Programme Area: Smart Systems and Heat

Project: WP2 Manchester Local Area Energy Strategy

Title: Local Area Energy Strategy - Bury Evidence Base Report

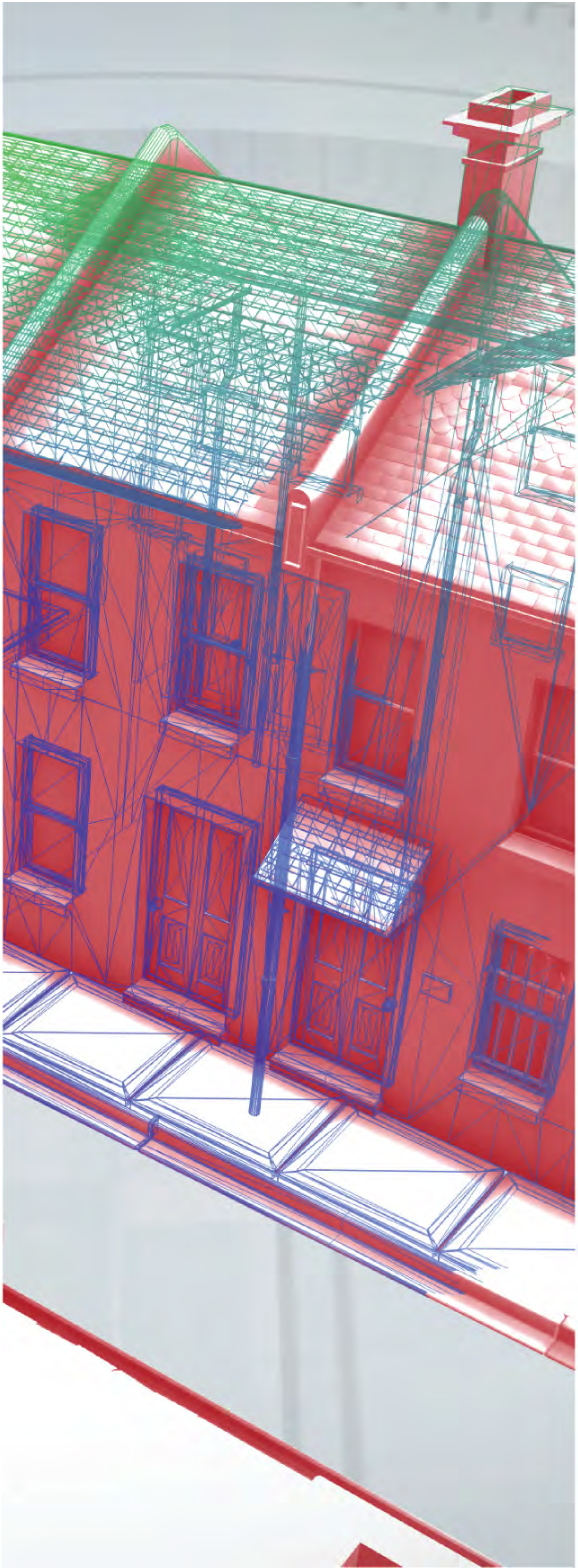
Abstract:

The Listed Deliverable package originally comprised a single document, the Local Area Energy Transition Plan. This has since been divided into two documents:

- The Strategy document is supplied as a draft working document for Bury Council to take forward in a format of their choice. It provides a high-level outlook and timeline for technological and related changes necessary to achieve the decarbonisation of heating in Bridgend.
- The Evidence Base is presented in final format the results of the underlying EPN analysis which underpins the Strategy and explains the modelling methodology, assumptions and limitations.

Context:

The Spatial Energy Plan for Greater Manchester Combined Authority project was commissioned as part of the Energy Technologies Institute (ETI) Smart Systems and Heat Programme and undertaken through collaboration between the Greater Manchester Combined Authority and the Energy Systems Catapult. The study has consolidated the significant data and existing evidence relating to the local energy system to provide a platform for future energy planning in the region and the development of suitable policies within the emerging spatial planning framework for Greater Manchester.



Bury Council

Local Area Energy Planning

Evidence Base Report

Delivered by

About This Document

This document sets out the evidence base in support of a local energy strategy for Bury.

This evidence base is divided into 6 key sections:

Section One explores the background to the project in Bury

Section Two explains the methodology and input data used in EnergyPath Networks[1]

Section Three sets out Bury's current energy system

Section Four sets out the methodologies, results and findings from the modelled scenarios

Section Five considers the results from an area based approach

Section Six draws the key conclusions

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[1] EnergyPath is a registered trademark of the Energy Technologies Institute LLP

Acknowledgements

The project was commissioned and funded by the Energy Technologies Institute (ETI) as part of the Smart Systems and Heat Programme and delivered by a public-private partnership between Energy Systems Catapult, Bury Council, Greater Manchester Combined Authority, Cadent and Electricity North West. Technical support was provided by Baringa Partners LLP and Arup (Ove Arup and Partners Ltd). The creation of the Strategy and its Evidence Base was motivated by the shared commitment to respond effectively to meet the requirements of International, European and national decarbonisation targets and the policy imperative to address climate change and transition to a low carbon economy.

Maps in this document contain OS data:

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This document acts as a full record of the modelling completed for Bury. It is not intended to be read in full but instead used as a reference to the work completed, to be consulted as necessary.

The phrase ‘optimal’ is used in this document as a shortcut for “shown by the Energy Path modelling to be the lowest cost to reach the set carbon target”. It only represents factors included in the model; there may be other considerations that make the model suggestions impractical or not the best choice.

References to carbon targets or emissions cover only those in-scope for the model and project. These are emissions relating to heat and energy use in buildings. Transport emissions are not in-scope, although electric vehicle charging load is considered.

Glossary

Term	Elaboration
Analysis area	An area within Bury used as a unit for analysis in EnergyPath Networks. These are defined by the existing electricity grid assets.
Characteristic (weather) days	A set of daily weather profiles. Each profile represents different seasonal average conditions or the coldest day, which represents peak heating demand.
Clockwork	An ESME scenario that assumes a well-coordinated, long-term investment plan, based on national-level planning, to ensure a steady decarbonisation of power, deployment of large scale heat networks and the phasing out of the current gas grid.
Patchwork	An ESME scenario that assumes less leadership from central government, resulting in a patchwork of distinct energy strategies at a local area level. Cities and regions compete for central support to meet energy needs tailored to local conditions.
Study area	The total land considered with the EnergyPath Networks analysis. In this report, the boundary contains the land that Bury Council is responsible for.
Transition one	The time period over which existing heating systems reach their end of life and require replacement.
Transition two	The time period over which transition 1 heating systems reach their end of life and require replacement.

Acronyms

Acronym	Elaboration
ASHP	Air Source Heat Pump
ATES	Aquifer Thermal Energy Store
AQMA	Air Quality Management Area
BEIS	UK Government's Department for Business, Energy and Industrial Strategy
CO_2	Carbon Dioxide (see Greenhouse Gases)
CCC	UK Committee on Climate Change
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
CIBSE	Chartered Institute of Building Services Engineers
DECC	(Former) Department of Energy and Climate Change (now part of BEIS)
DHN	District Heating Network
DNO	Distribution Network Operator
EHS	English Housing Survey
EPC	Energy Performance Certificate
ESC	Energy Systems Catapult
EfW	Energy from Waste
ENW	Electricity North West
EPN	EnergyPath Networks
ESCo	Energy Service Company
ESME	Energy System Modelling Environment
ETI	Energy Technologies Institute
EV	Electric Vehicle
GHG	Green House Gases
GIS	Geographical Information System
GMSF	Greater Manchester Spatial Framework (draft)
GSHP	Ground Source Heat Pump
HOM	Housing Options Module
HV	High Voltage (for the purposes of this study defined as 11kV)
LAES	Local Area Energy Strategy
LIDAR	Light Detection and Ranging
LPG	Liquified Petroleum Gas
LV	Low Voltage (for the purposes of this study defined as 400V, which is equivalent to 240V in a home)
NAM	Network Analysis Module
OS	Ordnance Survey
POM	Pathway Optimisation Module
RHI	Renewable Heat Incentive
SAM	Spatial Analysis Module
SAP	Standard Assessment Procedure
SNG	Synthetic Natural Gas
(Solar) PV	(Solar) photovoltaics
SSH	Smart Systems and Heat (programme)
UPRN	Unique Property Reference Number
VOA	Valuation Office Agency

Contents

1 Executive Summary

1.1 Context

This project was commissioned by the Energy Technologies Institute as part of the Smart Systems and Heat Programme. It has been undertaken through a collaboration between Bury Council, Greater Manchester Combined Authority, Electricity North West, Cadent and the Energy Systems Catapult, utilising the ETI's EnergyPath^{TM} Networks modelling capability to pilot an evidence-based whole system process of local area energy planning.

The UK has committed to a legally binding obligation to cut greenhouse gas emissions by 80% by 2050 (against 1990 levels). Energy use in buildings is a significant contributor to carbon emissions. Heating accounts for over 40%[2] of the UK's total demand for energy and so decarbonising heat is critical to achieve a low carbon energy system. During this project Bury Council committed to the UK100 target, which is described as being 100% clean energy by 2050, and Greater Manchester Combined Authority proposed the possibility of bringing carbon reductions forward to 2040.

1.2 EnergyPath Networks

EnergyPath Networks is a whole system optimisation analysis framework. It works out the pathway for a local area to cut its emissions between now and 2050 at the lowest total cost to society. The focus is decarbonisation of heat and energy used by buildings at a local level. To ensure that costs and benefits are correctly represented for the area being analysed it considers:

- gas, electricity and heat
- the construction, upgrading or decommissioning of buildings and networks, including upgrading building fabric and converting building heating systems
- the spatial relationships between buildings and the networks that serve them

1.3 Initial Modelling

Extensive data was collected and collated, and a representation of Bury's current energy system was built, with approximately 82,500 current homes and 9,500 non-domestic buildings. Modelling to 2050 without a local carbon target showed that there would not be widespread change from the current energy system, with around 95% of buildings staying on their current gas heating system. Some limited use of gas CHP-fed district heating was found to be cost effective, with approximately 4000 homes and 640 non-domestic buildings connecting to a heat network.

The first carbon target scenario modelled at this stage was to reduce in-scope emissions by 90% by 2050, requiring widespread and significant local energy system change in Bury. Approximately two-thirds of domestic buildings would need to move away from heating using gas boilers. Meeting this carbon target was modelled to cost an extra £560m, a 6.5% increase in the total local energy system cost compared to not having a local carbon target. Further details about this scenario can be found in sections 4 and 5.

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[2] October 2016, Next Steps for UK heat policy, Committee on Climate Change

1.4 Sensitivity Testing

A sensitivity analysis was undertaken testing how different external factors may influence the lowest cost plan for Bury to decarbonise heating in buildings. These scenarios gave insight into how the factors could influence Bury's future energy system.

Scenario	Summary
National Pathway	The lowest cost plan to decarbonise Bury is sensitive to changes in the national energy system. Testing a national scenario with more strategic centralised decision making revealed the plan would have almost 50% fewer homes connected to district heating and a lower total cost of decarbonisation, approximately half that of the original scenario.
Energy Costs	A range of different future gas and electricity costs were tested. The lowest cost plan to decarbonise Bury was sensitive to electricity cost, with greater district heat deployment as the cost increases. Several areas of Bury were identified as most sensitive to these costs.
Technology Cost	There is significant uncertainty in future technology and infrastructure costs. Testing this uncertainty shows how the lowest cost plan for decarbonising Bury varies as these future costs change. The use of gas boilers and district heat varied significantly, but if the Bury's plan adapts to the changes in costs then the overall cost of achieving the carbon target varied by only a few percent. The cost of district heat network infrastructure was a key factor in heating system choice.
Insulation for Fuel Poverty	Insulation has benefits other than carbon saving, such as reducing fuel poverty. The Fuel Poverty Strategy creates an obligation for Local Authorities to help insulate their fuel poor homes. Houses with the characteristics most closely associated with households in fuel poverty were identified and insulation was applied in the model. Generally, this extra insulation did not change the plan to decarbonise, except for some small adjustments in which buildings remained on gas.
Lower Carbon Gas	The model was tested with a gas hydrogen blend (up to 20% hydrogen) with a higher cost but lower carbon content than natural gas. If the blend was deployed before 2040 the cost made it less cost effective than natural gas. After 2040 it was of some use, and allowed 4,000 extra homes to remain on gas boilers until at least the end of the modelled period in 2050.
Domestic Battery Storage	Use of household batteries was explored to understand if it could mitigate network reinforcements. Household batteries were only found to be cost effective when there was sufficient difference between overnight and daytime grid electricity prices (2040 onwards). Their usage was not found to influence reinforcements or heating system choice.
Different Carbon Targets	Testing a number of different carbon targets indicated that an 85% target level was the point at which significant heating system change was required. Beyond this point the cost of cutting carbon rapidly increased. In general, increasing the local carbon target meant decarbonising more buildings, but not requiring different choices for buildings that are already low carbon under lower targets.
Max Carbon Reduction	This sensitivity tested a scenario where carbon was cut as quickly and completely as possible. In this scenario all low carbon heating systems were in place by 2035. Cutting the carbon as quickly as possible cost four times more than achieving the same reduction by 2050, and required immediate network and heating system change.

1.5 Final Modelling

After the sensitivity analysis a final set of scenarios were modelled, incorporating data and model improvements and lessons learnt from the sensitivities.

Scenarios **with almost complete decarbonisation (98% from 1990 levels) by 2050 and a decade earlier by 2040 were tested**, reflecting updated local priorities.

By 2050 **approximately one third of homes are connected to heat networks and two thirds have electric heat pumps in either scenario**. Detached homes are served by Ground Source Heat Pumps, and larger homes may need a gas-electric Hybrid Heat Pump.

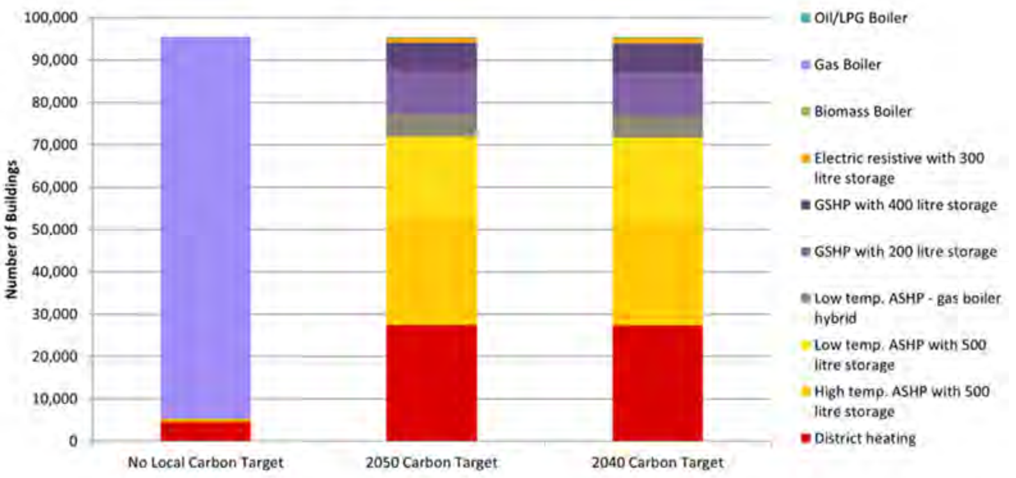

Figure 1-1 Domestic Heating Systems in 2050

Under the 2040 target heating system change needs to occur earlier, when current systems first reach their end of life.

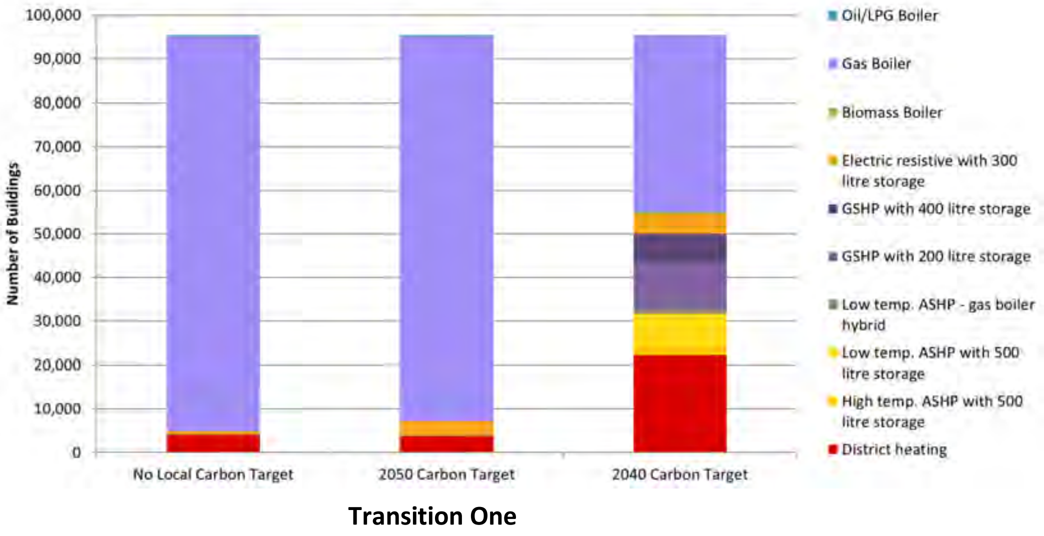

Figure 1-2 Domestic Heating Systems by 2035

There are modelled variations in heating system choice by building type and area across Bury.

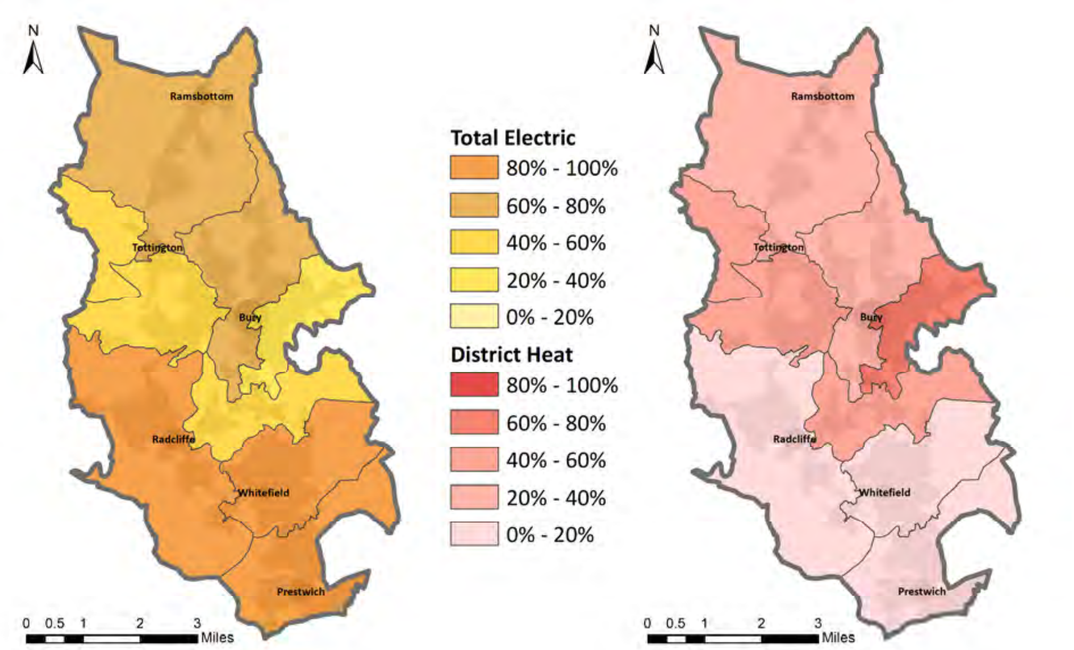

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Figure 1-3 2050 Electric and District Heat Deployment by Area

All non-domestic buildings that are considered suitable are switched to heat networks.

By 2050 there is widespread PV deployment, and under the 2040 target it is deployed earlier to save carbon, when emissions from grid electricity production are higher. Batteries are not shown to be cost effective based on current forecasts for battery and electricity costs.

Gas demand falls considerably across Bury, but there is still some demand in all areas. **Peak electricity demand increases, requiring significant network reinforcements**. **Heat network infrastructure is required across Bury**, and is needed earlier under the 2040 target.

In the early time periods gas CHP can be used as a cost-effective heat source for heat networks, but **the heat needs to be generated by electric heat pumps as the carbon target tightens**. At peak winter times some gas technologies are still used.

The 2050 carbon target[3] is modelled to cost £1.1bn[4] more than not having a local carbon target, an increase of 16%. The 2040 target **is modelled to cost a further £960m more, an 86% higher spend on carbon reduction compared to the 2050 target.** The main extra spend is on more electricity in earlier years.

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[3] A 98% reduction in in-scope emissions from 1990 levels. In-scope emissions are those relating to buildings. Transport emissions are not included, although electric vehicle charging at home is in scope.

[4] Discounted costs, methodology explained further in section 3.15

1.6 Network Influences by Area

To allowing modelling to 2050, assumptions have to be made about the future. There is significant uncertainty in some of these assumptions, for example in future costs and national policy. To help manage this uncertainty analysing the results of all the scenarios together identified the most consistent modelled domestic heating systems for the areas of Bury across different values of these assumptions. The results can be broken down further by building type within the areas.

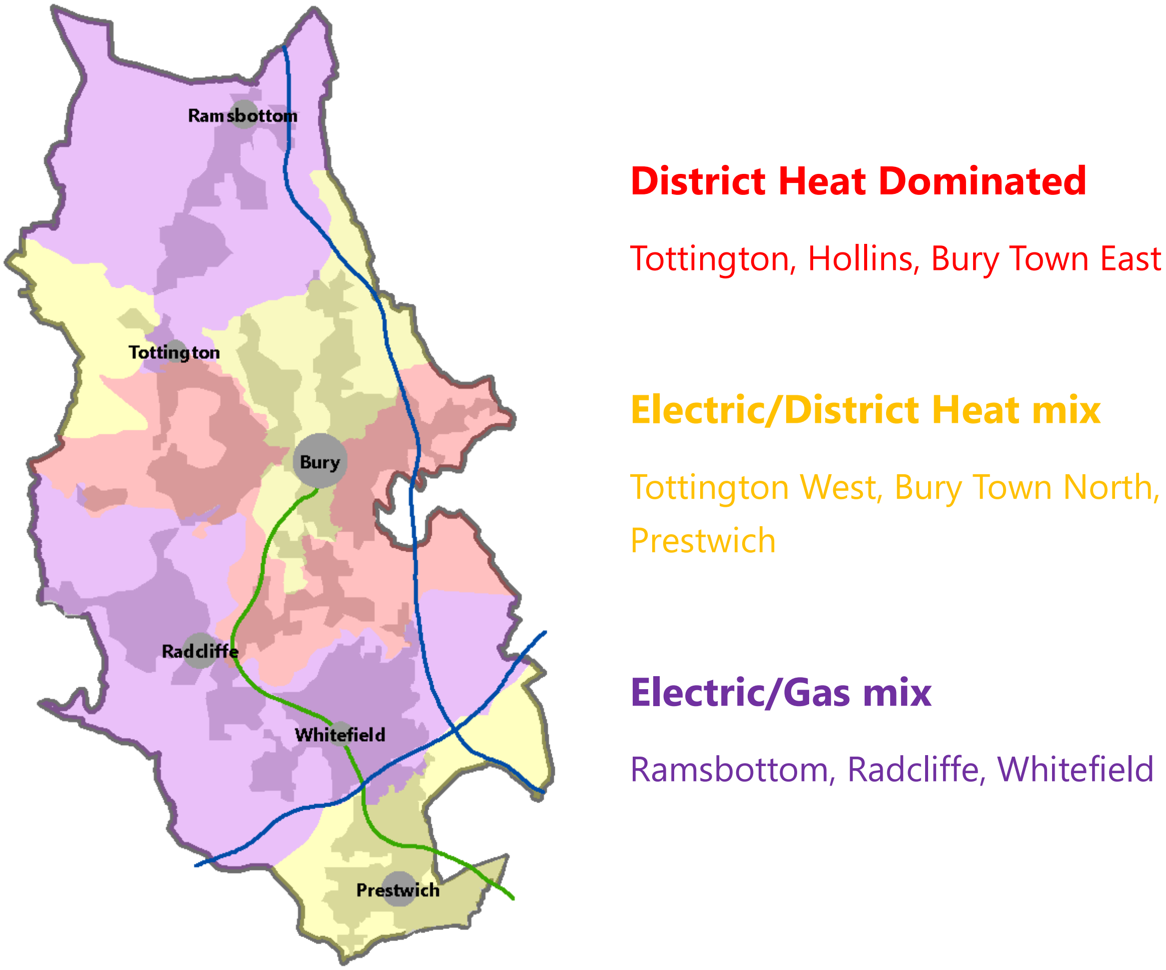

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Figure 1-4 Areas of Network Choice in Bury

1.7 Conclusions

By 2050 Bury can reduce its building emissions by 98% from 1990 levels, but significant change to domestic heating systems across Bury would be required, swapping gas boilers for a variety of electric heating and district heat systems.

There are limited windows of opportunity to replace domestic heating systems. Heating systems are naturally replaced at the end of their lifetimes, typically giving only two opportunities to replace between now and 2050.

If Bury and Greater Manchester aim for a more ambitious carbon target of nearly zero carbon by 2040 then low carbon heating needs to accelerate. Heating systems need to become low carbon at the earliest

opportunity i.e. gas boilers due to be replaced in the next couple of years need to begin to switch to low carbon options, otherwise the target will become unachievable.

For some areas and homes in Bury, electric heating is a cost-effective way to decarbonise, with the choice of system determined by the size and type of building.

For other areas district heating networks may be a lower cost solution. The modelling shows that in these areas the choice between heat pumps or district heat is very sensitive to the cost of grid electricity and the cost of installing heat network infrastructure, specifically the pipes in the ground.

Decarbonising non-domestic buildings is necessary. Non-domestic buildings vary more than domestics and the available data is poorer. The possible heating and building fabric changes are more complex and so they are more difficult to model.

Local renewable energy generation can play an important role. Increasing uptake of solar PV could play a role in reducing carbon and can be a cost-effective addition to the local energy system, as the modelling shows in the 2040s the cost of low carbon grid electricity increases above the cost of local PV. The sensitivity work showed that battery storage may be a cost-effective option if there is a large enough variation in electricity prices throughout the day and battery costs were lower than current projections.

Meeting carbon targets will come at a cost. The total cost of a local energy system is large between now and 2050. Meeting a 2050 carbon target[5]was modelled to cost an extra £1.1bn[6], but this is just 16% extra compared to not having a carbon target. Cutting carbon sooner will cost more. Aiming for a 2040 (rather than 2050) carbon target costs an extra £960m, although it brings much lower total emissions over the period.

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[5] A 98% reduction in in-scope emissions from 1990 levels. In-scope emissions are those relating to buildings. Transport emissions are not included, although electric vehicle charging at home is in scope.

[6] Discounted costs

2 Introduction

2.1 Context

The UK is committed to reducing its greenhouse gas emissions by at least 80% by 2050, relative to 1990 levels. Approximately 80% of the UK's greenhouse gas emissions are carbon dioxide[7]. Heat accounts for over 40% of the UK's demand for energy, and around 20% of the UK's CO_2 emissions come from domestic heating and hot water.[8]

Currently, in general, local energy planning and local energy system innovation is performed in response to the availability of funding and incentives. Existing network assets are managed by gas, electricity and (perhaps) heat network operators in silos. However, there is not a one size fits all solution to decarbonising our homes and buildings. Individual local areas have very different characteristics and are likely to require local solutions.

A new approach to planning and delivering local energy systems is needed if we are to meet the challenge of climate change and deliver a resilient and low carbon energy system that works for people, communities and businesses.

The transition to low carbon can deliver numerous benefits to the local area including the reduction of carbon emissions; the creation of new jobs associated with the installation of new energy networks and retrofitting domestic buildings; and a long-term legacy through the development of local skills. Where options include improving energy efficiency these may help to reduce levels of fuel poverty.

This Evidence Base provides background, methodologies and insights from detailed modelling analysis. It should be considered in conjunction with a Local Area Energy Strategy (LAES) that takes the findings of analysis forward and presents them in the wider context by considering consumers, policy & regulation and commercial factors.

Together they should enable Bury Council to prioritise specific projects that will support its carbon reduction ambitions. It will also support the development, demonstration and evaluation of low carbon technologies and infrastructure priorities in the near and long term, as well as forming part of the evidence base for updates to the council's statutory Development Plan in due course.

2.2 Project Overview

A project to pilot a process of local area energy planning was commissioned by The Energy Technologies Institute as part of the Smart Systems and Heat programme. This is one of three pilot studies with different local authorities and has been undertaken through a collaboration between Bury Council, Electricity North West, Cadent, Greater Manchester Combined Authority (the key stakeholders) and the Energy Systems Catapult, utilising the ETI's EnergyPath Networks modelling capability. This aims to provide a foundation for

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[7] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2017

[8] Committee on Climate Change, https://www.theccc.org.uk/publication/next-steps-for-uk-heat-policy/

the Council, Combined Authority and other key stakeholders to work collaboratively and plan positively for long-term energy system change and to design and demonstrate location-specific smart energy systems.

EnergyPath Networks is a whole system optimisation and option comparison framework which has been developed in partnership with local authorities to evaluate cost-effective local energy system design options. EnergyPath Networks:

- Is a multi-vector approach which allows trade-offs between energy vectors and networks to be understood.
- Has the ability to understand the spatial relationships between buildings and the networks that serve them so that costs and benefits correctly represent the area being analysed.
- Uses an optimisation process to compare a large number of combinations of options, made up of tens of thousands of different pathways.
- Optimisation for multiple analysis areas within the study area and for four separate time periods out to 2050.

A detailed explanation of EnergyPath Networks is provided in Section 3.

2.2.1 Key Scope

The development of the Evidence Base is based upon the analysis of low-carbon heating options to enable Bury to decarbonise. Studies have shown the elimination of emissions from buildings is more cost effective than deeper cuts in other energy sectors such as heavy goods or international transport[9], so it is an appropriate place to focus initially. The key parameters of the analysis include:

- Heating systems and building fabric improvements for domestic buildings.
- The potential for non-domestic buildings to connect to heat networks.
- The resulting impacts on network infrastructure including upgrades to existing (e.g. reinforcing the electricity network) and the building of new infrastructure such as a heat network.

It should be noted that:

- Transport and associated emissions are not included in the EnergyPath Networks modelling. However, their implications for the overall carbon budget were considered in the process of setting a local carbon reduction target for heat. Expected uptake of electric vehicles has been considered so that the emissions and cost of charging and the impact of electric vehicles on the electricity network is assessed within the modelling approach.
- The Evidence Base does not consider the conversion of the gas grid for pure hydrogen, but does consider a gas-hydrogen blend.
- The model focuses on identifying the options with the lowest total cost (capital and operational) to reduce carbon emissions. When developing an LAES the council will need to consider these options in the wider context of their impact on energy costs and fuel poverty for local residents.

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[9] http://www.eti.co.uk/insights/heat-insight-decarbonising-heat-for-uk-homes/

3 EnergyPath Networks Modelling Approach

This section describes the EnergyPath Networks modelling approach that has been used in Bury. It explains the data and inputs that are created on a building-by-building level of granularity, along with the process EnergyPath Networks uses to assess the options through its Decision Module. The Decision Module compares decarbonisation pathways and selects the combination that meets the CO_2 emissions target set for the local area at the lowest possible total cost to society[10].

A variety of local energy system pathways are possible to meet 2050 emissions targets. Running multiple EnergyPath Networks scenarios and doing detailed sensitivity analyses reveals decarbonisation themes that are prevalent across all scenarios.

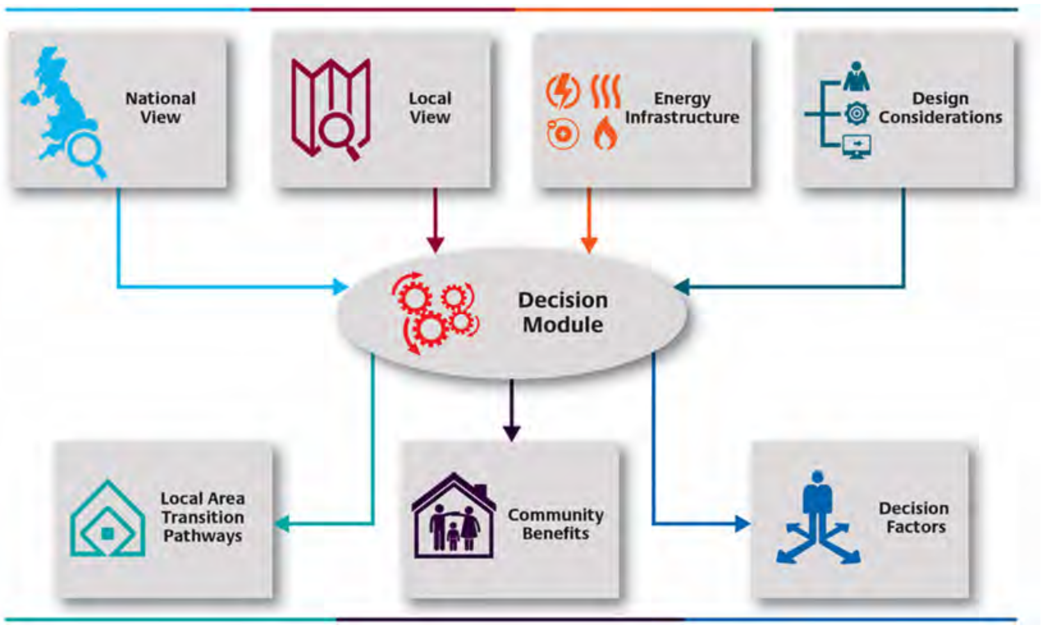

Figure 3-1 Overview of EnergyPath Networks

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[10] For the total costs considered in the model and as set out in the following sections. Some costs are not considered, for example electricity network reinforcements outside of the study area or the disruption to the local economy during construction.

3.1 Overview

EnergyPath Networks is a whole system optimisation analysis framework. It uses optimisation techniques in a Decision Module to compare many combinations of options (tens of thousands) rather than relying on comparisons between a limited set of user-defined scenarios. The focus is decarbonisation of heat and energy used by buildings at a local level. This enables informed, evidence-based decision-making.

The analyses are set in a national energy strategy context, using scenarios created with input from industry and government stakeholders. The analyses include:

- Integration and trade-off between gas, heat and power as methods of meeting heat demand.
- Integration through the energy supply chain from building, upgrading or decommissioning assets (production, conversion, distribution and storage) to upgrading building fabric and converting building heating systems.
- Integration of existing and new build domestic and commercial buildings.
- The spatial relationships between buildings and the networks that serve them, so that costs and benefits are correctly represented for the area being analysed.
- Spatial granularity down to building level when the input data is of appropriate quality.
- A modelled time frame of 2015 to 2050.

Taken together, the analyses can be used to ensure long-term resilience in near-term decisions, mitigating the risks of stranded assets.

3.2 Data

EnergyPath Networks requires data for the local buildings and energy networks within the study area. Primary sources of data used in this study on building types, condition and thermal properties are shown in Table 3-1. Primary sources of gas and electricity network data, such as network configuration, topography and heat networks, are shown in Table 3-2.

