-energy-planning-guidance-for-local-authorities-and-energy-providers/

Step 1: Identify and engage stakeholders
Stakeholder engagement should begin early in the LAEP process and continue throughout the development of the plan. The process and outputs should be led by a single organisation (the Local Lead Organisation).

Step 2: Set area vision, targets and objectives
The overall aim of the LAEP process should be to build a compelling, aspirational and realistic vision for decarbonisation in light of local goals. Additional objectives could involve the creation of jobs, alleviation of fuel poverty, or improving other social aspects related to energy systems. The specific goals of the LAEP process, as it applies to the local area under consideration, should be established in this second step.

Step 3: Create and understand the local energy system
Understanding the local area's current and future energy demand is crucial. The data gathered in this step will provide the evidence base for the analysis and investigation of future local energy scenarios.

Step 4: Investigate future local energy scenarios
This step should be based on modelling various future scenarios. A whole-system analysis should be used to explore and test a full range of potential changes and their impact across the whole energy system, with the goals set out in Step 2 as the desired objectives, before identifying preferred options. A baseline scenario should be used as a reference point from which to compare alternative low-carbon solutions.

Step 5: Produce a Local Area Energy Strategy
This is the output of the LAEP process, which will provide a long-term framework for decarbonising the energy system. The Strategy will consolidate the findings of Steps 3 and 4.

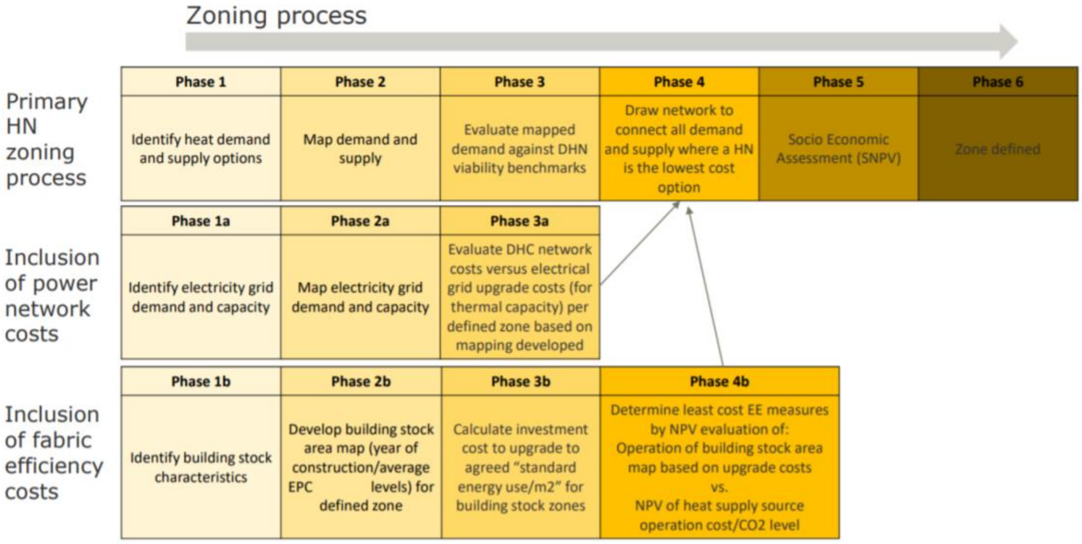
Step 6: Lead and implement
An effective LAEP strategy requires consistent leadership and support from all stakeholders. The Local Lead Organisation will need to continuously assess the plan and develop the strategy according to local or national guidance, and consider the long and short term implementation.

Step 7: Monitor and review
Successful delivery of the LAEP Strategy will require management and review over time. Elements of the Strategy may be affected by major political change, market forces, tech developments, or national emission targets.

BEIS Heat Network Zoning Methodology

Local Area Energy Planning is a broad methodology that considers the possible impacts of various decarbonisation strategies — including, but not limited to, heat network zoning. The BEIS Heat Network Zoning Methodology, in contrast, was designed specifically to support the planning and implementation of heat networks. Developed by BEIS in collaboration with Ramboll[11], it presents various possible scenarios which could be used to identify heat zone boundaries which deliver the lowest cost low-carbon solutions for the consumer. While the detailed scope of the methodologies has not yet been set, these scenarios are designed to initiate early-stage discussions among stakeholders.

Of the 6 scenarios presented, Cambridge County Council has identified Scenario 5 as the most appropriate for identifying heat zones in Huntingdon, Ely and March. Scenario 5 is the most comprehensive of the scenarios and resonates well with the Local Area Energy Planning method because it uses a whole-system analysis to inform its zoning procedure — but, unlike LAEP, it does this specifically with heating in mind. An outline of the methodology of Scenario 5 is shown in Figure 3.



Primary HN zoning process	Phase 1 Identify heat demand and supply options	Phase 2 Map demand and supply	Phase 3 Evaluate mapped demand against DHN viability benchmarks	Phase 4 Draw network to connect all demand and supply where a HN is the lowest cost option	Phase 5 Socio Economic Assessment (SNPV)	Phase 6 Zone defined
Inclusion of power network costs	Phase 1a Identify electricity grid demand and capacity	Phase 2a Map electricity grid demand and capacity	Phase 3a Evaluate DHC network costs versus electrical grid upgrade costs (for thermal capacity) per defined zone based on mapping developed			
Inclusion of fabric efficiency costs	Phase 1b Identify building stock characteristics	Phase 2b Develop building stock area map (year of construction/average EPC levels) for defined zone	Phase 3b Calculate investment cost to upgrade to agreed "standard energy use/m2" for building stock zones	Phase 4b Determine least cost EE measures by NPV evaluation of: Operation of building stock area map based on upgrade costs vs. NPV of heat supply source operation cost/CO2 level		

Figure 3: An outline of Scenario 5 from the BEIS Heat Zoning Methodology.

Phase 1:

The first phase involves identifying energy demand and capacity (including heating and electricity), identifying the characteristics of the current building stock, and identifying potential heat supply sources.

Phase 2:

In this phase, energy demand and supply are mapped in GIS (Geographic Information System Mapping) alongside building stock characteristics.

Phase 3:

The third phase identifies a first cluster of buildings that would perform well on a heat network — e.g. buildings with similar characteristics and heating demand. The cost of that potential heat network is then compared to the cost of upgrading the electricity grid to provide electrically-sourced heating in that area.

Phase 4:

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[11] Ramboll (2021). Heat Network Zoning Methodology: Scenarios To Explore Methodology Approaches (Presentation given to CCC)

At this stage, a heat network is drawn up and priced using benchmarked values. Suitable heat sources for the network are determined and priced. The LCOE (Levelised Cost of Energy) is defined as the average net present cost of energy in £ per kWh. The LCOE of the proposed network is assessed for various possible heat network technologies, and compared with the current cost of heat generation in the region. If the heat network is revealed to be more economically viable than the current energy infrastructure, it is extended to include more buildings. These steps are repeated until the point where adding more buildings would render the network economically unviable.

Phase 5:
A full socio-economic analysis of the heat network is conducted in Phase 5. The goal is to consider the wider benefits (or disadvantages) of installing the proposed network.

Phase 6:
The heat network is officially defined in this final phase. But it only reaches this stage if it has passed the socio-economic viability assessment in Phase 5.

Heat Zoning Methodologies in Our Research

Our report links to Stages 3 and 4 of the LAEP process and Phases 1-3 of Scenario 5 of the BEIS heat zoning methodology. By mapping out the current heat demand in Huntingdon, Ely, and March, we will develop an understanding of their local energy systems. We will then be able to identify priority areas for the implementation of heat networks, based on where heat demand is highest. At the same time, these assessments will help to inform the strategies and stakeholder engagement that could be used to help Cambridgeshire reach its net zero objectives.

We do, however, use a simplified approach to heat zoning methodology — given the project time constraints and our limited access to data. We outline this methodology in Sections 6 and 7 of our report. If Cambridgeshire County Council were to conduct a larger-scale study on both the technical viability and the cost-benefit analysis of heat zoning, either the LAEP or the BEIS methodology could be used in full, building on the initial analysis presented in this report.

3. Heat Network Technologies

Overview

Heat networks, also known as district heating, deliver heat from a central heat source to multiple buildings and dwellings. They help to reduce overall carbon emissions by reducing the heat and/or electricity losses associated with energy transportation. They can also utilise renewable or low-carbon heat sources like geothermal energy, waste heat, and biofuels, reducing emissions even further.

Heat networks are comprised of[12]:

1. One or more energy centres, which collect or generate energy from a centralised heat source;
2. Pipes connecting the buildings within the network (typically hot water pipes);
3. Heat exchangers which transfer heat from the pipe network to a secondary network of pipes within each building.

Networks can also include Heat Interface Units (HIU), which regulate heat flow into dwellings or buildings, and heat pumps, which upgrade the temperature of the heat provided by the network for use in domestic heating.

Energy Sources

Here we discuss the energy sources which may be feasible for heat networks in Cambridgeshire: boilers and combined heat and power (CHP), geothermal heat, waste heat, and hydrogen.

Boilers and Combined Heat and Power (CHP)

Large-scale gas boilers have been used as a centralised heat source for heat networks. A combined heat and power (CHP) plant burns fuel to generate electrical energy, but also captures the waste heat from the combustion process (which can be up to half of the total energy produced) to be distributed through the network. CHP plants traditionally burn fossil fuels; they emit less CO2 than individual gas boilers but ultimately they are not a zero (or near zero) carbon technology. Some CHP plants use lower-carbon biomass fuels like wood pellets or food waste, but issues relating to availability of sustainable biomass, air pollution and transportation have prevented biofuels from replacing the prevalence of gas-powered plants. Currently CHP plants are often combined with back-up gas boilers for use in periods of high heat demand. More than half of the existing UK heat networks are powered by gas boilers (52%), and nearly a third by gas-fired combined heat and power (32%)[13]. As the carbon intensity of the UK electricity grid decreases, CHP plants provide less and less CO2 savings compared to grid electricity. Those savings will continue to decline into the

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[12] https://www.theade.co.uk/assets/docs/about/ADE_Shared_Warmth_Report_Jan2018.pdf

[13] https://www.theade.co.uk/assets/docs/resources/Heat%20Networks%20in%20the%20UK_v5%20web%20single%20pages.pdf

future. Gas-powered CHP plants therefore should not be Cambridgeshire's first choice as a heat network energy source[14].

Geothermal heat

Heat generated within the Earth can provide a renewable, low-carbon heat source. Shallow geothermal heat, collected from boreholes up to 100m deep, can supply water between 10-40°C. Deeper geothermal heat, from boreholes several kilometres deep, can bring water to the surface at 70°C or more. To provide viable low-carbon heat for a heat network, the geothermal source (and associated boreholes) must be located close to the built-up target area of the network — thereby minimising transportation needs and increasing efficiency.

Waste heat

Surplus heat is generated by many natural or industrial processes. This waste heat is of increasing interest to heat network developers. Waste heat can be gathered from industrial plants, water sources (rivers, canals, sewage treatment plants), data centres, or large commercial areas (supermarkets or shopping centres). Waste heat is typically obtained at a low temperature and must be upgraded by a heat pump for use in domestic settings.

Hydrogen

The combustion of hydrogen generates heat and results in no direct greenhouse gas emissions. However, the real carbon footprint of hydrogen heating technologies can vary greatly depending upon how the hydrogen is sourced — for example, whether it is produced from natural gas or coal[15]. In addition, hydrogen combustion provides very low end to end efficiency compared to heat pumps. Very crudely, one unit of low carbon electricity produces half a unit of green hydrogen by electrolysis and almost half a unit of heat in a boiler, but one unit of low carbon electricity supplies three to five units of heat from a heat pump.

High vs. Low Temperature Networks

One of the main decisions to make when designing a heat network is whether to supply heat at a low or high temperature. Heat networks have traditionally supplied heat at high temperatures, but recent studies have shown that low-temperature networks are more efficient and come along with lower carbon emissions[16].

High temperature

A high temperature network (also known as a 2nd- or 3rd-generation heat network) circulates pressurised hot water at a temperature between 70-100°C. After circulating through the network, the water returns to the energy centre at a temperature between 40-60°C. In such systems, buildings are connected only to the pipe network, not to each other — there is no exchange of heat between buildings or dwellings. High-temperature

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[14] https://researchbriefings.files.parliament.uk/documents/POST-PN-0632/POST-PN-0632.pdf

[15] https://researchbriefings.files.parliament.uk/documents/POST-PN-0523/POST-PN-0523.pdf

[16] https://www.plymouth.gov.uk/sites/default/files/HeatNetNWEPlymouthTransitionRoadmap.pdf

networks are typically powered by boilers or CHP plants, but can alternatively use ground or air source heat pumps. One advantage of high-temperature networks is that they can operate at a temperature sufficient for domestic heating; the heat they provide does not always need to be upgraded for use in domestic settings. However, high-temperature networks suffer from especially severe inefficiency and heat loss[17].

Low temperature

Low temperature heat networks (also known as 4th- or 5th-generation heat networks) can make use of lower temperature heat sources such as geothermal heat. A 4th-generation network circulates water at a temperature between 40-60°C, which results in less heat wasted from the pipes and thus greater efficiency and lower overall carbon emissions. 5th-generation networks are currently under development and are being designed to carry water at temperatures closer to ambient ground temperatures. This will minimise heat loss and perhaps even eliminate the need for pipe insulation. Heat pumps installed in each property will then upgrade the heat from the network for hot water or space heating. 5th-generation networks will be able to take advantage of even lower temperature heat sources, including, for example, waste heat from industry and sewage treatment plants. Low-temperature networks are also being designed to facilitate heat exchange between buildings; this will optimise efficiency even further.

Individual Heat Pumps vs. Heat Networks

It is important to compare the pros and cons of installing a heat network with the pros and cons of installing individual heat pumps for buildings in the same region. Heat pumps can be incorporated into the operation of a heat network — either as the central energy source itself or to upgrade heat from a low-temperature source — but can also be used as an individual heat supply in domestic settings.

Heat pumps work like reverse refrigerators or air conditioners: they take some external source like air or water, use electricity to increase its temperature, and then pump that higher-temperature output through buildings and homes to provide space heating or hot water. More precisely, heat pumps use an external heat source, combined with electricity, to heat a refrigerant and convert it to a gas. That gas enters a compressor, where, due to the increased pressure, it condenses to a liquid. It releases heat as it condenses, and that heat is released into the building. The liquid refrigerant then enters an expansion valve, where it becomes a gas once again, and the cycle continues.

Heat pumps produce less carbon emissions than gas boilers because they run on electricity — and, when working efficiently, they can even use up to 4 times less electricity than electric heaters. This is because, unlike electric heaters, they only have to *upgrade* the temperature of a source that already holds significant thermal energy. The precise carbon emissions associated with a heat pump will depend on the carbon intensity of the electricity that it uses to run.

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[17] https://www.bre.co.uk/filelibrary/SAP/2016/CONSP-04---Distribution-loss-factors-for-heat-networks---V1_0.pdf

Heat pumps can use the thermal energy in ambient air, water, or the ground as their source. These different types of heat pump are known as air source, water source, and ground source, respectively; they will be discussed in more detail below.

Air Source Heat Pumps

Air Source Heat Pumps (ASHPs) are the most common type of heat pump in domestic settings. They absorb heat from air external to the property and transfer it to the internal heating system. They can be retrofitted to existing properties and consist of an external ground or wall-mounted unit, requiring only a small land footprint. ASHPs can either be "air-to-water" systems, in which heat is transferred to a standard hot water heating system, or "air-to-air", in which heat is transferred directly to air that will be distributed around the home. A drawback of air-to-air heat pumps is that they do not provide hot water.

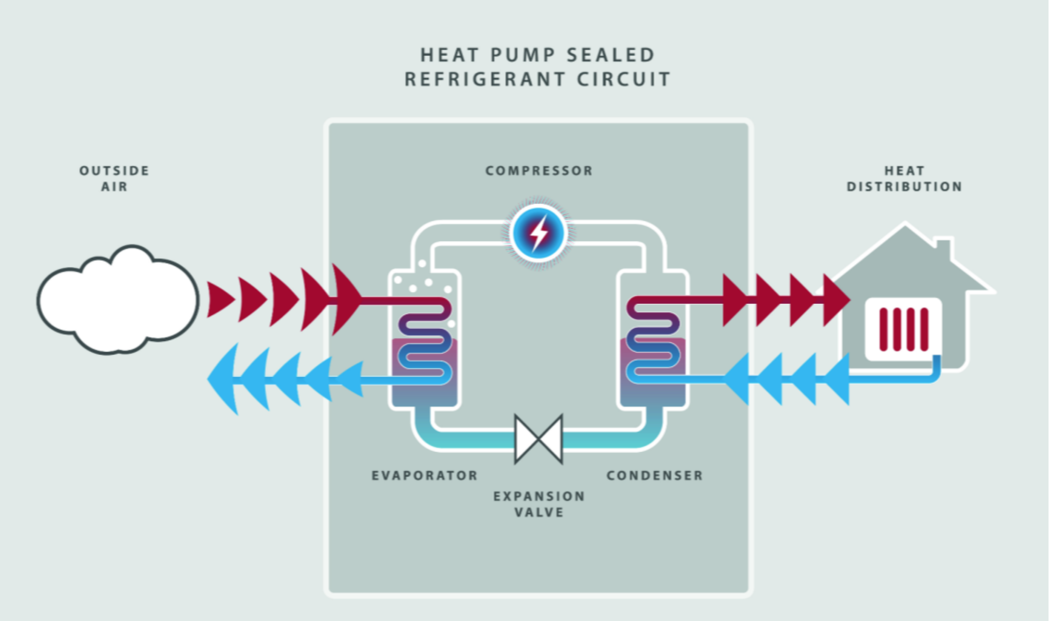

Figure 4: Diagram of an air source heat pump, showing how the refrigerant is cycled through the system[18].

The total cost to purchase and install an ASHP typically falls between £7,000-13,000 in the UK.[19] However, this excludes the cost of installing new radiators, pipework and insulation that might be needed to provide comfort from low temperature heat. ASHPs are most efficient when the external ambient temperatures are closer to the temperatures required for domestic heating.

Ground Source Heat Pumps

Ground Source Heat Pumps (GSHPs) use copper or plastic tubes buried underground as an external heat exchanger. An open-loop system draws water from, and returns it back into, a river or another groundwater resource — for example, an aquifer or spring. Closed-loop systems are more common; they use a sealed loop

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[18] https://www.refrigeration-mitton.co.uk/renewable-energy/air-source-heat-pump/

[19] https://energysavingtrust.org.uk/advice/air-to-water-heat-pumps/

to extract heat from the surrounding soil or rock. Ground heat sources are more stable and reliable than air heat sources, but installation of GSHPs is more costly and disruptive than installation of ASHPs. The heat output of a GSHP is directly related to the size of its underground heat collector.

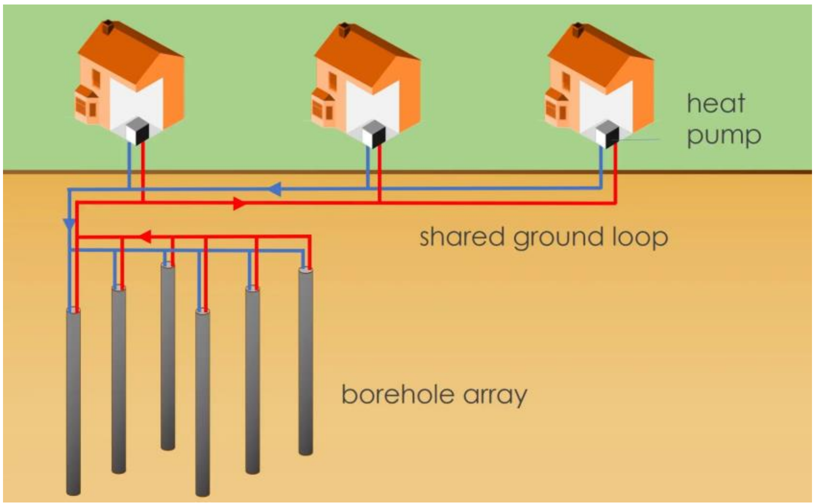

Figure 5: Diagram of a ground source heat pump distribution network[20]*. Individual heat pumps are used to "upgrade" the temperature for use in domestic settings.*

Installation costs for GSHPs are high: as much as £3,000 per kW of heating capacity[21]. But they do not require much maintenance. More boreholes might be needed to maintain the temperature of the network over long periods of time. But otherwise, a GSHP, once installed, is fairly stable. In a closed-loop system, the ground loops should last up to 100 years. The heat pumps themselves have a ~20-25 year life cycle.