Table 3-1 Primary Data Sources used in EnergyPath Networks Study of Bury - Buildings

Building Data	
Item	**Primary Data Sets**
Domestic building archetype	GeoInformation building classification, Ordnance Survey (OS) AddressBase, Bury Council data, Six Town Housing social housing data
Domestic building thermal properties	Buildings Research Establishment: Standard Assessment Procedure calculator
Domestic building current condition	Bury Council data, Six Town Housing social housing data, English Housing Survey
Domestic appliance use profiles	DECC household electricity survey[11]
Domestic retrofit costs by building type and quantity of insulation	Energy Technologies Institute data[12]
Domestic heating system prices	DECC inputs into domestic RHI
EV charging profiles	National Travel Survey analysis[13]
Non-domestic building use class	Valuation Office Agency (VOA), Ordnance Survey, GeoInformation building classification
Non-domestic building energy profiles	University College London CARB2 data[14], CIBSE energy benchmarks[15]

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[11] https://www.gov.uk/government/publications/household-electricity-survey--2

[12] ETI's Optimising Thermal Efficiency of Existing Housing project .Element Energy report "Review of potential for carbon savings from residential energy efficiency Final report" https://www.theccc.org.uk/wp-content/uploads/2013/12/Review-of-potential-for-carbon-savings-from-residential-energy-efficiency-Final-report-A-160114.pdf

[13] Internal Project. Unpublished

[14] http://www.ucl.ac.uk/energy-models/models/carb2

[15] The Chartered Institution of Building Services Engineers*: Energy benchmarks (TM46: 2008)*

Table 3-2 Primary Data Sources used in EnergyPath Networks Study of Bury – Networks

Network Data	
Item	**Primary Data Sets**
Electricity network: current configuration	Distribution Network Operator (Electricity North West)
Gas network: current configuration	Gas Network Operator (Cadent, formerly National Grid Distribution), Xoserve[16]
Topography – building locations, building heights and existing road network	Ordnance Survey
Electricity network costs	Distribution Network Operator (Electricity North West), ETI Infrastructure Cost Calculator[17]
Electricity network technical parameters	Distribution Network Operator (Electricity North West)
Gas network costs	ETI Infrastructure Cost Calculator
Heat network costs	ETI Infrastructure Cost Calculator, Arup[18]
Heat Network technical parameters	Arup[19]
Energy Centre costs	ETI data (Macro Distributed Energy project)[20]
Energy Centre technical parameters	ETI data (Macro Distributed Energy project) [21]

3.3 Practical Constraints

Bury contains a broad mix of rurality, tenures, levels of affluence, building types and geographies. EnergyPath Networks relies on good data to produce a model of the local energy system which reflects existing energy networks, energy use and physical constraints for technology deployment.

Engineering consultants Ove Arup & Partners (Arup) were commissioned to consider proposed decarbonisation options for analysis areas within Bury and assess their practicality. The results of this review were used to refine the options available for decarbonisation and inform investigation of future local energy scenarios.

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[16] http://www.xoserve.com/wp-content/uploads/Off-Gas-Postcodes-V2.xlsx
[17] http://www.eti.co.uk/programmes/energy-storage-distribution/infrastructure-cost-calculator
[18] Arup. Support for EnergyPath Networks: Task 007: Non-domestic Heat Systems Costs. Unpublished
[19] Arup. Support for EnergyPath Networks: Task 007: Non-domestic Heat Systems Costs. Unpublished
[20] http://www.eti.co.uk/library/macro-distributed-energy-project/
[21] http://www.eti.co.uk/library/macro-distributed-energy-project/

The review included:

- Feasibility of building heating system and insulation retrofit options where identified by EnergyPath Networks. Constraints examined included costs of transition, flood risks, ground conditions, noise (construction and operational), air quality, floor area required for transition, civils/highways, heritage/planning/permitting/visual impact and fuel supply chain and delivery constraints.
- Analysis of area-wide development of district heating networks and energy centres, including technology suitability/feasibility in terms of highways, air quality and visual impact, as well as any value/risks associated with significant heat transmission between energy centres.

Two previous pilot projects in other local areas have had similar reviews performed. Relevant findings from these were incorporated into this project from the beginning.

3.4 Domestic Buildings

The thermal efficiency of domestic buildings is related to the construction methods used, the level of any additional insulation that has been fitted and any modifications that have been undertaken since construction. The oldest buildings in the UK generally have poor thermal performance compared with modern buildings. In addition to building age, the type and size of a building also have a direct influence on thermal performance. For example large, detached buildings have a higher heat loss rate than purpose-built flats, due to their larger external surface area per m2 of floorspace.

Buildings are categorised into five age bands in EnergyPath Networks, from pre-1914 to the present, shown in Table 3-3. These are broadly consistent with changes in building construction methods and so represent different levels of 'as built' thermal efficiency. The thermal efficiency of future new homes represents the minimum efficiency level required by current building regulations. There are ten modelled domestic building types, shown in Table 3-4. This allows approximately 60 different age and building type combinations which are used to define the thermal characteristics of existing and planned domestic buildings.

Table 3-3 Domestic Building Age Bands

Property Age Band
Pre – 1914
1914 – 1944
1945 – 1964
1965 – 1979
1980 – Present
New Build

Table 3-4 Domestic Building Types

Property Type
Converted Flat: - Mid Floor / End Terrace
Converted flat: - Mid Floor / Mid Terrace
Converted Flat: - Top Floor / End Terrace
Converted Flat: - Top Floor / Mid Terrace
Detached
End Terrace
Mid Terrace
Purpose-Built Flat: - Mid Floor
Purpose-Built Flat: - Top Floor
Semi-detached

3.5 Current Housing Stock

Once the current characteristics of a building have been defined, based on its age and type, the basic construction method can then be categorised. For example, the oldest buildings in the region can be expected to be constructed with solid walls. Buildings constructed between 1914 and 1979 are more likely to have been built with unfilled cavity walls. Buildings constructed from 1980 onwards will have filled cavity walls. Where data shows that they are likely to be present, thermal efficiency improvements that have been carried out since construction (such as filling cavity walls) are also included.

Where available, address level data is utilised in the EnergyPath Networks modelling to provide accurate building attributes. Six Town Housing were able to provide detailed building data for their social housing. Missing building attributes, for example types of wall or windows are filled using rules based on English Housing Survey data.

The retrofit measures used in EPN in the study are shown in Table 3-5. Table 3-6, Table 3-7 and Table 3-8 show the effectiveness of the different types of insulation studied in the model.

Table 3-5 Domestic Retrofit Measures

Domestic Retrofit Measures
Cavity wall insulation
Double glazing
Energy-efficient doors
External wall insulation
Floor insulation
Internal wall insulation
Loft insulation
Mechanical ventilation
More than triple glazing[22]
New build upgrade to High Thermal Efficiency
Reduced infiltration 1 (Draught proofing)
Reduced infiltration 2 (Whole dwelling)
Triple glazing

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[22] Consideration of improving the thermal performance of glazing above that of the assumed level of triple glazing, for example improving the U value from 1.8 W/m²K to 1 W/m²K

Table 3-6 Loft U-values

Loft Insulation	U-Value (W / m^2 k)
None	2.3
less than 100 mm	0.93
100 up to 199 mm	0.37
200 mm or more	0.17
New build loft insulation	0.13
No loft	0

Table 3-7 Window U-Values

Window Type	U-Value (W / m^2 k)
Single glazing	4.81
Double glazing	2.3
Triple glazing	1.8
New build glazing	1.4
More than triple glazing	1

Table 3-8 Wall U-Values

Example Wall Type	U-Value (W / m^2 k)
Pre-1914 unfilled cavity wall	2.07
Pre-1964 solid uninsulated wall	1.74
1914-1979 unfilled cavity wall	1.58
1914-1979 filled cavity wall	0.64
1980-present unfilled cavity or uninsulated solid wall	0.6
Pre-1980, solid external/internal insulated wall	0.45
1980-present, solid external/internal insulated wall	0.24

3.6 Current and Future Domestic Heating Systems

The definition of current heating systems is handled in a similar way to the definition of the building fabric. Information is used to identify the heating system by:

1) Xoserve[23] data is first used to identify which buildings in the local area are not connected to the gas grid.
2) Direct user input is used where the actual heating system in individual buildings is known. This is often possible for social housing where more detailed datasets are available.
3) Defining logic rules based on the most likely heating system combinations within each archetype group. For example, 95% of all mid terraces have a gas boiler[24].

Once the current thermal efficiency of a building has been defined, Ordnance Survey MasterMap and LIDAR data is used to establish its floor area and height. With this knowledge of a building's characteristics there is sufficient information to perform a Standard Assessment Procedure (SAP) calculation[25]. SAP calculations were used to calculate the overall heat loss rate and thermal mass of domestic buildings in the study area. EnergyPath Networks utilises these SAP results, as well as detailed retrofit and heating system cost data, to group buildings into similar archetypes. EnergyPlus[26] is used to calculate dynamic energy profiles for heat and power demand for each group, for the current and all potential future pathways. These pathways include potential to install varying levels of retrofit and different future heating systems. Restrictions are applied so that inappropriate combinations are not considered, so for example loft insulation cannot be fitted to a mid-floor flat. EnergyPath Networks also filters out heating systems and storage combinations that cannot be sized to a large enough power within a home to meet a predefined target comfort temperature and hot water requirements based on the EnergyPlus analysis.

Possible current and future heating system combinations are shown in Table 3-9. Three primary elements are defined in each heating system combination:

1. The main heating system.
2. A secondary heating system which can provide additional heat or hot water.
3. Thermal storage – either not present or a hot water tank[27].

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[23] Xoserve provide services to the gas industry, including management of gas supplier switching and transportation transactional services, www.xoserve.com

[24] English Housing Survey

[25] The Standard Assessment Procedure (SAP) is the methodology used by the UK Government to assess and compare the energy and environmental performance of dwellings. (https://www.gov.uk/guidance/standard-assessment-procedure)

[26] EnergyPlus is a widely used dynamic building energy modelling tool developed by the US Department of Energy

[27] The heating tank sizes were chosen so that the heating system combinations had sufficient capacity to meet demand in a range of buildings, without being infeasibly large for the available space.

Table 3-9 Heating System Combinations

Primary Heating System	Secondary Heating System	Heat Storage Technology
Gas Boiler	None	None
Gas Boiler	Electric Resistive	None
Oil / LPG Boiler	None	None
Oil / LPG Boiler	Electric Resistive	200 litre water tank
Biomass Boiler	None	None
High Temperature Air Source Heat Pump	None	500 litre water tank
Low Temperature Air Source Heat Pump	None	500 litre water tank
Low Temperature Air Source Heat Pump	Gas Boiler	None
Low Temperature Air Source Heat Pump	Solar Hot Water	500 litre water tank
Electric Resistive Storage Heating	Electric Resistive	300 litre water tank
Electric Resistive	Solar Hot Water	None
Ground Source Heat Pump	None	200 litre water tank
Ground Source Heat Pump	None	400 litre water tank
District Heating	None	None
Gas Source Heat Pump	None	200 litre water tank
Low Temperature Air Source Heat Pump with electric resistive top up	None	500 litre water tank
Low Temperature Air Source Heat Pump with electric resistive top up	Solar Hot Water	500 litre water tank

3.7 Non-Domestic Buildings

Non-domestic (commercial and industrial) building stock is more diverse than domestic stock. There are a wide variety of construction methods and few robust data sets are available defining the design of any particular building, its heating system or thermal performance. Due to these limitations, an energy benchmarking approach is used to establish the energy demand of the non-domestic stock. Different building types are given an appropriate energy use profile per unit of floor area. The building type represents how the building is used (e.g. industry, retail, offices, school) and is sourced from a variety of datasets including OS Address Base and VOA data. Benchmarks are defined for electricity, gas and heat demand in 30-minute time periods for different characteristic heat days. The characteristic heat days for which energy demand profiles are defined are shown in Table 3-10. Benchmarks are defined for current and future use to represent changing energy use over time.

Table 3-10 Characteristic Heat Days

Characteristic Heat Day
Autumn Weekday
Autumn Weekend
Peak Winter
Spring Weekday
Spring Weekend
Summer Weekday
Summer Weekend
Winter Weekday
Winter Weekend

The footprint floor area and height for each building is derived from the OS MasterMap and LIDAR data. The building height is then used to establish the number of storeys, from which the total building floor area is estimated. Using an energy benchmark (derived from CIBSE and CARB2 data) appropriate to the particular use class, the half hour building energy demand for gas, electricity and heat is calculated for each of the characteristic days.

It was challenging to assign use classes to many Bury non-domestic buildings due to data quality. Where possible, other datasets were used to validate alongside a process of manual checking using satellite and street imagery and a checking process designed to identify buildings with a floor area untypical for the assigned use class.

Non-domestic heat network connections are considered where buildings currently use gas as a heating fuel but do not use gas for industrial purposes. EnergyPath Networks provides pathway options for these buildings, with transition costs and feasibility based on a data review by Arup.

For both domestic and non-domestic pathway options, EnergyPath Networks includes costs of replacing all technologies at their end of life. At these points technologies can be replaced with a lower carbon system or like-for-like. For example, even in a scenario without a local carbon target, costs will be incurred when gas boilers and windows are replaced with analogous technologies.

3.8 Energy Network Infrastructure

In order to assess potential options for future changes to energy systems, knowledge of current electricity, gas and heat network routes and capacities is required. From this the costs of increasing network capacities in different parts of the local area, as well as extending existing networks to serve new areas, can be calculated. The road network is used in EnergyPath Networks as a proxy to calculate energy network lengths. Current and future capacities are established using steady-state load flow modelling of networks. For example, EnergyPath Networks will find the load at which a Low Voltage (LV) feeder will require reinforcement and the costs associated with doing so. The cost of operating and maintaining the networks varies with network capacity and is modelled using a cost-per-unit length, broken down by network asset and capacity.

The EnergyPath Networks method does not replicate the detailed network planning and analyses performed by network operators. Rather, the energy networks are simplified to a level of complexity sufficient for numerical optimisation and decision-making. The method is used to model the impact of proposed changes to building heat and energy demand on the energy networks that serve them, for example increased or reduced capacity. The costs of these impacts can then be estimated and the effects of different options on different networks can be compared. Only network reinforcements required inside the study area are explicitly considered as options in EPN. Reinforcements outside Bury are considered in the ESME model and so are costed in the future electricity price that is then used in EPN. A significant increase in electricity demand in Bury is likely to require reinforcements at transmission and distribution levels outside of Bury, but these costs are not considered in the model.

Electricity North West provided the following data for the current electricity network:

1) Locations and nameplate capacities of the HV (33kV to 11kV) and LV (11kV to 400V) substations.

2) HV to LV substation connections.

3) Average costs of replacing network assets.

EnergyPath Networks synthesises the routes of the HV to LV substation connections assuming that feeders follow the shortest route allowed by the road network. Customer connections are then derived based on nearest substation and peak load constraints for each feeder. Non-domestic buildings with high demands are assumed to connect directly to the HV network[28]. Network feeder capacities are then calculated based on the current load on each feeder and a headroom allowance. Voltage drop and thermal limits are considered when establishing asset capacity requirements. EnergyPath Networks performs steady state load flow modelling for electricity and heat networks using the Siemens tool PSS®SINCAL[29].

To establish which buildings in the study area are currently connected to the gas grid, data from Xoserve[30] is used. Buildings for which the user explicitly specifies non-gas heating systems are also assumed not to have an existing gas connection.

Xoserve data was supplemented by data from Cadent, providing the points at which the gas network enters the study area and the routes of the local transmission system through the local area. EnergyPath Networks does not carry out detailed modelling of gas networks. It is assumed that the current network has sufficient capacity to meet current demand and that, in general, gas demand will decline over time due to efficiency improvements and the wider need to decarbonise energy systems. This assumption can fail when gas Combined Heat and Power (CHP) energy centres are deployed in the modelling in areas where the gas network does not have sufficient capacity to meet their demand.

If the modelled heating system changes mean no gas is used across an entire analysis area, then EPN can decommission the local gas network. This incurs a one-off cost to decommission but saves ongoing maintenance costs. This is unlikely to occur as the use of hybrid heat pumps and the presence of industrial non-domestics in the model means that a small amount of gas remains in each analysis area, and so the ongoing costs of maintaining the gas network remain.

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[28] In the final modelling for Bury this was buildings with demands above 500kW, following consultation with Electricity North West.

[29] http://w3.siemens.com/smartgrid/global/en/products-systems-solutions/software-solutions/planning-data-management-software/planning-simulation/pss-sincal/pages/pss-sincal.aspx

[30] Xoserve provide services to the gas industry, including management of gas supplier switching and transportation transactional services, www.xoserve.com

3.9 Spatial Analysis

Once all the building data has been analysed and the buildings located, it is possible to identify their nearest roads, which shows where the buildings are most likely to be connected to energy networks.

As described in Section 3.8, it is assumed within EnergyPath Networks that energy networks follow the road network. Identification of the road nearest to each building allows the energy demand (for gas, heat and electricity) of that building to be applied to the appropriate energy networks at the appropriate point on those networks. In this way the total load and the load profile for each energy network can be calculated at different scales from individual building level, through local networks up to aggregate values for the whole study area. This allows an understanding of different energy load scenarios in different parts of the local area and the energy flows between those locations. In addition, an understanding of network lengths and required capacities can be established.

3.10 Analysis Areas

Due to the complexity of the number of different options available in EnergyPath Networks (for buildings, networks and generation technologies) the total problem cannot be solved at individual building or network asset level. The study area (Bury) is divided into a number of spatial analysis areas. Decisions are made at this level based on aggregating similar buildings and network assets within each area.

The analysis areas are necessary within the EnergyPath Networks model but do not correspond directly to local districts, wards or neighbourhoods.

Within each analysis area, different components of the system are aggregated. Aggregation of buildings is performed based on energy demand and cost of retrofitting insulation and new heating systems. This way, similar buildings within an individual analysis area will all follow the same pathway. Similarly, decisions on network build and reinforcement are made at an aggregated level. If the electricity loads in one analysis area increase, such that the aggregated capacity of the low voltage feeders is exceeded, then reinforcement of all low voltage feeders within that area will be assumed to be required. The same applies for all other aspects of the energy networks such as low voltage substations, high voltage feeders and substations and heat network capacity.

Since the network options are aggregated it is important that the boundaries between analysis areas do not cut across the electricity network. It would not be realistic to reinforce the 'downstream' end of an electricity feeder without considering the impact of the loads on those components further upstream in that network. To ensure consistency in the analysis of electricity network options, the study area was divided by considering each high voltage substation within the local area and all of the electricity network downstream of each substation to give the analysis areas discussed above. Some simplifications to create continuous areas and to remove a low usage private wire substation were applied. Once the analysis areas had been defined, energy network links between them were defined. This allows transmission of heat and gas across the analysis area boundaries.

Figure 3-2 shows the relationship between ward boundaries and analysis areas in Bury.

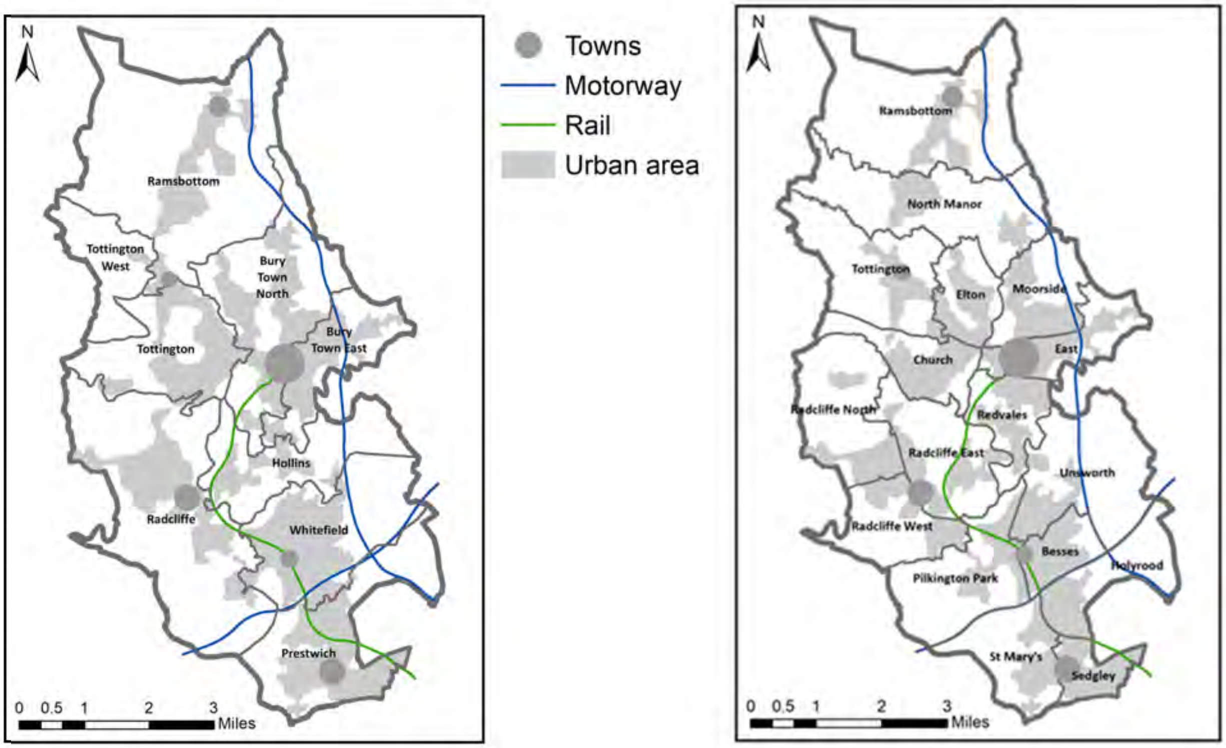

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Figure 3-2 EnergyPath Networks Analysis Areas (Left) Relative to Bury Ward Boundaries (Right)

3.11 Local Energy System Design Considerations

Options which are not considered technically feasible are excluded from EnergyPath Networks, for example, fitting loft insulation into a mid-floor flat or cavity wall insulation to a building which has solid walls.

There are other options which, whilst they may be possible, are not practical in a real-world environment. For example, the use of ground source heat pumps in areas of dense terraced housing: a lack of space means that cheaper ground loop systems cannot be fitted, whilst there is insufficient access for the equipment required to create vertical boreholes. In addition, the heat demand for a row of terraced houses may cause excessive ground cooling in winter leading to inefficient heat pump operation and a need for additional top-up heat from an alternative source.

Consumer preferences also influence suitability of certain options. The installation of domestic hot water tanks for heat storage is a good example. Many households have removed old hot water tanks and fitted combi-boilers to provide hot water on demand. This allowed the space previously occupied by the hot water tank to be repurposed for other uses, which householders find valuable, such as additional storage. Many low-carbon heat technologies, such as air source heat pumps, work at a lower output power than conventional gas boilers. This can require the use of heat storage in order to be able to meet peak demand for heat on cold days.

Re-installation of a hot water tank might be technically feasible, and the cheapest low-carbon choice for heat provision to a particular building. However there are challenges associated with integrating heat storage into existing homes as many homes have removed their hot water tank and installed a combi-boiler. For example, the English Housing Survey[31] shows that 54% of homes had a combi-boiler in 2016 with this figure rising by around 2% a year since 2001. These consumers often place a high value on the space that has been made available by doing this and are unlikely to embrace heat solutions that require large amounts of domestic space to be sacrificed. A proxy for the value that consumers place on space in their homes is property market values normalised by floor area. With median house price costs in England and Wales in 2017 varying from £32,000 (within County Durham) to £2,900,000 (within Westminster)[32] it is clear that the options for using space for domestic heat storage are likely to be heavily dependent on local factors. Consumer behaviour cannot credibly be predicted at this level but factors like this are considered in an LAES and any resulting feasibility studies.

Table 3-9 illustrates the storage tank sizes considered in EnergyPath Networks for each primary and secondary heat combination. Particular primary and secondary combinations may be capable of providing the necessary output if paired with larger storage options, e.g. an ASHP in a pre-1914 large detached building may not be able to meet necessary heat demand with a 500 litre storage tank but combining with a larger storage tank is not considered a credible option.

In some cases, it is appropriate to force or constrain different technology options in EnergyPath Networks for particular building types and geographic areas, to reflect technical, commercial, social and consumer choices. For example, if a Local council is planning a wide scale home improvement programme in a particular part of a local area with the objective of tackling fuel poverty then a retrofit programme should be included in the EnergyPath Networks analysis. Alternatively constraints on building modification can mean technologies are restricted, e.g. in listed buildings or inside conservation areas.

3.12 Limitations and Uncertainties

Any technical modelling exercise requires decisions to be made as to the level of complexity and detail that is appropriate. There are several areas where limitations have been applied to limit the complexity of the EnergyPath Networks analysis to keep the scale of the analysis practical, such as grouping buildings into archetypes.

3.12.1 Fixed Input Parameters

Some parameters are considered as fixed inputs within EnergyPath Networks. That is, they are derived externally and presented as inputs to the tool. Any options to vary these parameters are excluded from the decision module. The following energy demands are modelled as inputs:

1. Domestic lighting and appliance demands are based on data from DECC's (Department of Energy and Climate Change)[33] household electricity survey which gives these demands for different house types.
2. Electric vehicle charging profiles are based upon assumed take-up rates[34] for electric vehicles and are based on car journeys extracted from the Department for Transport's National Travel Survey. This means that distances travelled (level of charge required) and times of arrival (time of charging) reflect the diversity of real world use. The profiles reflect a vehicle charging immediately after it returns home and

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[31] https://www.gov.uk/government/statistics/english-housing-survey-2016-to-2017-headline-report
[32] https://www.ons.gov.uk/peoplepopulationandcommunity/housing/bulletins/housepricestatisticsforsmallareas/yearendingseptember2017
[33] Now part of BEIS (the department of Business, Energy and Industrial Strategy)
[34] These were developed in conjunction with Bury Council and GMCA

so represent a worst case scenario for peak network loads. It is possible that an approach to charging management may partially mitigate this.

3. Non-domestic building demands for current systems and future transition options are calculated based on building use and a set of energy benchmarks.

3.12.2 Building Modelling

Within the domestic building simulation, a standard target temperature profile is taken from SAP and used for all domestic buildings. This is intended to reflect typical building use patterns. It is recognised that real-world building use will deviate from this profile, as shown by the Energy Follow-Up Survey (EFUS). [35]To reflect this, diversity factors are applied within EnergyPath Networks when individual building energy demands are aggregated to calculate total network demands. These diversity factors modify both the magnitudes of the demands and the times at which they occur.

Construction standards are assumed for buildings of different ages. For example, all pre-1914 buildings are assumed to have solid walls. Similarly, for some building ages the thermal conductivity of the walls is assumed to be the same for each level of insulation. For example, all walls in buildings constructed between 1945 and 1964 which now have filled cavities are assumed to have the same thermal performance. Note that these performance assumptions are based on ‘traditional’ brick construction and assume that insulation is correctly installed and performs to its technical potential. Buildings constructed in other ways may not be correctly represented in terms of their thermal performance.

3.12.3 Network Modelling

The network modelling approach assumes that development of future energy systems should be driven by consumer needs. On this basis, the EnergyPath Networks modelling framework works on a traditional network reinforcement model. If load on a network is calculated to exceed capacity, then the network will be reinforced to meet that load.

There is no capability within the model to consider ‘Smart’ network control or all aspects of Demand Side Response. For example, if a particular feeder in a street was overloaded, a demand side response could be to raise the price of electricity at peak times to decrease consumer demand on the network. EnergyPath Networks will deploy technologies that minimise electricity use at times of peak costs if it is cost effective to do so, but it is not designed to model the behaviours of the DNO or the consumer in this scenario.

ENW provided data on HV to LV substation connections for Bury. The building level electricity connections were synthesised based on the road network. There were no existing heat networks in Bury.

The load-flow modelling is not intended to replace full dynamic network modelling conducted by network operators. EPN uses a steady-state approach which is appropriate for establishing peak loads and the capacity required to meet them, to understand the influence of different options on network costs.

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[35] https://www.gov.uk/government/statistics/energy-follow-up-survey-efus-2011

3.12.4 Technology Cost and Performance

EnergyPath Networks models the future energy system which is considered to have the lowest cost to society whilst meeting defined carbon targets. The selected options are influenced by the costs associated with different technologies. The modelled technology cost should represent the cost in a fully competitive UK market, with significant volumes of the technology being sold. This is currently the case for markets for some technologies such as a gas boiler, but not for others such as heat pumps.

Where the market is not fully developed it is not appropriate to use the current price charged to consumers. Instead, an estimate of the current costs of buying and installing is made using a variety of data sources to ensure that estimated costs are within reasonable bounds.

With these data sources it can still be difficult to establish the true costs of a technology when deployed at scale, as current costs for small scale trials or deployment may not reflect the cost of widespread future implementation. There may also be reductions in future costs due to improved design and manufacturing methods which are difficult to estimate. To account for this uncertainty a range of likely future costs has been defined for each technology. These ranges are smaller where the technologies are more mature and the uncertainty is less, and larger where the technology is immature and its future is less predictable. A series of sensitivity runs have been performed where different values were selected randomly from the range to generate a set of possible outcomes. The results of this sensitivity are discussed in Section 5.7.

3.12.5 Validation of Modelling Approach

This study has been developed in partnership with a Key Stakeholder Group including Bury Council (including wholly owned social landlord Six Towns Housing), Greater Manchester Combined Authority, Electricity North West and Cadent. This group has been involved throughout the process and has been given the opportunity to review:

- The modelling process used.
- Setting of the carbon target.
- Outputs from all model runs.
- Decisions based on those outputs that have been used to define inputs for subsequent runs.
- The emerging LAES.

The group also chose the items to be assessed via sensitivity analyses.

In addition, Arup[36] were engaged to assess the engineering feasibility for specific technical options and provide additional insights for the EnergyPath Networks model, as described in section 3.3

The EnergyPath Networks team have also completed internal validation of module results at each stage of the tool. Outputs have been compared to data that is publicly available or provided by key stakeholders. Internal validation included:

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[36] An independent firm of designers, planners, engineers, consultants and technical specialists. (http://www.arup.com/)

- Postcode-level demand for domestic buildings with BEIS data[37]
- Lower Super Output Area (LSOA) level demand for non-domestic buildings with BEIS data[38]
- Domestic building attributes for the rest of the study area against data provided by Six Town Housing on their building stock (~7,500 buildings)
- LV and HV substation demand and number of connections with ENW data
- Investigation into individual non-domestic buildings showing unexpectedly high demand with BEIS sub-regional data and Cadent large loads data

This improved confidence in results, by identifying any areas needing deeper investigation early in the modelling process. Where issues were identified and reasonable assumptions had to be made they were confirmed in meetings with the stakeholder group.

3.13 Technologies

A variety of technologies have been considered within the EnergyPath Networks analysis. These are described below.

3.13.1 Primary Heating Systems

Different current and future heating system combinations have been considered within the analysis. Table 3-9 shows details of how the main and secondary heating systems have been considered in combination with building level heat storage. Some of these, such as gas and oil boilers, are significant contributors to a building's carbon footprint. Electrically powered heating systems have the potential for much lower emissions, particularly if the electricity is sourced from low-carbon generation. The heating systems assessed are as follows:

- Gas boilers are the main source of heat for domestic premises in the UK at present.
- Oil / LPG boilers are a popular heat source for those buildings which are not connected to the gas network.
- Biomass boilers can provide a low-carbon heat source by burning fuel derived from sustainably sourced wood products.
- Heat pumps use electrical energy to transfer heat energy from one source to another. They are similar to a domestic refrigerator which transfers heat from a cold space to the surrounding room. This is reversed in a heat pump system so that the internal space is warmed by transferring heat from outside. Heat pumps have an advantage compared to other electrically powered heat sources as they produce more heat energy than the electrical energy required to power them. Different types of heat pump are considered:
    - Low Temperature Air Source Heat Pumps (ASHPs) use the outside air as the source of heat and provide hot water to the heating system at temperatures around 45°C. This temperature

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

[38] As 17

  is lower than that normally used for domestic heating with a gas boiler and so may require changes to heating distribution systems, such as the provision of larger radiators to allow the building to be heated effectively. These changes are accounted for in the costs of the technology used in the model.

  - Low Temperature Air Source Heat Pump – Gas Boiler Hybrids use a combination of a low temperature ASHP to provide a large proportion of the heat demand but can top up this heat using a conventional gas boiler at times when it is not efficient to operate the heat pumps, or the heat pump cannot meet the required demand.
  - Low Temperature Air Source Heat Pumps can also have supplementary heat provided by direct electric heating when required.
  - High Temperature Air Source Heat Pumps are similar to a low temperature Air Source Heat Pump but provide hot water at a higher temperature (typically 55°C) which may remove the need for other modifications to the heating system.
  - Ground Source Heat Pumps use heat energy stored in the ground to provide hot water to the heating system. Since ground temperatures are higher than air temperatures in winter they can operate more efficiently and provide higher water temperatures than air source heat pumps. Space is required, however, to install pipework to extract heat from the ground and this adds considerably to the cost of installing these systems.

- Electric Resistive storage heating is the most commonly used system for buildings which have electric heating. Room heaters are typically charged overnight (where there can be an option to charge the system at a lower, night rate electricity tariff) and then release this heat over the course of the following day.
- Electric Resistive heating without storage provides instant heat through panel, fan or bar heaters.
- District heating provides heat to buildings through pipes that carry the heat from a central heat source. In current systems, this is typically a large gas boiler or gas fired Combined Heat and Power (CHP) plant which provides heat to the network and generates electricity which is either consumed locally or exported to the electricity network. Once installed these systems can be converted from using gas to lower carbon alternatives such as a large-scale Ground Source Heat Pump or a biomass boiler.

3.13.2 Building Retrofit Options

Domestic buildings in the UK have been constructed to a wide variety of building regulations depending on their age. Many older buildings have low levels of insulation and require much more energy to keep them warm in winter than those built to more recent regulations. There are many options available to reduce heat loss from older buildings some of which could also be applied to more modern buildings. Loft insulation, wall insulation (cavity or solid depending on existing building fabric) and triple glazing retrofit options are modelled within the EnergyPath Networks model. In addition, some minor improvements are considered as secondary measures. That is, “quick wins”, such as draught proofing, that could be installed at the same time as more substantial building fabric upgrades.

3.13.3 **Solar**

EnergyPath Networks considers the deployment of solar panels within a local area to generate electricity and hot water. Both systems can produce significant amounts of energy in summer months but may produce close to zero energy on winter days when the sun is low in the sky and days are much shorter. This may coincide with times of greatest heat demand, so alternative energy generation options need to be available at these times. Battery options can also be considered in EPN, which are able to store electricity at times of excess supply and discharge at times of high demand.

In the case of electricity generation (solar photovoltaics) the power might be used by the home owner or might be exported to the electricity network if the amount being generated exceeds the demand of the generating building.

Solar hot water systems typically heat water in a hot water tank by circulating a fluid between a heating coil within the tank and the roof mounted panel heated by the sun.

3.13.4 **Energy Centre Technologies**

A central heat source or Energy Centre is connected to a District Heat Network, providing heat to buildings through pipes. A wide variety of technologies are available that can provide this heat:

- Any available excess heat identified in the local area and input into the model, for example heat from power station or industrial processes can be used directly to provide energy to heat networks.
- Heat pumps can be used at a large scale in a similar way to that discussed above for individual building heating systems. They can use a variety of heat sources:
    - Ground Source Heat Pumps typically use deep boreholes to take advantage of the higher temperatures underground.
    - Water Source Heat Pumps take advantage of the fact that most rivers and seas have reasonably stable temperatures throughout the year. This makes them a good source of heat in the winter.
    - Waste Heat Pumps typically use warm air that is emitted from industrial or commercial purposes. Examples have included warm air vents from the London Underground and heat emitted from the computers within data centres.
- Biomass can provide a low carbon source of heat in two main ways:
    - Boilers burn the biomass to provide heat directly to a network.
    - Combined Heat and Power (CHP) systems work like small-scale power stations where the heat that would normally be discarded to the atmosphere is used to provide heat to a network and the electricity generated is either consumed locally or exported for use in the local electricity network.
- Domestic and industrial waste can be incinerated to provide heat for networks. This can be done in conjunction with a generation system that produces electricity as well as heat.
- Gas can be burnt in three different technologies to provide heat for networks:
    - Gas Boilers are large-scale versions of domestic systems.

  - Gas Engine CHP runs a large engine, similar to that in a heavy goods vehicle. This drives a generator to produce electricity and the heat that would be wasted in the truck radiator and exhaust gas is captured and delivered to the heat network.
  - In Gas Turbine CHP, an engine similar to that on a jet airliner is used to power a generator to produce electricity. The exhaust heat is captured and delivered to the heat network. These types of systems are only likely to be used where there is considerable demand for both heat and electricity.

The technologies selected by EPN in energy centres are often a combination of the above, for example air source heat pumps providing low carbon heat for the majority of the year but gas technologies available to help meet seasonal peak demands. Multiple technologies can also be used together to avoid a single point of failure, for example where EPN models a single large air source heat pump it may be better to deploy several smaller ones to provide greater resilience.

3.13.5 Heat Storage

Heat storage can be considered at two scales:

- Individual domestic storage in hot water tanks.
- Large-scale storage in association with heat networks.

In both cases, it is assumed that more heat could be produced at certain times than is required to meet demand. This provides an option to store that heat and then release it back into the heating system at times when the peak demand is high. It can sometimes be a cost-effective solution as it allows a less powerful heat source to be installed that can be topped up using stored heat at times of peak demand.

Depending on the location in the UK, the value of the floor space lost could outweigh the capital savings associated with installing a heating system with a hot water tank over a more powerful heating system without a hot water tank.

3.14 Carbon Emissions

EPN optimises to calculate the lowest cost route to meeting a defined carbon target. Domestic, industrial and commercial emissions (i.e. those related to buildings) are in scope for the model. Transport emissions and those resulting from land use change are excluded from the analysis. Some types of non-domestic buildings are projected to have reductions in demand and so emissions over the time period to 2050, even if their heat demand continues to be met using gas or electricity. Emission reductions from these buildings can occur due to:

- Conversion of the national grid to low-carbon electricity which decarbonises the emissions associated with local electricity consumption.
- Reduced gas use in buildings where there is historical evidence to support this trajectory – mainly associated with professionally managed buildings whose managers have a commercial incentive to improve energy efficiency.

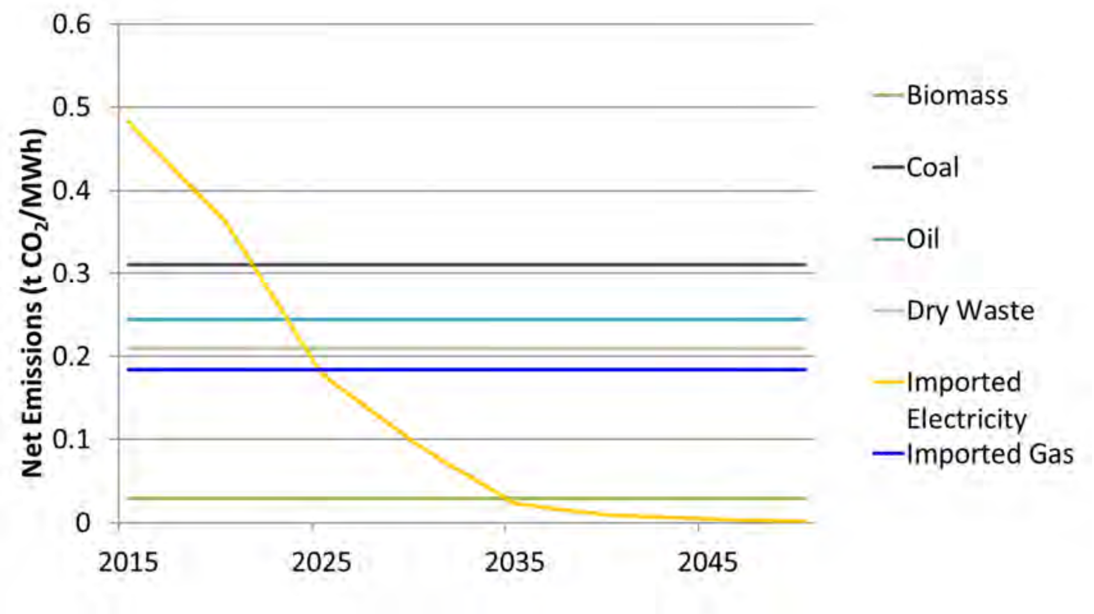

Figure 3-3 CO_2 Emissions Inputs to EnergyPath Networks

3.15 Decision Module

EnergyPath Networks has been used to provide evidence to support local area energy planning and the development of local energy system designs able to meet local carbon reduction targets. The importance of other factors such as fuel poverty and health benefits should be recognised in the planning of the future energy system but they are not core parameters in EnergyPath Networks.

Once a set of potential options for the buildings and energy networks in the local area have been identified, the Decision Module compares all valid option combinations and selects the set that meets the local CO_2 emissions target at minimum cost. The costs considered are the total cost to society for the whole energy system including capital costs, fuel costs and operation and maintenance costs to 2050.

The future costs are discounted. Discounting is a financial process which aims to determine the "present value of future cash flows", or in other words: calculating what monies spent or earned in the future would be worth today. Discounting reflects the "time value of money" – one pound is worth more today than a pound in, say, one year's time as money is subject to inflation and has the ability to earn interest. A discount rate of 3.5% is used, as suggested in the UK Treasury's "Green Book"[39] (used in the financial evaluation of UK Government projects).

Taxes and subsidies are excluded as these are transfer payments with zero net cost to society. Their inclusion in the analysis might result in the selection of sub-optimal solutions. The intention is that, once evidence has been used to define a local area energy strategy and possible future local energy system designs, the deployment and innovation projects needed to implement it can be developed.

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[39] Appendix 6: HM Treasury (2018) The Green Book:Central Government Guidance on Appraisal and Evaluation https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/685903/The_Green_Book.pdf

For each domestic building the modelling assumes that the heating system will be replaced twice between now and 2050, (referred to as transitions one and two). This assumes that heating systems are replaced at their end of life (generally around 15-20 years). On each of these occasions there is an opportunity to change to an alternative heating system and perform some level of building fabric retrofit. Different heating systems reach end of life at different times, but there would need to be some coordination of the change if transitioning to a district heat or community system. Three different levels of retrofit (thermal performance enhancement) are considered, ranging from do-nothing to a full retrofit[40]. In addition, each heating system option (see Table 3-9) can be combined with advanced heating controls [41]and each level of retrofit. Options will be excluded if a new heating system technology is unable to provide sufficient power to meet heat demand in a building with a given level of retrofit. These combinations mean that for each building there can be as many as 126 different future pathways which must be considered.

Buildings are aggregated into base archetypes as described in Section 3.6 and the study area is divided into analysis areas. This generates over 120,000 building pathways for analysis in Bury. Additional options for new-build, non-domestic buildings, reinforcement and decommissioning of energy networks, and for heat network technologies further increase the number of options in EnergyPath Networks.

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[40] A basic retrofit package consists of cavity wall and loft insulation only, whereas a full retrofit would also include external wall insulation and improved glazing (up to triple glazing).

[41] Which are assumed to provide a small reduction in energy demand through better control. There is an extra cost to installing these controls.

4 Bury’s Current Energy System

4.1 Introduction

An accurate whole system representation of the current energy system is needed to consider potential future local energy scenarios and designs to decarbonise the local area. This has been developed for Bury using EnergyPath Networks, requiring the collection, processing and validation of a large number of local datasets.

This section summarises some of this information to set out the current heat demands and energy systems in Bury. Area-by-area fact files are available in Appendix A. Figure 4-1 shows the Bury analysis areas.

Currently Bury has 82,700 homes, 9,500 non-domestic buildings and 3.5 million m^2 of non-domestic floor space. It has a peak electrical demand of 255 MW and peak demand for gas of 570 MW.

Annual electrical consumption is 785,000 MWh/yr and gas consumption 1,279,000 MWh/yr. There are around 3,000 homes off the gas grid. There is 4.2 MW of solar PV installed in the local area. Current carbon emissions are already over 50% below 1990 levels.

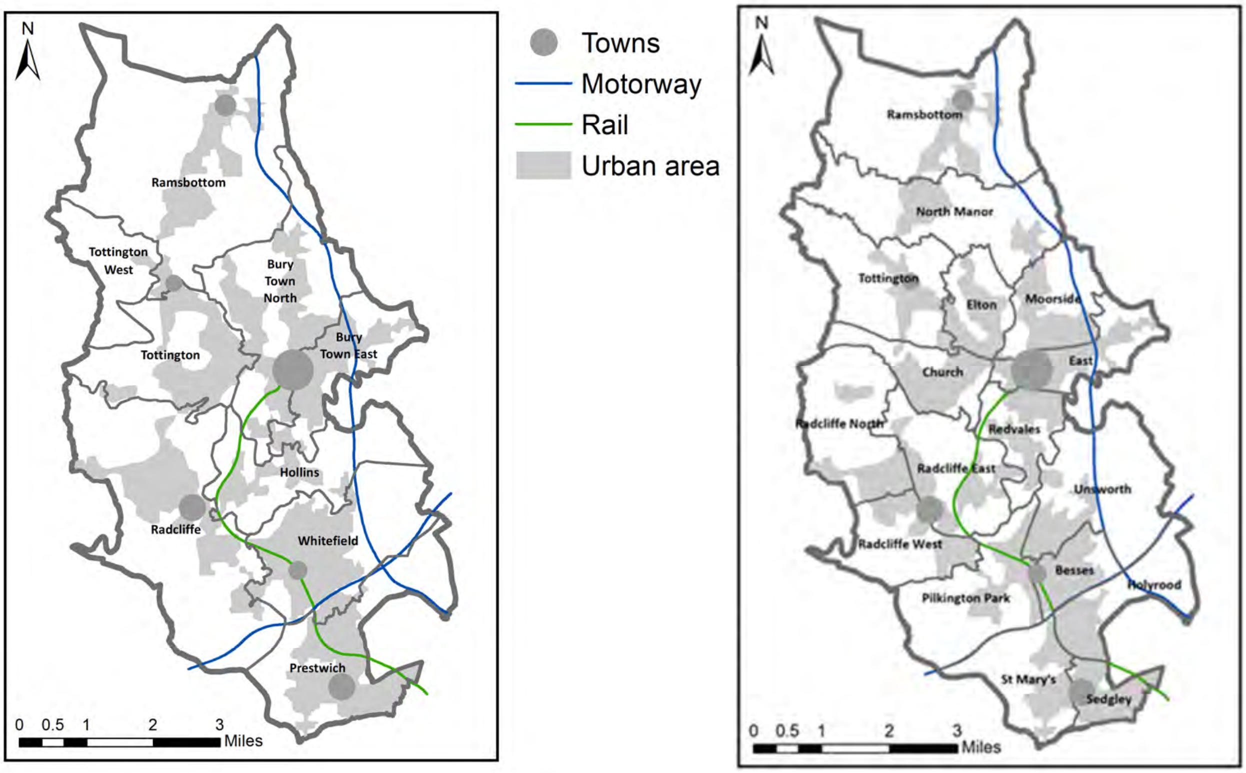

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Figure 4-1 Bury Analysis Area and Wards

4.2 Existing Households

Approximately 82,700 existing households in Bury have been considered in this study. Their types and ages that have been derived from the input data and used in the model are summarised in Figure 4-2.

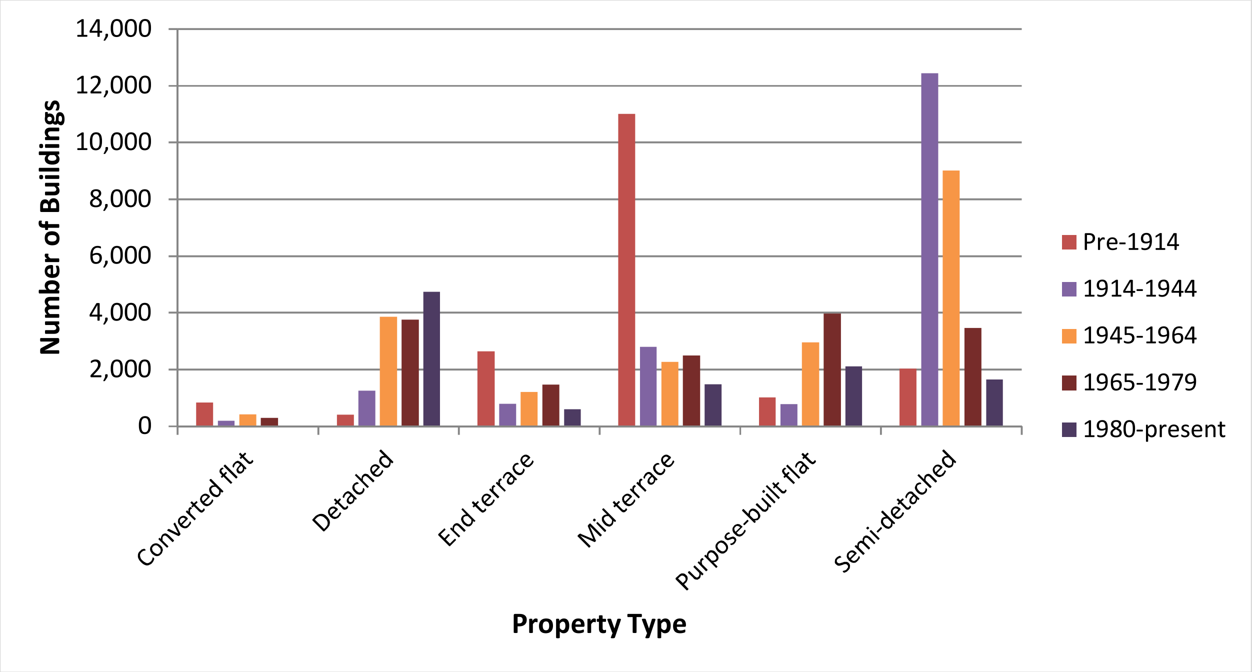

Figure 4-2 Types and ages of existing homes in Bury

A breakdown of the property types for each analysis area in EnergyPath Networks (Table 4-1) reveals the distribution of property types. Some analysis areas are typical of the average for Bury whereas others differ. These characteristics of property type and age, in conjunction with other metrics such as network lengths and building density, influence the types of heating systems selected by EnergyPath Networks tool. Bury Town East, for example, has a higher proportion of both purpose-built flats and buildings converted into flats, which is understandable as this area covers part of Bury town centre. Tottington West is a rural area characterised by larger, detached properties and a low housing density.

The combination of age and building type is a strong indicator of the thermal performance of the building and is mapped across Bury in Figure 4-3 and Figure 4-4.

Table 4-1 Property Type breakdown by Analysis Area in Bury

	Ramsbottom	Tottington	Bury Town North	Bury Town East	Hollins	Tottington West	Radcliffe	Whitefield	Prestwich	Bury Total
Detached	23%	27%	16%	7%	23%	32%	19%	17%	14%	18%
Flats	11%	9%	16%	24%	15%	6%	15%	15%	20%	16%
Semi-detached	19%	27%	27%	28%	24%	23%	25%	32%	36%	28%
Terraced	47%	37%	40%	41%	39%	39%	41%	36%	30%	38%

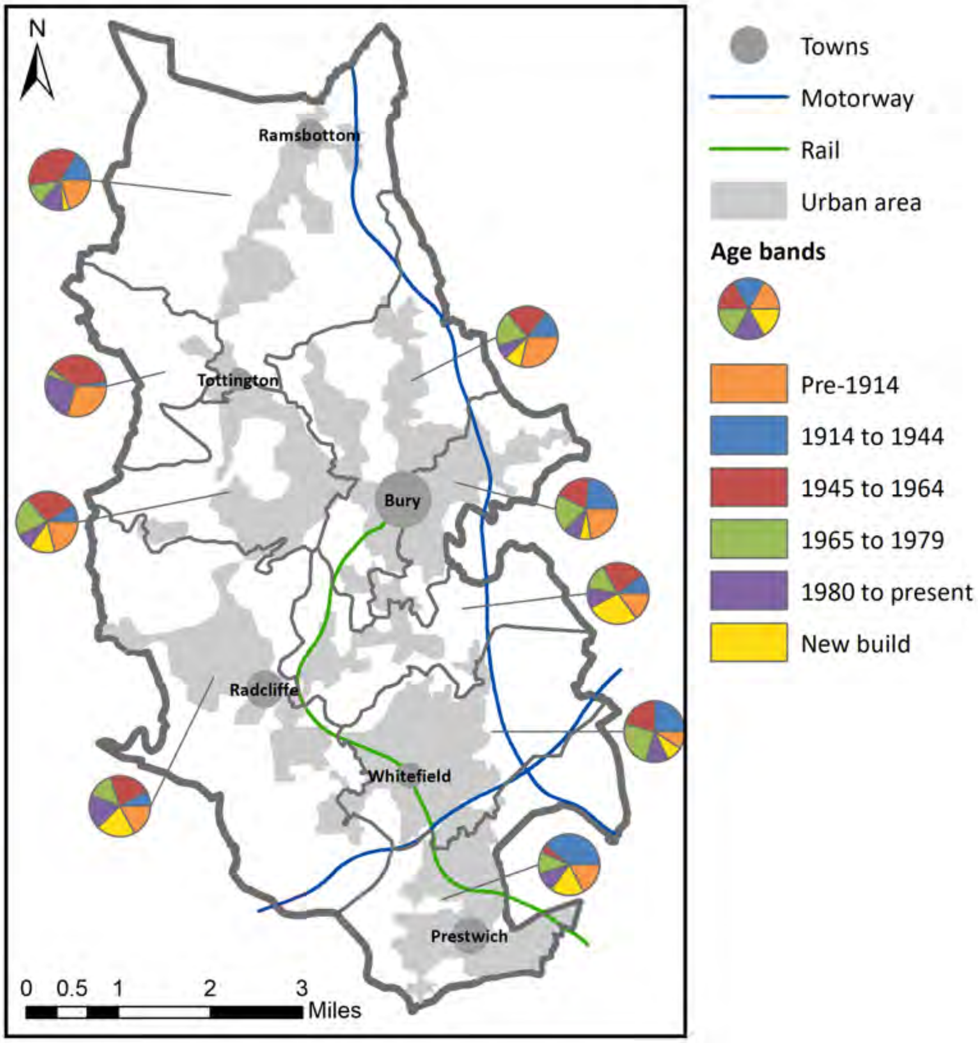

Figure 4-3 Mapping of property age across Bury

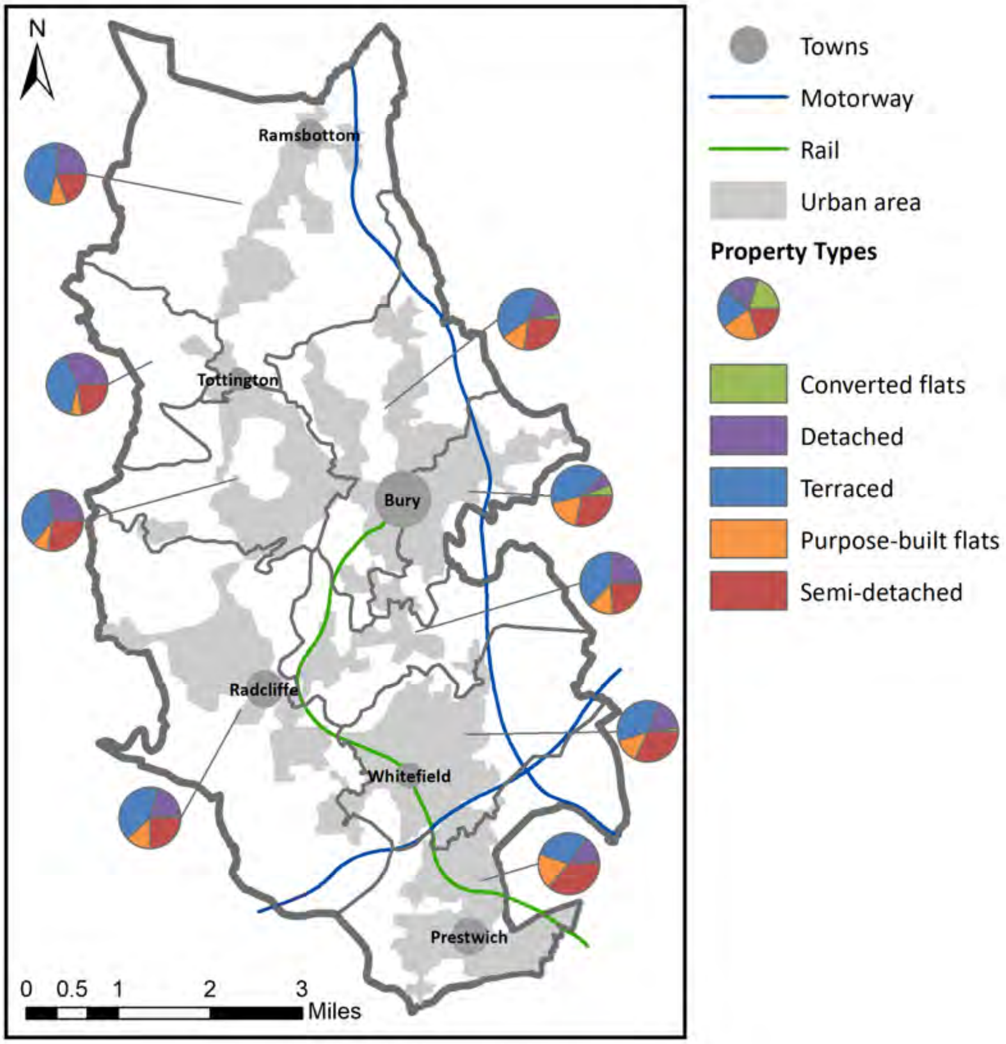

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Figure 4-4 Mapping of property type across Bury

The study area is a mix of rural and urban. The density of buildings is highly variable across Bury (Figure 4-5 and Table 4-2), but there are six main towns: Bury, Radcliffe, Ramsbottom, Tottington, Whitefield and Prestwich.

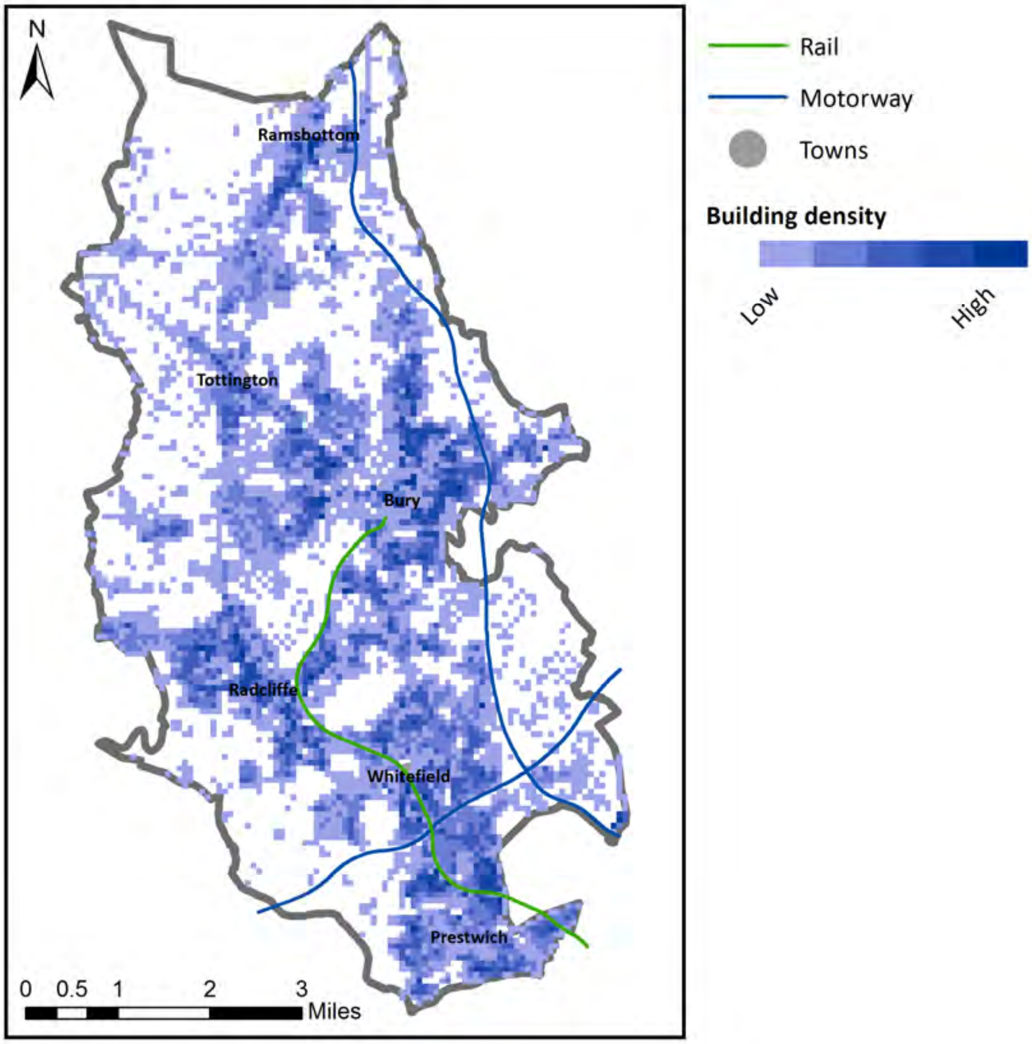

Figure 4-5 Building Density across Bury

Table 4-2 Building Density by Analysis Area

	Number of homes	Analysis Area (km^2)	Homes per km^2
Ramsbottom	10,165	21.9	463
Tottington	11,360	8.2	1,393
Bury Town North	11,552	11.7	989
Bury Town East	9,032	5.8	1,549
Hollins	6,262	7.6	828
Tottington West	484	4.8	102
Radcliffe	16,769	19.2	873
Whitefield	13,483	10.4	1,295
Prestwich	16,367	10.0	1,644

Building and heat density can have a significant impact on the viability of district heat networks.

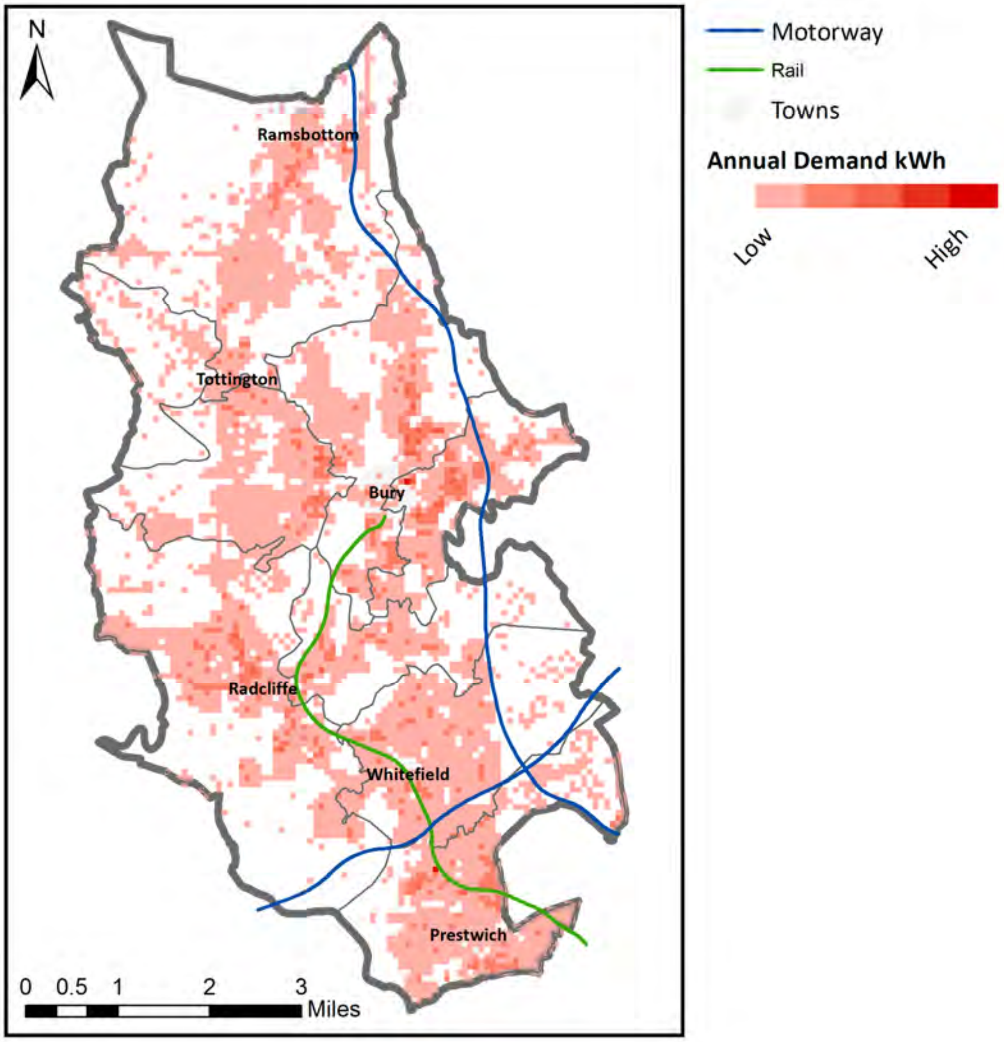

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Figure 4-6: Current Annual Heat Demand – Shown as relative total heat demand per area

Figure 4-7 and Figure 4-8 show the modelled existing wall and loft insulation in Bury's housing stock.

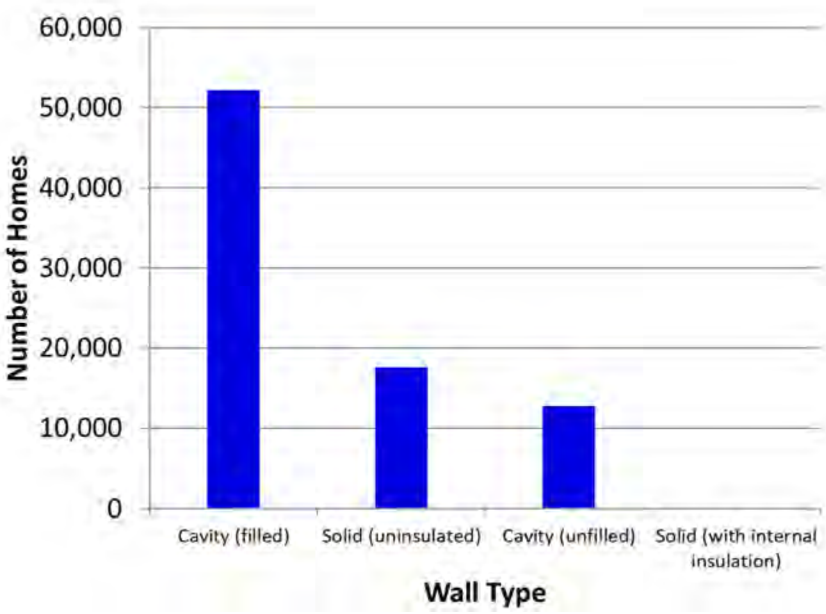

Figure 4-7 Wall Insulation in Homes in Bury

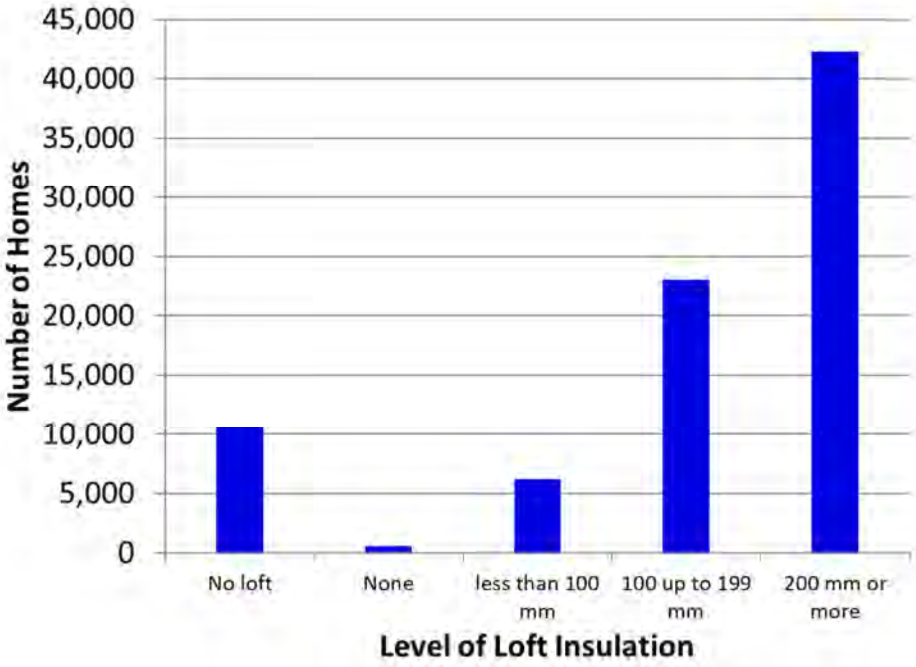

Figure 4-8 Loft Insulation in Homes in Bury

4.3 Existing Non-Domestic Buildings

Bury's existing non-domestic building stock is varied. By number of buildings retail is the most common (Figure 4-10), but the largest floor areas are factory or industrial (Figure 4-9).

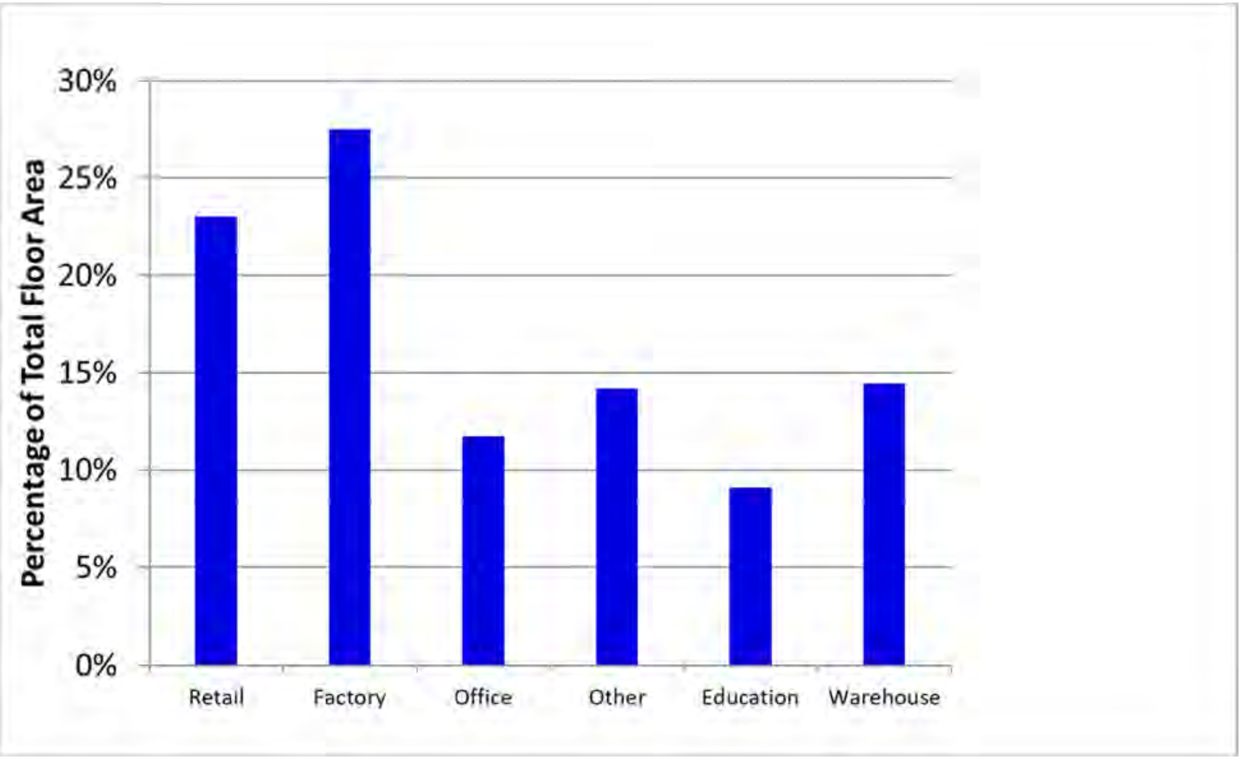

Figure 4-9 Non-Domestic Activity Classes by Floor Area

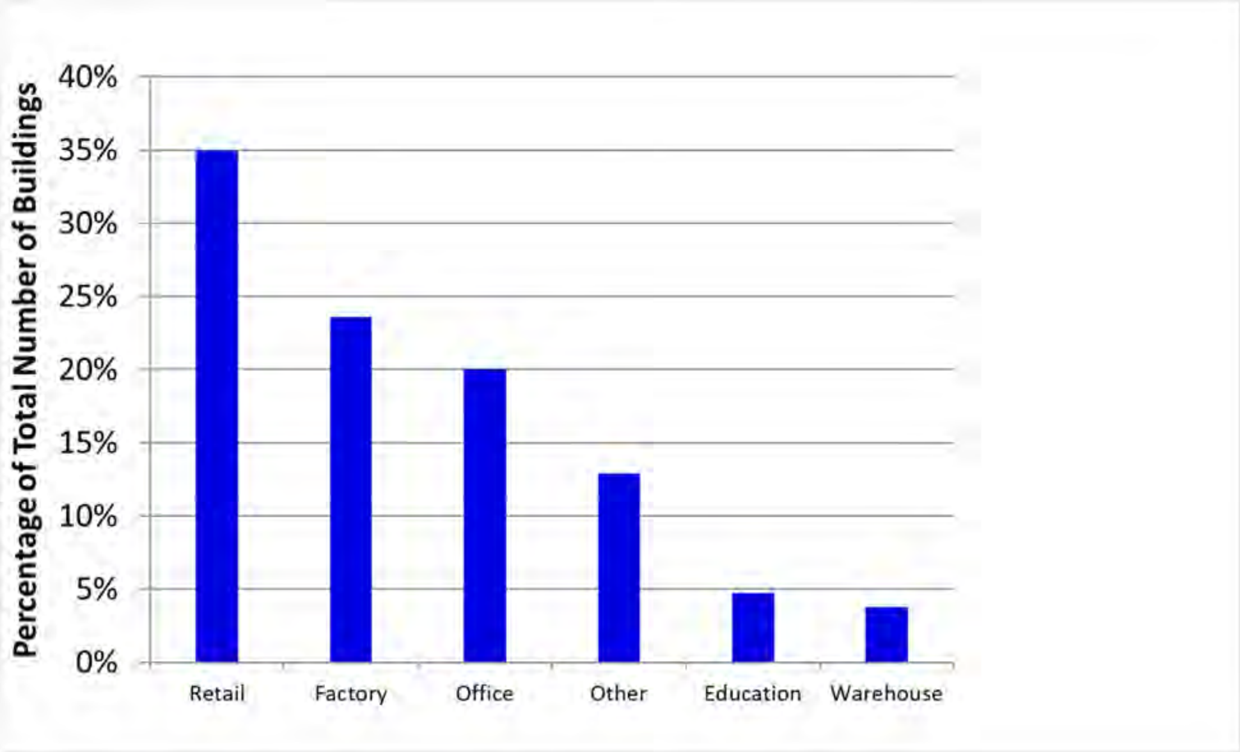

Figure 4-10 Non-Domestic Activity Classes by Number of Buildings

4.4 New Developments

Data was gathered and assumptions agreed on likely new build developments in the Bury area between now and 2035, based on the draft Greater Manchester Spatial Framework (GMSF)[42]. It was agreed with the KSG to not include any new builds beyond this date due to the high uncertainty in what could occur.