A GSHP can only be installed after a geological survey has been performed to assess the viability of the heat source and the suitability of the site for borehole and piping infrastructure.

Water Source Heat Pump

Water Source Heat Pumps (WSHPs) use a series of submerged pipes containing a working fluid (e.g. antifreeze) to absorb the heat from a river, lake, large pond or borehole. WSHPs are often more efficient than ground and air source heat pumps, because water has a high specific heat capacity — it holds and transfers heat well. Furthermore, water temperatures tend to be relatively constant and predictable throughout the year (between 7-12 degrees), providing a more stable and higher temperature heat source than the air during winter.

Any large body of water can be used as a source for heat pumps, but urban areas near fast-flowing rivers have been identified as the most promising type of site for the technology, according to the DECC's water source

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[20] https://bhesco.co.uk/rural-heat-networks-sussex-kent

[21] https://www.gshp.org.uk/ground_source_heat_pumps_Domestic.html

heat map[22]. Fast-flowing rivers provide access to a large volume of water and will not change much in temperature throughout the year.

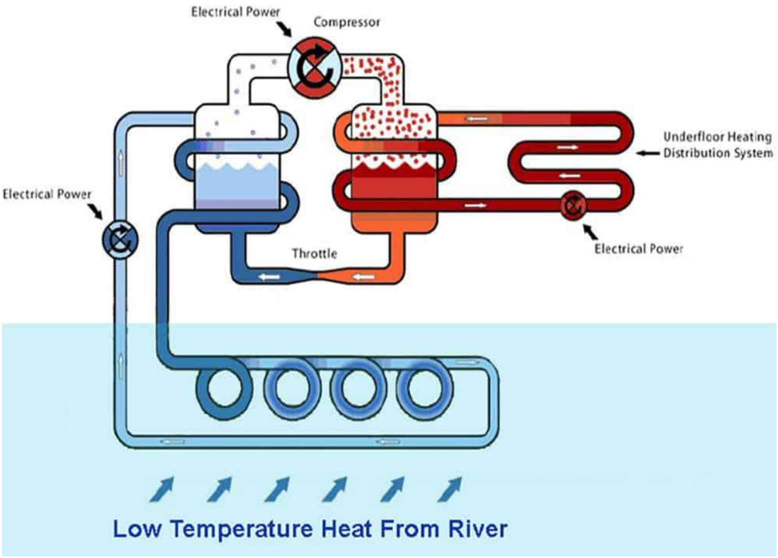

Figure 6: Design of a water source heat pump, in which heat is extracted from a river or other water source[23].

A water source heat pump will soon be installed at Robinson College, Cambridge, to offset approximately half of the main building's gas heating demand[24]. The heat exchange will be with Bin Brook, a tributary of the Cam which runs through college grounds. A weir has been constructed across the brook, and water will be circulated from the weir to the heat pump and back to the brook. The heat pump will provide heating and hot water delivered at temperatures similar to those issued by the original gas boilers. The existing gas boilers will be retained as a back-up to supplement the water source heat pump on cold days. By moving from gas to this new sustainable heat source, it is estimated that the College will save over 5,000 tonnes of CO2 emissions over the next twenty years.

Carbon Emissions

If multiple energy sources are found to be viable for a proposed heat network, the carbon emissions of the different sources should be compared to find the lowest-carbon solution. In reality, this situation might be rare — factors like land availability and local policy will often only allow for one option.

While the precise carbon emissions of a heat network will depend on the details of its location, building stock, and size, many studies have sought to estimate the amount of carbon emitted by networks powered using different heat sources. Some of these estimates, compiled by the Parliamentary Office for Science and

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[22] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/416660/water_source_heat_map.PDF

[23] https://www.renewablesfirst.co.uk/water-source-heat-pumps/free-heat-pump-initial-assessment/attachment/heat-pump/

[24] https://www.icax.co.uk/Robinson_College.html

Technology in a 2016 report[25], are shown in Table 1. The Table provides a carbon footprint range for various heat sources in grams of carbon dioxide equivalent per kilowatt-hour of heat. The number of estimates column refers to the number of studies used to estimate each carbon footprint range.

The carbon emissions of electric technologies depend almost entirely on the carbon footprint of the electricity grid, and as the UK's electricity grid moves further towards decarbonisation, carbon emissions of electric technologies will continue to fall. In Table 1, the carbon footprints of electric technologies are listed under three scenarios, which we have labelled CIG 181, CIG 100 and CIG 14[26]: where the carbon intensity is assumed to be at its 2020 level (181 gCO2eq/kWh)[27], its projected 2022 level (100 gCO2eq/kWh)[28], and its projected 2050 level (14 gCO2eq/kWh)[29]. Values for the 100 gCO2eq/kWh scenario are taken directly from the estimates compiled by the Parliamentary Office for Science and Technology; values for the 181 gCO2eq/kWh and 14 gCO2eq/kWh scenarios have been extrapolated from the 100 gCO2/kWh scenario by us, rounded to the nearest 5 gCO2eq/kWh for values over 10 gCO2eq/kWh, and rounded to the nearest 1 gCO2eq/kWh for values less than 10 gCO2eq/kWh.

Direct carbon emissions from the combustion of natural gas or biomass could, in future, be captured and stored underground using carbon capture and storage (CCS). However, CCS is currently expensive; cost reductions would be necessary to deploy CCS widely in the UK on a cost effective basis.[30] Teesside, Merseyside and Grangemouth are currently hosting ongoing initiatives to test the potential for CCS development in the UK, but significant deployment of CCS is not expected to take place for at least a decade.

The carbon emissions of hydrogen technologies depend greatly on the associated hydrogen generation and combustion processes. Use of hydrogen should sit within the wider context of a local energy system. For example, green hydrogen is most easily produced in areas with significant solar or wind capacity. In future, demand for hydrogen will likely be concentrated in industrial areas that require intense heat — for example, in areas that produce steel. The scenarios listed in Table 1 include estimates of the carbon footprint of hydrogen when produced from natural gas without CCS, from natural gas with CCS, and from electricity under the CIG 100 scenario.

Technology	**Carbon footprint range (gCO2eq/kWh)**	**Number of estimates**
Gas boilers	210-380	6
CHP (natural gas)	220-650	4

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[25] https://researchbriefings.files.parliament.uk/documents/POST-PN-0523/POST-PN-0523.pdf

[26] We use "CIG" as an abbreviation for Carbon Intensity of the Grid.

[27] https://www.nationalgrideso.com/news/record-breaking-2020-becomes-greenest-year-britains-electricity

[28] According to the Steady Progression National Grid ESO Future Energy Scenario.

[29] According to the Steady Progression National Grid ESO Future Energy Scenario.

[30] https://www.gov.uk/guidance/uk-carbon-capture-and-storage-government-funding-and-support#the-governments-approach-to-ccus

Geothermal	10	1
Biomass boilers	5-200	9
Bio-sourced gases	20-100	2
Ground-source heat pumps (CIG 181)	35-90	Extrapolated from below
Ground-source heat pumps (CIG 100)	20-50	15
Ground-source heat pumps (CIG 14)	3-7	Extrapolated from above
Air-source heat pumps (CIG 181)	55-125	Extrapolated from below
Air-source heat pumps (CIG 100)	30-70	11
Air-source heat pumps (CIG 14)	4-10	Extrapolated from above
Hydrogen (produced from gas, no CCS)	220-545	8
Hydrogen (produced from gas, with CCS)	30-90	3
Hydrogen (produced using electricity, CIG 100)	125-250	4

Table 1: Carbon footprint associated with different heat sources for heat networks.

For an electricity grid with a carbon intensity (CIG) of 181 gCO2eq/kWh (2020 level), ground-source heat pumps have the lowest carbon emissions, with air source heat pumps close behind. This still holds true for an electricity grid with a carbon intensity (CIG) of 14 gCO2eq/kWh (2050 level). However, the Table does not consider all possible technologies — for example, it does not provide carbon footprint estimates for water-source heat pumps.

Government Investment

Grants and funding available from the Government or third-party investors may affect decisions regarding the design of local heat networks. Currently there are several schemes available to local councils or heat networks developers, including the Heat Network Investment Project[31] and the Green Heat Network Fund[32]. These have been developed to contribute to low-carbon heating technologies in domestic settings, and they include grants to support the installation of individual heat pumps in private homes.

The Government's Domestic Renewable Heat Incentive (RHI) provides financial compensation per kWh of renewable heat supplied, but it ends in March 2022. The Boiler Upgrade Scheme, announced as part of the Government's Heat and Buildings Strategy, will provide up to £5,000 per home towards the installation of an air source heat pump — or £6,000 for a ground source heat pump — from April 2022[33]. However, the

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[31] https://www.gov.uk/government/collections/heat-networks-investment-project-hnip-overview-and-how-to-apply

[32] https://www.gov.uk/government/publications/green-heat-network-fund-ghnf-transition-scheme

[33] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1032119/heat-buildings-strategy.pdf

£450m scheme translates into funding for only 90,000 homes, a small fraction of the ~30 million homes across the UK[34].

Insulation and Other Factors

Other factors to consider when planning a heat network include the details of the local building stock and the availability of possible sites for an energy centre.

In particular, the age, EPC ratings, and internal infrastructure of the building stock should be considered. The cost of installing a heat network should be weighed against the cost of upgrading the energy efficiency of buildings in the same region, through double glazing and/or wall or roof insulation. Different technologies should be weighed according to how well they fit with the existing infrastructure of the buildings. A high temperature heat network, for example, can act as a direct substitute for existing gas boilers, feeding straight into homes' existing hot water and radiator infrastructure. The majority of existing buildings would, in contrast, require significant upgrade insulation and a supplementary heat pump to connect to a low temperature heat network.

At the same time, there is no use in planning a heat network unless the local area under consideration includes an area (or areas) that could reasonably be used to house an energy centre. Various factors should come into play in assessing the viability of possible energy centre locations — including local plans and restrictions, citizens' views, possible visual obstruction and possible interference with the natural landscape. Each energy source will require an energy centre with different features.

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[34] https://www.theccc.org.uk/wp-content/uploads/2019/02/UK-housing-Fit-for-the-future-CCC-2019.pdf

4. Future Energy Scenarios

To assess future heating and electricity demand, we refer to the modelling presented in the 2021 National Grid ESO Future Energy Scenarios (FES) report[35,36]. The report details four different future energy scenarios.

Today, around 76% of domestic energy demand can be traced back to heating[37]. Current residential demand for heating in the UK is 480 TWh. The FES report predicts that by 2050, total residential demand will be as low as 172 TWh, with air and ground source heat pumps in widespread use and district heat networks installed in some areas.

Some features are common to all four future scenarios. In each, insulation and retrofitting efforts will be combined with a push towards low carbon heat sources. The sale of natural gas boilers for existing homes will be banned from 2035, and all new homes will have heat pumps installed from 2025. Thermostats will be turned down by 0.5-1C to reduce overall demand and reduce the electricity system peak — and that peak will also be reduced through the installation of thermal storage devices. Overall energy efficiency will increase due to widespread use of LED lighting and smart appliances.

The scenarios differ in the low carbon heating technologies that they adopt, in what ratios, and in whether changes are driven by policy or by the consumer.

The Four Scenarios

Scenario 1: Steady Progression

The Steady Progression world sees the least amount of societal change and corresponds to the slowest rate of decarbonisation. Significant progress can be made towards net zero in this scenario — but ultimately, it results in a failure to meet the government's net zero target by 2050. It includes widespread uptake of electric vehicles for personal use, but much slower decarbonisation of Heavy Duty Vehicles (HDVs). Natural gas continues to act as the primary fuel for heating, although heat pumps are successfully rolled out in some areas — especially in new builds where gas and oil boilers will be banned from 2025. The electricity generation capacity of the UK increases significantly, with growth in both small- and large-scale solar photovoltaic installations and an increase in distributed generation from waste, biomass and energy crops. However, this increase in renewable electricity capacity is not enough to compensate for the increase in demand, and a significant number of new gas fired power plants are installed. The public shows limited appetite for participating in the energy market via smart mechanisms like demand side response and time of use tariffs.

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[35] https://www.nationalgrideso.com/document/202851/download

[36] For more details on the different scenarios, see https://innovation.ukpowernetworks.co.uk/2021/01/11/distribution-future-energy-scenarios-2021/.

[37] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1020152/2020_Energy_Consumption_in_the_UK__ECUK_.pdf

Scenario 2: System Transformation

In a System Transformation world, the UK reaches its net zero target in 2050 by relying on hydrogen to decarbonise heat and heavy transport — two sectors that are especially difficult to decarbonise. Sales of electric vehicles, especially cars and vans, ramp up, resulting in greater demand for rapid public electric chargers. Global production of hydrogen fuel cells increases at the same time, enabling large-scale supply of zero emission HDVs, including buses, coaches and heavy goods vehicles, to be available from the mid-2030s. The Government chooses to install electric heat pumps in new-builds. For existing buildings, the natural gas grid is repurposed to distribute low-carbon hydrogen — but the cost of carbon capture and storage associated with hydrogen generation presents a major issue. Development in renewable electricity generation is steady, as is development in battery storage. A moderate level of grid flexibility is brought about by demand side response and electric vehicle smart charging.

Scenario 3: Consumer Transformation

The Consumer Transformation world also sees the UK reach net zero by 2050, this time thanks to widespread electrification, decarbonisation of the electricity supply, and consumer behaviour change. Decarbonisation efforts are aided by innovative new revenue streams designed to encourage and reward consumers to adopt new routines — including, for example, Time-of-Use Tariffs (ToUT), which offer cheaper electricity to consumers at off-peak times. Uptake of electric vehicles, especially cars and vans, is widespread. The decarbonisation of larger vehicles progresses more slowly, but by the mid 2030s, a wide range of zero emissions Heavy Duty Vehicles are available. A nationwide refuelling network is completed by 2045. The Government decides to decarbonise heat through electrification. New-build homes are forbidden from installing gas boilers from 2023 onwards, and gas boilers are banned outright by 2035. A nationwide programme for improving building energy efficiency is established and implemented, reducing the amount of electricity needed for heating. Various subsidies for the installation and operation of heat pumps are put in place and kept in operation until the late 2020s. Electrification of heating and transport significantly increases demand on the electricity grid. This increase in demand is met predominantly through the expansion of solar and wind farms, which become ever more affordable to install and maintain. As renewable generation expands, so does grid capacity and domestic battery storage.

Scenario 4: Leading the Way

This scenario requires the highest level of societal change, but results in the fastest change. In a Leading the Way world, we reach net zero well before 2050. All ICE and PHEV vehicle sales are banned from 2030, boosting adoption of electric vehicles and engagement with vehicle-to-grid network flexibility. At the same time, consumers are more willing to take public transport and opt for active transport like cycling and walking, resulting in a significant reduction in demand for passenger cars and a lower growth of van stock compared to other scenarios. For HDVs, both batteries and hydrogen fuel cells are developed at scale, and diesel ICE vehicles are completely phased out by the 2040s. Decarbonisation of heat is achieved via a hybrid approach, through widespread deployment of heat pumps combined with distribution of hydrogen through the existing gas infrastructure. This provides a platform for the installation of hybrid heat pump systems, which combine electric heat pumps with hydrogen boilers. The electricity capacity required to support the many electric vehicles and heat pumps deployed in this scenario is high, and must be met with a more centralised approach than in the Consumer Transformation scenario. Large solar PV is more popular than in the other scenarios, and corresponds to a high uptake of co-located battery storage. Consumers are willing to participate in flexibility programmes, with over 40% of those with EV charging at home taking part in some form of smart charging.

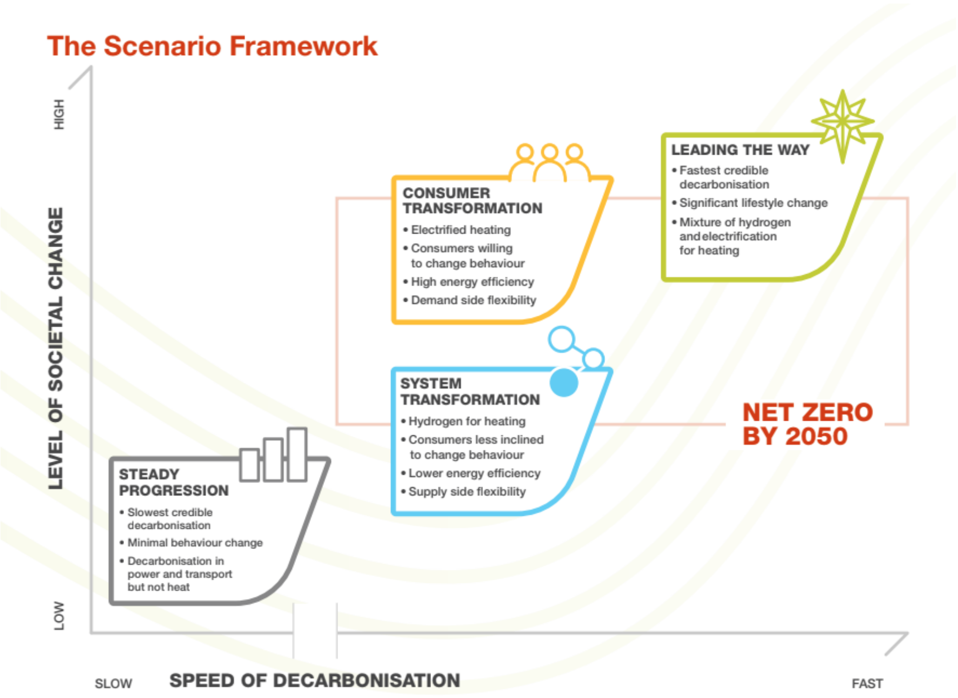

Figure 7: An overview of the four future energy scenarios proposed by UK Power Networks.

Energy Demand for Domestic Heating

80% of domestic heat demand is currently met by gas boilers[38]. In all four future energy scenarios, the energy required to meet domestic heat demand is predicted to significantly decrease (Figure 8). This decrease corresponds to the adoption of more efficient methods for heat generation. Today, and in the Steady Progression scenario, gas boilers dominate (Figure 9). In Consumer Transformation and Leading the Way, air-source, ground-source and hybrid heat pumps dominate. In System Transformation, the whole energy supply is transformed such that hydrogen boilers dominate. All future energy scenarios require a substantial change in heat generation and infrastructure, and Local Authorities will need to play a key role in supporting that change — by, for example, installing heat networks and encouraging individuals to switch to low-carbon heating technologies.