Figure 4-11 shows purely residential developments dotted around the Bury area in green, and the large areas of mixed development in yellow (taken from the draft GMSF).

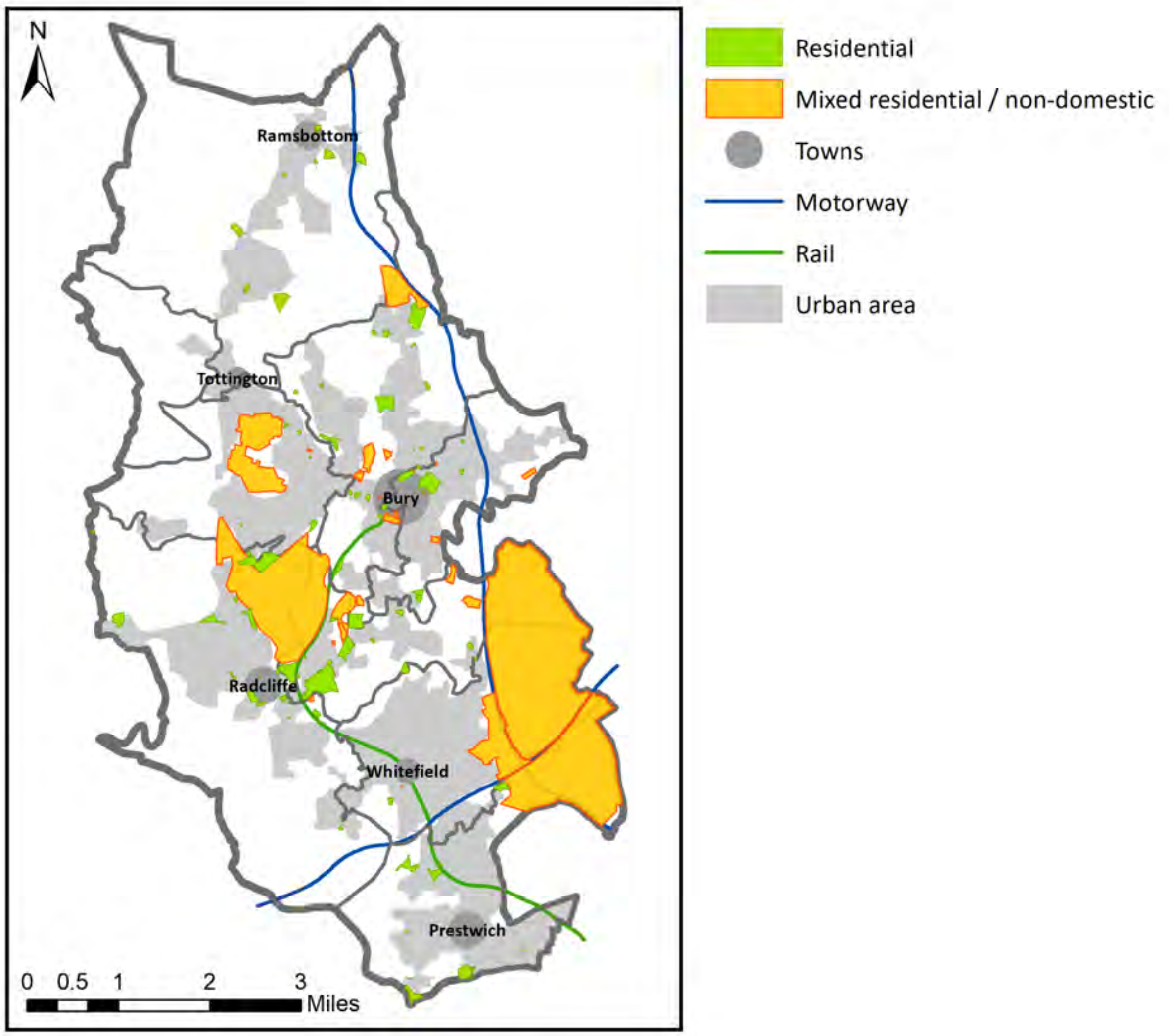

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Figure 4-11 New-build Areas

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[42] https://mappinggm.org.uk/gmsf-consultation-2016/?lyrs=gmsf_allocations_20161018#os_maps_light/10/53.5069/-2.3201

Table 4-3 shows Bury's allocation of new housing requirements from the GMSF.

Table 4-3 GMSF Requirement for Domestic New-builds

Site Name	Number of Houses
NG1a North of M62	200
NG1b South of M62	3400 (split between Bury and Rochdale)
NG1c Whitefield	600
OA2 Elton Reservoir Area	3,460
OA3 Walshaw	1,250
OA3 Holcombe Brook	100
OA5 Seedfield	135
OA6 Baldingstone (Gin Hall and Bevis Green)	60

4.4.1 New Build Domestic Modelling Assumptions

Bury Council provided a breakdown of proposed new domestic housing which was incorporated into EnergyPath Networks, based on the draft GMSF allocations as defined above. The large mixed development sites gave the total numbers of homes per area but not a detailed breakdown of property types and size. The breakdown was devised using data from Bury Council's Local Plan Housing Topic Paper published in 2013[43] to give typical proportions of new build property types for the period 2003-2013. This was slightly modified using the draft GMSF's stated ambition of providing an 85-15 mix of houses to flats. This resulted in the allocation of property types in Figure 4-12.

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[43] Bury Council (2013) *Bury Local Plan: Housing Topic Paper (5th Edition)*

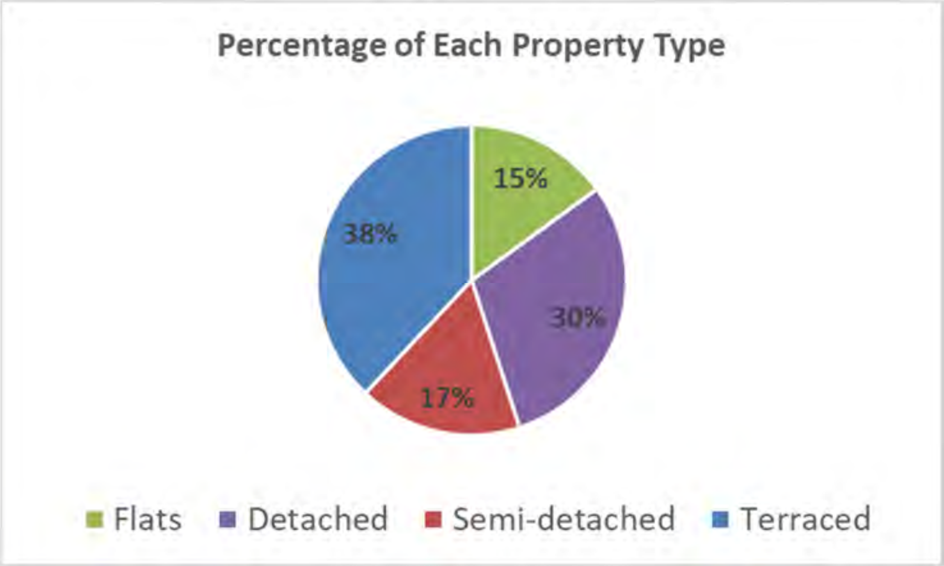

Figure 4-12 Final Breakdown Used for Domestic New-build

Floor area bands were allocated to all domestic new builds using average floor areas of post-1990 houses form English Housing Survey data (Table 4-4).

Table 4-4 New-build Floor Area Allocation

Property Type	Floor Area Band	Range (m^2)
Terraced House	2, 3 and 4	50 - 110
Semi-detached	3	70 - 90
Detached	5	110 - 200
Bungalow	3	70 - 90
Purpose-built Flat	2	50 - 70

4.4.2 New Build Non-Domestic Modelling Assumptions

The total floor area for each type of non-domestic activity class was provided in the draft GMSF (Table 4-5) and Bury Council's Local Plan. In cases such as schools the plans also provided the number of individual buildings. For the remainder, the number of individual buildings had to be inferred. For instance, in each site in the draft GMSF that specified new 'community facilities' it was assumed that one doctor's surgery, one dentist's surgery and one post office would be built. Their floor areas were calculated as being the mean of the floor area of existing buildings of the same activity class in Bury. In other cases such as for shops, the number of individual new buildings was calculated by taking the average number of dwellings per non-domestic building of the same type in the rest of Bury, and applying this rule to new builds. For instance, there are roughly 300 homes per shop in Bury currently, so it was assumed that for every 300 new build homes, a shop will be built.

Table 4-5 GMSF Requirement Non-Domestic New-build

Site Name	Non-domestic Floorspace
NG1a North of M62	1,580,000 m^2 (split between Bury and Rochdale)
NG1b South of M62	New school provision for homes
NG1c Whitefield	New school provision for homes New district centre and community facilities
OA2 Elton Reservoir Area	New school provision
OA3 Walshaw	New community facilities and local shopping provision
OA6 Baldingstone (Gin Hall and Bevis Green)	32,000 m^2 industrial and warehousing floorspace

4.5 Electricity Network

The nine modelled HV substations and their downstream connections define the analysis areas. 570 LV substations were mapped for the modelling, serving an electricity network modelled to be 2,400 km long. The length of network per number of buildings served for each analysis area is important, as this impacts reinforcement costs and also influences the types of heating system modelled as being cost-effective to decarbonise.

Figure 4-13 shows the substations used in the modelling. Some simplifications were made, including a private wire substation serving part of Bury town centre not being modelled separately and the HV substation in the Tottington West analysis area being modelled as on the boundary of Bury, when in fact it is outside the study area but serves buildings inside the study area.

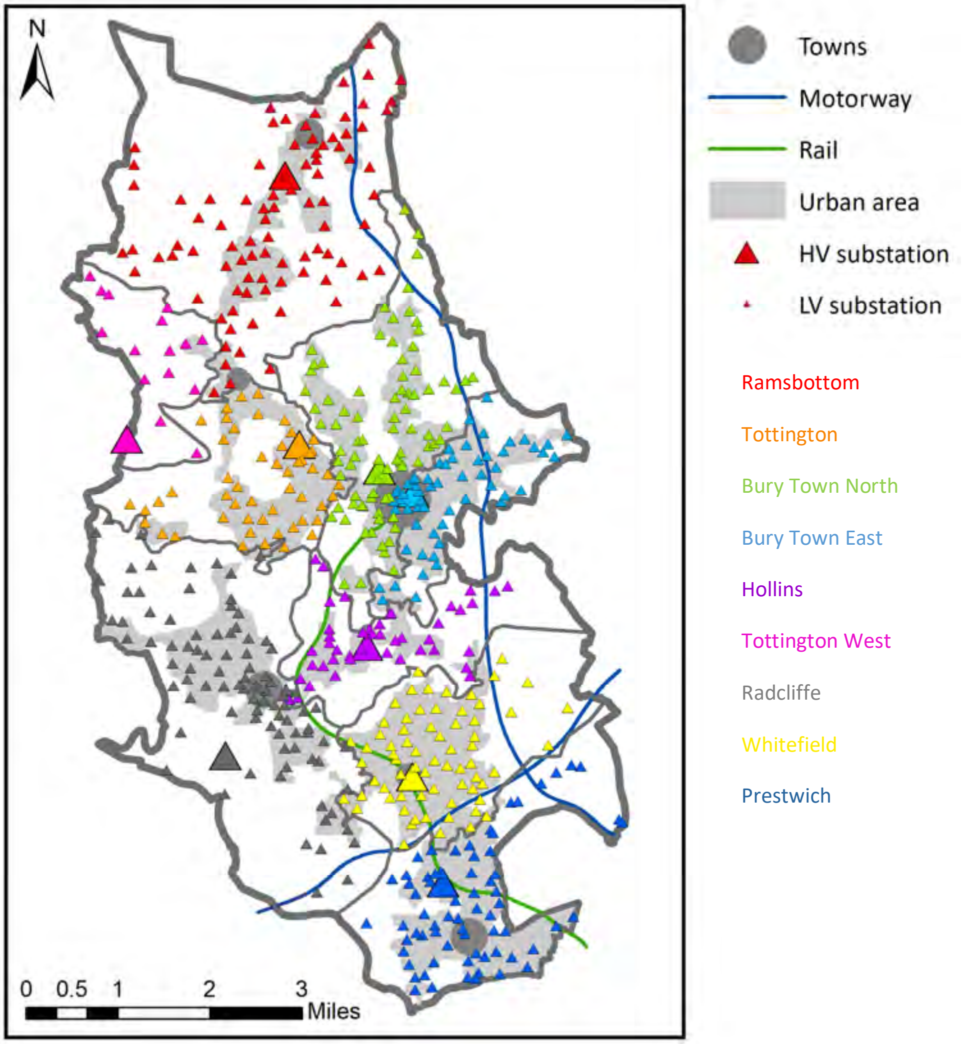

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Figure 4-13 Modelled Locations of HV and LV Substations in Bury

Figure 4-14 shows the current annual electricity demand intensity in Bury's analysis areas. Demand is highest in Bury town and Whitefield where building density is highest, and also in the analysis area corresponding with Radcliffe. It is lowest in Tottington West which is characterised by low housing density.

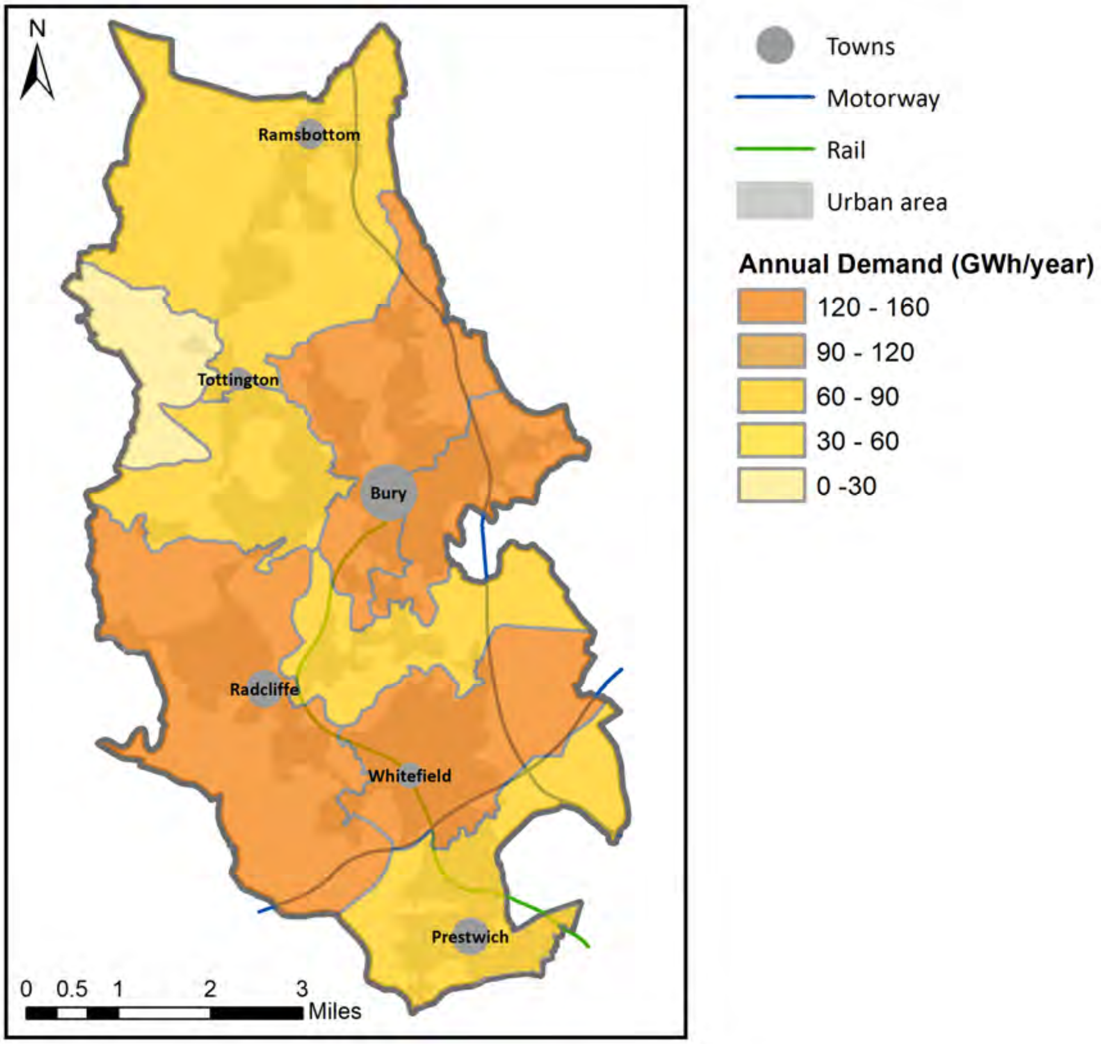

Figure 4-14 Current Annual Electricity Demand

4.6 Gas Network

Figure 4-15 shows the intermediate and high pressure gas network in Bury. For the purposes of the model, the gas entry points provide the source of gas into the Bury network area. Figure 4-16 shows areas with buildings that are off the gas grid, according to Experian postcode data.

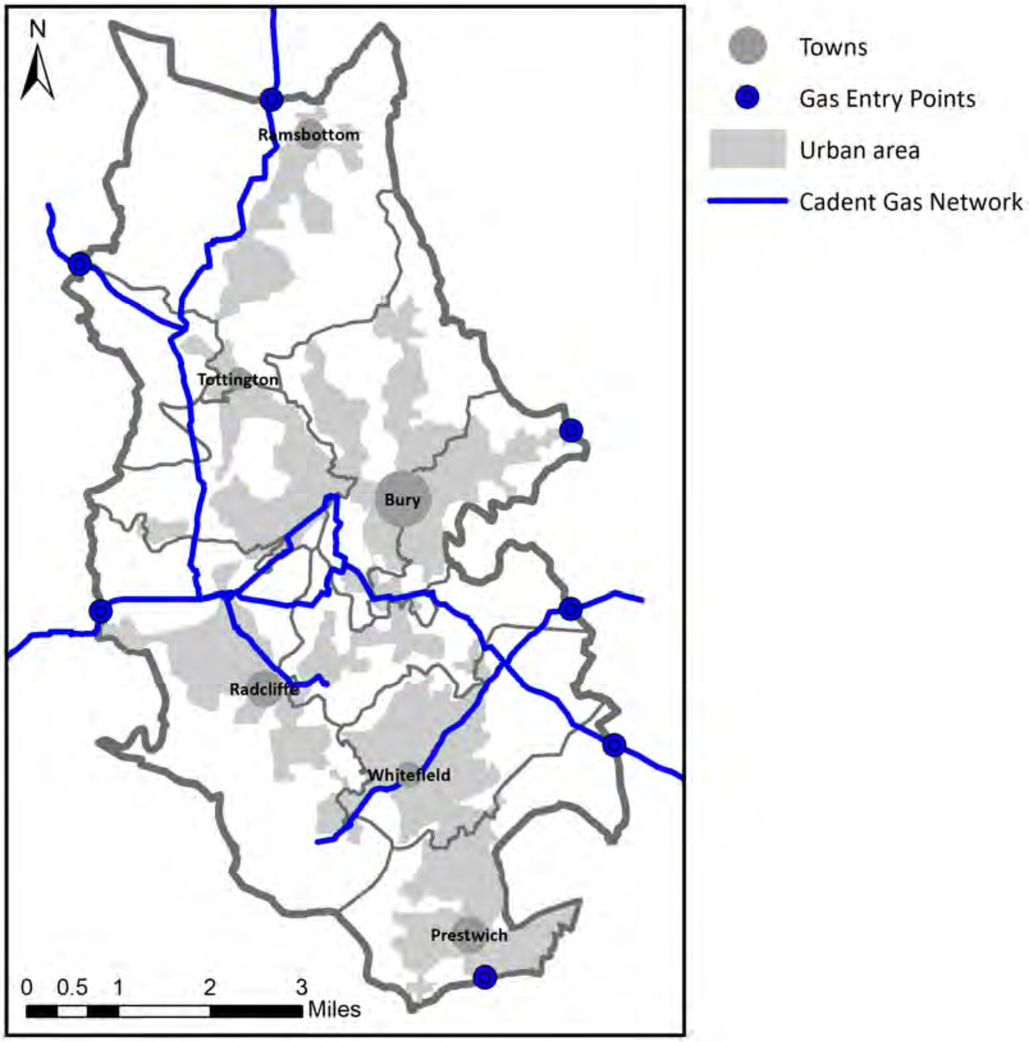

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Figure 4-15 Local Gas Network in Bury

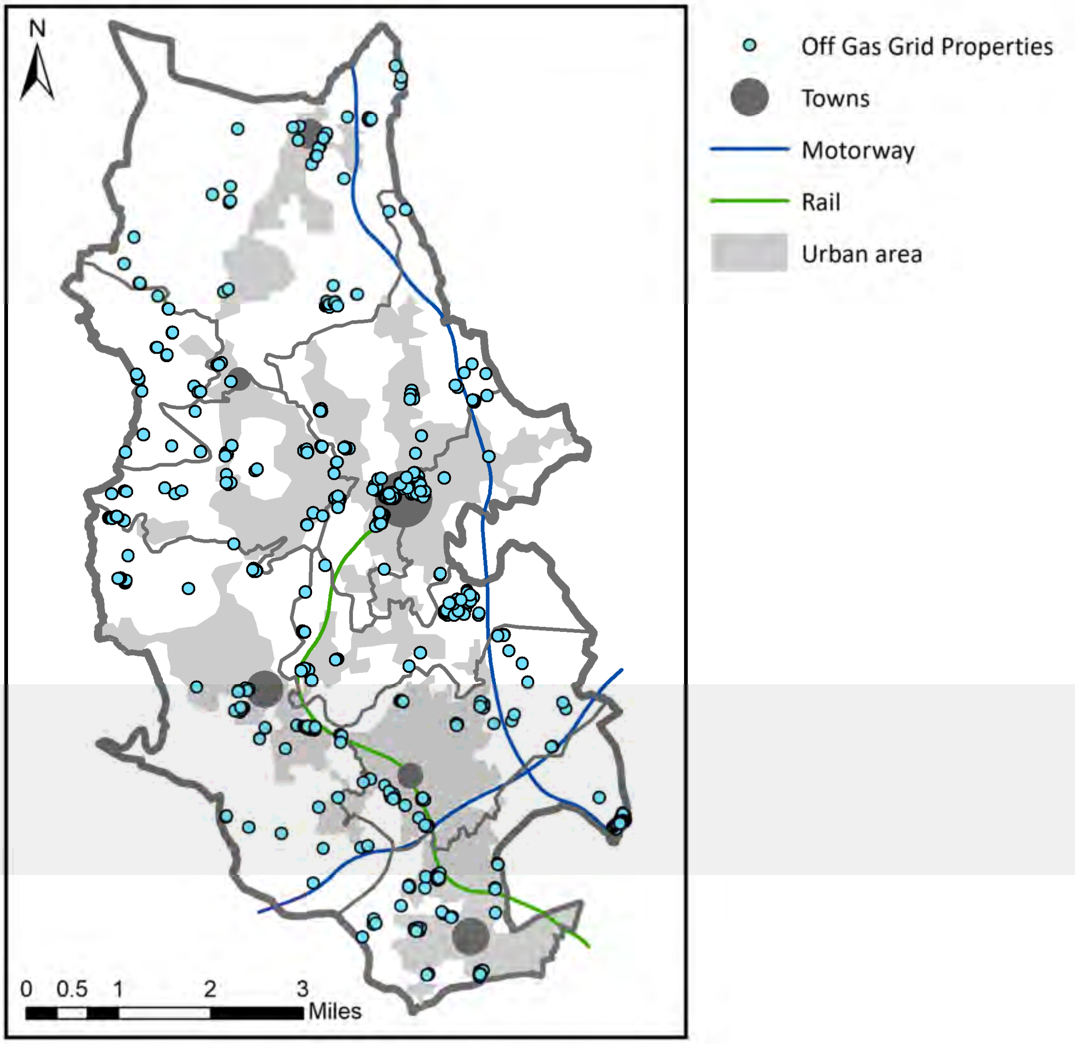

Figure 4-16 Postcodes shown as not being connected to the gas grid

Figure 4-17 shows the current annual gas demand intensity in Bury's analysis areas. Similarly to electricity demand, the highest demand corresponds to analysis areas with the highest building density.

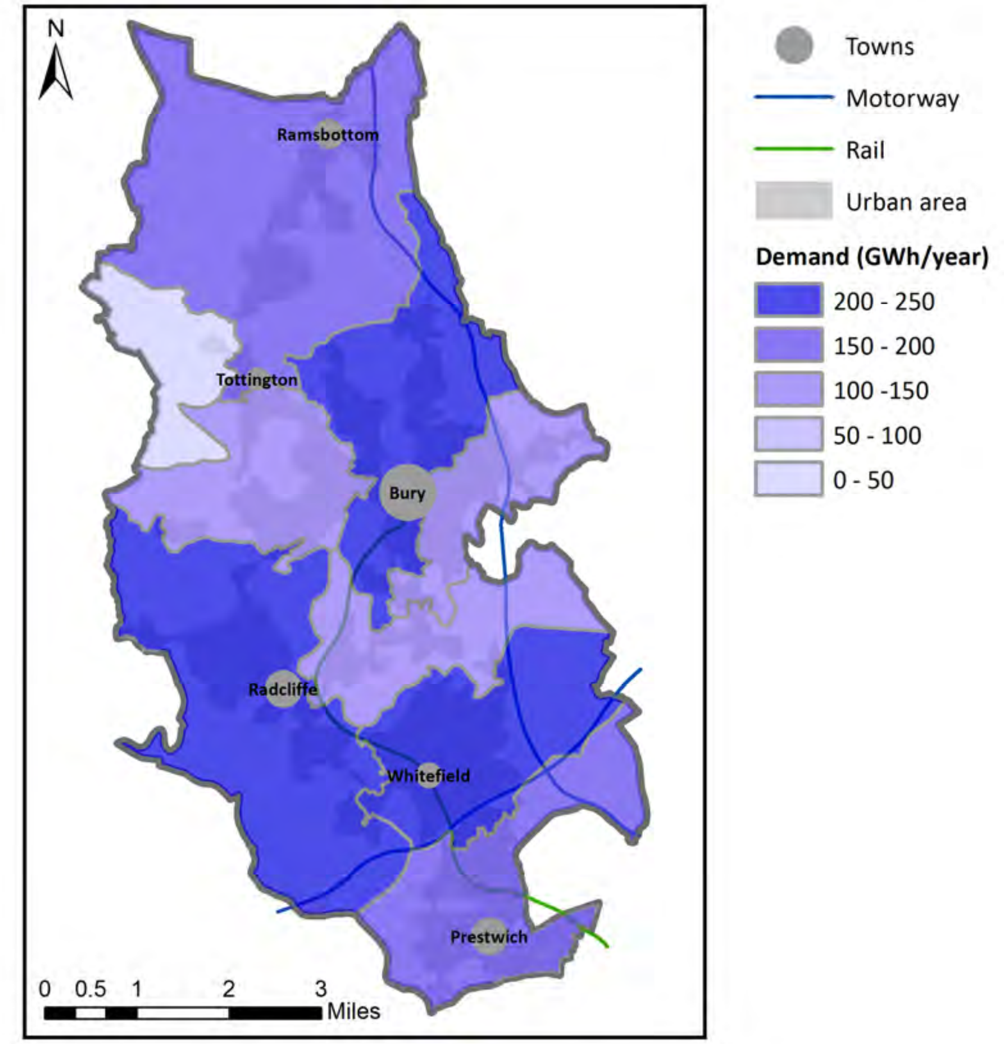

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Figure 4-17 Current Annual Gas Demand

4.7 Existing Low Carbon and Renewable Energy Infrastructure

A number of existing low carbon schemes in Bury were identified, including combined heat and power plants at Fairfield Hospital and Bradley Fold garden centre. There was no excess heat identified at these sites that could have been used for wider networks. This was also the case for a water treatment site sewage gas scheme. The building benchmarks for the hospital were modified to reflect the available data.

4.8 Future Low Carbon Options

Future potential wind sites and locations for water source heat pumps were identified, agreed with the stakeholder groups and included in the modelling as options.

The potential wind sites included were 500kWe turbines at Phillips Park and Redisher Wood, identified as possible medium sites by the local wind feasibility study[44]. A 3MW option was given at the Rhodes Farm sewage works site as identified by the Inner Radcliffe energy study[45].

Two water source heat pumps were given as options and were sized from the heat available in the national heat map[46].

The proposed future Bury Town heat network was considered and given as an option in the model.

The quantity for sustainable local biomass availability in Bury was determined from the Greater Manchester Tree Audit[47] and agreed with the key stakeholders.

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[44] Bury Council Phase 1 Feasibility Study. JBA Consulting, September 2014.

[45] Inner Radcliffe & Town Centre Energy Framework. AECOM and URBED. March 2011.

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

[47] Data analysed by Stockport LA and sourced from Redrose Forest and via 2009 and 2011 aerial photography – Greater Manchester Tree Audit (GMTA Consortium/Bluesky) Tonnes at 35% calculated as if 100% of the woodlands are managed and 100% of the yield is used for wood fuel feedstock

5 Options and Choices for a Low Carbon Energy System

The modelling for Bury consisted of three main phases:

1. Building a representation of the local energy system and developing the initial modelled views of the future. This initial modelling was an iterative process, improving the representation based on local stakeholder feedback. The outcome was two runs, one representing by 2050 a 90% reduction in in scope carbon emissions from 1990 levels and one for comparison showing the energy system impact of No Local Carbon Target.
2. Sensitivity testing: this built on the 90% carbon reduction initial run and tested the impact of changing different external factors. This provided a body of evidence to influence choices for the final runs and to help assess the level of sensitivity to and risk from external factors.
3. Final modelling runs after the sensitivity analysis. This incorporated learning from the sensitivities, data updates and model improvements developed during the project. It also reflected increased ambitions from Bury LA to cut carbon.

The modelled scenarios considered in this document are listed below:

Initial Modelling *The first modelling for Bury, providing an initial view of the future local energy system*		
No Local Carbon Target	An initial scenario without a local carbon target for Bury. This is used as a comparator for the carbon reduction scenarios, to illustrate which changes and costs are due to the local carbon target.	p62
90% Carbon Reduction by 2050	The initial carbon target scenario for Bury, representing a carbon reduction trajectory that gives a 90% decrease in in-scope emissions by 2050.	p65
Sensitivity Testing *A set of modelling building on the initial scenarios and testing the sensitivity to external changes*		
National Pathway	To test how national policy changes may influence the lowest cost plan to decarbonise for Bury.	p71
Energy Costs	To investigate how the plan for decarbonising Bury is sensitive to the cost of energy between now and 2050.	p80
Technology Cost	A Monte Carlo approach to test the influence of technology and infrastructure costs on Bury's future energy system.	p89

Insulation in households most likely to be fuel poor	Considering whether the targeting of insulation into homes most likely to be fuel poor influences decarbonisation.	p93
Lower Carbon Gas	Exploring if the availability of a lower carbon blend of hydrogen and natural gas would change the opportunities for decarbonisation in Bury.	p98
Domestic Battery Storage	Examining the potential role of domestic battery storage in the decarbonisation of Bury.	p106
Different Carbon Targets	Investigating how the most cost-effective plan for Bury varies by different carbon targets, identifying similarities and differences between them.	p114
Maximum Carbon Reduction	Exploring the impact of trying to cut carbon as quickly as possible.	p125
Post Sensitivity Modelling ***The final phase of modelling, incorporating decisions from the sensitivity analysis and updates to data and model***		
No Local Carbon Target	The final model scenario representing Bury's future energy system without a local carbon target. This acts as a baseline for the other post sensitivity runs to be compared to.	p132
98% Carbon Reduction by 2050	A final model scenario representing Bury's updated ambition for 100% clean energy by 2050.	p132
96% Carbon Reduction by 2040	A scenario run testing an earlier carbon reduction ambition for Bury. A 96% reduction in in-scope emissions is the greatest the model suggests is achievable by 2040.	p132
Possibilities for Gas	An investigation of where and how a limited amount of gas could be best used in Bury's future energy system.	p163

5.1 Initial Modelling

The initial modelling described in this document was used as the base for the sensitivity and scenario analysis.

These initial attempts to model Bury's energy system were analysed and presented in detail to key stakeholders to aid their understanding of the approach and to allow them to identify any issues or concerns. Their feedback enabled improvement of the modelled representation of Bury.

The results from this initial modelling are presented in brief in this document as they were superseded by the final 'post sensitivity' modelling (p132 onwards) which includes updates and improvements to model data and functionality.

5.2 No Local Carbon Target

Summary

Modelling Bury's energy system to 2050 without a local carbon target showed that there would not be widespread change from the current system – with 95% of domestic buildings and 93% of non-domestic floorspace staying on their initial gas systems. Some limited use of Gas CHP fed district heating was found to be cost effective, with approximately 4000 homes and 640 non-domestic buildings connecting to a heat network.

5.2.1 Context

To assess the costs and impacts of a plan to decarbonise it is necessary to compare it to a scenario without an emissions reduction required in the model. This represents what would be expected to happen to the energy system without a local carbon target in place.

This model scenario was the initial representation of Bury's energy system. Although No Local Carbon Target was modelled, the national level inputs (e.g. from the ETI ESME tool) reflected expected national decarbonisation to 2050. The UK has a legally binding national carbon reduction target under the Climate Change Act, 2008[48]. This scenario assumes that, regardless of local action, national action will be taken towards meeting this national target. This means that input values in the model still change over time, for example national generation technologies decarbonise, which causes the grid electricity price to increase.

5.2.2 Methodology

A scenario was tested with no local carbon reduction required. A constraint was applied to stop the modelled emissions exceeding present day levels. Changes to the energy system only occurred if they gave a financial saving, as the model had no incentive to decarbonise.

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[48] http://www.legislation.gov.uk/ukpga/2008/27

5.2.3 Results

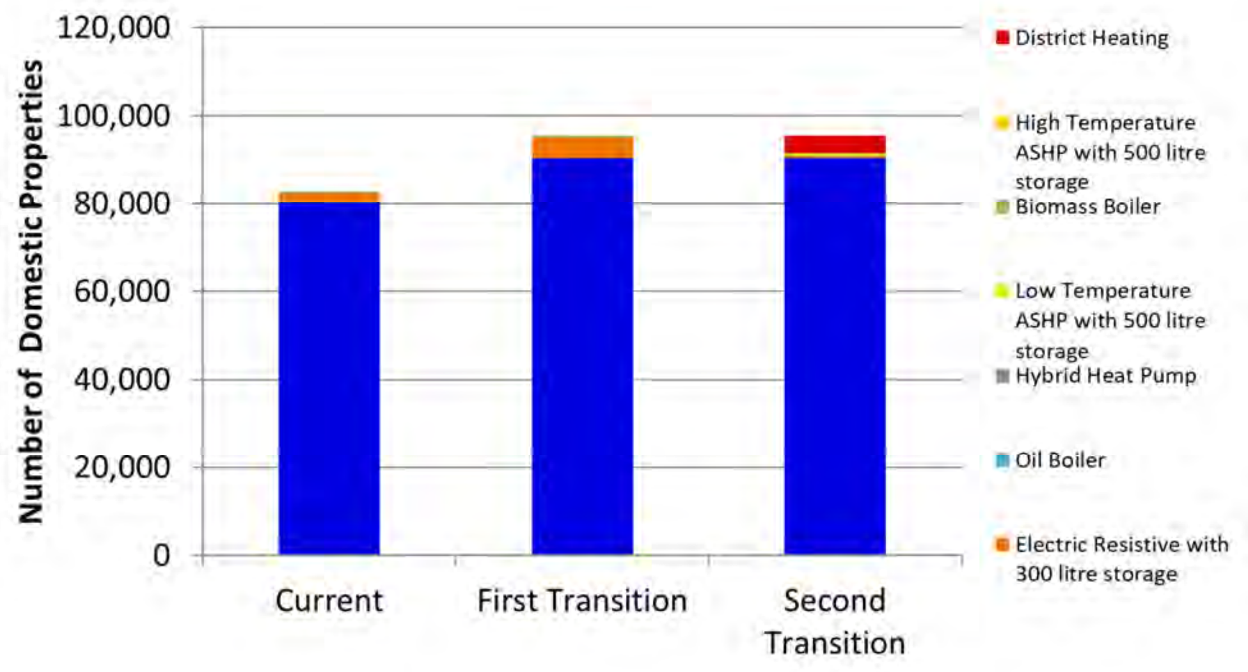

Figure 5-1 Modelled Domestic Heating Systems under a No Local Carbon Target Scenario. The first transition is prior to 2035 and the second 2035-2050.

Without a local carbon target there is little change expected to domestic heating systems, with 95% of domestic buildings in Bury remaining on gas in 2050 (Figure 5-1). Around 4,500 properties connect to a heat network fed by gas CHP. These properties are concentrated in Bury town and Prestwich. The increase in total building numbers shown between the two transitions represents planned new build developments in the Bury area.

For non-domestic buildings 93% of the floorspace remains on its initial heating system. The 7% that transitions to a heat network consists of 640 non-domestic addresses, and makes use of gas CHP to generate heat cost effectively.

5.2.4 Key Findings

- Without a local carbon target there is little modelled change in Bury’s future energy system.
- A small number of homes and non-domestic buildings were found to be cost-effective to connect to a heat network. If national decarbonisation of the electricity grid occurs and increases the electricity price then these would seem to be good options, regardless of local ambition or targets.
- In this scenario the heat networks are gas-fuelled. The model shows that these are cheaper than ones where the heat is generated in a low carbon manner. If the heat network was required to be low-carbon then in this scenario it may not be financially viable.
- Without a local carbon target modelling suggest a carbon reduction of 65% from 1990 levels would still be achieved. This is due to decarbonisation of the national grid and changes in local industry since 1990.

5.3 90% Carbon Reduction by 2050

Summary

To reduce in-scope emissions by 90% by 2050, widespread and significant local energy system change would be required in Bury. Approximately two-thirds of domestic buildings would be required to move away from heating using gas boilers. Meeting this carbon target is modelled to cost an extra £560m, a 6.5% increase in the total local energy system cost compared to not having a local carbon target.

5.3.1 Context

This scenario was the first attempt to model how Bury's local energy system would change with a local carbon target in place.

At this stage of the project Bury as a Local Authority did not have a defined carbon target. A discussion was held with the key stakeholder group to agree an initial target for the modelling, and this was set to be a straight line trajectory which achieved a 90% reduction in emissions from 1990 levels by 2050.

5.3.2 Methodology

A carbon constraint was applied in the model, limiting emissions for 2050 to be 90% of the estimated in-scope 1990 value. Intermediate targets were set for 2030 and 2040 to force a linear reduction over time.

5.3.3 Results

The model selected a set of options that met the carbon requirements, leading to a gradual reduction in carbon emissions (Figure 5-2).

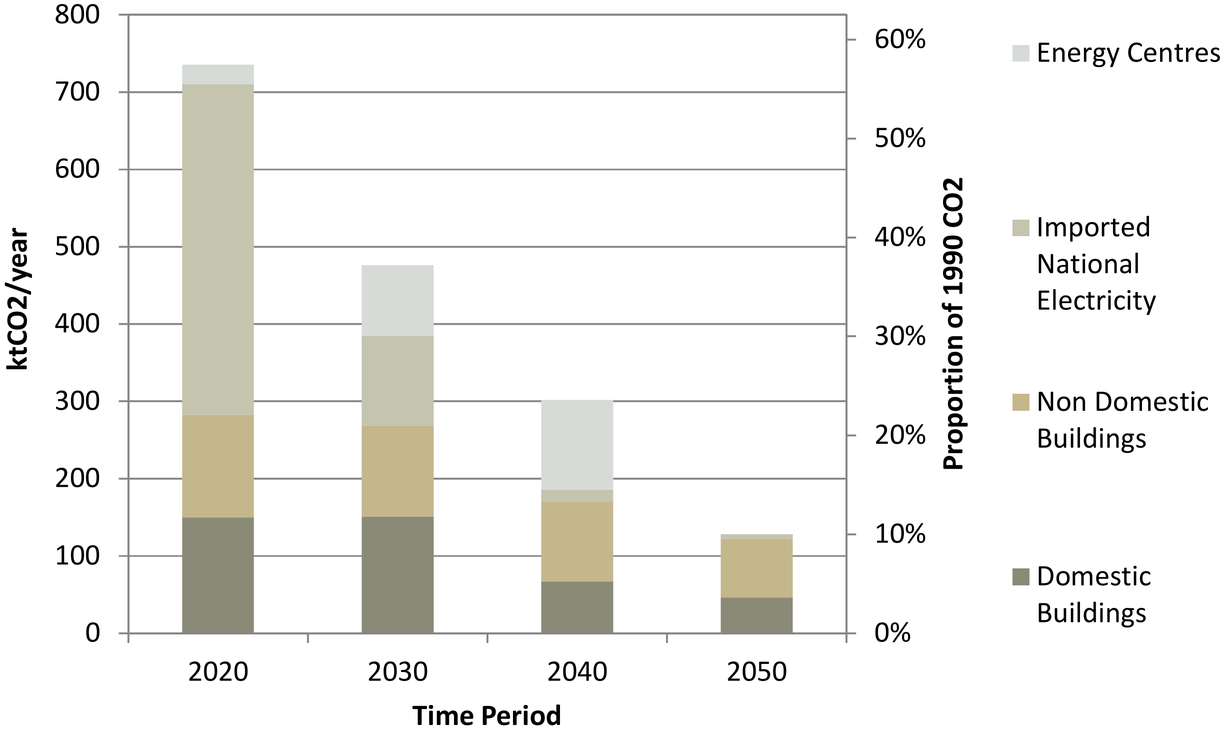

Figure 5-2 The modelled carbon trajectory to achieve a 90% reduction in emissions by 2050 (in-scope emissions, compared to 1990 levels)

By 2050 the national grid is expected to have decarbonised and so the emissions associated with grid electricity generated nationally and used in the study area drop to virtually zero. The emissions remaining are from remaining gas usage in domestic and non-domestic buildings. Before 2050 there are emissions from gas technologies used in energy centres, but by 2050 these are modelled to switch to low carbon options.

At transition two domestic heating systems change from gas to low carbon (Figure 5-3), leading to the decrease in emissions from domestic buildings.

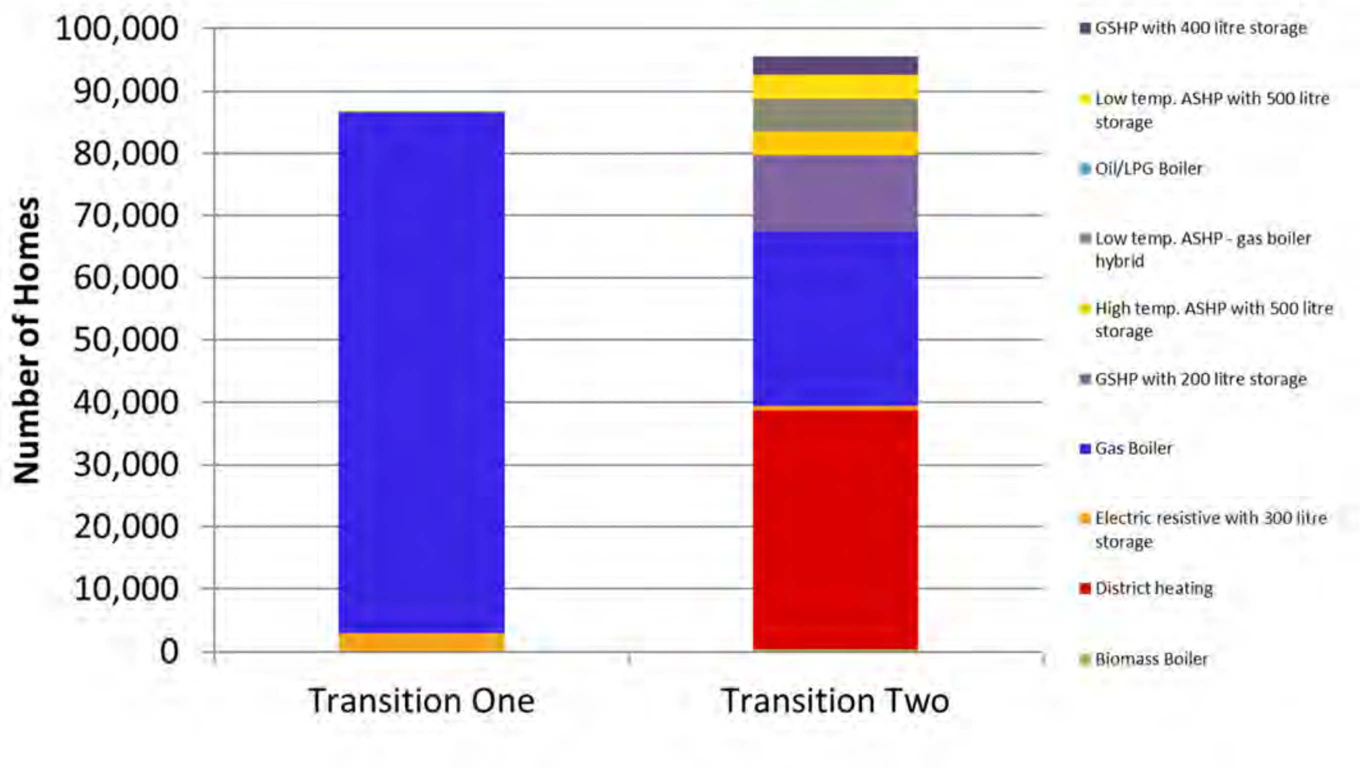

Figure 5-3 Modelled Domestic Heating Systems under the 90% Carbon Reduction Scenario

Figure 5-3 shows heating systems across the two transitions between now and 2050. Transition one shows little change from the current situation, as the carbon target in place at this point does not require it and so it is cheaper to remain on gas. By the end of transition two approximately two thirds of domestic buildings are modelled to have switched to a low carbon option. In 2050 a third of homes have their heat provided by a low carbon heat network, a third have an individual electric heating system (usually a heat pump) and the final third remain on a gas boiler.

The selected heating systems vary by area of Bury (Figure 5-4).

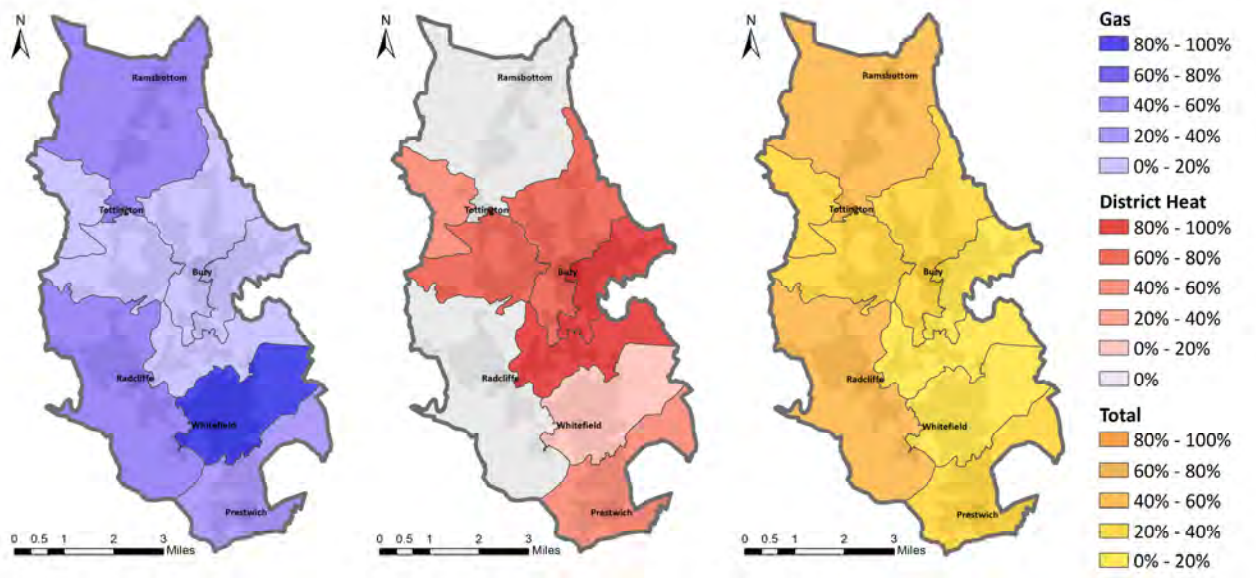

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Figure 5-4 Modelled Spatial Distribution of Categories of Domestic Heating Systems in 2050

Domestic district heat is most prevalent in the central eastern area of Bury, which partially covers Bury town centre. Electric heating systems are greatest in the north and west of Bury, which are generally more rural areas. The highest levels of remaining gas boilers are in the north and south.

Some of the non-domestic heat in Bury was modelled to be provided by low carbon heat networks (Figure 5-5). The estimates of non-domestic heat in these maps represents the modelling at this stage of the project and were revised for the final phase based on improvements to input data.

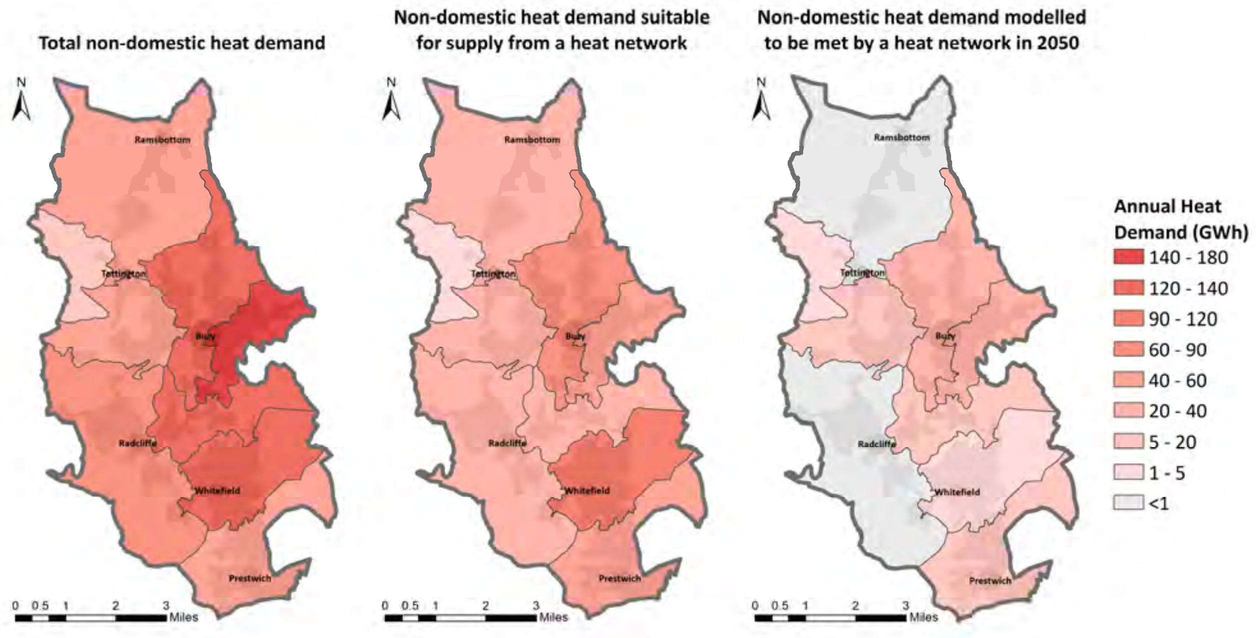

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Figure 5-5 Non-domestic heat demands modelled to be met by a heat network in 2050.

The middle map shows the level of non-domestic heat considered to be suitable for supply by a heat network. The difference between this and the left-hand map represents heat that the model considers not suitable for supply in a low carbon manner, such as high-grade process heat in heavy industry.

The areas with greatest levels of non-domestic heat supplied by a network coincide with the areas of greatest domestic heat network connections.

The model aims to achieve the carbon target at the lowest costs. In this scenario the minimum cost of achieving the 90% carbon target was modelled to be £570 million (Figure 5-6). This was a 6.5% increase on the cost of the local energy system if there had not been a carbon target.

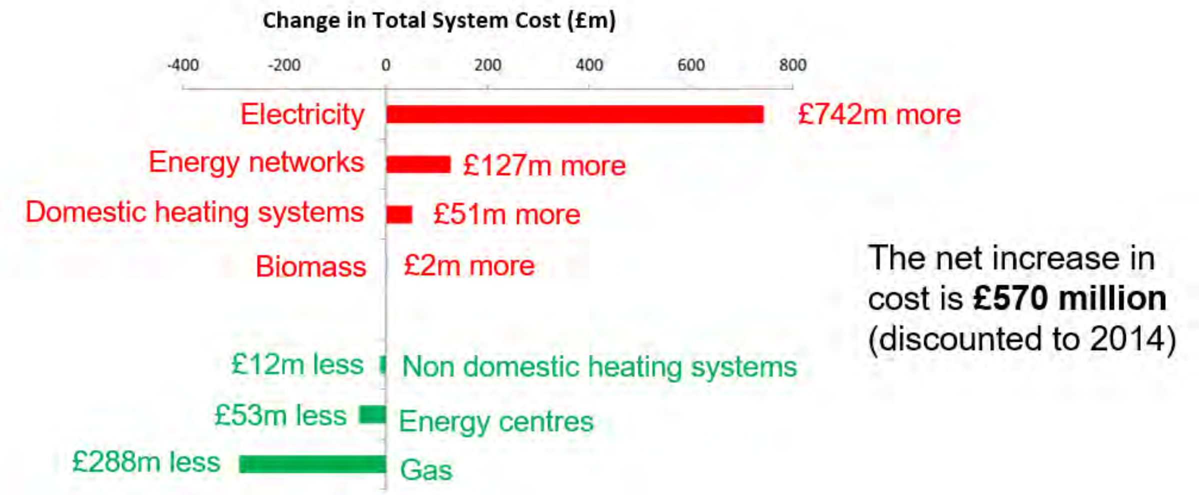

Figure 5-6 Changes in total energy system cost modelled to occur with a local carbon target

The greatest increase in spend is on electricity. Using less gas provides a smaller saving, so the net increase in energy spend is £450m. Greater spend is also required to switch domestic heating systems and reinforce the electricity network to meet the increased demands for electric heat.

5.3.4 Key Findings

- A 90% carbon reduction in Bury is achievable through a combination of gas and low carbon heating systems in the Bury area. The gas systems are cheaper and so designing a policy that allows some but not all households to remain on gas may be challenging.
- There are clear variations in heating system deployment across Bury, which suggests that planning and policy need to consider the characteristics of the local area.
- The total cost of Bury's energy system is significant regardless of a carbon target. A 90% carbon reduction is modelled to have an additional total discounted cost of £570m, but this is a 6.5% increase on the cost without a local carbon target.

5.4 Sensitivity Modelling

This phase of modelling consisted of a series of sensitivity scenarios, tested on the initial 90% carbon reduction by 2050 plan. These identify how different external factors might influence the lowest cost plan for Bury. They were also used to help build consensus with the stakeholders as to which factors should be included in the definition of future local energy scenarios and system designs.

Looking at the results across all the sensitivity modelling together also allows an assessment of the level of risk of different options, highlighting which parts of a plan to decarbonise the local energy system in Bury is likely to be most sensitive to external factors and which may be lowest regret. This analysis is discussed further in section 6 (p167 onwards).

To ensure consistency and enable comparison between the runs, the initial 90% carbon target scenario was used as a base, and the only changes made were the specific factors tested in that sensitivity.

Any general data modifications or improvements that were identified over the course of this modelling (e.g. a new dataset coming available) were not applied at this stage, but were instead incorporated into the final modelling.

5.5 National Pathway Sensitivity

Summary

The lowest cost plan to decarbonise Bury is sensitive to changes in the national energy system. Testing a national scenario with more centralised decision making revealed the plan would have almost 50% less homes connected to district heating and a lower total cost of decarbonisation, approximately half that of the original scenario.

5.5.1 Context

The ETI ESME (Energy System Modelling Environment) tool[49] generates pathways for the national energy system to 2050. These act as inputs for key factors in EPN, including prices for energy imported into the study area and the carbon content of nationally generated electricity.

ESME scenarios reflect policy, economic and societal choices and there are alternative scenarios where these choices differ. The initial modelling for Bury used an ESME scenario known as Patchwork. This represents a society-driven solution to decarbonisation, where there is less central government involvement. This leads to a patchwork of distinct energy strategies at a regional level. Cities and regions compete for central support to meet energy needs tailored to their local conditions.

The main alternative scenario is Clockwork, which represents a more centrally mandated solution, where well-coordinated, centralised, long-term investments based on national-level planning ensure steady decarbonisation of power, deploying large scale heat networks and phasing out of the gas grid.

This sensitivity looks at how local energy system designs and costs of the decarbonisation of Bury may differ under the Clockwork scenario. This helps assess the extent and direction in which Bury’s approach should be different if there are a stronger set of national energy policies developed in the future.

The sensitivity also allows the identification of decisions for Bury that are most sensitive to national energy policy changes.

5.5.2 Methodology

The ESME scenario used as an input in the model was switched from Patchwork to Clockwork and the No Local Carbon Target and the 90% Carbon Target scenarios were modelled using the new inputs.

The input changes between the two scenarios considered to be most important in EPN were the carbon content and cost of grid electricity, shown in Figure 5-7 and Figure 5-8.

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[49] http://www.eti.co.uk/programmes/strategy/esme

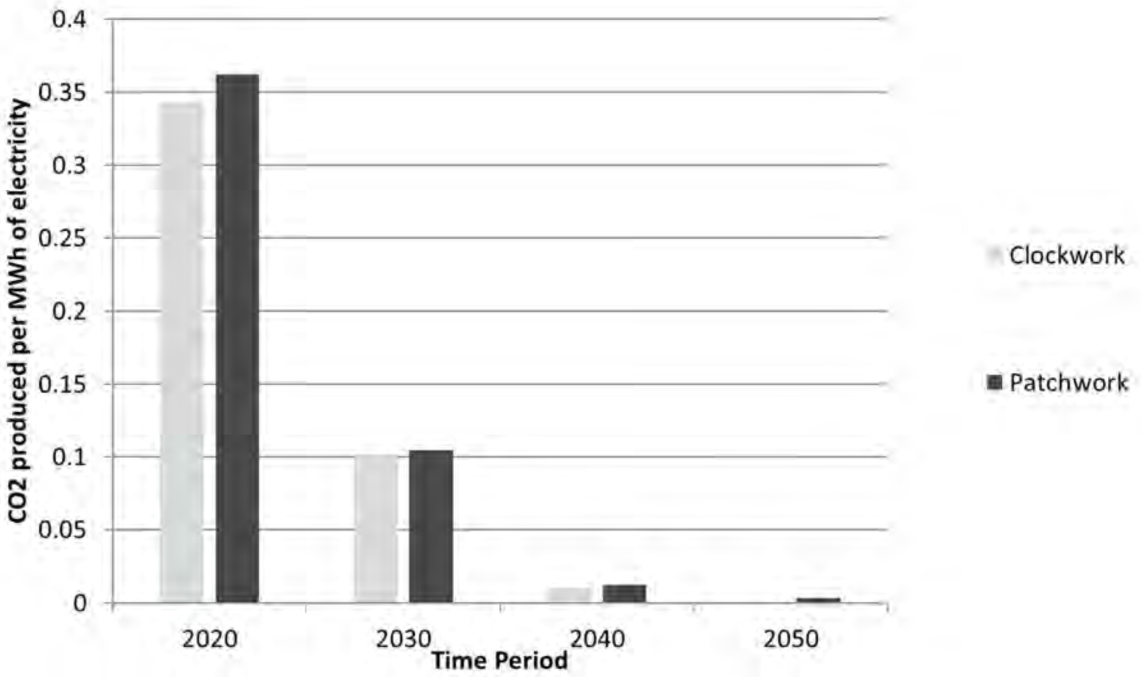

Figure 5-7 Grid Electricity Carbon Contents under ESME Clockwork and Patchwork Scenarios

In the Clockwork scenario the carbon content of grid electricity is consistently lower than in Patchwork (Figure 5-7). In the Clockwork scenario there is more national low carbon generation capacity built.

Initially electricity starts off more expensive under the Clockwork scenario, but by 2040 it is significantly cheaper than Patchwork (Figure 5-8).

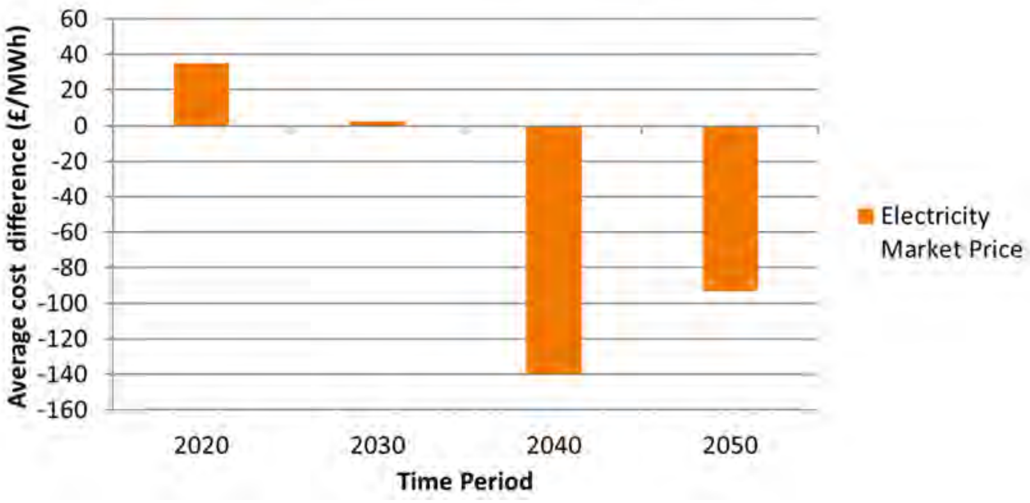

Figure 5-8 Difference in Grid Electricity Costs between ESME Clockwork and Patchwork scenarios (Expressed as Clockwork price minus Patchwork price), i.e. a positive number indicates electricity is more expensive in Clockwork.

Overall grid electricity in Clockwork is both cheaper and lower carbon than in Patchwork. These factors increase its appeal as an energy source for decarbonisation, so it can be expected that electricity will be play a bigger role in a decarbonisation plan based on Clockwork than it would in a plan based on the Patchwork scenario.

5.5.3 Results

The changes in grid electricity price and carbon changed the modelled lowest-cost plan for Bury to cut its carbon emissions by 90%.

Under Clockwork 20% of domestic buildings are supplied by a district heat network by 2050 (Figure 5-9), compared to 40% in the original Patchwork scenario. Most of the buildings no longer on heat networks remain on gas, with a small number switching to an electric heat pump.

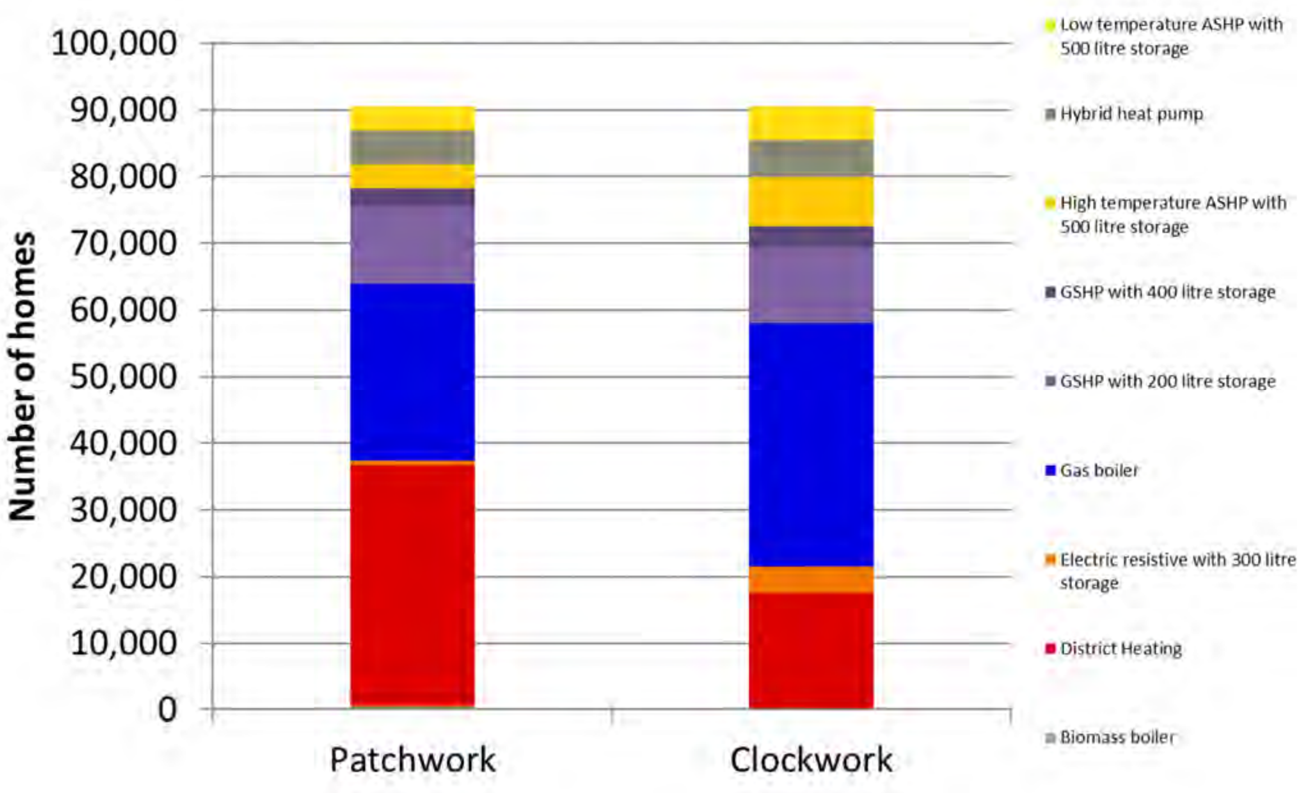

Figure 5-9 Modelled breakdown of 2050 domestic heating systems under two national scenarios with a 90% carbon target

The differences in the heating systems occur for two main reasons:

- The lower carbon content of grid electricity means fewer buildings need to transition to a low carbon option to achieve the local carbon target. Gas boiler systems are modelled as cheaper than low carbon options, so it is cost effective to keep more buildings on gas.
- District heat networks are more efficient users of electricity than single building heat pumps and so they become more cost-effective as electricity costs increase. As electricity prices are lower in Clockwork the heat networks are less cost effective. This is explored in detail in the energy costs sensitivity (p80).

The level of change in heating system is not equal across Bury. Figure 5-10 shows where changes happen, identifying the areas of Bury most sensitive to the changes in national policy. Bury Town North and Prestwich show significantly less uptake of district heat in Clockwork, with no domestic district heat left in Bury Town North and only 700 buildings in Prestwich. The heating systems chosen in Ramsbottom, Tottington, Radcliffe and Westfield show little sensitivity to national policy changes.

	National Policy	
Homes on District Heat	Patchwork	Clockwork
Bury Total	38,300	18,500
Areas showing most change:		
Bury Town North	8,600	0
Prestwich	7,500	900

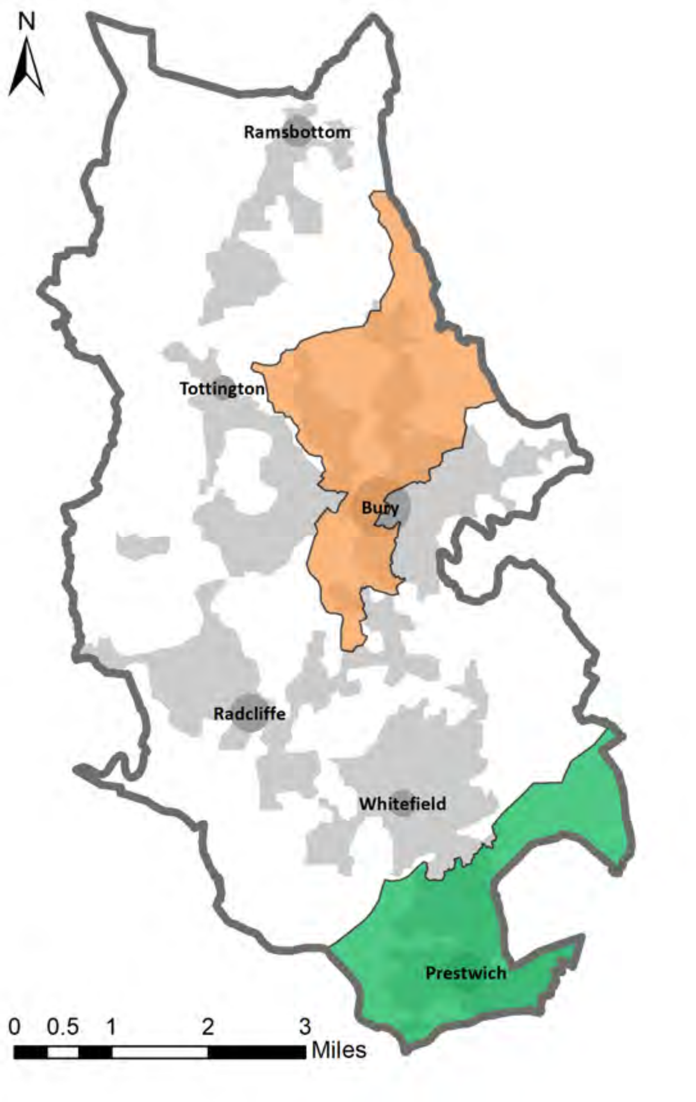

Figure 5-10 Areas of Bury showing greatest changes in district heat deployment under different national policy scenario

The sensitivity testing of energy costs (p80) indicates that the two areas indicated in Figure 5-10 as being most sensitive to national policy changes were also highly sensitive to electricity cost changes.