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[38] https://www.sciencedirect.com/science/article/pii/S0301421518307249

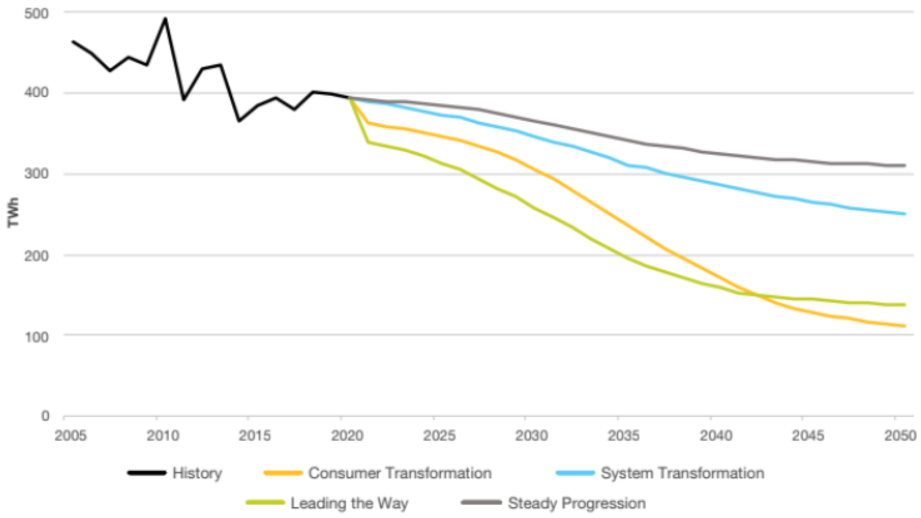

Figure 8: Total annual energy demand for heating homes in each future energy scenario.

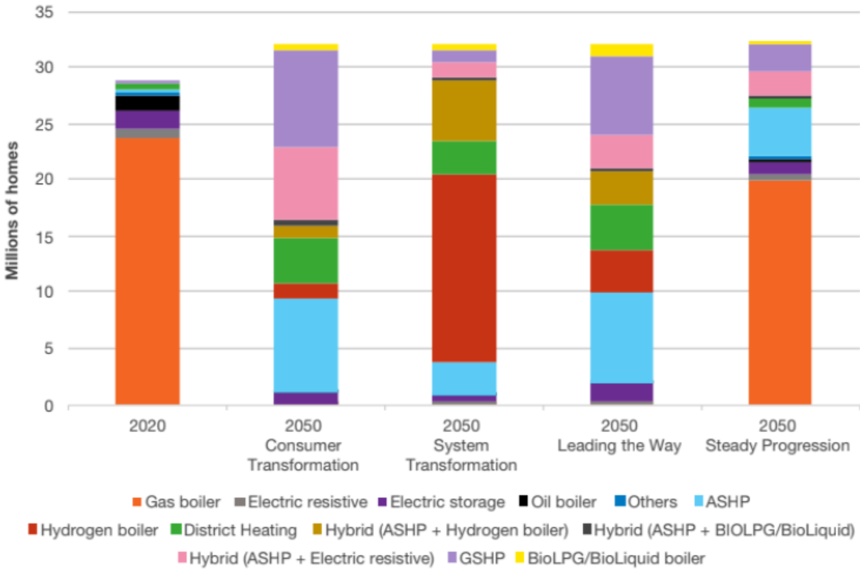

Figure 9: The predicted mix of domestic heating technologies in each future energy scenario.

Electricity Demand for Domestic Heating

The FES report models future electricity demand for domestic heating in each of the four scenarios. As traditional gas boilers are phased out and heat pumps begin to dominate, the electricity required to provide space and hot water heating in homes will increase by up to four times compared to current levels (see Figure 10). This will require a complete overhaul of the current electricity distribution system, in order to avoid power cuts and blackouts. However, a fourfold increase in electricity demand will not necessarily require a fourfold increase in electricity generation capacity if smart technologies are used to spread electricity demand throughout the day.

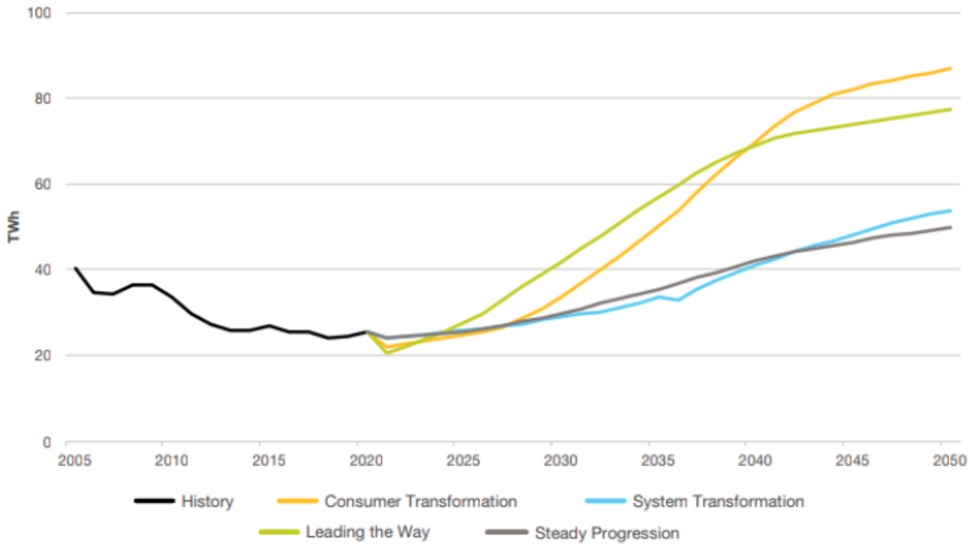

Figure 10: Electricity demand for heating homes for each future energy scenario.

Currently, the non-domestic sector uses the majority (~63%) of the UK's electricity consumption[39]. An increase in domestic heat demand is therefore not the only factor that will put pressure on the electricity grid over the next few decades. It will be important to consider electricity demand trends in other sectors, including industry and transportation, when upgrading the electricity grid in Cambridgeshire.

Carbon Intensity of the Electricity Grid

The FES report models the carbon intensity of the power grid in each of the four scenarios outlined above: Steady Progression, Consumer Transformation, System Transformation and Leading the Way.

National Grid ESO aims to make the UK's electricity system carbon neutral by 2025.[40] Under the Steady progression scenario, "Emissions from the power sector fall below 42 gCO2/kWh by 2030, and decline gradually after this point driven by the shift away from unabated gas".[41] This will be combined with an increase in supply, with a 1.5 times increase in total electricity output by 2050.[42] 79 TWh of that total will, according to projections, be exported.[43] By 2050, even in this least ambitious scenario, the carbon intensity of electricity generation will have fallen by over 90% to 14 gCO2/kWh.

The three more ambitious scenarios take negative emissions from Bioenergy with Carbon Capture and Storage (BECCS) into account, bringing overall emissions from the power sector to below zero from between 2030 and 2035. But, according to their 2021 report, even "[e]xcluding BECCS, emissions in the power sector

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[39] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/853760/sub-national-electricity-and-gas-consumption-summary-report-2018.pdf

[40] National Grid ESO Future Energy Scenarios Report 2021, pg. 114.

[41] National Grid ESO Future Energy Scenarios Report 2021, pg. 118.

[42] Ibid.

[43] Ibid.

fall below 10gCO2/kWh by 2043 in all net zero scenarios".[44] Electrified heating will therefore become zero carbon, or very low carbon, by 2050.

The Carbon Intensity API[45] gives short-term projections of regional carbon intensity and generation mix for the power grid, available 96+ hours in advance for each region of the UK.

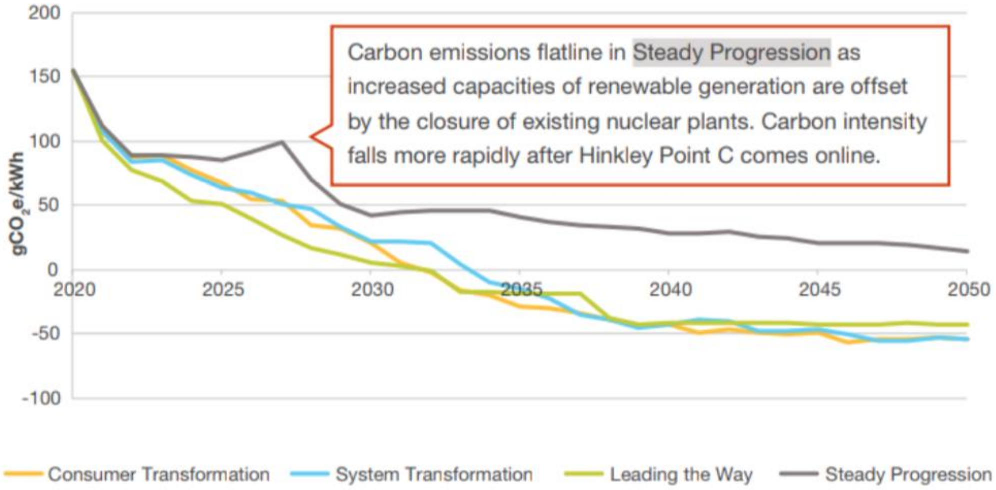

Figure 11: Power sector carbon intensity for each future energy scenario.

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[44] National Grid ESO Future Energy Scenarios Report 2021, pg. 120.

[45] https://carbonintensity.org.uk

5. Case Studies

Here we review the Greater Manchester Spatial Energy Plan and five existing heat network projects in the UK to inform our recommendations for Huntingdon, Ely, and March.

Greater Manchester Spatial Energy Planning

The Greater Manchester Spatial Energy Plan[46] provides an assessment of the technical potential for installing low carbon energy solutions in Greater Manchester (GM) to support the city's climate goals. The plan was compiled before the emergence of the LAEP and BEIS methodologies discussed in Section 2. Therefore it uses its own methodology, composed of 5 steps presented below.

1. **Identification of energy and heat demand.** Energy and heat demand data for all sectors was obtained using BEIS and the CSE National Heat Map data[47]. Space heating and hot water were estimated to account for 77% of domestic energy demand, with gas as the heating fuel for 96% of homes.
2. **Assessment of electricity and gas network capacity.** The existing electricity and gas distribution networks in GM were assessed. This assessment found that major shifts in heating technology would require a significant increase in electricity network capacity in some areas to accommodate new demand.
3. **Evaluation of building stock.** The energy efficiency ratings of domestic and public buildings were assessed using EPC and DEC data. Non-domestic buildings were not considered due to a lack of EPC data. Arround 60% of domestic buildings and 80% of public buildings in GM were found to have low thermal efficiency.
4. **Analysis of existing energy trends.** Carbon emissions trends in GM between 2005 and 2014 were analysed and assessed in the context of targets laid out in The Climate Change Act (2008).
5. **Development of future energy scenarios.** Using the background information collected in steps 1-4, two future energy scenarios were developed for GM. The first, 'Business-as-Usual', assumes a continuation of current trends. The second, 'Green Aspiration', includes widespread implementation of low carbon heating and transport. Models of these scenarios revealed that buildings would have to change almost entirely to different sources of energy for space heating and hot water to reach Greater Manchester's carbon emissions targets. The Business-as-Usual scenario would miss GM's 2050 target by 4 MtCO2.

We use the methodology and results of this study, together with the LAEP and BEIS methodologies reviewed in Section 2, to guide our identification of priority areas for district heating in Huntingdon, Ely and March.

Our report links mainly with the first and fifth steps outlined above: we will estimate the gas and energy demand on our three demonstrator sites to identify priority areas for the installation of heating districts, and then assess how much their installation could save in carbon emissions.

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[46] https://www.greatermanchester-ca.gov.uk/media/1277/spatial-energy-plan-nov-2016.pdf

[47] https://www.cse.org.uk/projects/view/1183

More details on the GM Spatial Energy Plan can be found in Appendix 1.

Heat Networks in the UK

We reviewed 5 existing heat network projects in the UK — projects in Swaffham Prior[48], Gateshead, Leeds, Islington[49], and Solihull[50] — before conducting our own analysis on the viability of heat networks in Cambridgeshire. The similarities among these existing projects provide important background information for the selection of priority areas for district heating in Huntingdon, Ely and March.

Most of these five existing (or planned) sites use a combination of air and ground source heat pumps as their main heat source. Leeds and Islington instead use waste heat already produced by other uses: heat from Leeds' recycling and energy recovery facility and the Northern tube line, respectively.

All five cases include a contingency plan to deal with higher-than-usual peak demand on colder days. To provide that buffer, most include back-up energy or gas boilers.

The energy centre is usually built on government land. And in all cases, the carbon impact of the network depends on the carbon intensity of the electricity grid and on climate variations.

Each of the five heat networks will be able to provide space heating at around 23 degrees Celsius for homes, businesses, and government buildings. Usually they begin by connecting to a small portion of properties and gradually increase their coverage.

Most homes are able to connect to the new networks without upgrading their central heating systems, but electrically heated homes present an exception — they need to install a wet system of radiators and pipes.

More detailed information about each of the five projects can be found in Appendix 2.

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[48] http://www.swaffham-prior.co.uk/pc/CLT/study.pdf

[49] https://www.dezeen.com/2020/03/11/bunhill-2-energy-centre-london-underground-uk-architecture/

[50] https://www.birminghammail.co.uk/news/midlands-news/new-details-designs-revealed-energy-19973178

6. Gas and Electricity Demand in Huntingdon, Ely and March

Methodology

We have investigated the evidence base for installing heat networks in three areas of Cambridgeshire: Huntingdon, Ely, and March. Huntington is a market town in the Huntingdonshire district with a population of ~26,000[51]. Ely, the second smallest city in England, lies in the East Cambridgeshire district with a population of almost 18,000[52]. It has undergone rapid growth in recent years, with a significant amount of new housing development on its north-western edge. March is a market town in the Fenland district with a population of ~23,000[53,54].

We began our analysis by identifying the spatial distribution of the current gas and electricity demand in those three areas, using data from the Department for Business, Energy & Industrial Strategy (BEIS) Subnational Electricity and Gas Consumption Statistics[55]. The data is based on an aggregation of Meter Point Administration Number (MPAN) readings throughout Great Britain, which are obtained directly from electricity and gas suppliers.

The data is aggregated in 5 different geographic levels: regional level, local authority level, Middle Super Output Area (MSOA) level, Lower Super Output Area (LSOA) level, and postcode level. The regional level, local authority level, and MSOA level did not provide sufficient detail to map the spatial distribution of gas and electricity demand in the urban areas of Huntingdon, Ely, and March. Therefore we used the LSOA and postcode level data to map energy demand.

Furthermore, we limited our analysis to domestic meters, since LSOA- and postcode-level electricity and gas data is only available for domestic meters. It is important to note, however, that an industry standard consumption threshold of 73,200 GWh per annum of gas is used to categorise meters into domestic and non-domestic, which may result in misclassification of some smaller commercial properties as domestic.

We extrapolated heating demand directly from the gas demand. In the domestic sector this extrapolation is appropriate, since gas consumption is predominantly used for heating purposes. It would not be appropriate in the non-domestic sector, where gas is used to fuel a variety of activities.

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[51] https://www.huntingdonshire.gov.uk/council-democracy/council-open-data-and-information/statistics/

[52] https://www.eastcambs.gov.uk/sites/default/files/agendas/061112%20Ely%20Vision_0.pdf

[53] https://en.wikipedia.org/wiki/March,_Cambridgeshire

[54] https://www.fenland.gov.uk/media/16583/Fenland-Monitoring-Report-2018-2019/pdf/Fenland_Monitoring_Report_2018-2019.pdf?m=637261848570770000

[55] https://www.gov.uk/government/collections/sub-national-electricity-consumption-data

Consumption Trends

Electricity

In 2019, a total of 272,541 GWh of electricity was consumed across the UK via 31.3 million meters, 1.5% less than in 2018. Total domestic electricity consumption hit 102,737 GWh, accounting for 38% of total consumption. This was 0.3% lower than in 2018 (103,050 GWh), and 14% per cent lower than in 2005 (119,425 GWh).

Comparatively, Fenland (where March is based) saw a reduction of 12% in the domestic electricity demand between 2019 (181 GWh) and 2005 (205 GWh). Huntingdonshire (where Huntingdon is based) saw a reduction of 12% between 2019 (302 GWh) and 2005 (345 GWh). Finally, East Cambridgeshire (where Ely is based) saw a reduction of 11% between 2019 (179 GWh) and 2005 (160 GWh).

All three districts fell short of the UK-wide reduction trend. However, with the exemption of East Cambridgeshire, which had a mean domestic electricity consumption of 5,671 kWh, both Fenland (5,001 kWh) and Huntingdonshire (4,834 kWh) fell below the UK-wide mean domestic consumption of 5,046 kWh.

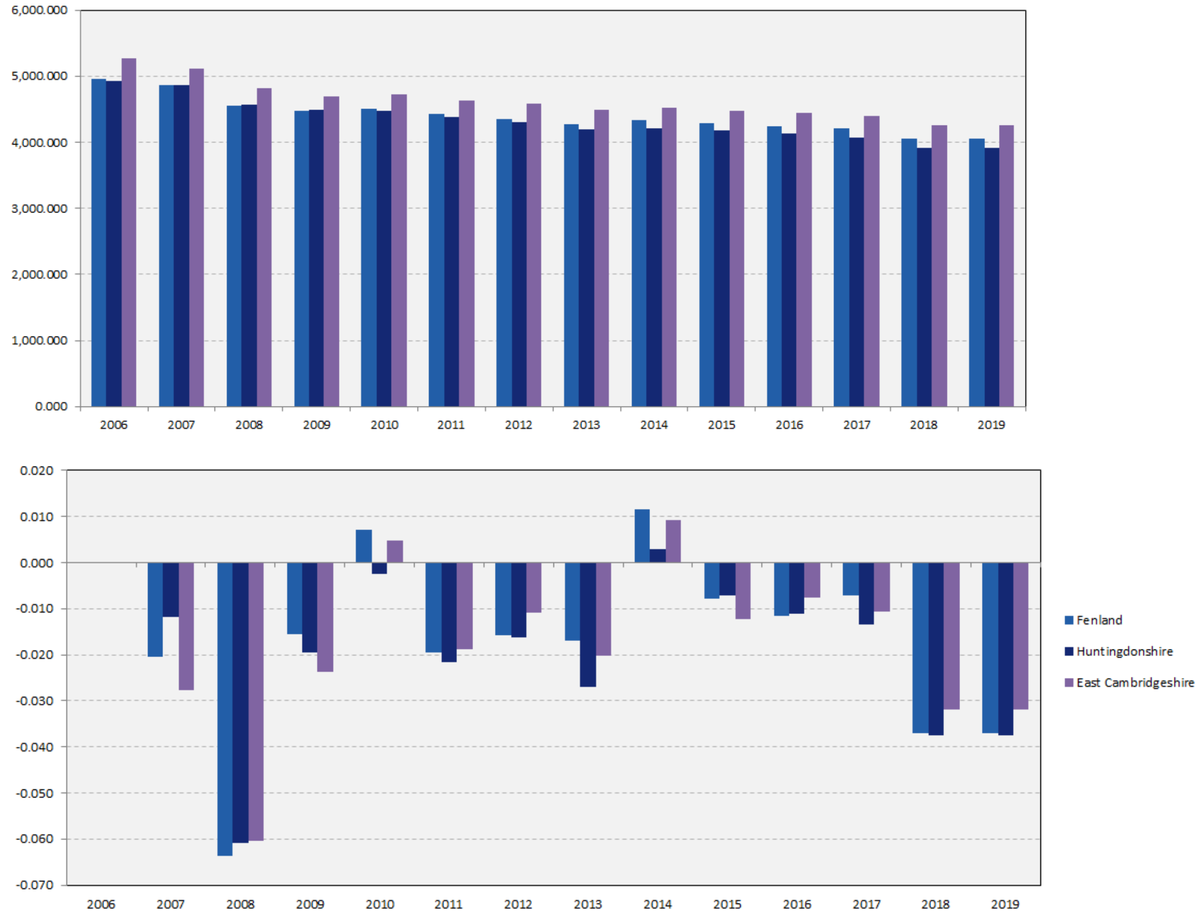

Figure 12: Total domestic electricity sales changes in kWh and percentage points between 2006 and 2019 in Fenland, Huntingdonshire, and East Cambridgeshire.

Gas

The electricity year aligns with the calendar year, but the gas consumption year runs from mid-May to mid-May. During 2019/20, total annual gas consumption in Great Britain was 505,499 GWh (via around 24.4 million meters), 0.7% lower than in 2018/19. UK-wide mean domestic gas consumption decreased by 29.0% between 2005 (19,020 kWh) and 2019/20 (13,495 kWh). The long-term downward trend in gas consumption is explained by energy efficiency improvements in buildings, installation of new boilers and energy efficient appliances, and increased gas prices[56]. However, this trend has flattened somewhat since 2015.