Despite the decrease in domestic district heat connections, the modelling shows a substantial increase in non-domestic floorspace connected to a heat network in the Clockwork scenario (Figure 5-11).

The non-domestic heating systems are less sensitive to the lower electricity costs. This greater level of decarbonisation of non-domestic buildings creates some of the decrease in emissions that allows more domestic buildings to remain on gas boilers.

The net effect is that under Clockwork less heat is generated in energy centres after 2025, and a different combination of technologies can be used to produce it (Figure 5-12).

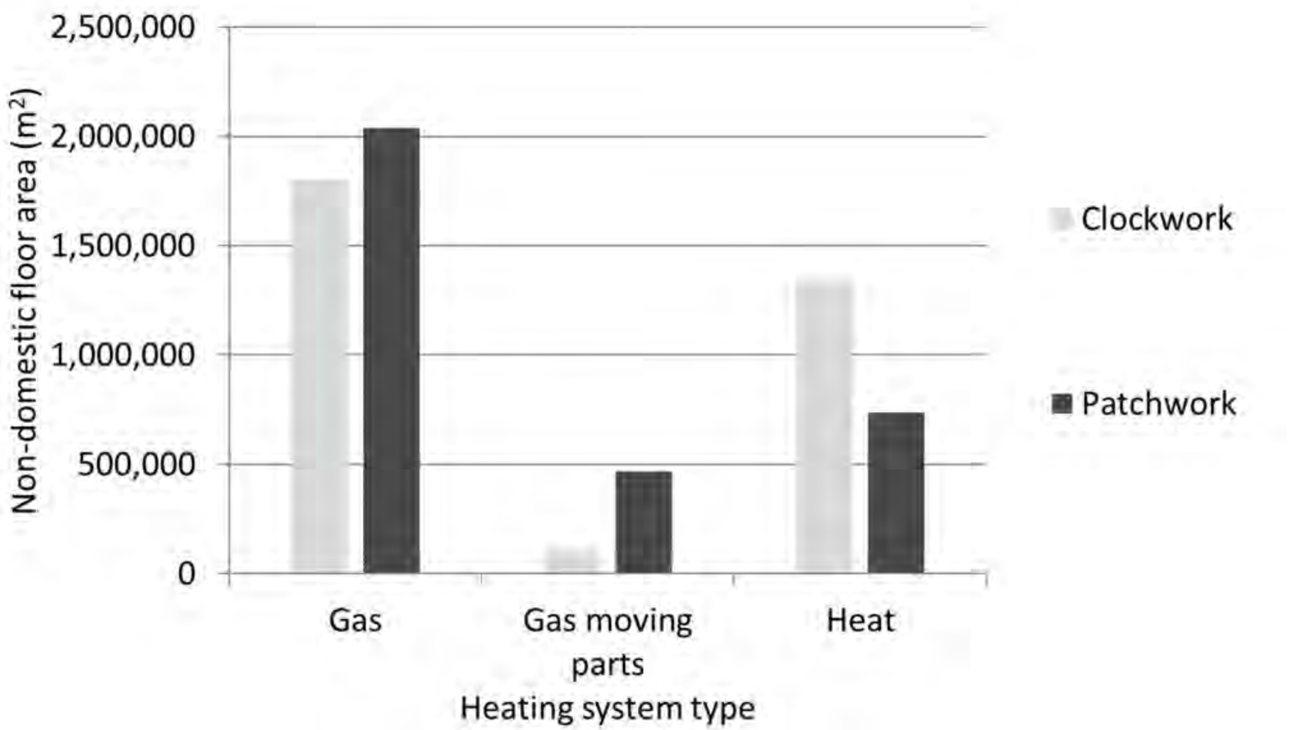

Figure 5-11 Non-Domestic Floor Area under Different Heating Systems by ESME Scenario

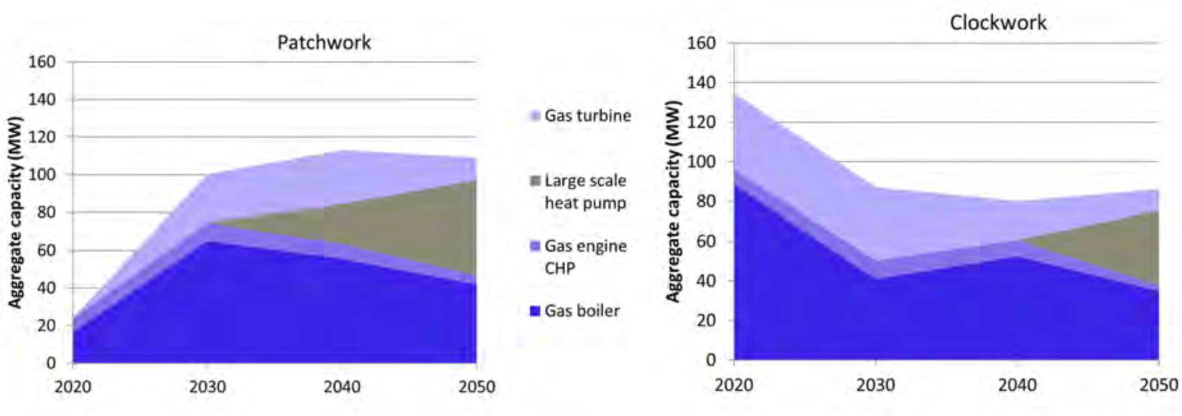

Figure 5-12 Energy Centre Aggregate Capacity by Technology and National Policy Scenario

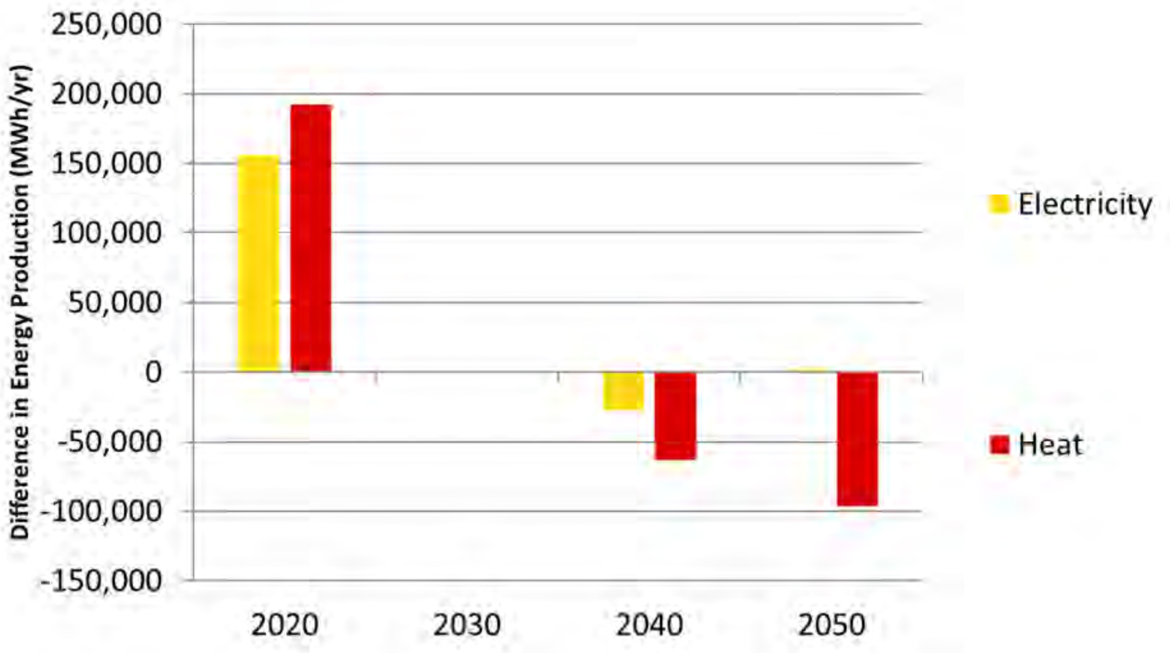

Figure 5-13 Difference in Energy Centre Production between National Policy Scenarios *(where positive values indicate more in Clockwork*)

Under the Clockwork scenario a greater proportion of the heat generation in 2050 is gas based. This is the same pattern as the domestic heating system deployment and is because the lower carbon content of grid electricity allows greater use of cheaper, higher carbon heat sources.

The initial high energy centre capacity in Clockwork is due to the higher electricity costs making local electricity generation more cost effective. The technology used for generation varies by the level of demand: by 2050 the base load is provided by the low carbon technologies and the gas capacity used only to meet peak demands. On an annual basis only a small amount of heat is produced by a gas technology, and the majority of this is from the CHP rather than the boilers. The boilers are available to provide top up heat on the coldest days.

The future energy system for Bury would be cheaper under the Clockwork scenario. This applies with and without a carbon target, but the difference between having a target and not having a target is less. This implies the extra cost of cutting carbon is less (Table 5-1).

Table 5-1: Modelled energy system cost differences between national policy scenario

	Clockwork	Patchwork
No Local Carbon Target	£8,300m	£8,750m
90% Carbon Target	£8,550m	£9,300m
Extra cost of the carbon target	£250m	£550m

The extra spend required to achieve the carbon target in Clockwork is £250m, less than half of the extra cost under Patchwork. The carbon target sensitivities (p114) identified that spending the £250m under the Patchwork scenario would only cut Bury's emissions by 85%.

Considering the breakdown of costs (Figure 5-14), the most significant contributor to higher system costs under the Patchwork scenario is grid electricity. This is particularly true in the second half of the study period. Even with a larger proportion of houses on district heat, in the 2040's Patchwork electricity costs are around twice that of Clockwork.

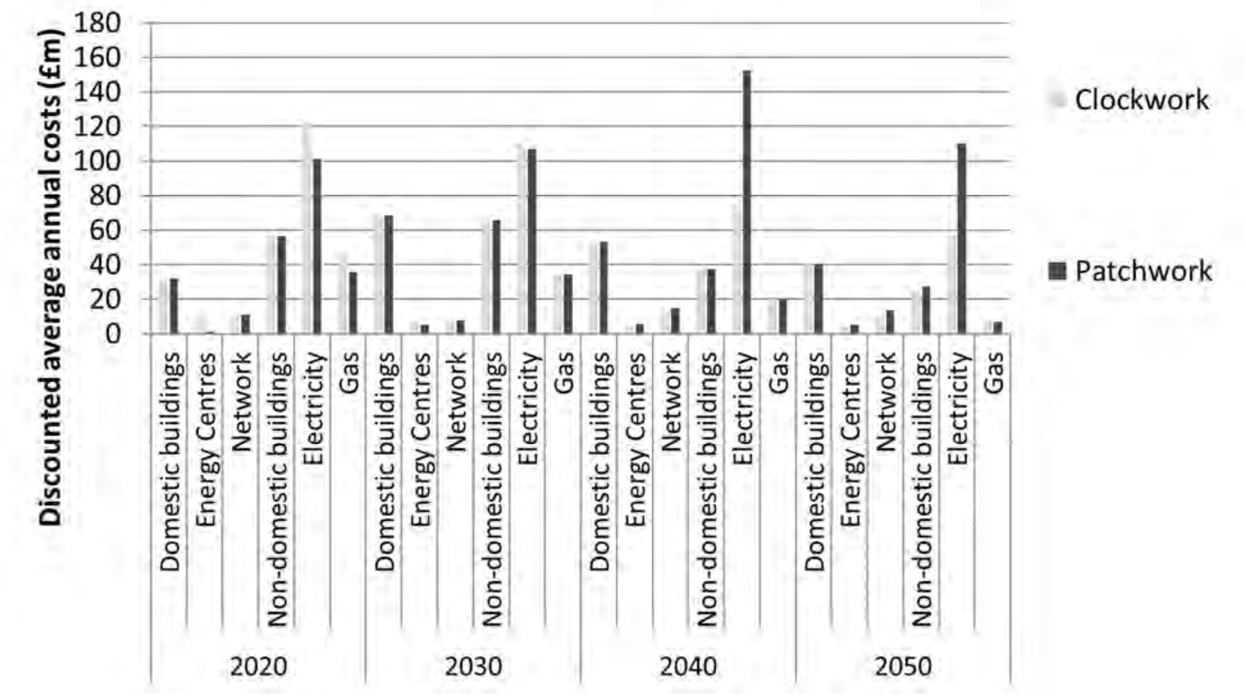

Figure 5-14 Discounted costs (£m) for two national scenarios under a 90% Carbon Target

5.5.4 Key Findings

- National energy policy will significantly impact the cost of decarbonisation in Bury.
- National policy can be unpredictable and is outside of the local areas direct control. Bury's local area energy strategy needs to be able to adapt to changes and uncertainty in the national energy landscape.
- Testing a more cohesive national energy scenario with cheaper and lower carbon grid electricity shows a lower uptake of district heat for domestic properties and greater numbers of gas boilers.
- Some areas of Bury have greater levels of difference in heating system under the different scenario, and so these areas should be considered less certain and higher risk.
- The total cost of decarbonising the energy system also changes, with transition costs under Patchwork higher than under Clockwork. The most significant cost difference is in the electricity price and usage. Without a clear view of future national policy there is significant uncertainty about the cost of meeting a carbon target.

5.6 Energy Cost Sensitivity

Summary

A range of different future gas and electricity costs were tested. The optimal plan to decarbonise heating of buildings in Bury was found to be sensitive to electricity cost, with greater district heat deployment as the cost increases. Several areas of Bury can be identified as most sensitive to the cost and future planning should take this into account.

5.6.1 Context

Between now and 2050 national energy costs can be expected to change significantly. These costs are a key input into the model and impact on the cost of and optimal plan for decarbonisation.

The ETI ESME model provides projections of these national energy costs, but testing a wider range accounts for uncertainty in these values. This assesses whether changes in cost lead to changes in the optimal decarbonisation plan for Bury.

5.6.2 Method

A series of scenarios were tested with adjustments to individual energy product costs. These represent the costs of energy imported across the boundary into Bury. Each run changed only one product cost (i.e. electricity or gas), and the cost was scaled by a fixed percentage in all time periods (Table 5-2).

The percentage adjustments were iteratively chosen to try and identify thresholds where the changes in cost changed the optimal plan.

Biomass cost changes were not tested as the limited quantity available to Bury means they cannot significantly impact the plan.

Table 5-2: Energy Cost Scenarios Tested

Product	Cost Scaling Tested
Electricity	50%, 75%, 125%, 150% ,175%, 200%
Gas	50%, 75%, 125%, 150%, 200%, 250%

Having run the scenarios, the following factors were considered:

- How does the total cost of a plan vary with changes in energy costs?
- Are there thresholds at which changes in energy costs make a significantly different plan for Bury the lowest cost?
- What is the risk of planning for one set of energy costs and experiencing another? How much extra would it cost compared to planning for the correct energy costs in the first instance?

5.6.3 Electricity Cost Sensitivity Results

The cost of electricity is found to be a major decision factor between electric heat pumps and domestic district heat. Figure 5-15 shows how the uptake of district heat and electric heating systems vary with the scaling applied to electricity costs.

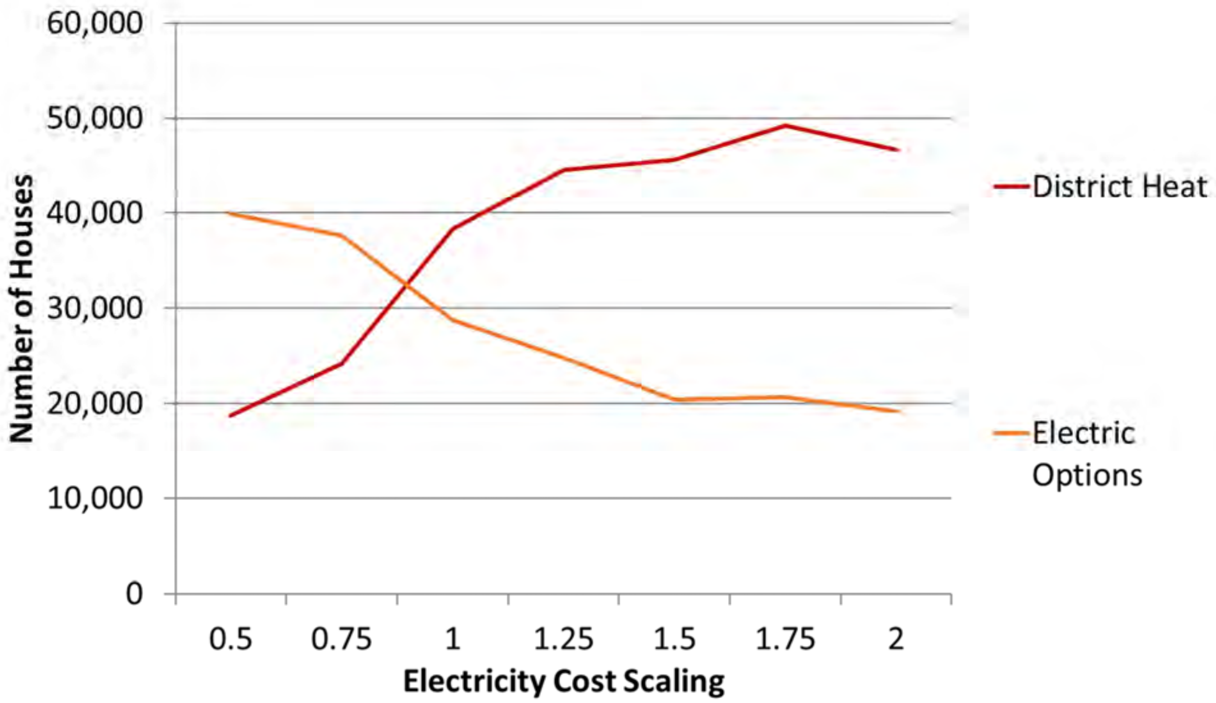

Figure 5-15 The impact of electricity costs on 2050 domestic electric and district heat deployment

As the electricity cost increases there is a shift in the generation of domestic heat from an electric heat pump in the home to district heating from energy centres. This occurs even though the district heating also uses electricity to generate low carbon heat, as the carbon target means that using more gas is not an option.

The level of this change varies across Bury (Figure 5-16). Ramsbottom, the most northerly ward, only gains a heat network when the electricity cost is 1.5x the default scenario, whereas areas further south have heat networks even if electricity costs are half the ESME value.

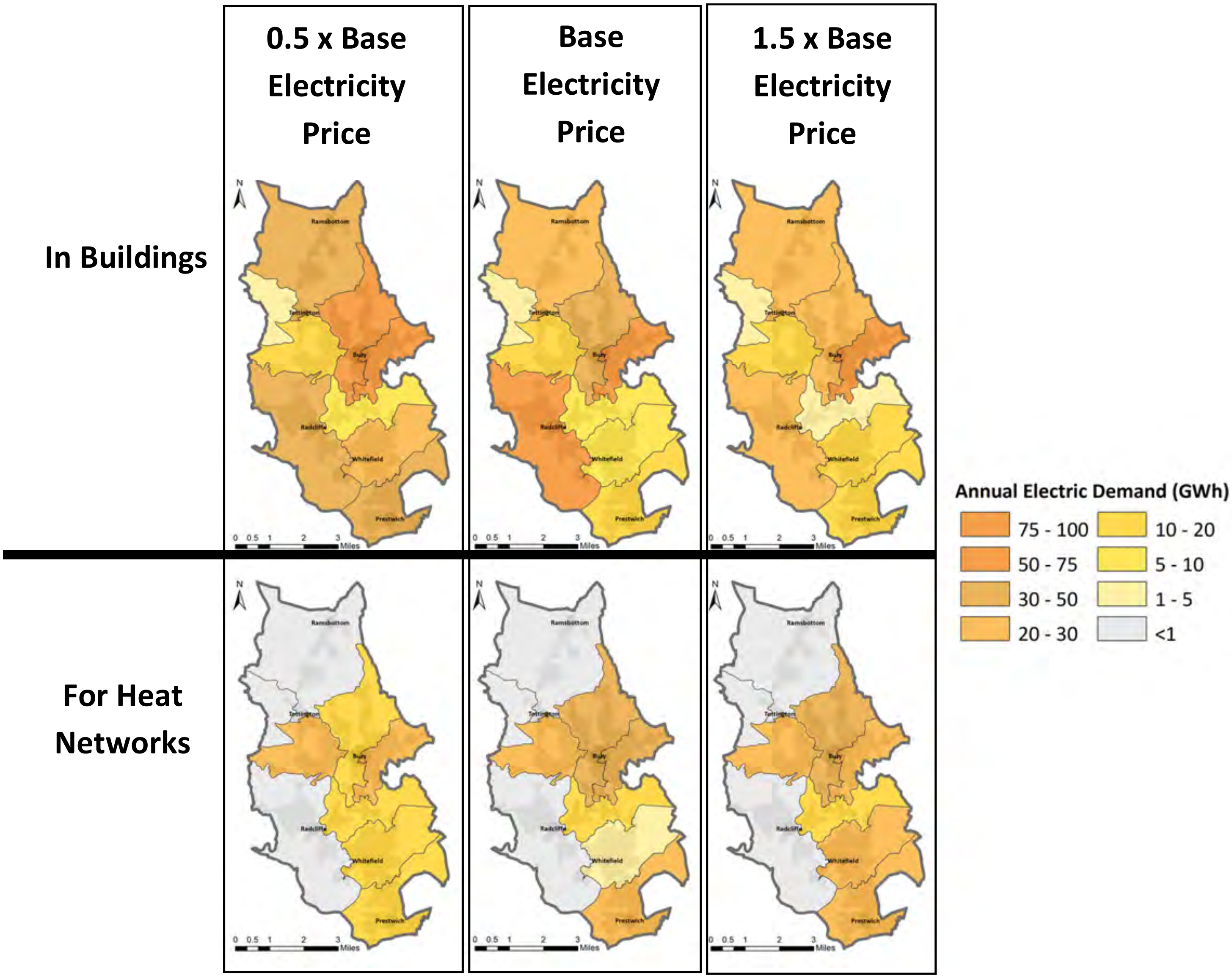

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Figure 5-16 Spatial changes in the form of electricity demand across Bury as the electricity price increases

This change in the use of district heat or heat pumps as electricity costs change is due to their different levels of efficiency – the amount of heat produced from one unit of energy and the amount lost in delivering that heat to the point of demand. An example summarising the average efficiency of different heating options in Bury as determined by the model is given in Figure 5-17.

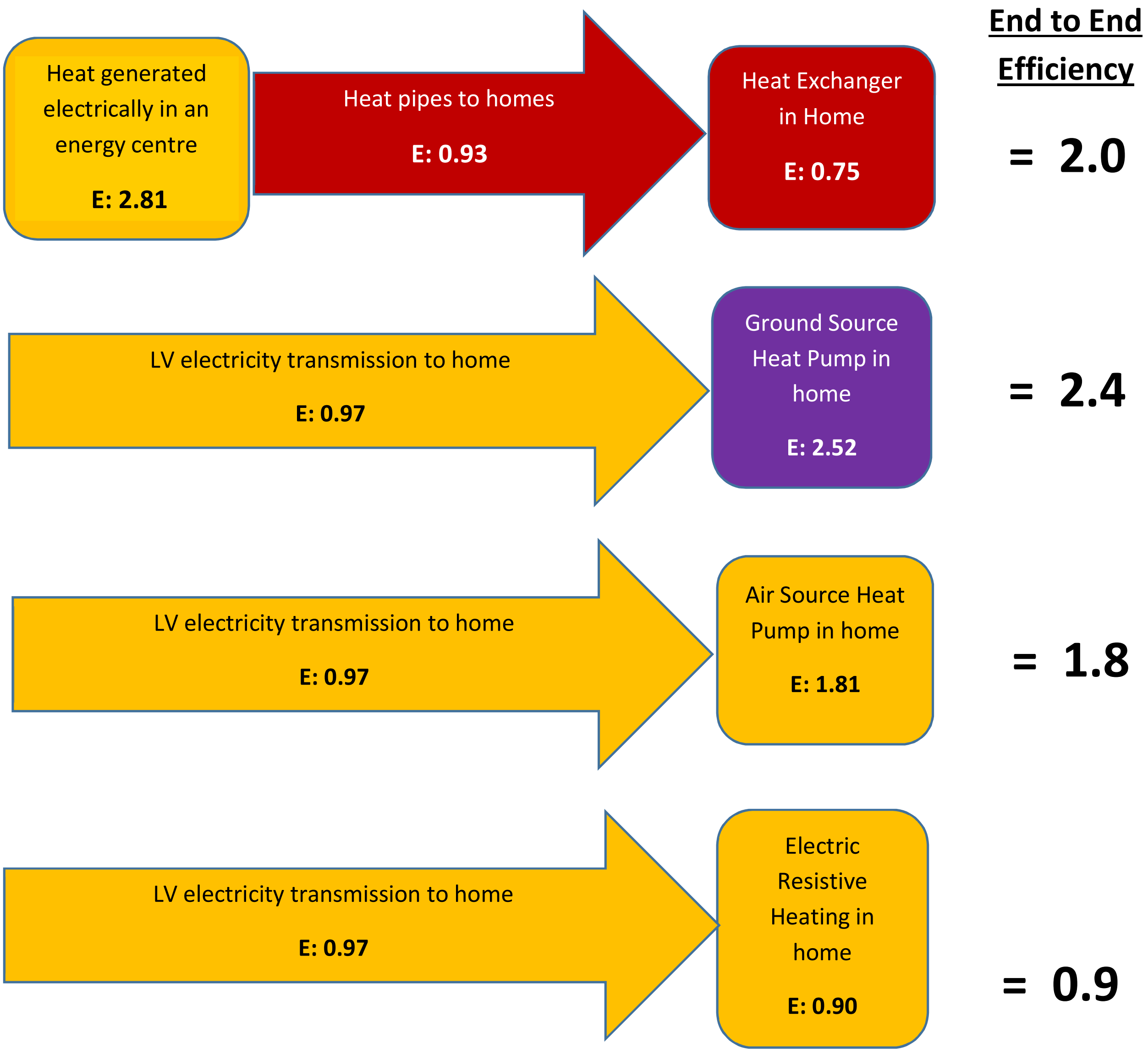


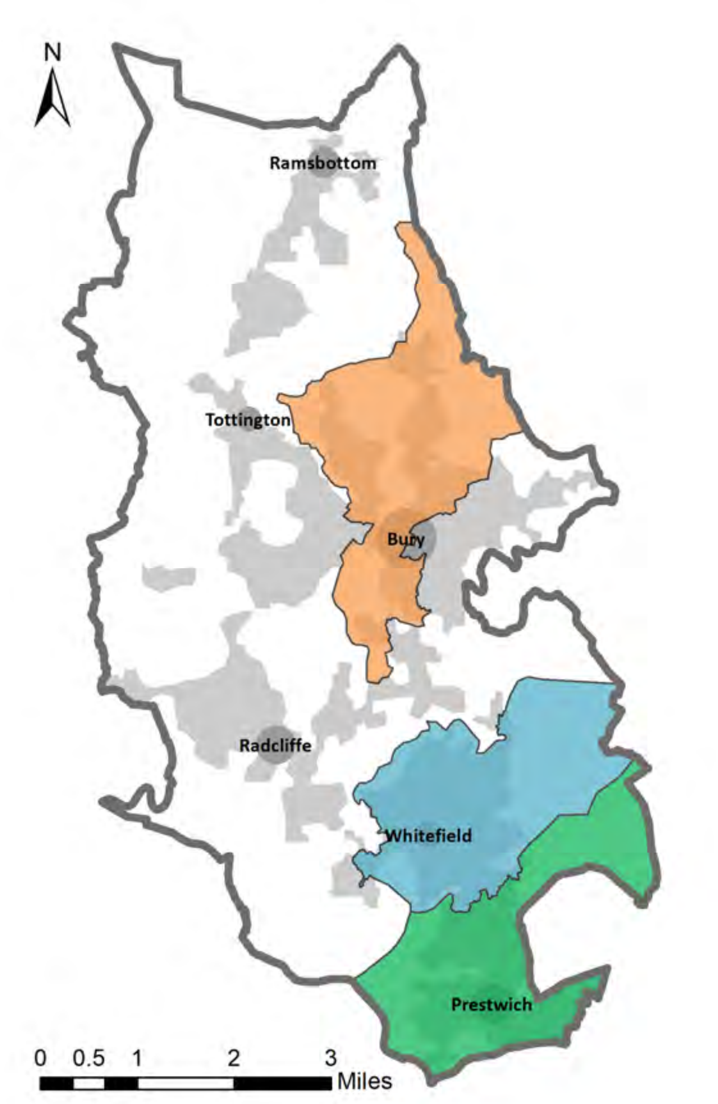
Figure 5-17 The relative efficiency of different heating options for Bury. The E value indicates the efficiency of that part of the process. The transmission efficiency values are the average across the whole of Bury.

Domestic ground source heat pumps currently have the highest expected overall efficiency. This is supported by the model generally deploying them when a building is suitable - 14,000 larger, more rural homes are best served by ground-source heat pumps across all the different electricity costs.

On average district heating is shown to be more efficient than a domestic air source heat pump as the generation technology is more efficient at a larger scale. When the electricity cost increases this greater efficiency provides a greater saving, as the electricity saved is worth more.

Although more efficient, the cost of installing the heat network infrastructure is generally higher than the equivalent reinforcements required on the electricity network. To be the cheaper option, the money saved through greater efficiency needs to be able to cover the extra costs of the heat infrastructure. This is more likely when electricity costs are greater.

The full range of costs tested was large, but even considering just a 25% modification in each direction (i.e. 0.75x to 1.25x) triggered significant changes in district heat uptake in three areas of Bury.



Electricity Price Multiplier			
Homes on District Heat	**0.75x**	**1x**	**1.25x**
Bury Total	24,200	38,300	44,500
Areas showing most change:			
Bury Town North	2,200	7,500	8,700
Whitefield	2,700	8,600	9,100
Prestwich	0	500	5,100

Figure 5-18 Changes in District Heat Deployment under Changing Electricity Costs

In the areas shown in Figure 5-18 the choice between district heat and electric heat pumps is seen to be marginal and the most sensitive to changing electricity costs. When planning heating systems for these areas careful consideration should be taken of the latest projections of energy costs.

5.6.4 Gas Cost Sensitivity Results

With few exceptions gas is the cheapest energy source. The use of it in Bury's future energy system is constrained by the carbon content, not the cost. Without the local carbon target most heating systems would remain on gas.

Changing the gas cost within the range of 50-250% has virtually no impact on the total quantity of gas used within Bury (Figure 5-19)

Figure 5-19 Total 2050 gas demand under different gas price scenarios

Alongside no change in demand there is also no meaningful change in the number of buildings with gas heating systems. This is because even at the highest tested cost the total cost of gas heating is still less than that of a heat pump. The level of gas use is constrained by the carbon target, which is consistent across the different gas price scenarios.

5.6.5 Influences on System Cost

Changes in both gas and electricity costs will influence the total cost of decarbonisation, even when they do not change the plan for Bury.

Table 5-3 Example of how changes in electricity cost change the total cost of following the plan generated from the initial modelling for Bury

	Electricity Cost Multiplier						
	0.5x	0.75x	1x	1.25x	1.5x	1.75x	2x
Changes in cost if following Patchwork plan	£2,130m less	£1,070m less	0	£1,070m more	£2,130m more	£3,200m more	£4,270m more

Changing electricity costs without changing the plan followed changes the total cost for Bury. Table 5-3 shows how the total cost would change if the initial plan for the 90% reduction scenario was followed and the electricity cost changed. Each percentage point change in electricity cost changes the total cost by £43m. Similarly, a percentage point change in gas cost changes the total cost by £9m.

5.6.6 The influence of energy prices being different to those which have been planned for

The varying electricity costs showed that in certain areas the lowest cost plan for Bury would change significantly under different cost scenarios. Future energy costs are uncertain, which makes planning difficult.

Planning for the wrong set of costs is more expensive than planning for the correct set of costs, but the level of risk varies.

Table 5-4 Example Impacts of Costs Planned for and Costs Experienced on the Total System Cost

Cost Experienced Plan Followed	Normal Electricity Cost	75% higher electricity cost
Patchwork Plan	£9,300m	£12,520m
Planning for 75% higher Electricity Costs	£9,350m	£12,480m

Table 5-4 shows that If Bury plans for the Patchwork price predictions but instead experiences an electricity cost 75% higher then the total plan cost is £12,520m. If Bury had planned for the 75% higher electricity cost in the first place, then the total cost is £12,480m, so planning for the wrong electricity cost an extra £40m.

If Bury followed the plan for 75% higher electricity costs but experiences the original patchwork costs then it would overpay by £50m compared to planning for the original costs in the first place.

5.6.7 Key Findings

- To cost effectively decarbonise it is necessary for any plan for Bury to respond to actual or predicted changes in energy costs.
- Gas costs are not an important influence as even when the cost is high they are still the cheapest energy source. Their use in Bury is constrained by their carbon emissions and the local target. Changes in gas costs change the total costs of the plan but not the heating options selected.
- Electricity costs have an important influence on the best heating system choices for Bury, particularly in the choice between electric heat pumps and district heat. Certain areas of Bury (in particular Bury Town North, Prestwich and Whitefield) are more sensitive to electricity prices, and so heating system deployment in these areas should be timed such that it can react to the future market conditions.

5.7 Technology Cost Sensitivity – Monte Carlo Analysis

Summary

There is significant uncertainty in future technology and infrastructure costs. Testing this uncertainty shows how the lowest cost plan for decarbonising Bury varies as these future costs change. The use of gas boilers and district heat can vary significantly, but as long as the plan adapts to the changes in costs then the overall cost of achieving the carbon target varies by only a few percent. The cost of district heat network infrastructure is a key factor in heating system choice.

5.7.1 Context

A modelling approach to reflect the uncertainty in future cost projections is to represent each of these costs as a range of likely values and a probability weighting for where in the range the value is considered most likely to fall. This better accounts for the uncertainty in these future predictions.

To make use of this approach EPN was run as a Monte Carlo analysis. A Monte Carlo analysis is where the model is run many times, each time randomly selecting all the cost values from within their defined ranges. This technique gives approximately 100 sets of results from the model which are then analysed together to look for similarities or differences. Analysing all the Monte Carlo simulations together helps understand the impact of the future uncertainty.

This approach could not be used for all the Bury modelling due to the time required to run the model multiple times. In the other scenarios modelled for Bury, future cost parameters are modelled as single values for any one technology and year.

In the Monte Carlo the following cost parameters were defined as ranges rather than single values:

- Domestic building storage capital costs
- Domestic heating control capital costs
- Domestic retrofit measure capital cost
- Electricity, gas and heat network capital costs
- Domestic heating system capital costs
- Energy centre technology capital costs

The ranges for different costs varied. They were chosen based on any available data on cost variations and on a judgement as to the maturity of the technology. For example, substation infrastructure costs were given a range of 5%, as data was available from the 2050 calculator showing likely ranges and the technology is mature and widely demonstrated in the UK. In contrast ASHPs were given a range of 30% as the technology is less mature and less demonstrated in the UK, increasing uncertainty.

The sampling of cost values ensured that similar technology costs always increased or decreased together. For example, the cost of Ground Source Heat Pumps was correlated with the cost of Air Source Heat Pumps so that if one of these has a higher cost then it is more likely that so will the other.

These correlations were defined as weak or strong depending on the technology pairs, so the cost of a gas boiler was very closely correlated to the cost of an oil boiler but the cost of a biomass boiler was less closely correlated to that of a gas boiler as there are larger technical differences between the technologies.

This approach was used to help identify:

- Parts of the optimal plan for Bury that may be particularly risky given their reliance on a single cost value.
- Elements of the plan that are common under a wide range of potential future costs and therefore lower risk.
- The costs of greatest importance to monitor and adapt to.