In addition, total and mean domestic gas consumption increased slightly (by 0.9 %) between 2018/19 and 2019/20. This small increase stems from the impact of COVID-19 restrictions put in place between March and May 2020, which required most non-essential workers to stay at home. During this period, when many business operations were put on hold, a significant portion of non-domestic sites consumed less than the 73,200 kWh threshold required for non-domestic classification. Around 5% of non-domestic meters were reclassified as domestic in 2019/20.

Domestic gas consumption in Fenland, Huntingdonshire, and East Cambridgeshire follows these UK-wide trends, showing long-term downward movement that has flattened since 2015, and a small increase in mean consumption between 2018/19 and 2019/20.

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[56] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/946968/sub-national-electricity-and-gas-consumption-summary-report-2019.pdf

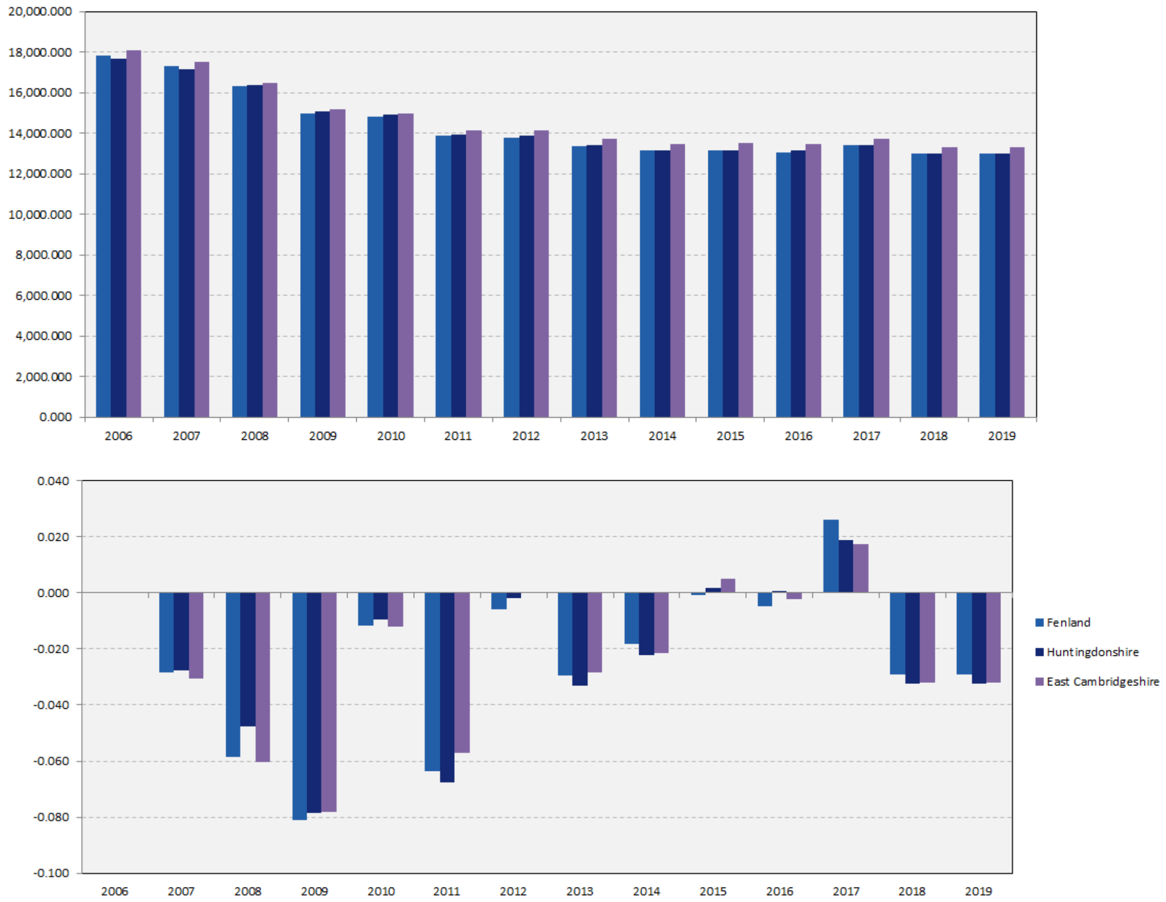

Figure 13: Total domestic gas sales changes in kWh and percentage points between 2006 and 2019 in Fenland, Huntingdonshire, and East Cambridgeshire.

Mapped demand

To map current electricity and gas demand in Huntingdon, Ely, and March, we began by defining an area of analysis for each city. We considered only the built-up urban areas of each site, defined according to the 2011 Office for National Statistics (ONS) data on Built-up Areas. This was the most up-to-date data available; Built-Up Areas are defined by the Census every 10 years. According to ONS[57], Built-Up Areas are areas which are 'irreversibly urban in character'. They are defined using an automated approach based on 50m grid squares, where settlements within 200m of each other are linked.

As mentioned earlier, we used electricity and gas data from the BEIS Subnational Consumption Statistics at the LSOA level and postcode level to map demand. Postcode-level data was not available everywhere — it is not provided for postcodes that include less than 5 meters, or for postcodes where a single meter consumes more than 90% of total consumption.

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[57] https://www.ons.gov.uk/peoplepopulationandcommunity/housing/articles/characteristicsofbuiltupareas/2013-06-28

Alongside the Built-up Areas and BEIS Subnational Electricity and Gas Consumption Statistics data, we used the following resources to map demand: High Resolution (25cm) Vertical Aerial Imagery (2020)[58] from Digimap Getmapping Plc, postcode boundaries from digimap Ordnance Survey Limited (OS Data) Code-Point® with Polygons, and the LSOA boundaries from ONS geography information[59].

Gas

The following maps show the spatial distribution of the domestic mean gas consumption in 2019 for Huntingdon (Figure 14), March (Figure 15), and Ely (Figure 16). The consumption data is divided into 5 classes. Class 1 (less than 12,000 kWh) and Class 2 (between 12,000 and 13,000 kWh) fall below the national and regional average of consumption. Class 3 (between 13,000 and 14,000 kWh) is in the national and regional average consumption range. And Class 4 (between 14,000 and 15,000 kWh) and Class 5 (greater than 15,000 kWh) are above the national and regional average.

Figure 14 shows that in Huntingdon the highest mean gas consumption rates are concentrated mainly in the northeast, northwest and south, while consumption rates in some central regions are below average.

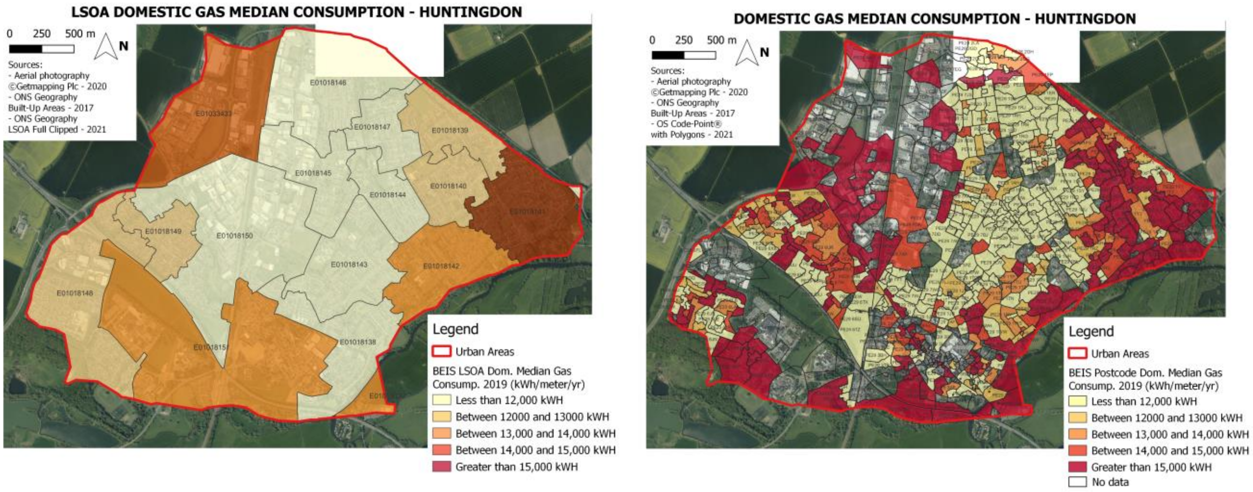

Figure 14: Huntingdon domestic mean gas consumption in 2019 at LSOA and Postcode levels.

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[58] https://digimap.edina.ac.uk/help/copyright-and-licensing/aerial_eula/

[59] https://geoportal.statistics.gov.uk/

Figure 15 shows that in March the highest mean gas consumption rates are concentrated in the centre and south, while the east and west have lower than average consumption rates.

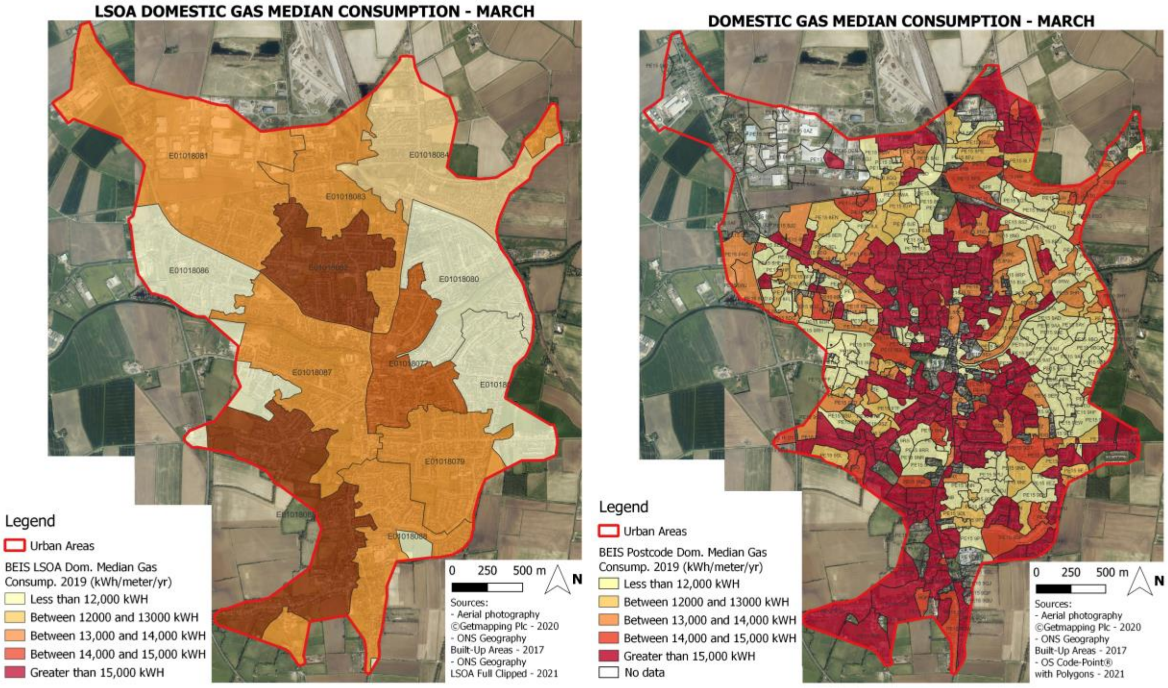


Figure 15: March domestic mean gas consumption in 2019 at LSOA and Postcode levels.

Finally, Figure 16 shows that in Ely the highest mean gas consumption rates are concentrated mainly in the central, southeast and west of the city, while the northeast has lower average consumption rates.

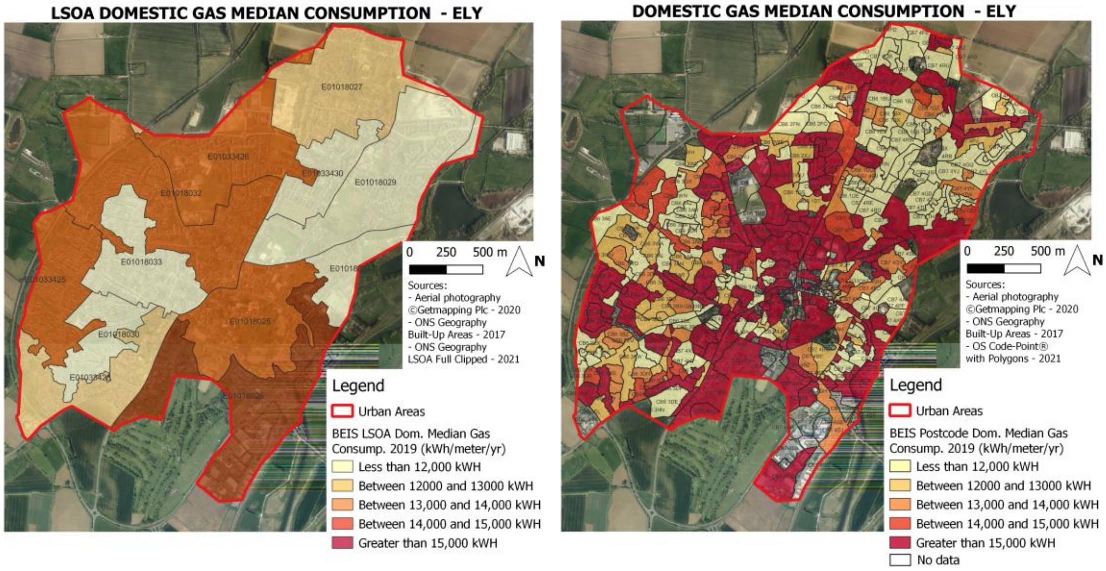


Figure 16: Ely domestic mean gas consumption in 2019 in the LSOA and Postcode levels.

Electricity

The following maps show the spatial distribution of domestic mean electricity consumption in 2019 for Huntingdon (Figure 27), March (Figure 28), and Ely (Figure 29). The data is again divided into 5 classes.

Class 1 (less than 3,400 kWh) and Class 2 (between 3,400 and 3,800 kWh) fall below the national and regional average. Class 3 (between 3,800 and 4,200 kWh) is in the national and regional average consumption range, and Class 4 (between 4,200 and 4,600 kWh) and Class 5 (greater than 4,600 kWh) are above the national and regional average.

Overall, we see in Figures 17, 18 and 19 below that in all three areas, the spatial distribution of electricity consumption is very similar to the spatial distribution of gas consumption.

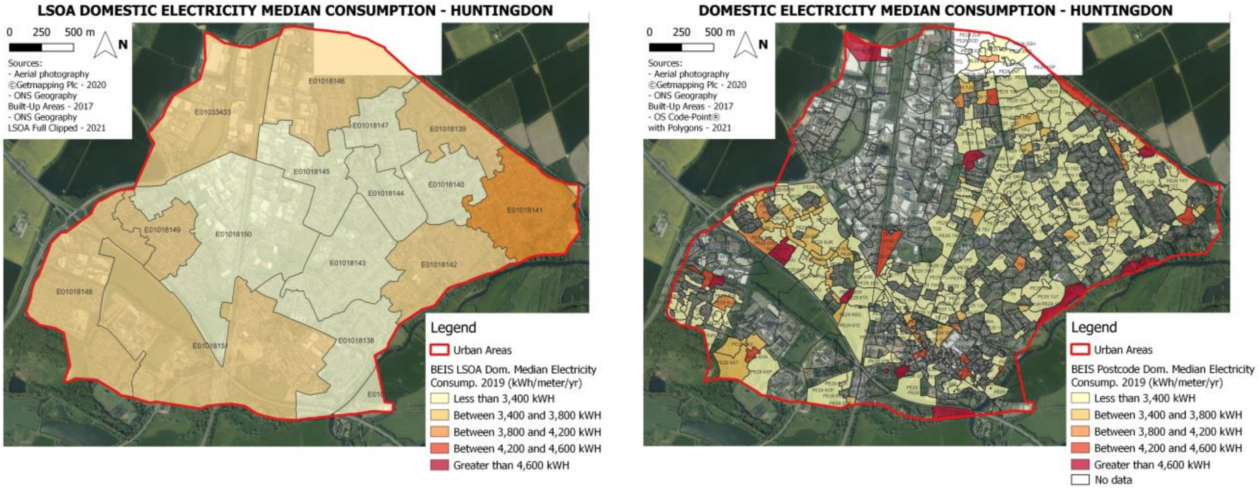


Figure 17: Huntingdon domestic mean electricity consumption in 2019 in the LSOA and Postcode levels

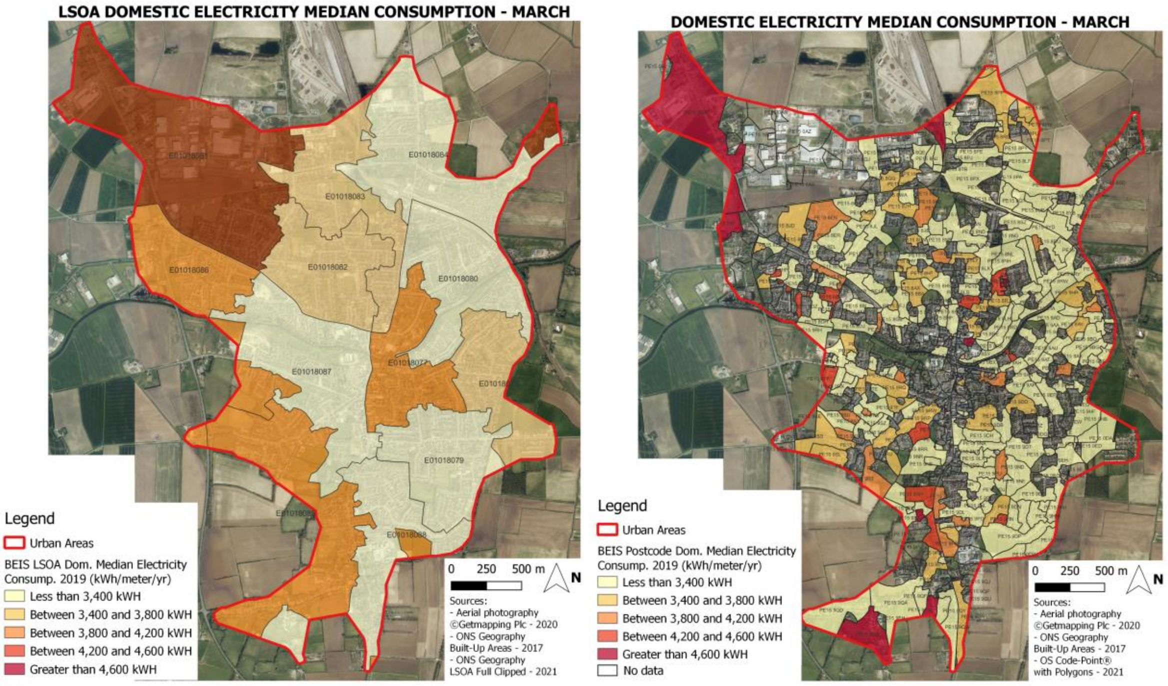
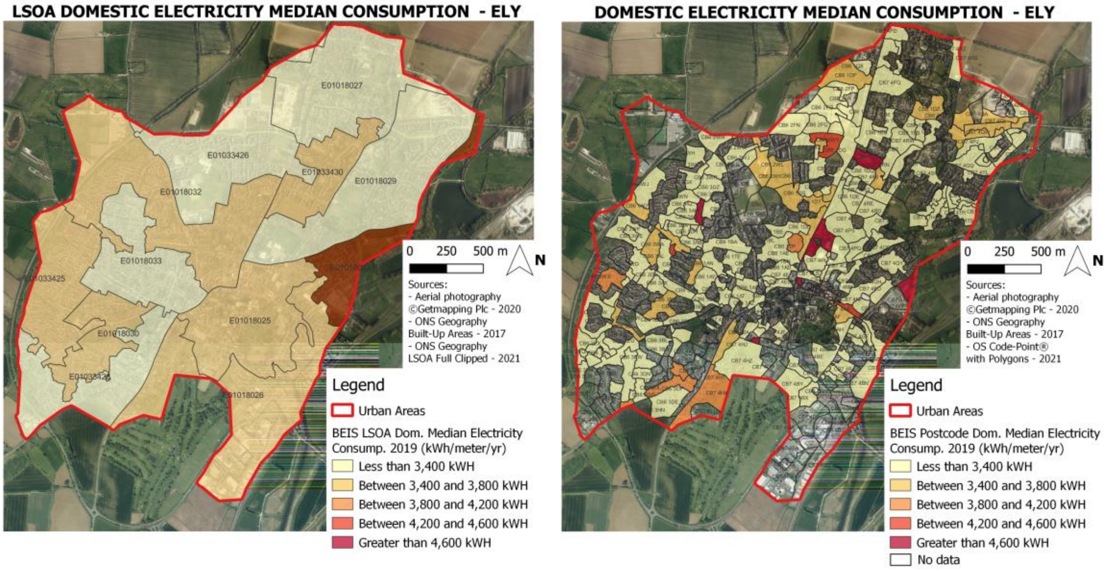


Figure 18: March domestic mean electricity consumption in 2019 in the LSOA and Postcode levels.