5.7.2 Methodology

Triangular distributions with minimum and maximum values were defined for all the costs involved in the Monte Carlo analysis, based on any available data on likely ranges. Figure 5-20 shows an example shape of a triangular distribution, where a range of prices is defined and the central part of the range are considered more likely to occur, and so have a higher priority.

Figure 5-20 Example shape of a triangular distribution

One hundred sets of EPN input data were produced by sampling values from these distributions. The model optimiser was then used with each of these sets of input values, generating the optimum plan to the carbon target under each set of parameters. This analysis was also repeated with the same input values for a No Local Carbon Target scenario.

The results were analysed to identify how aspects of the plan changed with variations in the input parameters.

5.7.3 Total System Costs

The Monte Carlo analysis allows us to estimate the level of uncertainty in the cost of achieving the carbon target. Modelling the 90% carbon target and No Local Carbon Target for each set of input values allows the extra cost of achieving the carbon target to be calculated for each set of values.

In all Monte Carlo simulations, the cost of achieving the carbon target was within 10% of the initial modelling. This cost is the difference between the carbon target and No Local Carbon Target costs for each set of input parameters

In over half of the simulations the cost was within 3%, showing that the variability in technology costs does not have a major influence on the total cost. The energy costs sensitivity (p80) shows energy costs having a larger overall influence.

This analysis assumes that Bury will be able to react perfectly, that there will be perfect information about future costs and the area is able to plan optimally for them. This certainty is unlikely, so there is a risk that the actual cost range would be greater as the plan does not react sufficiently to the costs. There is also a risk that future costs will vary across a greater range than modelled in this analysis.

5.7.4 Heating System Numbers

The use of different domestic heating systems varies throughout the Monte Carlo simulations, but some heating systems are more variable than others (Figure 5-21).

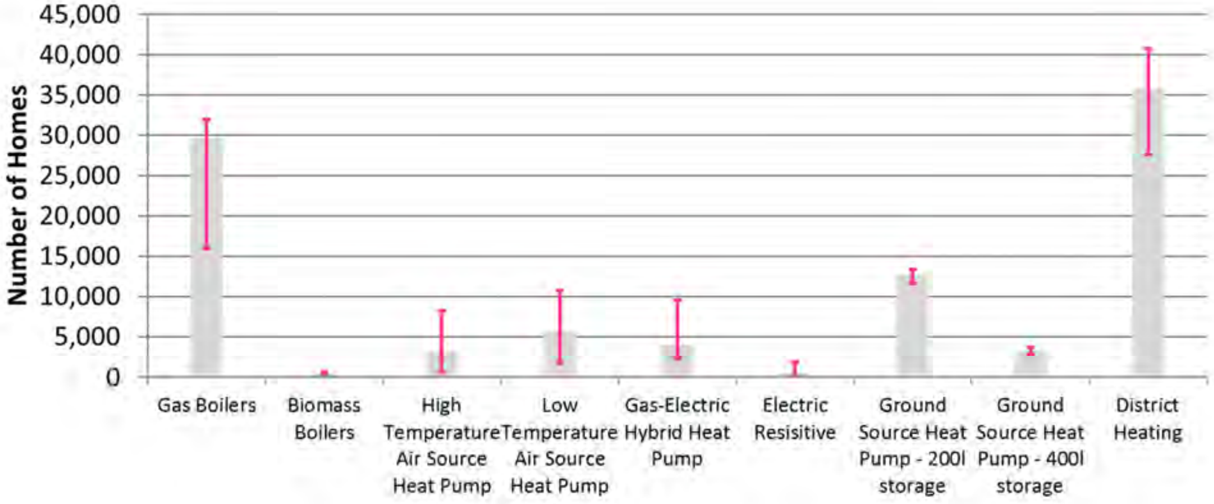


Figure 5-21 Heating System uptake across the Monte Carlo simulations. The grey bar represents the median value and the pink lines the minimum and maximum.

Gas boilers and district heat are both heavily used in the scenarios, but both also have relatively large ranges. Ground Source heat pumps have small ranges and so appear to be largely insensitive to costs.

5.7.5 Factors influencing heating system uptake

A correlation analysis was used to explore which costs had the most influence on heating system choices.

Notable correlations for some key heating systems are:

Gas Boilers – usage increased when it was more expensive to reinforce the electricity network.

High Temperature Air Source Heat Pumps – Numbers increased when the cost of installing district heat pipes was higher. Usage decreased when the cost of installing storage tanks in homes increased.

L ow Temperature Air Source Heat Pumps – Numbers chosen increased with the cost of in home systems for connection to district heat (e.g. heat interface unit) , district heat pipe network costs and the cost of gas boilers.

District Heating Systems – Increase as the cost of gas boilers increases. Decreases when heat pipe infrastructure and in home heat connections get more expensive.

The energy costs sensitivity (p80) showed that the choice between heat pumps and district heat was highly sensitive to electricity price. This Monte Carlo analysis also shows that the costs of installing the heat network infrastructure is a significant factor in that decision. EPN uses the technical costs of installation and does not account for any costs of disruption, i.e. economic losses during roadworks. Given the sensitivity to cost it may be necessary to consider these secondary costs further.

5.7.6 Use in further analysis

Section 6 (p167) looks for similarities and differences across all the modelled sensitivities. The Monte Carlo simulations provide a large part of the data for that analysis.

5.7.7 Key Findings

- Future technology costs are uncertain and a strategy for decarbonising Bury should account for this.
- If Bury is able to respond perfectly to future prices then the impact on the cost of achieving the carbon target is small. Perfect foresight is unlikely so the costs may be higher.
- Ground Source Heat Pumps were used in consistent numbers across the simulations and so appear low regret.
- The deployment of district heat systems and other electric heat pumps was more variable, and the choice between them seems uncertain, although both can be expected to be part of Bury’s future energy system.
- The key factor in this choice is the cost of installing the heat network infrastructure. It may also be necessary to account for the economic disruption that may be caused by installation works. Higher use of electric heat pumps will require greater levels of electricity network reinforcement, which may also cause disruption.

5.8 Building Insulation for Fuel Poverty

Summary

Insulation may be applied to buildings for reasons other than carbon saving, such as reducing fuel poverty. The Fuel Poverty Strategy creates an obligation for local authorities to help insulate their fuel poor homes. Houses with characteristics making them most likely to be lived in by fuel poor households were identified and insulation was applied in the model. Generally, this extra insulation did not change how to decarbonise, except for some adjustments in the choice of buildings best

5.8.1 Context

The 2015 Fuel Poverty Strategy for the UK[50] has a target to "ensure that as many fuel poor homes in England as is reasonably practicable achieve a minimum energy efficiency rating of Band C by 2030". This target influences Bury council's future planning.

This sensitivity examined the impacts on decarbonisation of increasing the energy efficiency of homes most likely to be lived in by fuel poor households across Bury. This reflects the local authority applying a range of retrofit insulation measures between now and 2030 to meet the requirements of the strategy.

As EPN is a least-cost optimisation model, if the insulation provided an overall cost saving it would be used in the 90% carbon reduction target scenario. When modelling carbon targets in EPN, building heating system changes are generally a more attractive route to decarbonisation than retrofit insulation as they can provide complete decarbonisation for a building.

There are wider societal benefits associated with improving the thermal efficiency of dwellings, such as reducing the levels of fuel poverty and improving comfort. There are good reasons to install further insulation which are not considered in the model.

The fuel poverty sub-regional statistics released by BEIS[51] indicate that 11.2% of households across Bury overall are in fuel poverty. Applying retrofit insulation measures in EPN by 2030 to homes most likely to be occupied by fuel poor households helps:

1) Provide insight into how the total cost of the plan might vary when improving the efficiency of fuel poor households.
2) Determine if installing this insulation might change the optimal plan for decarbonisation.

5.8.2 Methodology

The proportion of dwellings in fuel poverty was taken from the fuel poverty sub-regional statistics at the Lower Super Output Area (LSOA) level. The aim was to ensure the number of buildings identified as most likely to be occupied by fuel poor households in EPN broadly matched the LSOA fuel poverty levels. The BEIS data showed that at the LSOA level, fuel poor percentages varied from 3 to 22%.

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[50] https://www.gov.uk/government/publications/cutting-the-cost-of-keeping-warm

[51] https://www.gov.uk/government/statistics/sub-regional-fuel-poverty-data-2017

At the national level data is available about the types of building most likely to be occupied by households experiencing fuel poverty. This was used to allow the targeting of individual buildings within EPN, looking at age, size, building type and wall type.

The fuel poverty detailed tables[52] and the annual fuel poverty statistics report [53] were used to identify which building characteristics were typically associated with households experiencing fuel poverty. The data shows that wall type is the most significant factor, with uninsulated solid wall buildings the most likely to be fuel poor. Dwellings which have solid walls and are uninsulated were therefore primary target for retrofit upgrade. Inside this group the selection was based on those dwellings which were the oldest, had the largest floor areas and the least loft insulation.

A ranking was developed of buildings modelled to have the physical characteristics of those most likely to be occupied by fuel poor households, and buildings were selected from this list in ranking order until the correct percentage had been reached in each area

The private sector housing data available for EPN does not give full details for individual buildings, such as wall types and insulation. The English Housing Survey was used to fill in gaps in building characteristics. This provided data on the average level of insulation in place given the building characteristics, but means factors like wall insulation cannot be identified at the individual building level with confidence. The buildings selected provide a reasonable representation and give useful results when looking at the overall building type. EPN cannot be used to identify individual buildings that require further insulation, except for social housing where detailed building data was available.

A basic and an advanced retrofit package was defined within EPN (see Table 5-5). The advanced retrofit package (package two) was applied to the identified solid wall dwellings. For solid wall dwellings which already have insulation EPN applied alternative retrofit measures within the package such as increased loft insulation. The basic retrofit package (package one) was applied to cavity wall dwellings. For cavity wall dwellings which currently have insulation EPN applied alternative retrofit measures within the package.

This methodology is summarised in Figure 5-22.

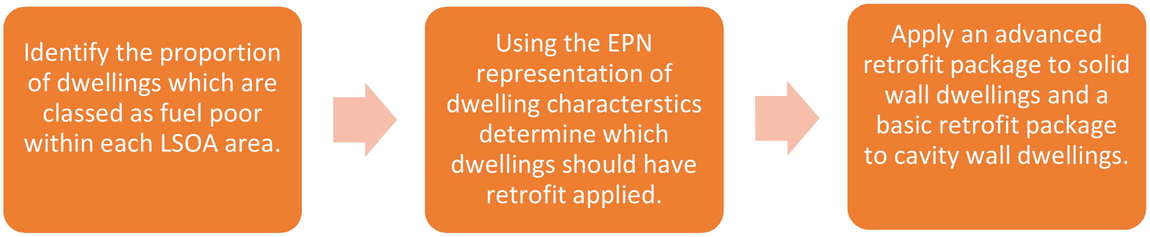

Figure 5-22 Process for identification of buildings to be targeted in this sensitivity

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[52] https://www.gov.uk/government/statistics/fuel-poverty-detailed-tables-2017

[53] https://www.gov.uk/government/statistics/annual-fuel-poverty-statistics-report-2017

Table 5-5 Suggested retrofit packages

Retrofit Package	Measure
Package One	Cavity wall insulation
	Loft insulation
	Energy-efficient doors
	Reduced infiltration (draught-proofing)
Package Two	External wall insulation
	Loft insulation
	Triple-glazing
	Energy-efficient doors
	Reduced infiltration (draught-proofing)

5.8.3 Results

If the extra insulation was cost effective or was the lowest cost option to meeting Bury's carbon target then it would have been selected in the initial model scenarios. Therefore the additional insulation in this scenario will be an extra cost to Bury's energy system.

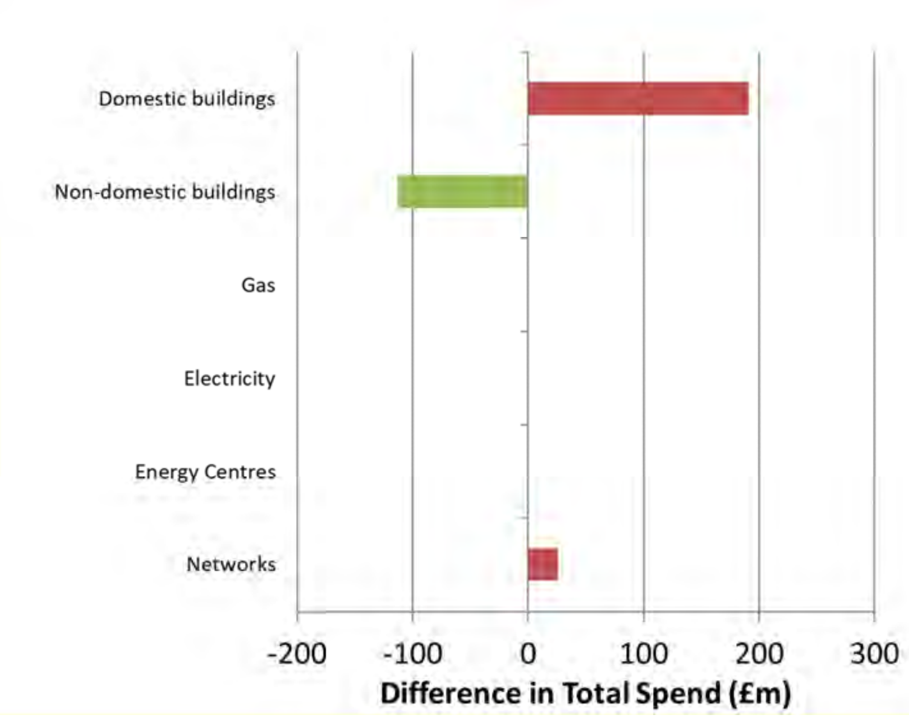

Figure 5-23 Cost breakdown of extra insulation run compared to base run

Figure 5-23 shows that the scenario with the extra insulation in buildings most likely to be occupied by households experiencing fuel poverty costs an extra £102m over the base scenario. Only 8% of the buildings identified as most likely to be occupied by fuel poor in this scenario had insulation installed in the base run.

At an individual building level the cost of the extra insulation on solid wall properties can be large (Table 5-6). This shows the average costs for the buildings targeted in this scenario. These buildings are likely to be larger, which increases the average cost as they have greater wall areas. The average cost across all buildings in Bury would be lower.

Table 5-6 Average cost of insulation deployed onto the buildings in this scenario

Insulation Measure	Average cost per targeted building to 2050 (undiscounted)
Loft insulation	£400
Solid wall insulation	£23,000
Cavity wall insulation	£4,000

On average the solid wall insulation applied in this scenario costed £23,000. The cost per building represents installing it on individual privately owned houses and so is likely to be much greater than current schemes which have undertaken large scale installation on socially owned properties.

The largest reduction in energy usage seen in this scenario at the individual building level as a result of this extra insulation was 42%. Where a reduction in energy use was shown in the model, the minimum change was 14%, and the average 22%.

Changing the insulation applied may change the heating systems chosen for buildings under the two scenarios (Table 5-7).

Table 5-7 Heating Systems Deployed in the Targeted Properties under the base run and extra insulation scenarios. The row indicates the heating system under the initial modelling, and the column shows the heating system when further insulation is applied. The numbers indicate the number of buildings for each combination.

		Insulation in Properties likely to be Fuel Poor							
	Heating System	Gas Boiler	Biomass Boiler	High Temp Air Source HP	Low Temp Air Source HP	Hybrid Heat Pump	Electric Resistive	Ground Source Heat Pump	District Heating
90% Carbon Target	Gas Boiler	2247	273		214				4
	Biomass Boiler		33				1		
	High Temp Air Source HP	588		4					11
	Low Temp Air Source HP	82			3				
	Hybrid Heat Pump	431				452			145
	Electric Resistive						194		
	Ground Source Heat Pump	3				2		304	
	District Heating	404	13	19	38	6	1		4459

77% of the buildings are found to have the same heating system deployed with and without the extra insulation.

The most common difference is to keep the building on gas, as the lower emissions post insulation make this more cost effective. Across all buildings in Bury there is no significant change in the number of gas boilers, so this is balanced by more low carbon systems elsewhere on the buildings which have not received the extra insulation.

5.8.4 Key Findings

- EPN does not show that this further insulation is a cost optimal way to reduce carbon (ignoring any existing subsidies).
- Further insulation may provide a way to alleviate fuel poverty and increase comfort of residents and could be deployed on that basis.
- Putting the insulation in place cannot produce the level of carbon reduction required to meet the target. The maximum energy use reduction seen on any one property was 42%, and this would not be sufficient to meet a 90% carbon target. Most properties had much lower reductions. Insulation alone cannot achieve the target, heating system change or a decarbonised gas supply would still be required.
- In most cases the presence of the insulation does not change the choice of heating system for carbon reduction.
- Overall, the decisions to insulate further may be a good one on fuel poverty or comfort grounds, but it should not be a significant influence on the carbon reduction decisions.

5.9 Lower Carbon Gas

Summary

The model was tested with a gas hydrogen blend with a higher cost but lower carbon content than natural gas. If the blend was deployed prior to 2040 the extra cost made it less cost effective than natural gas. After 2040 it was of some use, and allowed 4,000 extra homes to remain on gas boilers.

5.9.1 Context

The ETI ESME scenarios used in EnergyPath Networks assume a high level of decarbonisation of the electricity grid by 2050. They do not assume that the level of carbon in the gas network would drop over this timeframe.

The UK has strong gas grid infrastructure with currently over 80% of properties connected. Gas boilers provide easy heating controls that allow rapid ramping up of temperatures, offering flexibility and ease of use. They are relatively inexpensive compared to alternative heating solutions. Certain industrial processes cannot transition to current electrical or district heating sources so a lower carbon gas blend may be the only alternative to reduce emissions from these buildings. The potential for a lower carbon gas utilising the existing infrastructure is therefore appealing.

One method for achieving this would be to blend hydrogen with natural gas. This could be done at a level where it would still be compatible with current domestic heating systems, as all appliances sold post 1993 must comply with the 1990 Gas Appliance Directive 90/396/CCE (GAD). This requires them to demonstrate that they can operate on a wider range in gas quality, up to a gas composition of 23% hydrogen.

This sensitivity tests the extent to which the lowest cost plan for cutting Bury's carbon emissions would change if a low carbon gas was available.

5.9.2 Methodology

The natural gas product in EPN was replaced with a product representing a lower carbon blend of hydrogen (H_2) and natural gas (CH_4). The 90% carbon target scenario was tested, and the role of the gas blend in the lowest cost solution analysed.

The hydrogen blend was defined using data from the HyDeploy innovation project[54], using the projections of the volume of hydrogen to be blended and the future price of hydrogen.

There are two HyDeploy scenarios with varying levels of hydrogen blending (Table 5-8).

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[54] http://www.smarternetworks.org/project/nggdgn03/documents

Table 5-8 Hydrogen blend scenarios present in the HyDeploy project

	Scenario 1				Scenario 2			
	2020	**2030**	**2040**	**2050**	**2020**	**2030**	**2040**	**2050**
Hydrogen Blend by volume	9.5%	9.5%	20%	20%	4.8%	4.8%	10%	10%

Scenario 1 was chosen for the analysis as it represented a lower carbon option.

The hydrogen in this scenario is produced from a mix of electrolysis, bio-hydrogen and Steam methane reforming with carbon capture and storage. The amounts produced from each technology varies by decade.

To represent the blend of hydrogen plus natural gas within EPN, the carbon content of the existing natural gas was lowered to account for the hydrogen component.

The new gas blend was calculated by the percentage of the energy content of each component in the gas mix rather than the volumetric amounts, as hydrogen has about one third of the energy content of natural gas.

The HyDeploy project provided costs for hydrogen production from each source of hydrogen to calculate a total hydrogen mix cost. The cost of hydrogen that was produced from electrolysis was recalculated using the ESME patchwork electricity price as this ensured that the electricity price and carbon content were consistent with the rest of the EPN analysis. Similarly, the carbon content of the hydrogen produced from electrolysis was recalculated using the EPN grid electricity carbon value. This gives a different value than the HyDeploy project as that uses the electricity grid carbon level from National Grid’s Future Energy Scenarios (slow progression scenario), but is more consistent with the rest of the modelling in this project.

The final calculated costs and carbon contents of natural gas and the lower carbon gas blends are shown in Figure 5-24 and Figure 5-25.

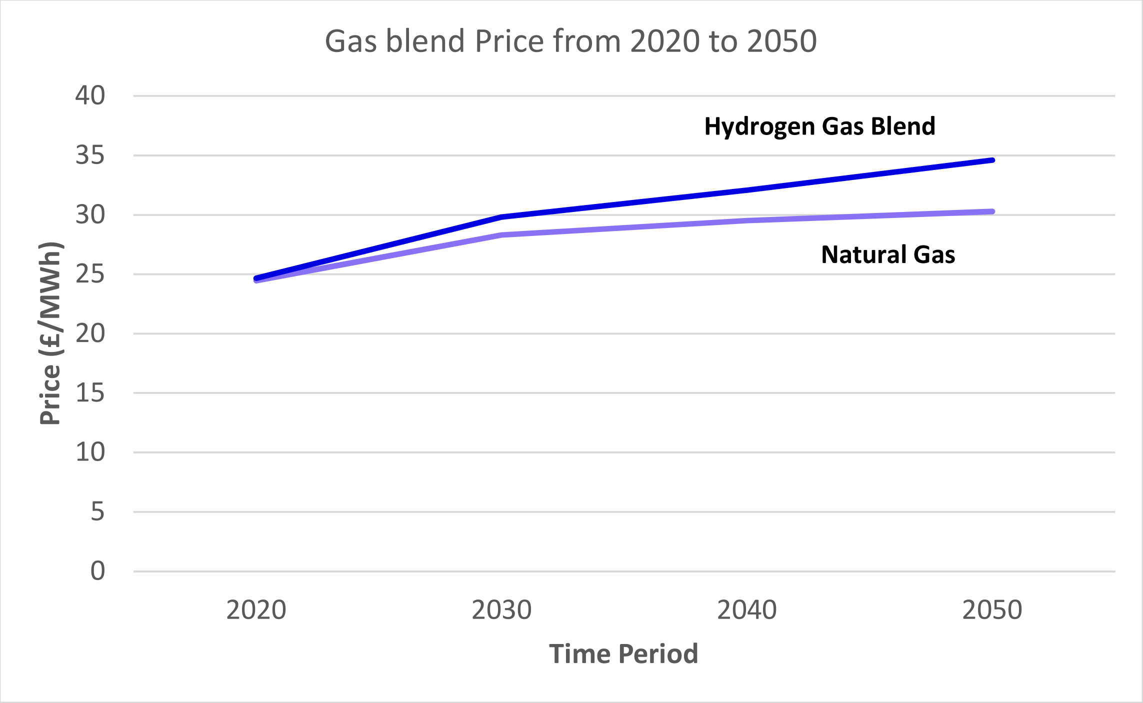

Figure 5-24 Cost of natural gas and the hydrogen blend calculated for use in the model

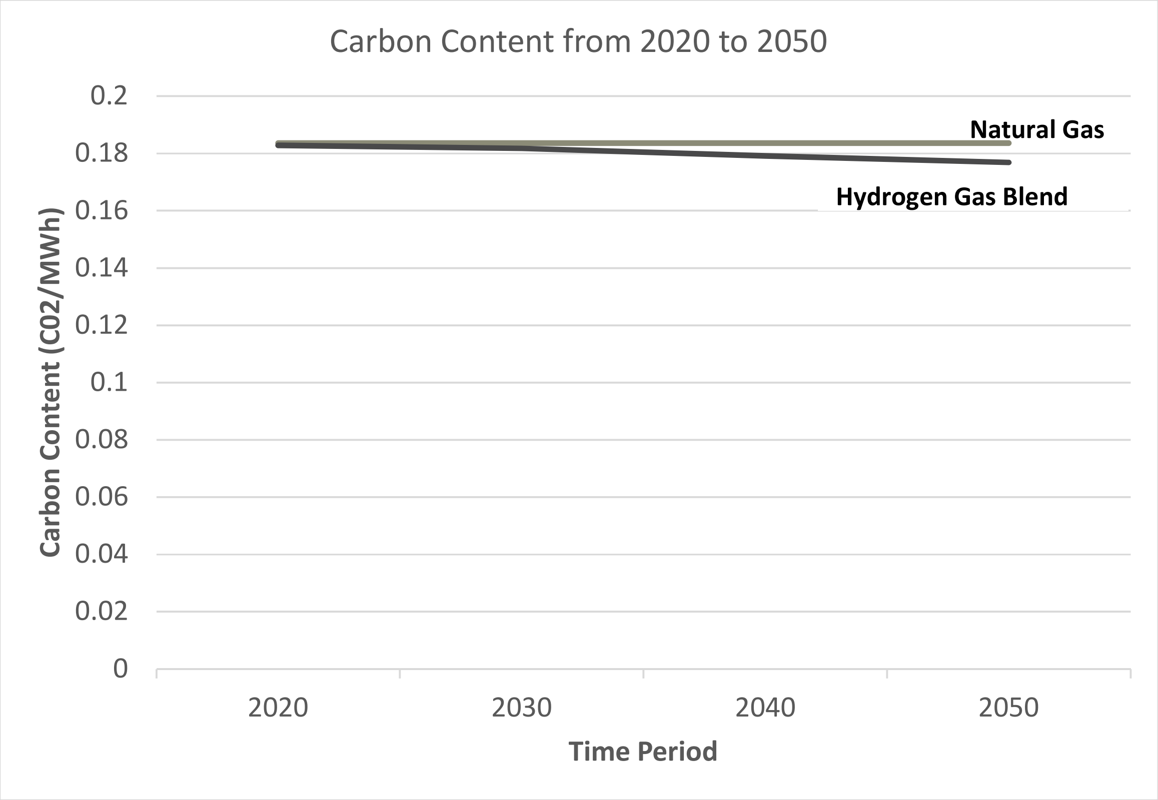

Figure 5-25 Carbon content of natural gas and the hydrogen blend calculated for use in the model

5.9.3 **Results**

A blend with 20% hydrogen by volume is only 7% hydrogen by energy. By 2050 the hydrogen has <50% of the carbon content of natural gas, but the overall blend is only 4% lower carbon per unit of energy. Therefore, the overall impacts are limited.

The initial test of this scenario was not lower cost than the 90% carbon target scenario where the lower carbon gas was not present. The results indicated that the lower carbon blend was not efficiently utilised in the early time periods as it was not required to meet the carbon target at this point, yet it was higher cost than the original natural gas.

A second scenario was therefore tested where the gas was kept in its original form prior to 2040 (when the lower price was more useful) and then introducing the lower carbon gas blend from 2040 allowing it to be used when the carbon target was at its strictest.

Figure 5-26 shows how EPN utilises the lower carbon gas under this scenario by showing the difference in gas consumption by sector (shown as the lower carbon gas sensitivity minus the standard 90% carbon target scenario). There is an increase in gas consumption in energy centres in the lower carbon gas run compared to the standard 90% carbon target run: circa an additional 166,000 MWh/year or an additional 2.3 %. Within the energy centres the additional gas use in the lower carbon gas sensitivity is attributed to the increase in production from all three gas technologies in 2050, as shown in Figure 5-27.

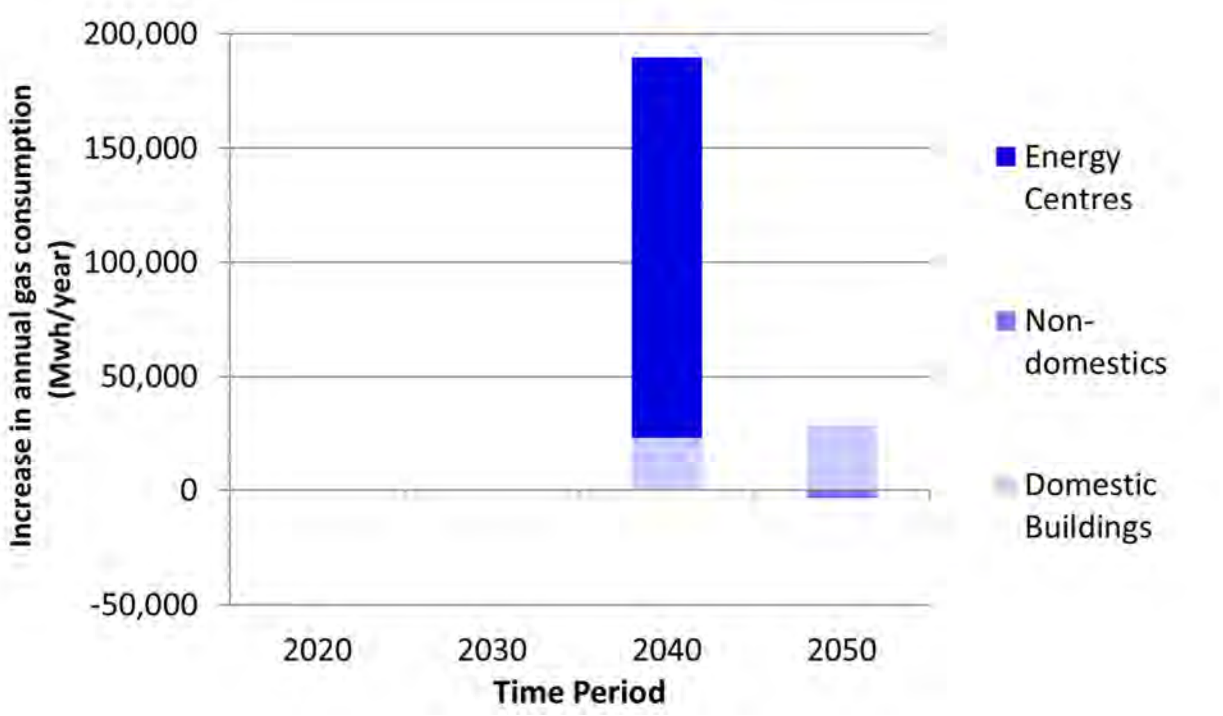

Figure 5-26 Increase in gas consumption in the lower carbon scenario compared to the standard 90% carbon target scenario

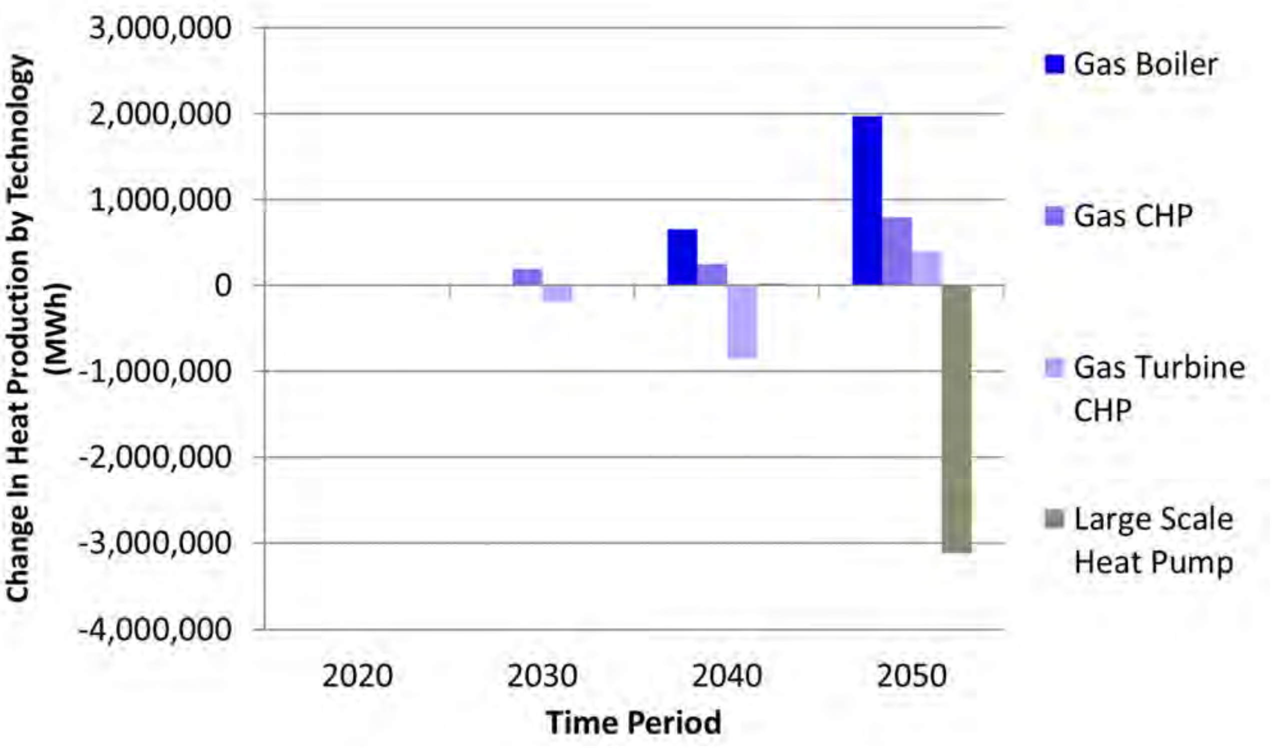

Figure 5-27 Change in aggregated Energy Centre Heat Production by technology between the Low Carbon Scenario and the Base Run

Figure 5-28 shows an increase in domestic buildings with gas boilers for the lower carbon sensitivity compared to the standard 90% carbon target scenario. In total there are approximately 4000 extra gas boilers in the lower carbon run, 20% more than the standard 90% carbon target scenario. The new gas boilers are in areas that already had relatively high gas uptake, and most of them previously had large electric heat pumps.

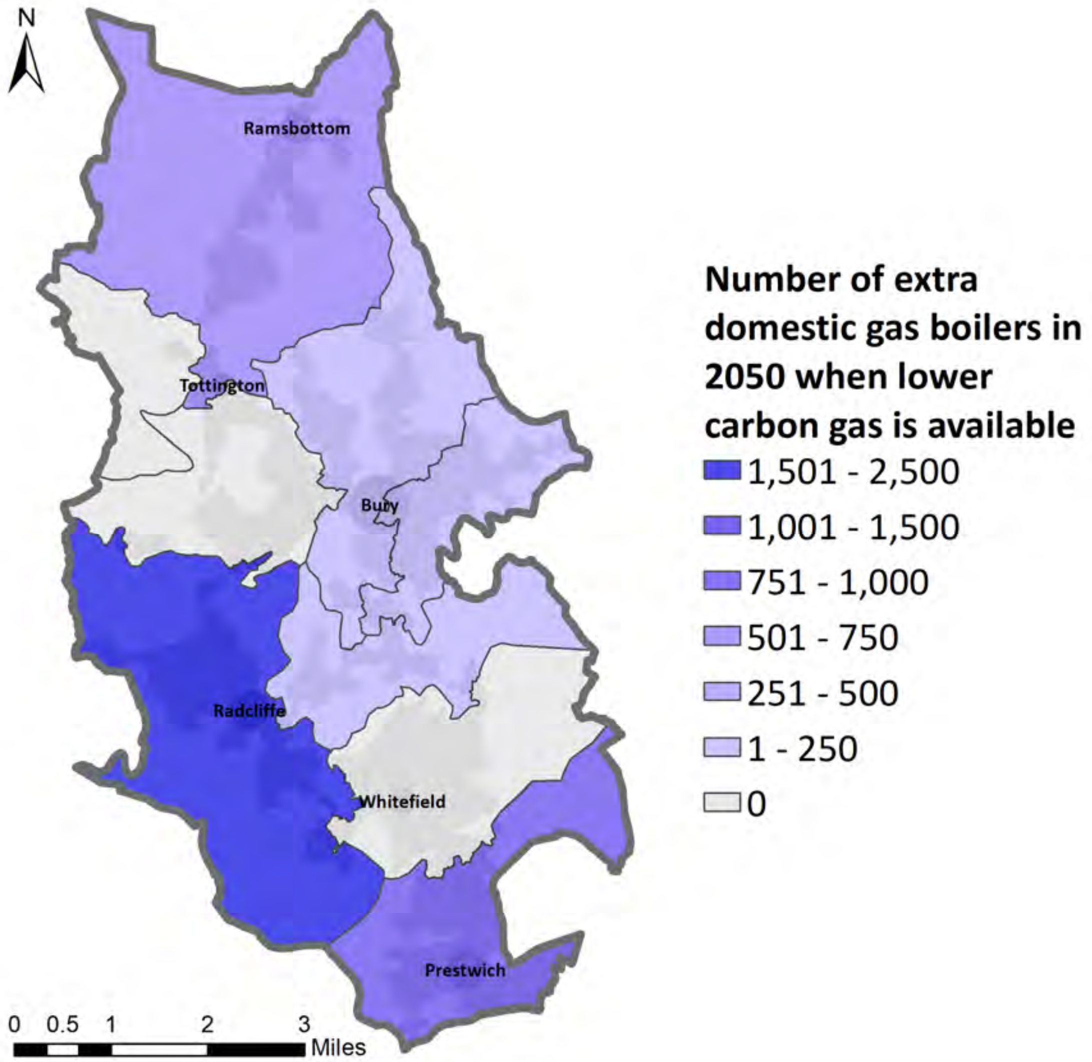

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Figure 5-28 Extra gas boilers in 2050

Some non-domestic buildings (e.g. heavy industry) are not able to transition away from gas in the model. This low carbon blend provides the only method of reducing their emissions in EPN.