LSOA DOMESTIC ELECTRICITY MEDIAN CONSUMPTION - ELY

Sources:
- Aerial photography ©Getmapping Plc - 2020
- ONS Geography Built-Up Areas - 2017
- ONS Geography LSOA Full Clipped - 2021

DOMESTIC ELECTRICITY MEDIAN CONSUMPTION - ELY

Sources:
- Aerial photography ©Getmapping Plc - 2020
- ONS Geography Built-Up Areas - 2017
- OS Code-Point® with Polygons - 2021

Figure 19: Ely domestic mean electricity consumption in 2019 in the LSOA and Postcode levels.

7. Heat Network Zoning in Huntingdon, Ely and March

PLEASE NOTE: ALL HEAT ZONES IDENTIFIED IN THIS CHAPTER ARE INDICATIVE ONLY AND SUBJECT TO FURTHER WORK.

Using the energy consumption data mapped in Section 6, we moved on to define regions in Huntingdon, Ely and March that should be prioritised for heat network development. We began this stage by briefly assessing the major council-owned assets and public buildings in each of the three demonstrator sites, as shown in Figure 20. Data was provided by Cambridgeshire County Council.[60]

The urban area of Huntingdon contains numerous schools, council office buildings, and a hospital. Ely is home to a number of schools and administrative council buildings, and March includes several schools and community buildings, including the offices of the Fenland District Council. Both Huntingdon and March contain areas of council-owned land that could act as sites for a potential energy centre.

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[60] https://my.cambridgeshire.gov.uk/myCambridgeshire-beta.aspx?mapsource=CCC/Energy_Investment&BaseMapSource=CCC/base_ADS_OSPremiumBW

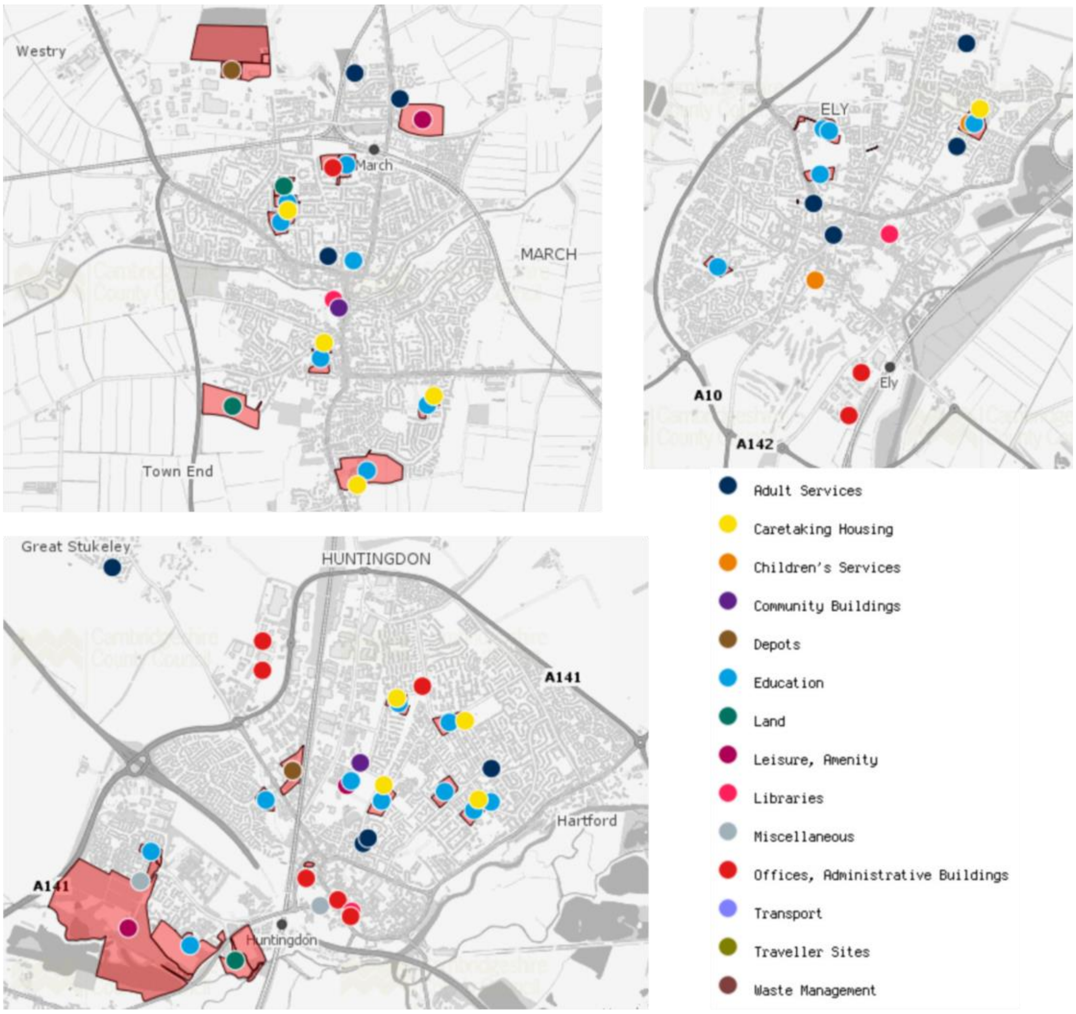

Figure 20: Maps of council-owned properties and land in Huntingdon, Ely and March.

Methodology

To define priority sites for heat networks in Huntingdon, Ely and March, we adopted a simple approach, informed by LAEP methodology (see Section 2), the BEIS heat network zoning methodology (see Section 2), and the BEIS report "Opportunity areas for district heating networks in the UK"[61].

First, we used the data from Section 6 to identify concentrated areas with high heat demand: these, if possible, should become high priority areas for heat network development. Then we assessed the availability of possible heat sources near those areas.

Step-by-step

In more detail, our methodology is captured by these seven steps:

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[61] https://www.gov.uk/government/publications/opportunity-areas-for-district-heating-networks-in-the-uk-second-national-comprehensive-assessment

1. Within the urban areas of each demonstrator site, generate a gas consumption map at postcode level, with data plotted as annual gas consumption per postcode (from 2019). Obtain gas consumption data from the BEIS Sub-national electricity consumption data reports[62].
2. For each postcode, divide total gas consumption by the number of gas meters to estimate gas consumption per building. Take these values as a proxy for annual heat demand.
3. Create a map to show postcodes where annual heat demand per building exceeds 13.5 MWh/yr (13.5 MWH/yr is the average gas consumption for domestic properties in the East of England).
4. Mark each of those postcodes as a high priority site for heat network planning.
5. Identify clusters of such high priority postcodes which are adjacent to each other to define the boundaries of a potential heat network (heat zone). Where possible, avoid defining a heat zone which crosses major roads or geographical boundaries.
6. Using OS maps and Cambridgeshire County Council's asset maps, consider the following factors:
    a. Does the zone contain any council assets, e.g. council buildings, council-owned land or council housing?
    b. Does the zone contain buildings of similar physical characteristics?
    c. Does the zone contain any large "anchor loads" like schools, hospitals or leisure centres?
7. If the answer to any of 6a, b or c is yes, proceed by considering potential heat sources for the heat network:
    a. Are there any existing heat sources within or geographically adjacent to the zone? (E.g. power plants, waste heat sources, significant bodies of water)
    b. Is land available for the construction of an energy centre (using a location-agnostic heat source such as CHP or biomass boilers)?

A wide variety of considerations informed the development of this step-by-step process, including but not limited to the following:

- Large buildings with high and relatively constant heat demand throughout the year (e.g. leisure centres, hospitals, schools, care homes), also known as anchor loads, can help to balance heating load and make a heat network more efficient[63].
- Networks that include a mix of residential, public and commercial customers tend to be more efficient, as heat demand from the various building types averages out to produce more stable demand overall[64].
- Heat networks are most efficient in dense areas where separation between buildings is low, so that the length of the pipe network and heat loss are both minimised[65].
- Units with similar characteristics often require similar upgrades to connect to a new heat network, and by connecting such clusters all at once, overall infrastructure and installation costs can be reduced (similarly, connecting many-unit buildings, like blocks of flats, is often cheaper than connecting separate buildings).

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[62] https://www.gov.uk/government/collections/sub-national-electricity-consumption-data

[63] https://www.sciencedirect.com/science/article/pii/S0301421516304281?via%3Dihub

[64] https://researchbriefings.files.parliament.uk/documents/POST-PN-0632/POST-PN-0632.pdf

[65] https://www.bre.co.uk/filelibrary/SAP/2016/CONSP-04---Distribution-loss-factors-for-heat-networks---V1_0.pdf

- Heat networks should be designed to minimise destruction or disruption of existing infrastructure and geographical features (e.g. roads or rivers), to reduce capital costs and minimise environmental damage.

Assumptions and limitations

One limitation to the approach outlined above is that it uses gas consumption as a proxy for heat demand — which is an approximation, albeit a relatively reliable one. However, this does mean that we do not account for properties that are disconnected from the gas grid. Further studies should include non-gas properties to provide a more accurate and fine-grained view.

We have also assumed that each building connected to the gas grid has only one gas meter. This assumption is unlikely to significantly affect our results, since less than one percent of properties in the UK had more than one gas meter in 2013, and that statistic is unlikely to have significantly changed since[66].

A more serious limitation of our study is that it prioritizes areas with high heat demand without undertaking a detailed study of building energy efficiency. Insulation upgrades should be implemented in combination with low-carbon technologies like heat networks to help Cambridgeshire achieve its emissions targets, and future studies should consider energy efficiency data alongside the heat demand data we have presented here.

Huntingdon

Using the heat demand maps in Section 6, we identified three potential heat zones in Huntingdon. These are marked in Figure 21 as zones 1, 2 and 3.

Zone 1

Zone 1 is in southwest Huntingdon. It contains residential properties, Hinchingbrooke Hospital, Hinchingbrooke School, Hinchingbrooke House, and the Cambridgeshire Constabulary HQ. Metered gas data was not available for the postcodes containing the hospital, school, Hinchingbrooke House and constabulary, but estimates of the heat demand of these buildings can be obtained from Energy Performance Certificates and Display Energy Certificates[67]. These public buildings would act as large anchor loads for the proposed heat network, ensuring a high and relatively constant heat demand.

Zone 1 does not include any existing heat sources — however, it is located next to Hinchingbrooke Country Park, a council asset. Options for installing a heat network in or near the park could be explored, but any plan would need to preserve the natural surroundings as best as possible.

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[66] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1021891/Sub-national_methodology_and_guidance_booklet_2021.pdf

[67] https://epc.opendatacommunities.org/

Zone 2

Zone 2 is in the Stukeley Meadows region of Huntingdon. It contains primarily residential properties, in addition to Stukeley Meadows Primary School and a large supermarket.

It might be possible to recover some of the waste heat from the supermarket for use in a low-temperature heat network — however, a survey would be required to determine the amount of waste heat produced and the technical feasibility of installing a heat recovery unit. Otherwise, Zone 2 includes council-owned land both on the site of Stukeley Meadows School and north of the A141. Either one of those areas could be developed to house an energy centre.

Zone 3

Zone 3 is in the Hartford region of northeast Huntingdon. This zone is similar to Zone 2 in that it contains primarily residential properties with high heat demand. Zone 3 is surrounded by several major roads, but includes some council-owned land along the edge of the A141 and the B1514..

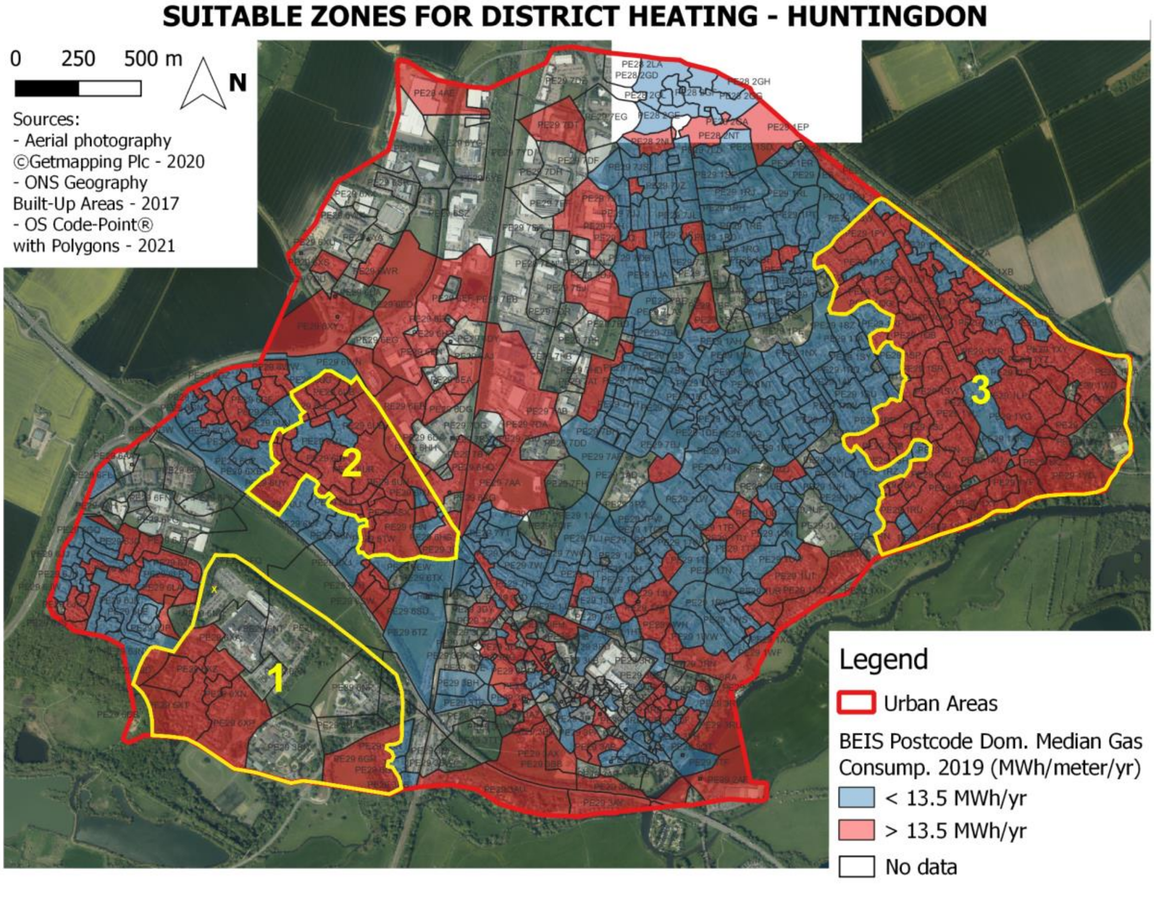
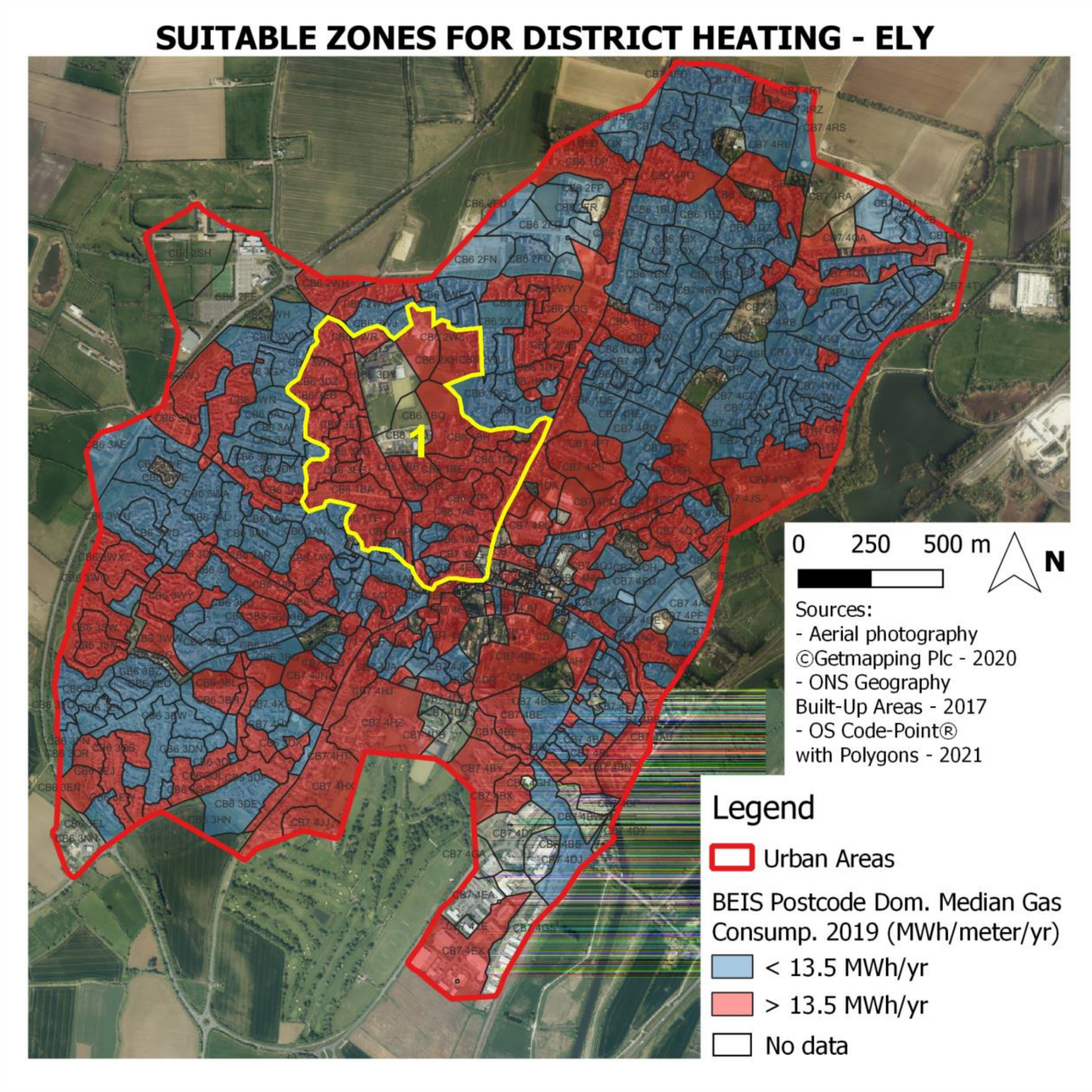


Figure 21: Potential heat zones in Huntingdon (each is outlined in yellow).

Ely

In Ely, we identified one indicative potential heat zone near the centre of the urban area (Figure 22). This zone comprises residential properties, Highfield Ely Academy, Bishop Laney Sixth Form, Ely College and The Lantern Primary School. It does not contain existing heat sources, but land on the school sites could be used to house an energy centre. We decided not to extend the zone east of Lynn Road to avoid disrupting major infrastructure.


SUITABLE ZONES FOR DISTRICT HEATING - ELY

Sources:
- Aerial photography ©Getmapping Plc - 2020
- ONS Geography Built-Up Areas - 2017
- OS Code-Point® with Polygons - 2021

Figure 22: A potential heat zone in Ely.

March

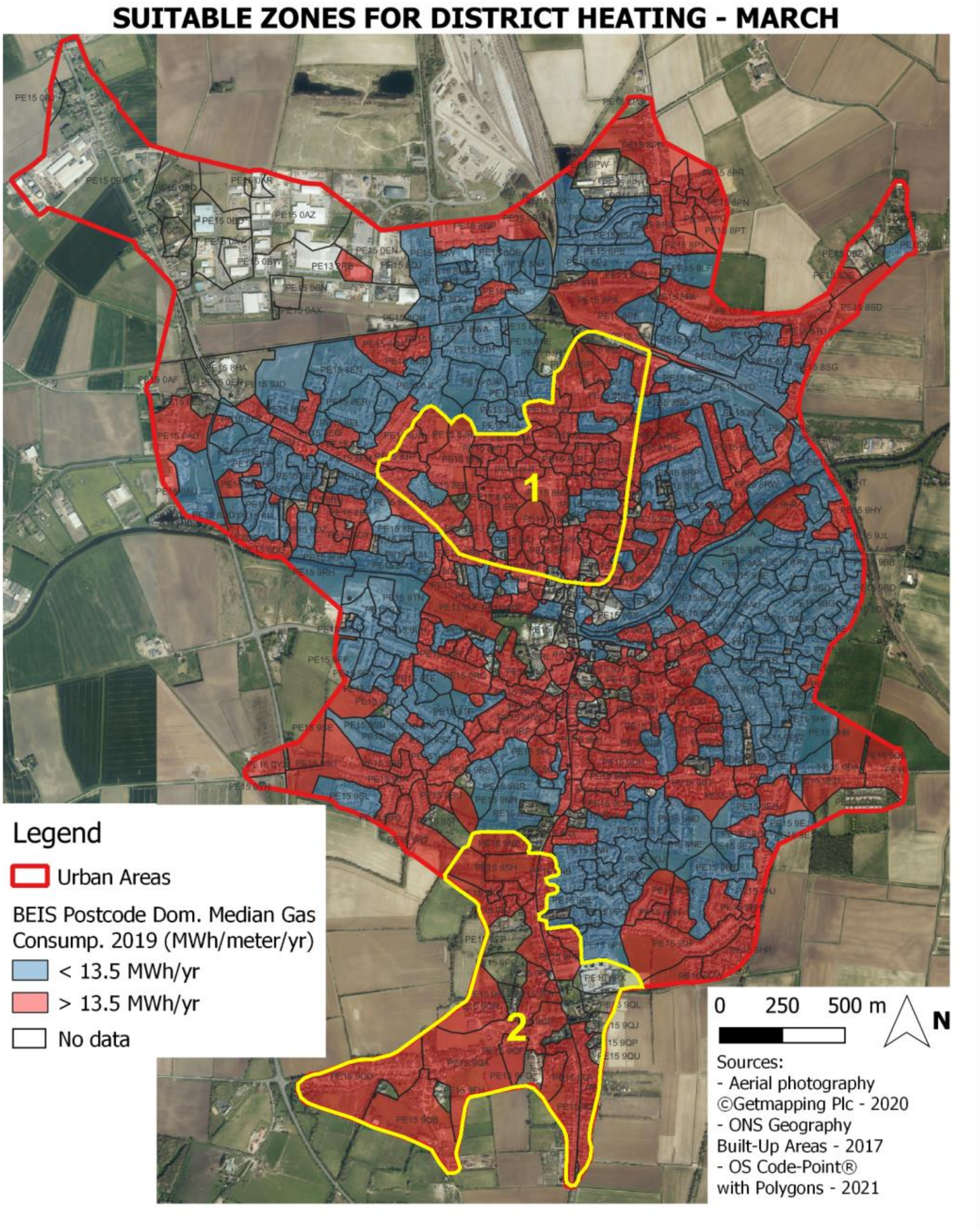
We identified two indicative potential heat zones in March (see Figure 23).

Zone 1

Zone 1 is located in the centre of the urban area. It includes a variety of building types, from residential properties to bigger sites like March Town United Football Stadium, Westwood Primary School, March Fire Station and the Fenland District Council building. It does not include existing heat sources, but land is available near March Train Station in the postcode PE15 8NE.

Zone 2

Zone 2 is in the south of the urban area. It contains a mix of building types, including a care home, the Neale-Wade Academy and residential properties. We have designated Zone 2 as a potential heat zone because of its proximity to a large plot of council-owned land (in the postcodes PE15 9SL, PE15 9SB and PE15 9SD). That plot could be an ideal location for an energy centre.


SUITABLE ZONES FOR DISTRICT HEATING - MARCH

Sources:
- Aerial photography ©Getmapping Plc - 2020
- ONS Geography Built-Up Areas - 2017
- OS Code-Point® with Polygons - 2021

Figure 23: Potential heat zones in March.

Recommendations

In Huntingdon, we recommend prioritizing Zone 1 for heat network planning. This zone contains a mixture of building types and several large anchor loads which would guarantee high future heat demand, minimising the risk associated with heat network development. Several of its buildings are county council assets, and could therefore be connected to a network at the council's discretion, without the need to convince private owners. Zone 1 includes several suitable locations for an energy centre, including the land attached to Hinchingbrooke School, Hinchingbrooke Country Park, and the council-owned land in the postcode PE29 6GP. Waste heat recovery from the hospital might also be possible, although a full technical study would be required to assess the viability of that option.

In Ely, we identified only one potential heat zone; this zone should become the highest priority site for heat network development in the city. It contains several schools and colleges, which could be connected as anchor loads. Land available on the school sites could be used to house an energy centre — or an energy centre could be located just north of the urban area. The zone is surrounded by several major roads, but it could be extended to include the leisure centres in postcode CB6 2FE. A full cost-benefit analysis would be required to determine whether the construction costs of extending the network outweigh the benefits of connecting those extra anchor loads.

In March, Zone 1 should be prioritized, as it contains council-owned assets and the Fenland District Council building. These properties would serve as excellent anchor loads. Zone 2 is also a promising option, and could even be implemented later on as an extension to Zone 1. It includes a good mix of building types and several anchor loads.

Carbon Savings

To estimate the carbon savings associated with installing heat networks in Huntingdon, Ely and March, we used data on the carbon intensity of different heat sources to compare the carbon intensity of the current heating infrastructure in those areas (currently dominated by gas boilers) with the carbon intensity of running heat networks powered by various sources.

The results of this analysis are displayed in Tables 2, 3 and 4 respectively. For the options that include heat pumps, we have used the predicted 2050 value for carbon intensity of the electricity grid (CIG): 14 gCO2eq/kWh.

In Huntingdon and Ely, all buildings included in the calculation of total heat demand which we assessed using EPCs and DECs are heated using natural gas. For March, we only used BEIS gas consumption data; there were no additional buildings within the proposed heat zone which had publicly available EPCs or DECs.

Huntingdon heat zone

Total current heat demand of heat zone	24,323 MWh/yr
Current heat source for heat zone	100% natural gas
Estimated current carbon emissions (natural gas)	5100–9230 tonnes CO2/yr
Equivalent carbon emissions from alternative heat sources	
CHP (natural gas)	5350–15800 tonnes CO2/yr
Geothermal	240 tonnes CO2/yr
Ground source heat pumps (CIG 14)	70–170 tonnes CO2/yr
Air-source heat pumps (CIG 14)	100–240 tonnes CO2/yr

Table 2: Total current heat demand and estimated current carbon emissions in the proposed heat zone in Huntingdon. We estimate the equivalent carbon emissions from alternative heat sources using the data in Table 1.

Ely heat zone	
Total current heat demand of heat zone	10,650 MWh/yr
Current heat source for heat zone	100% natural gas
Estimated current carbon emissions (natural gas)	2240–4050 tonnes CO2/yr
Equivalent carbon emissions from alternative heat sources	
CHP (natural gas)	2340–6920 tonnes CO2/yr
Geothermal	110 tonnes CO2/yr
Ground source heat pumps (CIG 14)	30–75 tonnes CO2/yr
Air-source heat pumps (CIG 14)	40–110 tonnes CO2/yr

Table 3: Total current heat demand and estimated current carbon emissions in the proposed heat zone in Ely. We estimate the equivalent carbon emissions from alternative heat sources using the data in Table 1.

March heat zone	
Total current heat demand of heat zone	15970 MWh/yr

Current heat source for heat zone	100% natural gas
Estimated current carbon emissions (natural gas)	3350–6070 tonnes CO2/yr
Equivalent carbon emissions from alternative heat sources	
CHP (natural gas)	3510–10380 tonnes CO2/yr
Geothermal	160 tonnes CO2/yr
Ground source heat pumps (CIG 14)	50–110 tonnes CO2/yr
Air-source heat pumps (CIG 14)	60–160 tonnes CO2/yr

Table 4: Total current heat demand and estimated current carbon emissions in the proposed heat zone in March. We estimate the equivalent carbon emissions from alternative heat sources using the data in Table 1.

Within the designated heat zones, a switch from natural gas to geothermal energy or heat pumps could therefore dramatically lower annual carbon emissions — by up to 96% at present, and up to 99% by 2050 (if decarbonisation of the electricity grid meets its predicted targets).

Although CHP plants are the most common heat source for existing heat networks, they do not provide significant enough savings compared to individual gas boilers. Geothermal energy, heat pumps, and waste heat recovery are lower-carbon technologies that will help the CCC to achieve its net-zero goals; these are the technologies that should be considered for powering heat networks in Huntingdon, Ely and March.

Land Use Planning

Since 2011, all heat pumps (air, ground and water) in England have been considered a permitted development, and in general they can be installed without planning permission. Some exceptions could apply, however — for example, the installation of a ground source heat pump within an area of conservation would only be able to proceed given permission from the relevant authorities and stakeholders.

Both national and local policies on land use and planning permission should be taken into account before progressing with the proposed heat zones. We summarise some key considerations below.

National

At a national level, relevant policy considerations include the planning regulations set out in the *National Planning Policy Framework*. In particular:

Chapter 2: Achieving sustainable development highlights that any planning interventions should contribute towards a sustainable pattern of development, and that there is a "general presumption in favour of sustainable development"[68].

Chapter 11: Making effective use of land concerns the importance of encouraging multiple benefits from both urban and rural land, recognizing that undeveloped land can itself be of great value, prioritizing previously-developed or 'brownfield' land where possible for development, prioritizing under-utilised land, accounting for changes in demand for land, and achieving appropriate density on land such as that it promotes equitable living standards[69].

Chapter 13: Protecting Green Belt land addresses the need to prevent urban sprawl by keeping some areas permanently open and unaffected by development. If a Green Belt site is proposed for a heat network, it will "comprise inappropriate development" unless the planning authority can demonstrate "very special circumstances," such as the positive externalities from increased renewable energy production.[70]

Chapter 14: Meeting the challenge of climate change, flooding and coastal change encourages authorities to become proactive in implementing measures to adapt to and mitigate against climate change. It stresses that development should avoid increasing vulnerability to climate change impacts while also reducing greenhouse gas emissions.

Local

Relevant literature on local policy includes: *Huntingdonshire's Local Plan to 2036* (henceforth HLP, which covers Huntingdon), the *Fenland Local Plan 2014* (henceforth FLP, which covers March), and the *East Cambridgeshire Local Plan 2015* (henceforth ECLP, which covers Ely).

The HLP notes that Huntingdonshire is vulnerable to the impacts of drier summers resulting from climate change: it is situated in the driest part of the UK and consequently only experiences two-thirds of the average annual rainfall for England and Wales. The area encompasses a flat landscape with little cloud cover, which provides opportunities for solar and wind renewable energy generation. There are former Ministry of Defence sites which may give rise to development opportunities that do not impinge on the countryside and historic rural settlements.[71] The area has an increasing number of older people[72], who may not be immediately obvious target consumers for a heat network, but should nevertheless be considered as potential users. The HLP sets out a strategic vision to "support the health and wellbeing of all its residents" by, among other things, "providing sufficient infrastructure to support healthy communities," "meeting the needs of a changing

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[68] *National Planning Policy Framework* (NPPF) (London: Ministry of Housing, Communities and Local Government, 2021), p. 6.

[69] Ibid., pp. 35-37.

[70] Ibid., pp. 41-44.

[71] *Huntingdonshire's Local Plan to 2036* (Huntingdon: Huntingdonshire District Council, 2019), p. 22.

[72] Ibid., p. 20.

population” and “working with our climate, landscape and heritage.” [73] As part of this, it identifies green infrastructure as a core part of its development strategy.[74].

The FLP presents a similar commitment to promoting sustainable development and reducing impacts from climate change, presumably informed by the NPPF’s messages in this direction. It identifies March as a priority site for growth and development, given its status as one of the four market towns in the area.[75] Local Plan 14 (LP14) considers the imperative of switching to renewable or low carbon energy sources, within the context of chronic fuel poverty in parts of the district, a desire to shift to a ‘green economy’ and create jobs in Fenland, the need to upgrade the energy performance of existing buildings and avoid capacity overload on the power infrastructure network, and the need to combat climate change. According to the FLP, renewable energy projects will be considered subject to their impact on the surrounding landscape, visual and residential amenity, noise pollution, highway safety, biodiversity, aircraft activity and high quality agricultural land. [76]

Aside from the analogous commitments to sustainable development, the ECLP mentions the possibility of establishing a Community Energy Fund as a way to finance renewable energy initiatives that benefit the local community.[77] The plan maintains that renewable energy projects should be sensitive to other considerations, such as: not disturbing key views (particularly of Ely Cathedral), maintaining biodiversity, avoiding areas earmarked for airfields, and protecting heritage assets.[78] It includes a particular Ely-focused remit to promote the historic “distinctiveness” of the city and have this reflected in new development applications, in tandem with ensuring the city’s climate resilience. Developments should enhance the rural setting and the city’s cultural heritage, while also contributing to sustainable growth of the local economy.[79]

Future Work

We have used a simple approach to map potential heat zones. In future, a full cost-benefit and socio-economic analysis should be conducted to determine whether these zones are truly viable, in line with the methodologies of LAEP or BEIS (Section 2).

By working with heat network providers and third-parties, the Council should conduct a technical analysis of the proposed zones to determine the approximate infrastructure costs associated with each. The installation and maintenance costs of the various possible heat sources should be weighed against their carbon emissions. But, as outlined above, we highly recommend that the Council only considers low- or zero-carbon heat sources.

In addition, it would be worth conducting a detailed and area-specific analysis to compare the pros and cons of installing a heat network with the pros and cons of installing other types of low-carbon heating

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[73] Ibid., p. 25.

[74] Ibid., p. 37ff.

[75] *Fenland Local Plan 2014* (Fenland District Council, 2014), p. 16.

[76] Ibid., pp. 64-65.

[77] *East Cambridgeshire Local Plan 2015* (East Cambridgeshire District Council, 2015), p. 73.

[78] Ibid., p. 74.

[79] Ibid., p. 155.

infrastructure — including, for example, heat pumps in individual homes. As noted previously, buildings with high heat demand may only have high heat demand because they suffer from poor insulation. The emissions of such buildings could be dramatically decreased by insulation retrofitting even without the help of a heat network. At the same time, however, almost all properties in the UK must ultimately transition to low-carbon heat sources in order to reach UK-wide emissions goals. So there should be no harm in installing heat networks in these areas regardless — they will be required to connect to a heat network or alternative low-carbon heat solution eventually.

We emphasize that we have estimated heat demand using only BEIS gas consumption data and EPCs/DECs, and we are therefore missing data from buildings without reported EPCs or a connection to the gas grid. Future analysis should include data for these buildings to map current heat demand even more accurately. Even for buildings with reported EPCs, updated data should be obtained for those whose certificates are more than a few years old.

We also note that we have only considered the current heat demand of the three demonstrator sites. In a follow-up study, the future energy demand of these areas could be modelled using the projections discussed in Section 4 (Future Energy Scenarios) and other growth scenarios. Relatedly, the possibility of installing heat networks for planned housing developments should be assessed. It is much cheaper and less disruptive to install heat network infrastructure for properties that are still being planned and built.

In addition, our analysis has been based primarily on gas consumption data. A whole-system analysis, incorporating current and future projections of electricity demand, would allow the Council to better model future demand on its electricity grid. This will become increasingly important as heat pumps and other electric heating technologie become more widespread across the UK.

Finally, future studies should engage with a range of stakeholders, including Local Authorities, businesses, UKPN, and residents. Consumers will need to be reassured that the cost of connecting to a heat network will not exceed the cost of installing alternative technologies like individual ASHPs.

8. Conclusions and future research

This report has identified potential priority zones for heat network development in three areas of Cambridgeshire: Huntingdon, Ely and March. By mapping current energy consumption data, we outlined three promising potential heat zones in Huntingdon and the first priority area. We outlined one zone in Ely. And we outlined two in March, again identifying the first as higher priority.

We have suggested that only low-carbon technologies like geothermal energy, heat pumps, and recovery of waste heat should be considered as heat sources for these heat networks. When powered by low-carbon sources, heat networks in Huntingdon, Ely and March could reduce heating-related carbon emissions in those areas by up to 99% by 2050.

As we progress towards 2050, Cambridgeshire must decide if it wants to lead the way towards UK-wide emissions reduction goals. Decarbonisation of its heat supply is one of the most important and decisive actions that it could take in that direction.

The research presented here is only a first step: future studies should expand on our results and conduct a full cost-benefit and socio-economic analysis of the proposed heat zones.

Appendix 1

Great Manchester Spatial Energy Planning

The Greater Manchester Spatial Energy Plan[80] is a study that provides an assessment of the existing energy demand and supply in Greater Manchester (GM); an analysis of the impact of planned future growth to 2035; and the technical potential for decentralised, low carbon and renewable energy in supporting GM energy and climate change goals.

GM is a metropolitan county in North West England, with a population of 2.7 million people and approximately 1.1 million homes. Almost all of GM is classified as a major urban conurbation, with some fringe areas classified as urban city or town and a small number of areas as rural town or village.

Energy and Heat Demand

GM uses 51.6 TWh/year of energy. Homes in GM account for 37% of this demand, while the non-domestic sector accounts for 35% and Road Transport for 28%. The heat demand for the GM region is identified to be 21.7 TWh/yr, which accounts for 42% of the total energy demand[81]. This is split between residential (67%), non-domestic (27%) and transport (6%) (Figure 12).

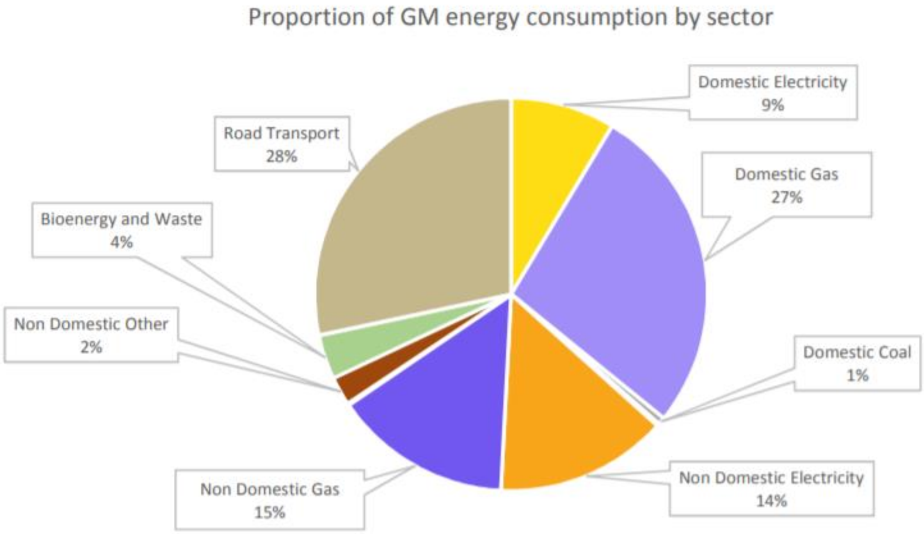

Figure 1: Proportion of Greater Manchester's energy demand.

Space heating and hot water are estimated to account for 77% of domestic energy demand. For domestic use, gas is the primary heating fuel for homes (96%), with electricity accounting for 2%, and coal and oil for 2%, particularly concentrated in Wigan. The areas that use coal and oil often have domestic buildings with poor thermal efficiency and high levels of fuel poverty. Around 35,000 properties (3%) have never had a gas

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[80] https://www.greatermanchester-ca.gov.uk/media/1277/spatial-energy-plan-nov-2016.pdf

[81] https://www.cse.org.uk/projects/view/1183

connection and can be considered off-grid. In the non-domestic sector, industry and retail accounts for the largest proportion of the demand, 20% each, while government buildings and education accounts for 10%.

Cooling demand, on the other hand, is difficult to estimate as the available benchmarks do not cover cooling, so it is included in the general electrical usage demand. However, the introduction of cooling demand methodologies into the building regulation energy requirements will be more important as temperatures increase and city centre densities get higher. Greater London has developed a methodology to benchmark new build residential buildings for cooling demand[82].

Electricity and gas distribution network

Greater Manchester has 137 33kV substations feeding 11,205 distribution substations. The capacity of a substation is an indication of how much development and increased load could be handled without infrastructure upgrade. All new developments and upgrades to existing buildings have to be assessed for network capacity and major shifts in technology can cause some issues. The capacity of GM's electricity network to accommodate increased demand is considered generally robust. However, there are a number of areas with limited capacity to accommodate new demand .

The network distribution of gas in the study area is carried out by National Grid Gas Networks. The UK gas pipeline network is extensive and just 5% of all postcode units in the GM region have been identified as having never had a gas connection.

Building Energy Performance

GM has a wide range of building ages and types which influences energy consumption across the region. The housing stock is predominately pre 1980s. Older buildings are likely to be more energy intensive due to lower levels of insulation and less efficient heating systems. While, newer buildings are typically more energy efficient. Two thirds (67%) of domestic properties have an Energy Performance Certificate (EPC), and 60% of the domestic buildings in GM have low thermal efficiency. And it is expected that as many as 90% of these buildings will still be in use in 2050.

Total energy usage in non-domestic buildings is complex to estimate due to sparse and inconsistent data, the wide variety of construction methods, multiple uses and constant change of use. Less than 1% of non-domestic floor area in GM has an associated EPC. Since 2015, public buildings with a floor area of over 250m^2 must display a Display Energy Certificate (DEC). These DECs show that more than 80% of public buildings are classified from D to G in GM. With around 10% in the worst category, G. Identifying cost effective pathways for the retrofit of energy efficiency, as part of a coherent whole systems approach, is essential to support GM's long term decarbonisation targets.

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[82] https://www.london.gov.uk/sites/default/files/gla_cooling_benchmarking_study_final2.pdf

Carbon Emissions

Greater Manchester's total annual carbon emissions are 13.5 $MtCO_2$ (2014), equivalent to 5 tonnes of CO_2 per capita. The UK national average is 6.3 tonnes CO_2 per capita. This lower value is due to much lower carbon emissions from heavy industry in the GM region, in comparison to the UK average.

GM's carbon targets are aligned with The Climate Change Act (2008), which established a target for the UK to reduce its greenhouse gas emissions by at least 80% from 1990 levels by 2050. However, sub-national data on energy use and emissions has only been collected since 2005, so the GM's environmental strategy team undertook its own analysis to produce a 1990 baseline for GM.

Carbon Emissions between 2005 and 2014 have reduced 26% (Figure 13). The industrial and commercial and domestic sectors had a greater reduction since 2005 (31%) than transport (14%). Furthermore, the transport sector is much less variable as it doesn't respond to factors like cold winters whereas the other sectors do. The emissions from change of land use are insignificant in comparison to the other sectors. To put local actions in context, the national electricity grid has reduced carbon emission associated with power generation by around 33% since 2005. In order to meet these long-term carbon targets near-full decarbonisation of both buildings and surface transport is required.

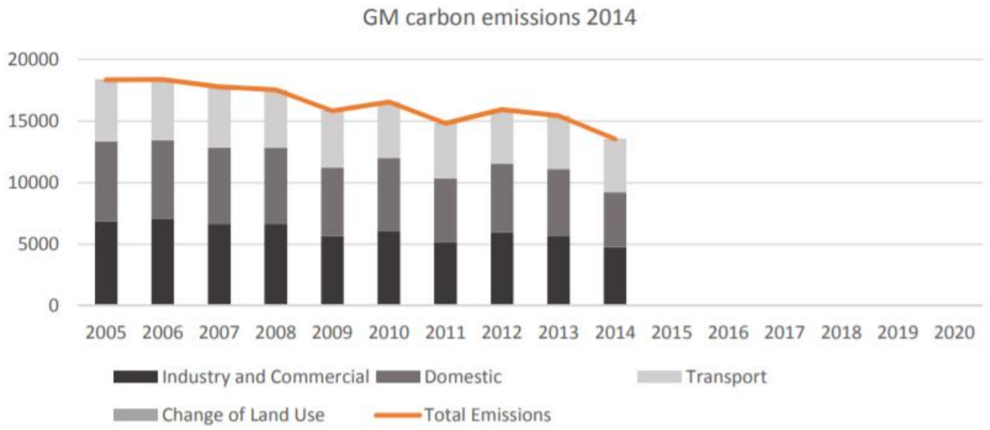

Figure 2: Carbon emissions in Greater Manchester 2005-2014.

Future Scenarios

Two future energy scenarios for Greater Manchester have been developed. These models are based on the National Grid Future energy scenarios methodology - more specifically in the Gone Green and No Progression figures - but recalculated using the regional projections for households and floor space. Buildings are dealt with on a domestic, commercial and industrial basis with new build and existing buildings modelled separately. Transport projections from DECC have been used alongside the FES assumptions. The two scenarios are the following:

- **Business-as-Usual** - this scenario is focused on achieving security of supply at the lowest possible cost. With low economic growth, traditional sources of gas and electricity dominate, with little innovation affecting how we use energy. There is low take up of low carbon heating technologies and efficiency of building stock is not prioritised

- **Green Aspiration** - this represents the scenario where government policy is strongly supportive of renewables and low carbon technologies while meeting carbon reduction targets. Low carbon heating and transport are widely implemented. The electricity grid is completely decarbonised and building efficiency is strongly pushed.

Household and non-domestic growth projections have been taken from the Greater Manchester Forecasting Model (GMFM). By 2035 GM is forecast to have 233,000 new homes (an increase of 17%) and 6.6 million m^2 of additional commercial and industrial floor space (an increase of 22%). Forecast growth of new homes and non-domestic buildings in GM could increase energy demand by around 3% by 2035. The current and projected future changes in floor area and households have been used to calculate future energy demand. For the Green Aspiration scenario, new stock is assumed to have better energy performance benchmarks and existing stock is upgraded through retrofit measures.

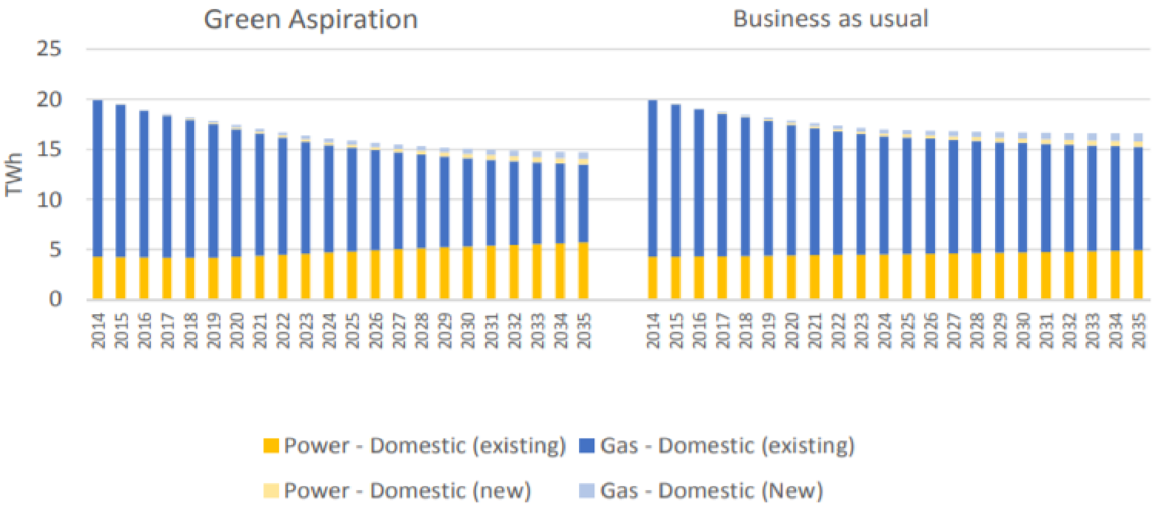

Figure 3: Domestic energy consumption projection for Greater Manchester.

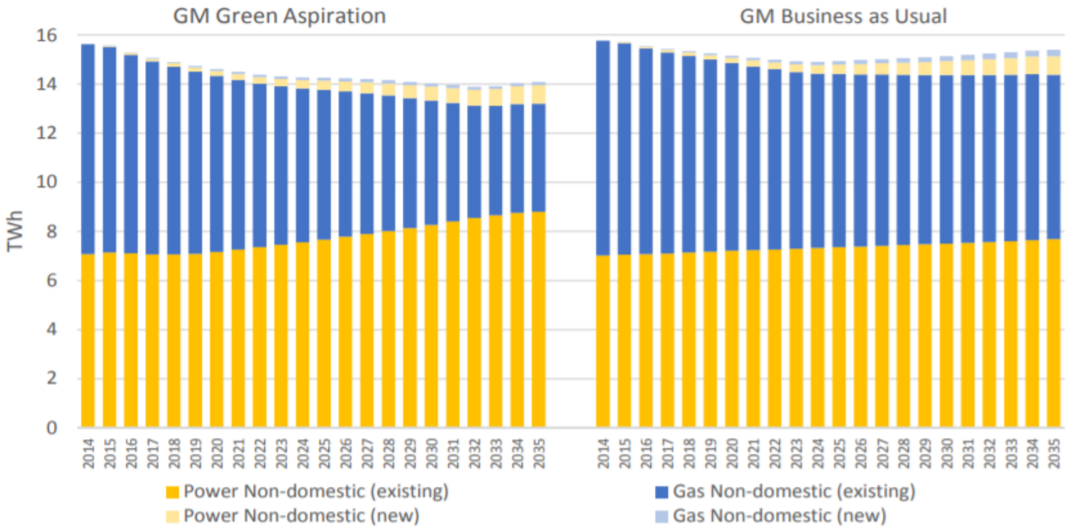

Figure 4: Non-domestic energy consumption projection for Greater Manchester.

To achieve the GM carbon emission target, buildings will have to change almost entirely to different sources of energy for heat and hot water. According to the study, the technologies with the highest technical potential to contribute to a low carbon energy system include district heating, individual electric heat pumps, and bio-fuels and solar technologies for both hot water and electricity.

According to the study, up to 68% of existing gas demand could technically be replaced with renewable heat from heat pumps, solar thermal and bioenergy within the GM region. Ground Source and Air Source Heat Pumps have the technical potential to contribute to 12,400 GWh/yr (50%) of current GM domestic and non-domestic heat consumption. Heat pumps could play a significant role in the decarbonisation of existing homes, particularly in the less built up areas.

District Heating has the technical potential to expand significantly in GM. District Heating can utilise a range of low carbon and renewable technologies and the technical potential for gas CHP led high efficiency District Heating in the North West has been estimated as 37,000 GWh/yr with a cost-effective potential of 4,000 GWh/yr21 under current market and regulatory arrangements.

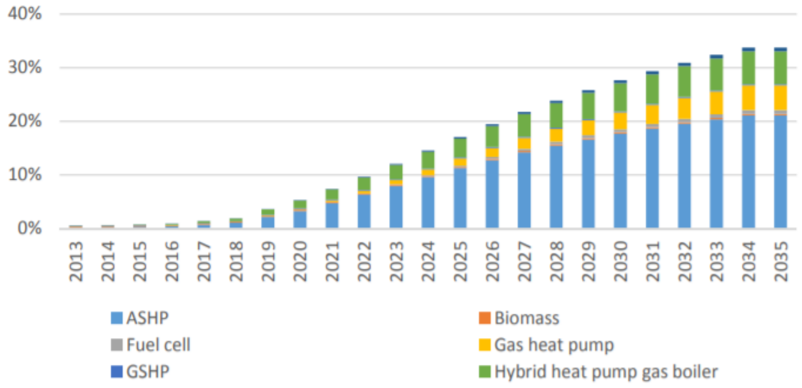

Figure 5: Installed low carbon technologies in the Green Aspiration scenario for Greater Manchester..

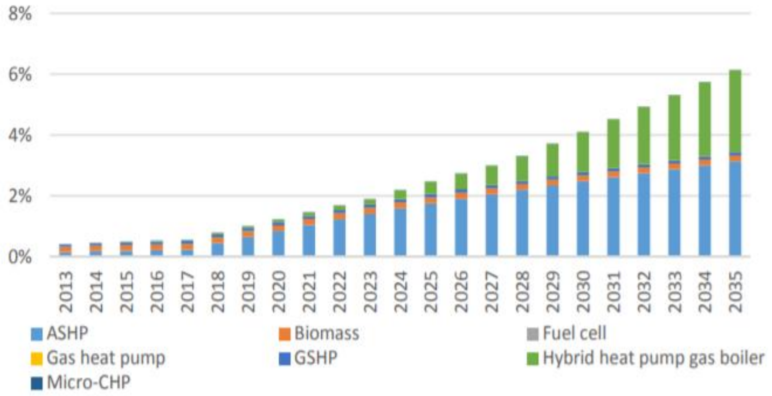

Figure 6: Installed low carbon technologies in the Business As Usual scenario for Greater Manchester.

In the Green Aspiration scenario, the 2050 target is reached (3.4 MtCO2 in 2050 compared to the 4.2 MtCO2 target), with the grid completely decarbonising and the residual gas demand reducing enough that the emissions remain close to the 2050 target despite significant emissions from the transport sector which make up 58% of all emission in 2050. In the Business-as-Usual scenario, the 2050 target is missed by 4 MtCO2, which shows that "Business as Usual" is not an option if targets are to be achieved. An aggressive decarbonisation of the grid alongside improved efficiency of existing stock, through retrofitting fabric and heating system measures, is necessary to achieve the carbon targets.

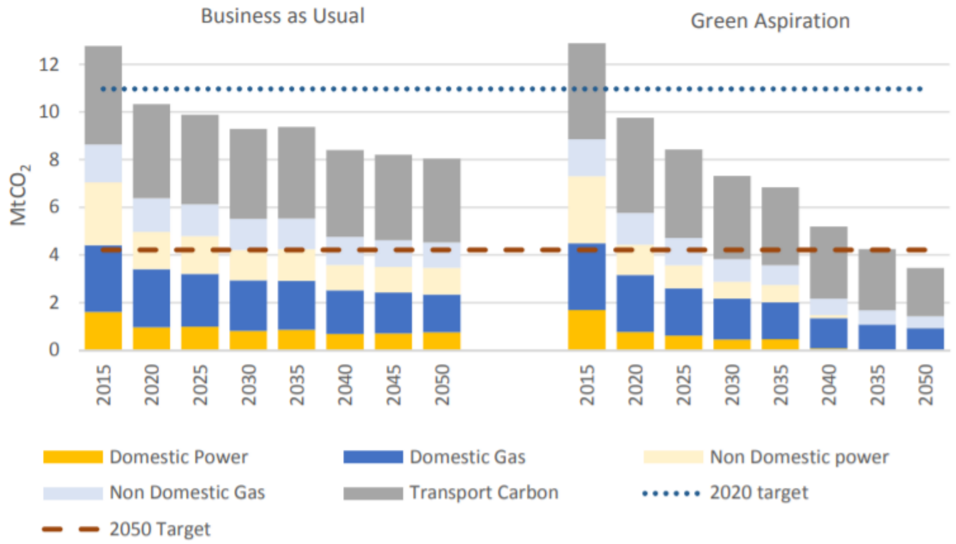

Figure 7: Comparison between Business as Usual and Green Aspiration scenarios carbon targets.

Appendix 2

Swaffham Prior[83]

One location in Cambridgeshire which has already begun transitioning to a low carbon heating supply is Swaffham Prior. Swaffham Prior is a rural village in Cambridgeshire (East Cambs) with 300 homes (>800 residents). One third of these homes are affordable housing and there are also two churches, a pub and a school. It is unconnected to the gas network, meaning oil is currently the main source of fuel. 75% of houses are heated with oil or LPG and 25% with electricity.

The district heating network needs to supply maximum (peak) demands. Therefore knowledge of typical annual and daily demands was needed to estimate the daily demand profile and peak heat demands. The data came from the National Heat Map[84] and the EPC (Energy Performance Certificate) database[85] (for 167/229 houses). The housing stock is predominantly detached and semi-detached houses with about 15% bungalows. Swaffham Prior Primary School's heat demand is based on the DEC (Display Energy Certificate) information and the demand profile based on monitored data for a primary school of similar construction. Raw data collection was also conducted by households in Swaffham Prior agreeing to the installation of a heat metre in their homes. These heat metres gave an indication of how much energy the village uses currently. Maximum (peak) demands are therefore estimated to be 8 kW for space heating and 33 kW for hot water.

Swaffham Prior's energy centre is a combination of an 1.5 MW ground source heat pump and a 500 kW air source heat pump with 200 m^3 of thermal storage. There will be a connection to the council's 29 MW North Angle Solar Farm via a private wire network. A 1,500 kW electrode boiler will be used as back-up, delivering 100% renewable energy. This combination will supply a minimum of 72°C to customers. A water source heat pump was dismissed because the nearest water source (Gutter Bridge ditch) was too far away to be effective. A straw biomass boiler which uses agricultural waste (abundant in Swaffham Prior) needed an operator, a year round supply of fuel and management of air pollution. Therefore, a straw boiler has a lower capital cost and cost of heat than a ground source open loop borehole heat pump, which is the chosen technology, but the boiler would have required more intervention and maintenance and local residents discounted this option.

The energy centre is located on council land with a network of pipes connected to individual homes. It is away from most houses but close to the main road, under which pipes can be laid. The Council has powers from the 1976 Local Government Act, that allows it to generate, distribute and sell heat. This allowed it to install services along the road network so there are no negotiations required to allow pipes to run through third parties' properties. With every increase in nominal pipe size the heat losses increase by 10% and the capital costs by 15%. A plastic twin pipe (two pipes wrapped in the same insulated outer pipe) is used with flow temperatures of 65-75°C. Return temperatures should be between 40 and 55°C. Copper pipes are used to service each house and traditional boilers are replaced with a heat interface unit (HIU), to supply hot water instantaneously or via a hot water cylinder, with a heat metre for billing. Therefore, most homes can connect without upgrading their central heating system. Electrically heated homes would need to install a wet system of radiators and pipes in order to be able to connect. The district heat network operator takes on the responsibility to maintain and replace the HIUs. The heat interface unit installed is property of the Council

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[83] http://www.swaffham-prior.co.uk/pc/CLT/study.pdf

[84] http://nationalheatmap.cse.org.uk/

[85] www.epcregister.com

and will replace existing boilers and be maintained by trained contractors. The installation of a heat network requires no upfront capital investment by the homeowner which might dissuade uptake of low carbon technologies. Customer satisfaction is paramount so the heat supply needs to be cost-effective and reliable.

Figure 1: A map of the heat network at Swaffham Prior, with hot water pipes (red) extending from the energy centre (white) underneath the roads to all the houses in the village

The financial assessment assumed that 50% of buildings would initially connect to the heat network, increasing to 90% over a five year period. The pricing for consumers was calculated based on the cost of oil heating. The assumed income from heat sales is equal to the current costs of provision of oil based heating in each house (EPC data used to estimate current heating costs). District heating does not have fixed costs associated with oil (e.g. boiler and oil tank servicing, replacement, repair) but these are spread over time as part of a standing charge. Importantly, the SPHN network needed to be equivalent to or cheaper than oil to attract customers and make it worthwhile to connect.

The total capital cost of the project is £11.9 million, to include £3.2 million of grant funding from the Heat Network Investment Project[86]. HNIP has £320 million to spend supporting the development of heat networks in the next 4 years, given out in grants or loans (although grants are mostly available to the public

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[86] https://cambridgeshire.cmis.uk.com/CCC_live/Document.ashx?czJKcaeAi5tUFL1DTL2UE4zNRBcoShgo=vKlVqcFqafxGke7QLsnMyI4IfKrXo1iz%2b8obHEKn%2fB8D%2blDfxN9gCw%3d%3d&rUzwRPf%2bZ3zd4E7Ikn8Lyw%3d%3d=pwRE6AGJFLDNlh225F5QMaQWCtPHwdhUfCZ%2fLUQzgA2uL5jNRG4jdQ%3d%3d&mCTIbCubSFfXsDGW9IXnlg%3d%3d=hFflUdN3100%3d&kCx1AnS9%2fpWZQ40DXFvdEw%3d%3d=hFflUdN3100%3d&uJovDxwdjMPoYv%2bAJvYtyA%3d%3d=ctNJFf55vVA%3d&FgPlIEJYlotS%2bYGoBi5olA%3d%3d=NHdURQburHA%3d&d9Qjj0ag1Pd993jsyOJqFvmyB7X0CSQK=ctNJFf55vVA%3d&WGewmoAfeNR9xqBux0r1Q8Za60lavYmz=ctNJFf55vVA%3d&WGewmoAfeNQ16B2MHuCpMRKZMwaG1PaO=ctNJFf55vVA%3d

sector). However, the HNIP funding is unlikely to exceed 50% of required investment. The feasibility of the project mainly depends on the connection rate; if there are fewer connections, only a small decrease in initial investment and operating costs is expected.

The Swaffham Prior heat network is installing a commercial-sized heat pump so planning permission was needed. To apply for planning permission, engaging with the community was key to understanding their concerns – these include visual landscape impact; heritage assets; biodiversity and geology; residential amenity; access and transport impacts.

The heat network in Swaffham Prior should save 70,975 tonnes of carbon over a 60 year period. However, the actual savings are very sensitive to carbon intensity of the electricity grid and the chosen period to average it over.

Gateshead

The heat network established in Gateshead is funded and owned by Gateshead Council via a grant from the European Regional Development fund. All customers receive a 5% discount compared to market energy prices.

Heat is provided through 5 km of pipes and high-voltage electricity to the domestic, commercial and public sectors. There is a mixture of battery storage and combined heat and power (4 MW engine) with heat storage. The energy centre provides customers with heat. When heat is provided by gas CHP engines, electricity is also generated and supplied through private wires at a lower cost to customers. Conventional gas boilers are used as a backup during periods of high heat demand.

Initially the project only supplied public buildings Gateshead Civic Centre, the Sage Gateshead, BALTIC and Gateshead College and homes managed by Gateshead Council. With time, the network has grown to connect other Council buildings and depots, leisure centre, Shipley Art Gallery and Talmudical College and new-build office building. It will be extended towards Gateshead Stadium, a 300-home new housing development, Gateshead Quays and 5 high rise social housing blocks.

The project aims to be zero carbon by 2030 by using a 6 MW mine water (from abandoned mine workings) heat pump energy centre to supplement the network. 0.5 MW is currently connected to the network, with increasing capacity by 2025. The mine water can also be used as a cooling network.

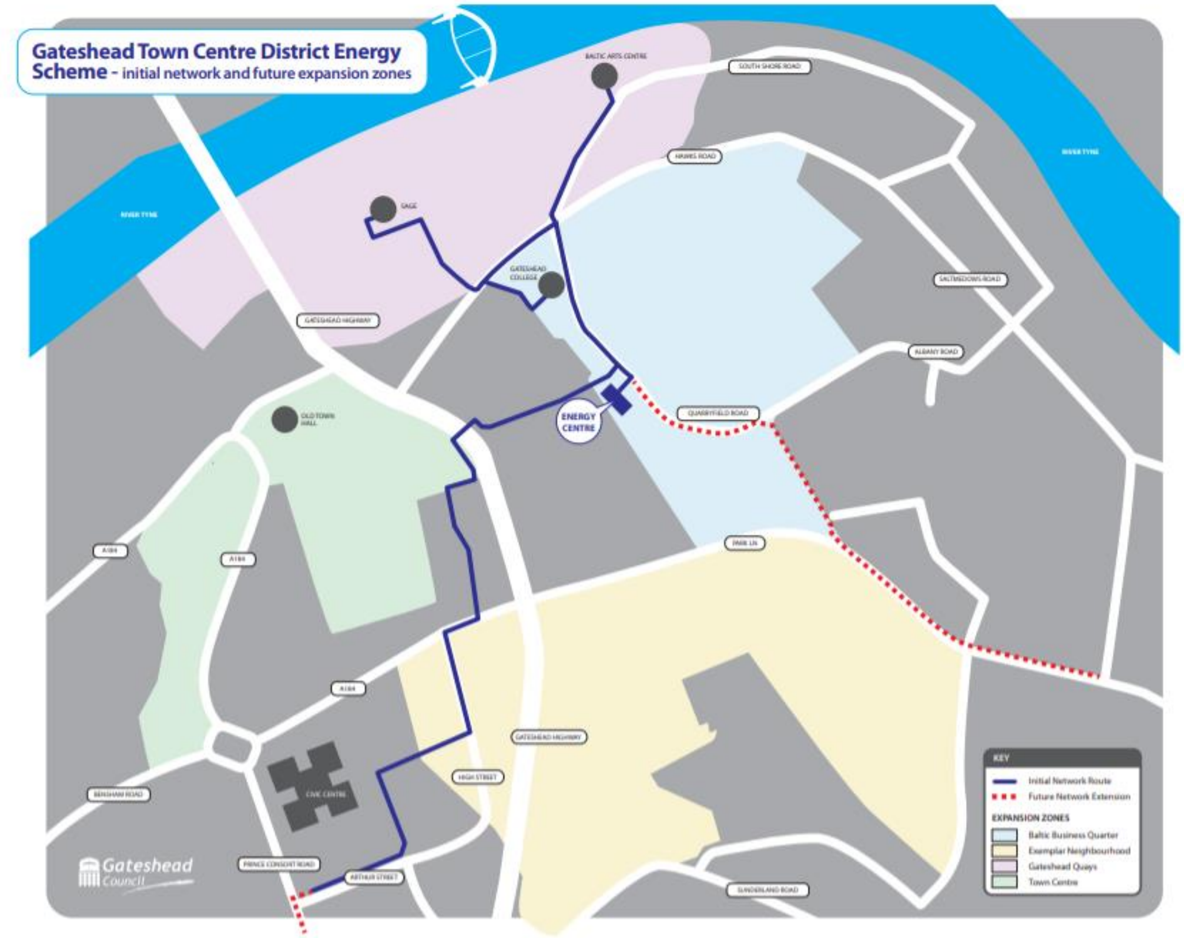

Figure 2: A map of the initial heat network (blue) and proposed future expansion zones (red dashed) extending from the energy centre (blue) in Gateshead.

Leeds

In Leeds, 1,983 council homes and numerous businesses will be connected to a low carbon heat and hot water network (19 km of pipes). The network is reusing heat (waste heat) that is already produced at Leeds' recycling and energy recovery facility. Steam generated from black bin waste is converted into hot water. Gas-fired boilers used as backup. Carbon emissions are predicted to be reduced by 11,000 tonnes per year for the city. The project will cost £36 million with £4 million of funding coming from the government's Heat Networks Investment programme.

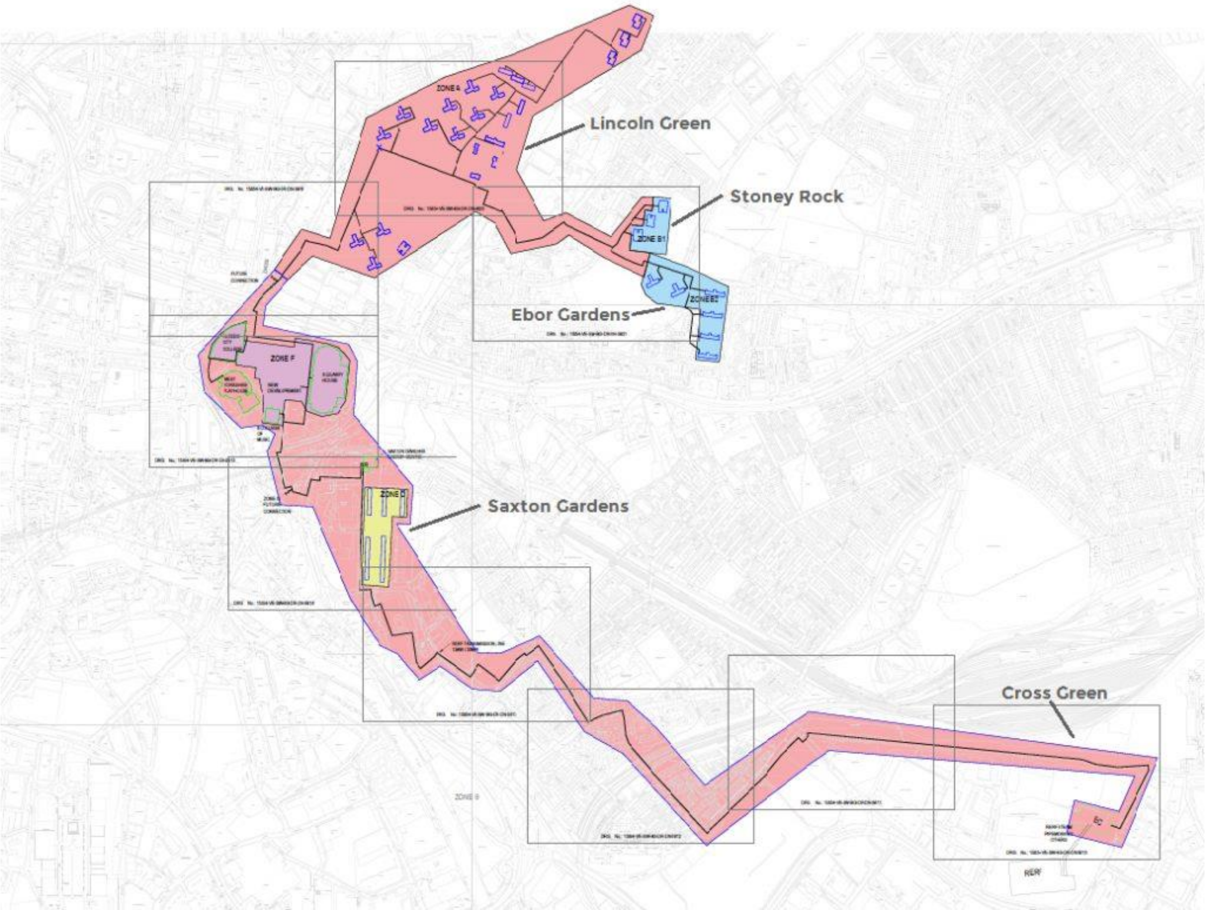

Figure 3: A map of the proposed heat network in Leeds city centre, connecting council homes and businesses to waste heat produced from the recycling plant

Islington, London (Bunhill 2)

Bunhill 2 is the second phase of Islington Council's Bunhill Heat and Power scheme – a heat network in Islington that was established in 2012 to warm approximately 800 homes and two leisure centres[87]. Islington had already built the first phase of the Bunhill heat network, delivering efficient heating to 850 homes through a gas combined heat and power (CHP) scheme at Bunhill Energy Centre 1. Ramboll[88] was commissioned by Islington Council in London to design and deliver the district-wide heating network to provide cheaper and greener heat by using unwanted heat from the London Underground.

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[87] https://www.dezeen.com/2020/03/11/bunhill-2-energy-centre-london-underground-uk-architecture/

[88] https://uk.ramboll.com/projects/ruk/heating-up-london

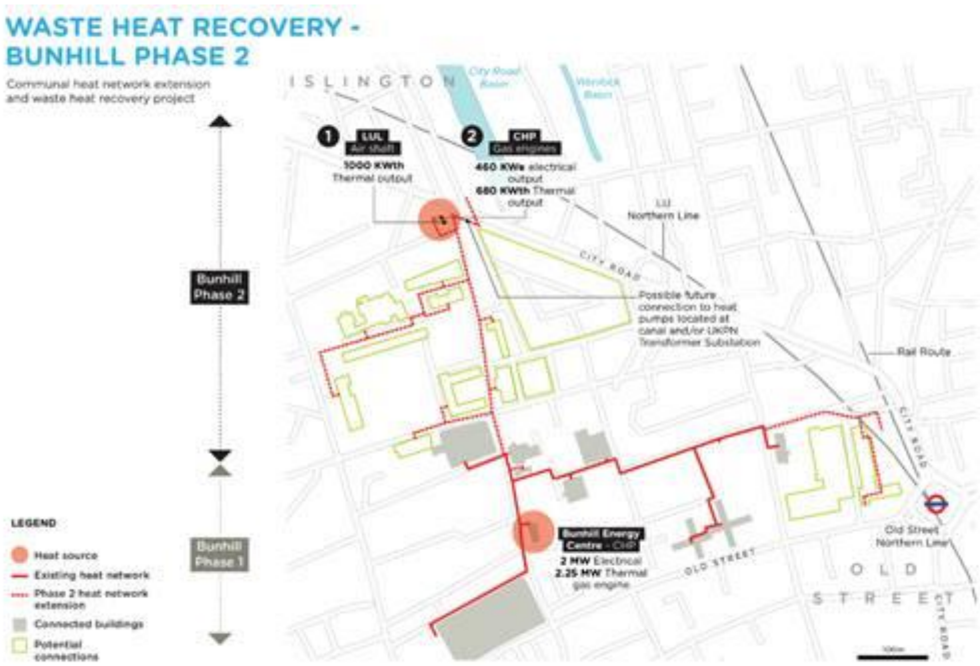

Figure 4: A map of the Bunhill district heating network

The Northern Line is used as waste energy to provide a low carbon, low cost heat source for local homes and businesses, which is largely council housing and leisure centres. A London Underground ventilation shaft is used as the heat source, where 18-28 degrees Celsius air is exhausted to the atmosphere from a long abandoned tube station (City Road, between Old Street and Angel), now part of the Northern Line tunnel ventilation system. This source of waste heat is exploited by heat pumps, which capture the waste heat and upgrade it to approximately 80 degrees Celsius. Northern Line passengers also benefit from cooler tunnels, while London residents as a whole benefit from lower carbon emissions and improved air quality as gas combustion is displaced. Ramboll investigated the impact of lower temperatures for the connected buildings' heating and domestic hot water loads to ensure demands could be met and end user comfort wasn't compromised. Ramboll's investigations proved the lower temperatures for the connected buildings' heating and domestic hot water loads met demands and end user comfort wasn't compromised. Another design innovation was to incorporate two smaller gas-fired CHP engines which, as well as providing heat, also supply electricity directly to the heat pump when the power from the grid is most expensive, helping reduce the cost of the heat. Funding for this innovative feature was supplemented by a grant from the GLA. A second thermal store also enhances system technical and economic performance.

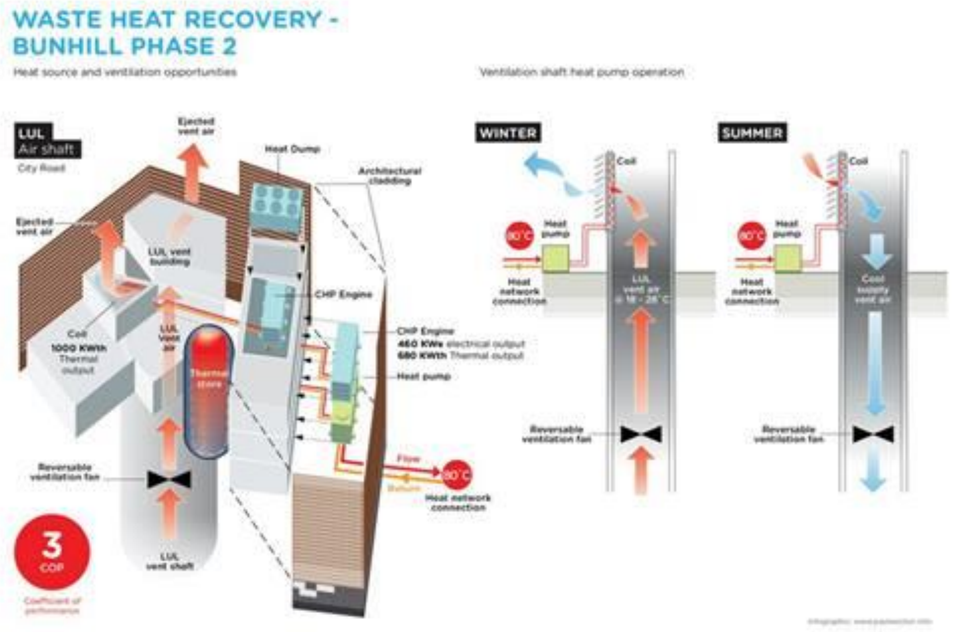

Figure 5: How waste heat is extracted from a London Underground air shaft and upgraded using heat pumps.

As well as being financed by the London Borough of Islington, the award-winning Bunhill Heat and Power Network was partly funded by the EU CELSIUS Project[89], and is supported by other London project partners including the Greater London Authority, TfL and UK Power Networks.

Figure 6: The design of the Bunhill 2 Energy Centre.

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[89] https://celsiuscity.eu/

Solihull[90]

Figure 7: Where the energy centre will be located in Solihull, in relation to the Tudor Grange Leisure Centre and other local landmarks.

In Solihull, a planned district heating network intends to provide low carbon heating and electricity to council buildings, offices and school/college sites in the vicinity.

The district heating network will mostly be powered by air source heat pumps although gas boilers will provide back-up on cold days. The heat pumps rely on evaporator units on the roof. This starts the process which allows for pressurised hot water to be carried via underground pipes to the various buildings which form part of the network.

The proposals also involve the removal of some vegetation, although the council has said that "the majority" of trees on-site would be retained. They have committed to planting new greenery as part of the scheme to ensure a "net gain" in wildlife habitat.

The striking structure of the energy centre, to be erected next to Tudor Grange Leisure Centre, is intended to serve as the "beating heart" of a district heat network which will plumb into buildings across the wider area. The two storey building will be built next to the car parking area at Tudor Grange Leisure Centre, in Blossomfield Road as it needs to be close to the various buildings that the system will serve in the vicinity of the town centre, while being large enough to house all the necessary equipment. The colour of the energy

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[90] https://www.birminghammail.co.uk/news/midlands-news/new-details-designs-revealed-energy-19973178

centre is intended to blend in with the surrounding parkland, while the perforated cladding is intended to resemble the tree canopy.

Figure 8: An artist's concept for the energy centre that will power the district heat network in Solihull town centre. The design is designed to blend in with local parkland although there is likely to be concern about the impact on trees.