In this scenario 49% of non-domestic floorspace was unable to transition away from gas due to its assumed industrial use but this was updated in the final modelling (p132) and dropped to about 25% following improvements to the non-domestic building data.

Slightly more non-domestic floorspace switches from gas to district heat in the lower carbon gas blend sensitivity but the largest change in an area is only approx. 3% of the total non-domestic floorspace in that area.

In 2050 these heat networks are electrically fed (apart from peak winter), but in 2040 the lower carbon blend sensitivity uses more gas technologies than in the standard 90% carbon target run. The explanation for this is likely to be that as the cost of the lower carbon gas blend increases, it is found to be more efficient to heat non-domestic buildings from gas powered district heating rather than using individual gas boilers. A similar effect was seen under the high electricity price sensitivity (p80), where increasing electricity price caused a shift from heat pumps to electrically fed district heat.

Figure 5-29 shows the changes in spend on different categories when the low carbon gas is used from 2040 onwards.

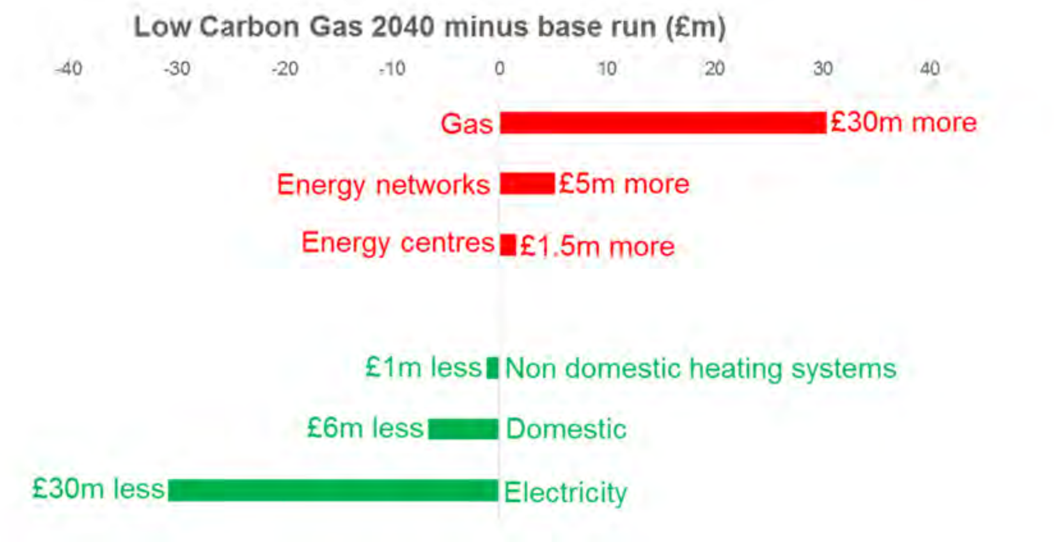

Figure 5-29 Change in total cost low carbon sensitivity minus base run

The difference in costs between the lower carbon gas sensitivity and the standard 90% carbon target scenario are shown in Figure 5-29. The cost changes are small as this scenario only differs from the standard 90% carbon target scenario after 2040. Spending more money on the lower carbon gas allows the model to spend less on electricity and domestic and non-domestic heating system changes, as a greater number of gas boilers remain in place.

5.9.4 Key Findings

- At the time of this project the options for modelling a lower carbon gas in EPN were limited to replacing the natural gas vector in the model with a lower carbon blend.

- This means it was necessary to be cautious about when the lower carbon blend is made available, as switching to it too early incurs extra costs when the associated carbon saving was not required to meet the carbon target.

- Using the low carbon blend from 2040 onwards, the modelling shows an extra 4,000 buildings can remain on gas boilers in 2050. These are the buildings which would have been hardest to switch to heat pumps (e.g. large, old buildings) so there may be significant practical benefits to not having to do so.

- The current modelled blend can only give a modest carbon reduction – the hydrogen has a lower energy level by volume and its production is not carbon neutral. Although it may have a useful part to play in the partial decarbonisation of hard-to-transition domestic and non-domestic buildings, by itself it is not capable of the scale of carbon reduction required for Bury to meet its targets.

5.10 Battery Storage

Summary

Increasing electrical heating may require expensive network reinforcements. Use of household batteries may be one way to mitigate this. Household batteries are only found to be cost effective when there is sufficient difference between overnight and daytime electricity prices (2040 onwards). Their usage is not found to influence reinforcements or heating system choice.

5.10.1 Context

The results from the initial modelling showed substantial deployment of electrical heating systems. This increases the peak load on the electricity networks, requiring reinforcement to the existing network infrastructure. EPN models the cost of reinforcing the network infrastructure up to 33kV. The cost of reinforcement of the national transmission network is incorporated in the cost of the electricity imported into the local area.

Reducing peak loads is generally expected to save money on network reinforcement. One option to do this may be batteries, which can be charged at off peak times and discharged at peak.

Household (low voltage level) batteries may be useful to reduce peak electricity loads. When electricity supply outstrips demand the price is cheaper; during this time batteries can be charged. During times when there is extra demand on the electricity grid the batteries can release the stored electricity to be used within the house, thereby reducing the impact of peak load on the network. The cumulative effect of installing batteries in houses and so reducing peak electricity demand may reduce the need for electricity network reinforcements.

The batteries could also be used in conjunction with domestic PV, to store excess energy generated at the sunniest times.

This analysis provides insights into the potential of domestic batteries to reduce peak electricity demands, and the resulting cost implications and energy system transitions. It also illustrates the price point at which household scale batteries would be cost effective in reducing peak demand.

5.10.2 Method

EnergyPath Networks does not include domestic household level battery storage technologies, but the equivalent capacity can be modelled at network level (Figure 5-30). A new electricity storage option was created for each analysis area. Cost and capacity information was obtained for typical domestic battery technologies currently available. Within each analysis area of Bury a proportion of houses to include battery storage was determined. Multiplying this number of houses with typical battery cost and capacity information provided an aggregation of the household batteries represented at a LV (400v) level.

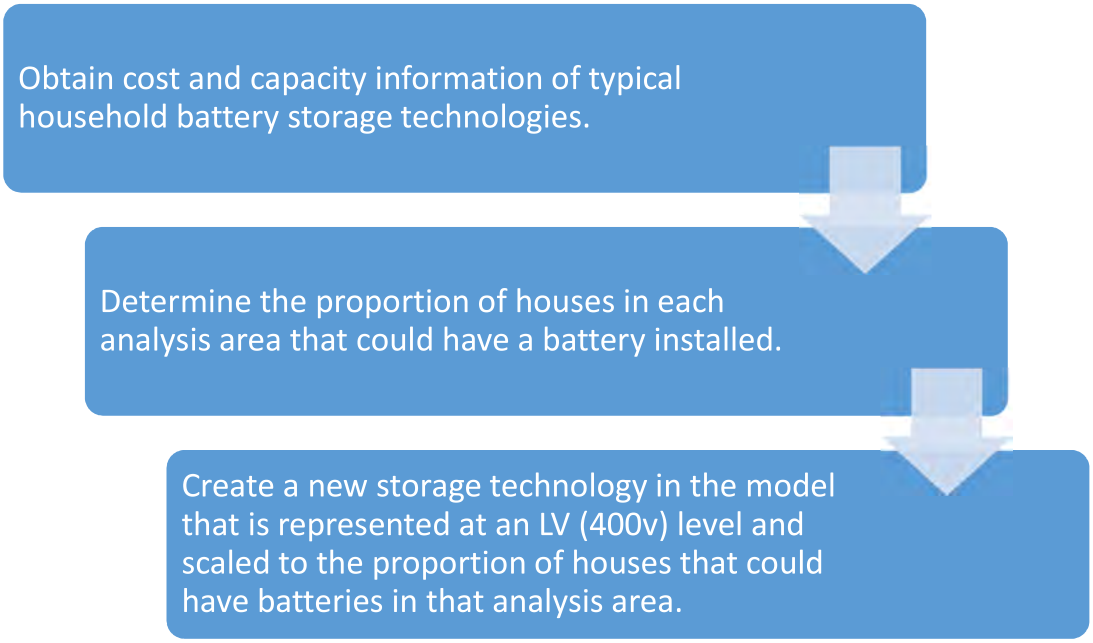

Figure 5-30 Method for modelling domestic battery storage technologies

Costs and technical specification were investigated for household level battery storage technologies that are available on the market in the UK. All the models included built-in inverters to convert DC energy to AC energy. The cost per kWh of capacity of the models was broadly similar, with the smaller capacity products having lower costs. The highest capacity option was chosen as the battery to represent the household level storage, as this should be more representative of future options (Table 5-9).

Table 5-9 Chosen Battery specification

Battery type	Lithium Ion Phosphate
Capacity	13.5 kWh
Usable Capacity	13.5 kWh
Continuous Power Output	5 kW
Typical life	Unlimited cycles 10 years Warranty Depth of discharge = 100%
Charge / discharge	5 kW charge/discharge power
Nominal voltage	230V
Efficiency	90%
Total installed cost	£6,700

The cost of the battery was scaled to decrease over time, in line with the ESME projections of network level battery storage costs. This represents ongoing technological advancements making the batteries cheaper in the future. The resulting cost trajectory per battery are shown in Table 5-10.

Table 5-10 Installation cost projections per decade of household battery storage

Build Year	Installation Cost per home
Now	£6,700
2020	£6,100
2030	£5,100
2040	£4,100
2050	£3,100

To determine the number of houses to be modelled with battery storage, a restraint was developed based on space available within the home. Batteries were not considered to be an option for the two smallest floor area bands of houses (Table 5-11). This is on the assumption that occupiers of these properties are least willing to give up space for energy storage.

Table 5-11 Floor area bands. Those considered not suitable for batteries are marked in red

Floor Area Band	Floor Area Min (m2)	Floor Area Max (m2)	Floor Area Value (m2)
Floor area band 1	0	50	42.5
Floor area band 2	50	70	61.3
Floor area band 3	70	90	80.1
Floor area band 4	90	110	91.3
Floor area band 5	110	200	133
Floor area band 6	200	300	250
Floor area band 7	300	10000	400

Once the number of suitable buildings in each analysis area were defined, the costs and performance characteristics shown in Table 5-9 were scaled up to represent all the batteries in that area.

The 90% carbon target scenario was modelled, and the role of batteries in the solution analysed. Further scenarios were tested with changes to the battery price to identify levels where their usage changed. Based on the building stock, the potential maximum battery deployment allowed in the model is shown in Table 5-12. The model is able to choose to build a proportion of the maximum number of batteries.

Table 5-12 Numbers of domestic batteries modelled in each analysis area

Area	Number of Domestic buildings	Number of Buildings Eligible for Battery Installation
Ramsbottom	10,200	8,500
Tottington	11,400	8,700
Bury Town North	11,500	9,300
Bury Town East	9000	6,600
Hollins	6,300	4,800
Tottington West	500	400
Radcliffe	16,800	13,000
Whitefield	13,500	9,600
Prestwich	16,400	11,000

5.10.3 Results

When modelling with default battery costs no batteries were deployed in homes until 2040 (Table 5-13). The batteries are modelled to have a 10 year lifetime so need installing in each time period if they are to be used in that time period.

Table 5-13 Deployment of batteries in each time period

Time Period	Number of homes with batteries deployed	% of possible deployment
2020	0	0%
2030	0	0%
2040	57,800	80%
2050	1,500	2%

The batteries are used in the 2040 time period because of the high price of peak electricity at this point. The cost of the peak electricity price by time period under the ESME Patchwork scenario is shown in Figure 5-31.

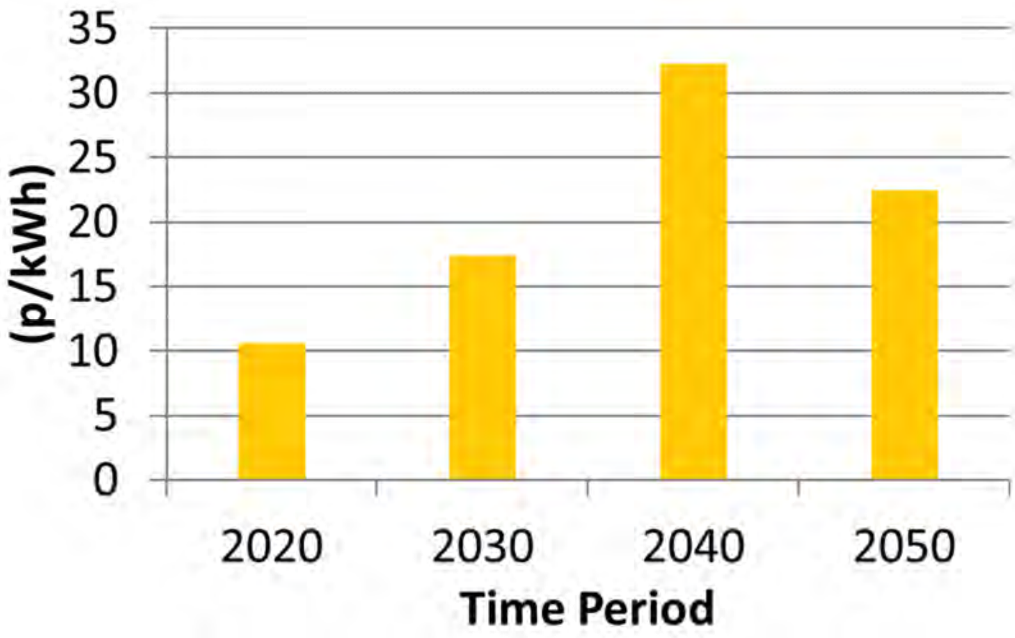

Figure 5-31 Maximum Electricity Price under ESME Patchwork Scenario

The average charging / discharging rates and times of the batteries deployed in 2040 are shown in Figure 5-32. On average the model shows the batteries are charged overnight from about 11pm to 6am with 124MW of power. A maximum of 260MW is modelled as discharged between 06:00 and 16:00. The discharge is completed before the evening and so there is no change in the amount of electricity required to be imported into the system at peak times. This means the batteries are not shown as being used to reduce peak loads and don't influence any required network reinforcements. There may be network reinforcement implications at a higher network level, above the scope of the model.

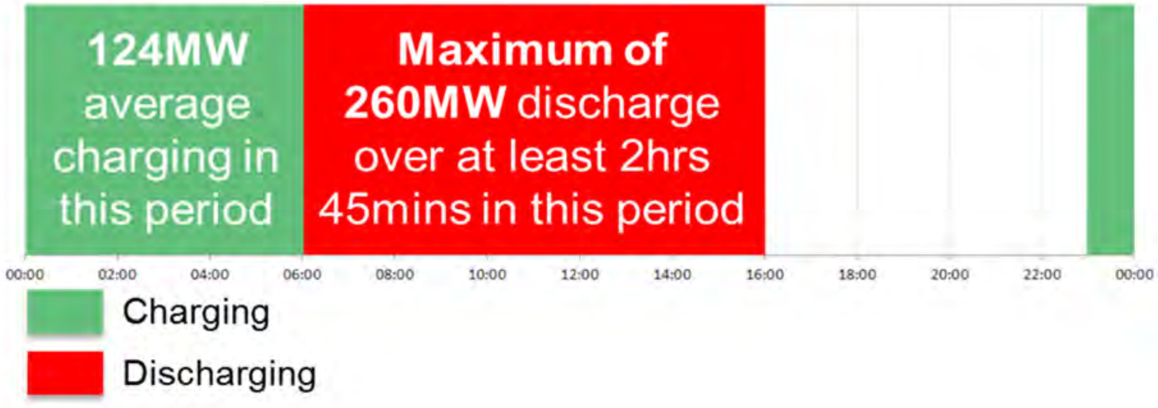

Figure 5-32 2040 Charge / Discharge rates of batteries

During the overnight charge period the price of electricity is at its cheapest: 15.2 p/kWh in 2040. At the time of discharge the price rises to 32.2 p/kWh. This is a difference of 17 p/kWh, which equates to £1.96 /day of additional income for each battery after efficiency losses of 10%.

To further assess the potential of domestic level batteries, scenarios were tested with battery costs decreased. This was to identify what the price would need to be for a greater uptake. The results of several scenarios with decreased battery costs are shown in Figure 5-33 and Table 5-14.

Table 5-14 Number of houses with batteries deployed (top) and associated battery installation costs (£/kwh) (bottom) under different prices

Number of Homes with Batteries Deployed				
	Battery Cost Scenario			
Build Year	x1	x0.75	x0.5	x0.25
2014	0	0	0	0
2020	0	0	0	0
2030	0	0	0	0
2040	57,800	58,000	67,000	72,000
2050	1,500	1,500	13,800	46,000

Battery Installation Costs (£/kwh)				
	Battery Cost Scenario			
Build Year	x1	x0.75	x0.5	x0.25
2014	496	372	248	124
2020	452	339	226	113
2030	377	283	189	94
2040	303	227	151	76
2050	228	171	114	57

Table 5-14 emphasises the importance of the electricity costs on battery uptake. Batteries can cost the same to deploy in 2040 and 2050s, but have a 30 times higher uptake in the 2040s because the electricity price is higher.

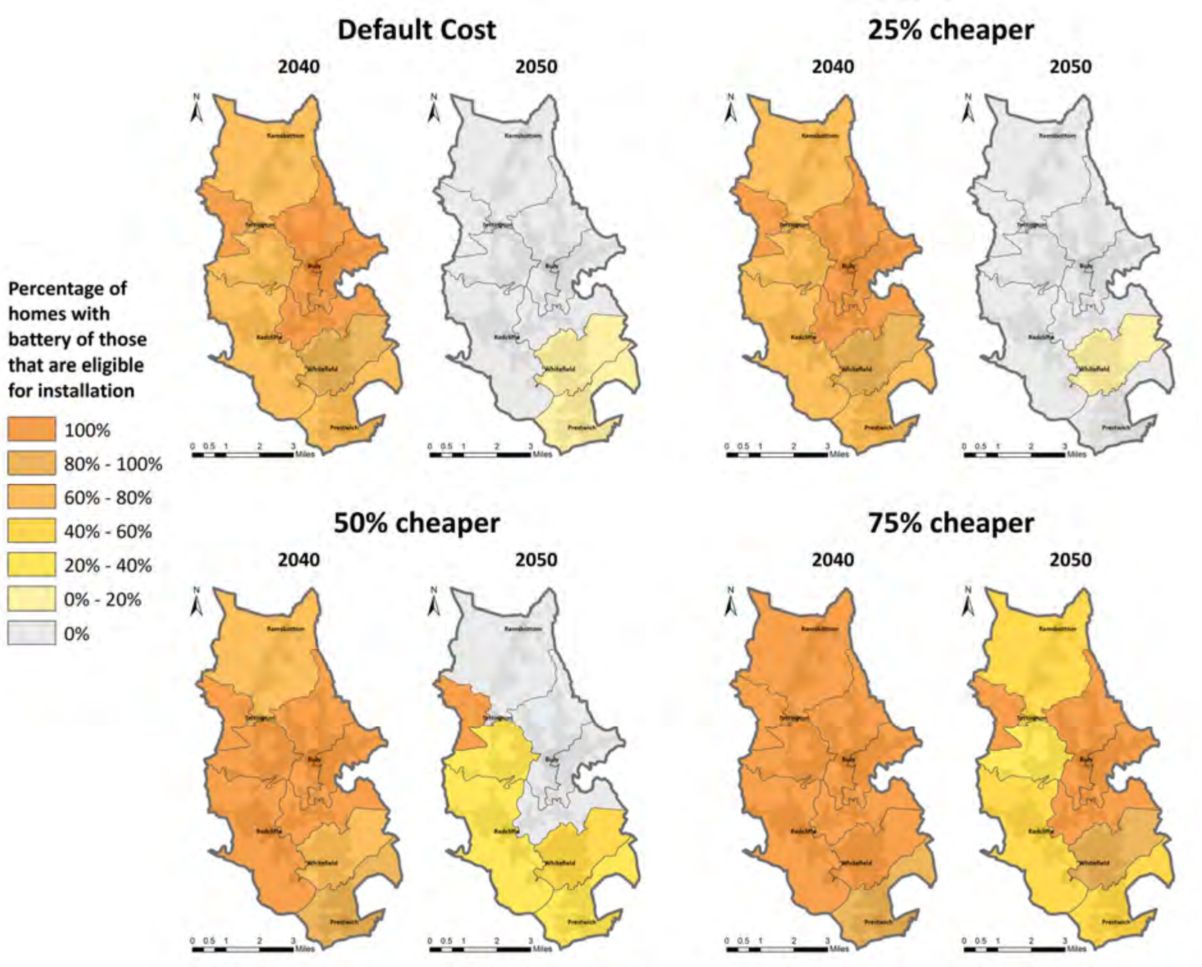

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Figure 5-33 Percentage of homes with batteries installed at A: default cost, B: 25% Cheaper, C: 50% Cheaper and D: 75% Cheaper

Decreasing the cost of the batteries increases the uptake in 2040 and 2050 (Figure 5-33). The total system cost savings in comparison to the 90% carbon target run are;

- £3 million when batteries are at default cost
- £14 million when batteries are 25% cheaper
- £70 million when batteries are 50% cheaper
- £130 million when batteries are 75% cheaper, this saving reduces the total cost of Bury's energy system by about 1.5%.

The 2050 uptake rises from just 2% under default battery costs to 64% when the battery was four times cheaper, however none of the cost sensitivities caused uptake in 2020 and 2030s.

The presence of batteries in the model does not cause significant heating system change: domestic heating systems chosen reflect those chosen in the base 90% carbon target run. As the heating system lifetimes exceed the battery lifetimes, so the batteries are only present for a proportion of the time that the heating system is in place.

5.10.4 Key Findings

- The use of domestic batteries is dependent on the price differential between the cost of generating electricity overnight and during the day.
- The model only shows usage from the 2040 time period onwards, when daytime electricity prices are the highest.
- As used in the model, the batteries have no impact on network reinforcement requirements or domestic heating system uptake and so do not change the lowest cost way to decarbonise.
- The cost of batteries would have to drop by a factor of 4 to see significant uptake in the 2050s, and even this isn't enough to drive any take up in the 2020s and 2030s.

5.11 Carbon Targets

Summary

Testing a number of different carbon targets indicated that an 85% target level was the point at which significant heating system change was required. Beyond this point the cost of cutting carbon rapidly increases. In general, increasing the local carbon target means decarbonising more buildings, but not necessarily needing to do different things to buildings that are already low carbon under lower targets.

5.11.1 Context

At the time of the initial modelling Bury Council had not set a local carbon emissions target. The initial modelling used a 90% in-scope carbon reduction from 1990 levels by 2050, but the local stakeholders were keen to understand what other reductions may be achievable and what the cost implications would be. This sensitivity explores the issue by testing a range of different carbon targets for Bury.

The following extra 2050 targets were tested: 70%, 75%, 80%, 85% and 95%.

Further work was also undertaken to identify the highest achievable in scope reduction for Bury, within the decarbonisation options modelled. This was found by setting the model optimiser to minimise carbon at any cost and then determining what emissions reduction was obtained. This was found to be 97% and was also tested. A linear emissions reduction trajectory was used to define intermediate 2030 and 2040 targets for each run.

Care must be taken when using these percentage reductions to compare between local areas. Without a local carbon target the model still shows Bury achieving a 65% in-scope carbon reduction by 2050. Some of this is due to projected reductions in grid electricity carbon contents, but a further element is the extent to which Bury’s industry has already changed since 1990, reducing in size and energy dependence.

Given the uncertainty in future carbon targets, these runs were also analysed to determine the extent to which different targets required different plans for Bury – looking at whether tighter carbon targets simply required more buildings to decarbonise or whether they required buildings already on a low carbon heating system to change to another.

This is important as it shows whether initially planning for a looser carbon target means implementing the wrong measures for a tighter carbon target, or whether the options you take up for a looser target are also correct for a tighter target and are just required on more buildings. This analysis was used to identify what appears to be a good choice no matter what the carbon target ('least regret’), therefore providing scope for projects that could be carried out in the more immediate future.

5.11.2 Results

Figure 5-34 shows the modelled costs of the different carbon targets tested. The costs are given as an increase over the no local carbon target total system cost. The 97% carbon reduction is a 14% increase over the cost of not having a local carbon target.

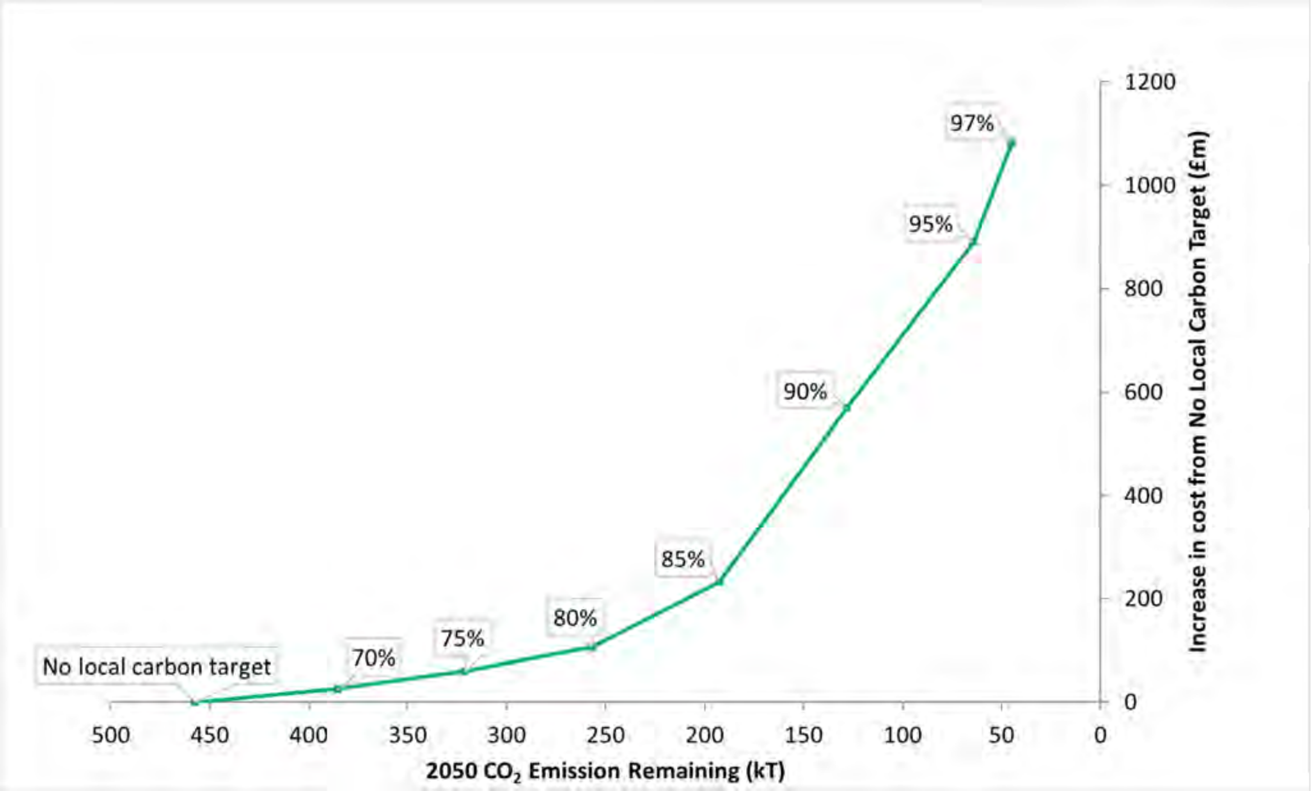


Figure 5-34 Increase in costs relative to reduction in emissions

The shape of the curve shows where the marginal cost of carbon reduction increases. Up to an 85% reduction the curve is shallow, showing that carbon can be saved at a relatively low cost. Between 85% and 95% the curve steepens as the cost of reduction increases. Going from 95% to 97% is modelled to cost almost the same as going from 65% to 85%. A 97% reduction instead of 95% reduction means eliminating 40% of all remaining emissions (2% out of 5%) and these are the most difficult and expensive reductions to achieve.

Figure 5-35 and Figure 5-36 show how the modelled total deployment of each type of domestic and non-domestic heating systems in 2050 varies by carbon target.

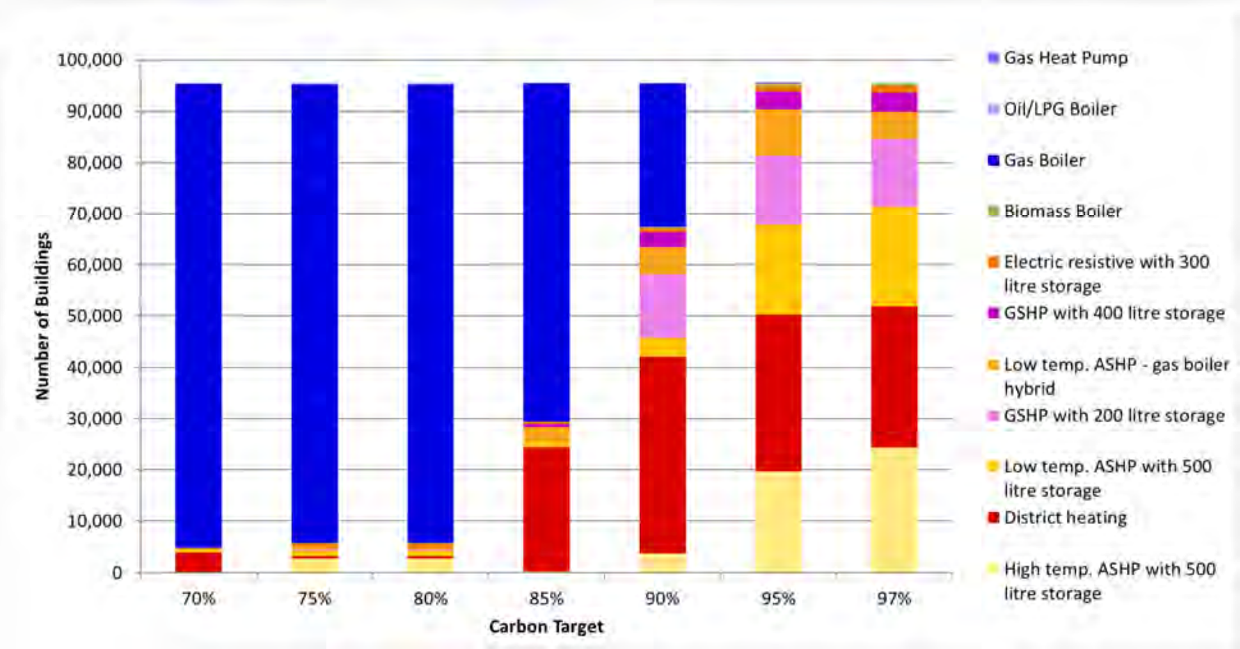


Figure 5-35 Domestic building heating system change by carbon target

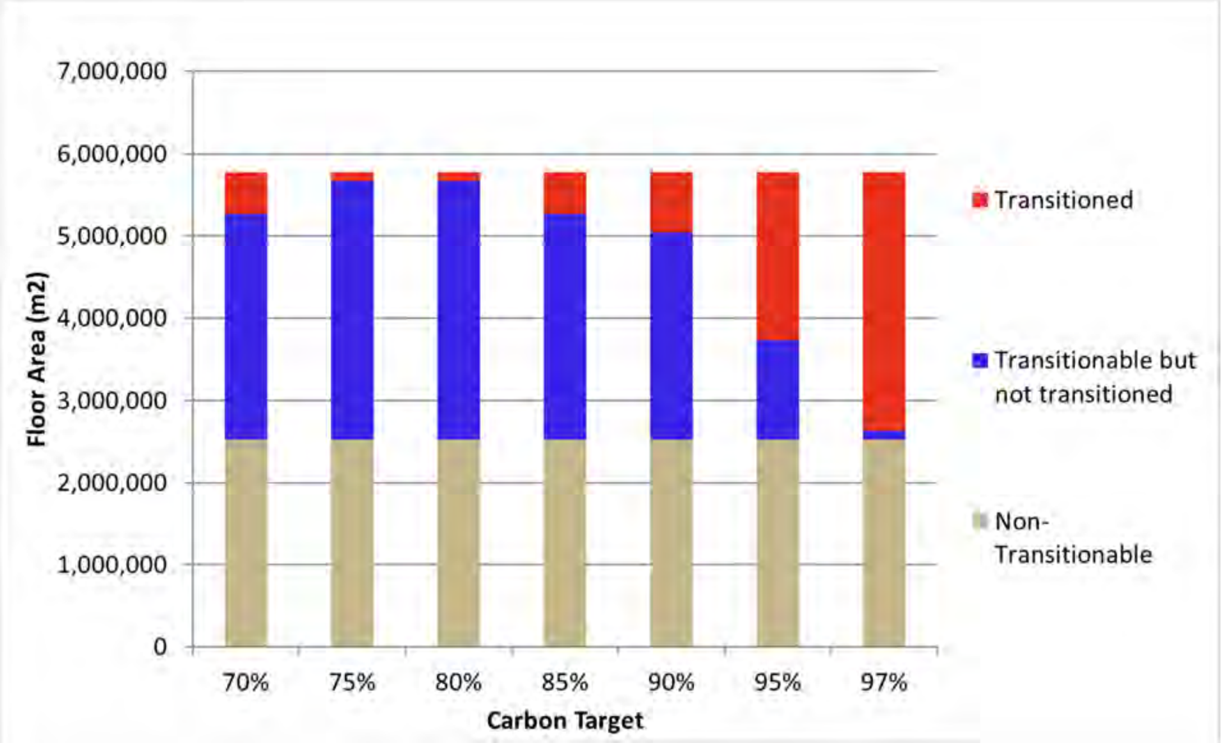


Figure 5-36 Non-domestic building heating system change by carbon target. Transitioned floor area has moved to district heat, not transitioned remains on gas and non-transitionable is heavy industry not thought suitable for a low carbon source.

Significant change to domestic heating system change is not shown to be required until Bury adopts an 85% carbon target. At 85% the lowest cost option is modelled to include approximately 25,000 domestic buildings switching to district heat. The small heating system changes prior to this are driven by the use of

CHP to generate electricity cheaper than the grid, when the carbon target allows. Beyond 85% the number of heat pumps increases, and by a 95% carbon target no gas boilers remain in Bury. The decrease in gas boilers is balanced by the increase in electric options; the level of domestic district heat does not increase considerably beyond the 85% target.

The heating systems for non-domestic floorspace (as shown in Figure 5-36) also follow a similar pattern, with change beginning at the 85% target, and the floor space transitioned to a low carbon heating option steadily increasing after that. Between 95 and 97% there is a large increase in floorspace transitioned to a low carbon option. This floorspace has relatively low energy demands, and so is expensive to switch given the amount of carbon saved. At this stage in the modelling approximately 40% of the non-domestic floor area was considered unsuitable for connection to a low carbon option. An update to our building data meant this estimate was revised downwards in the final modelling (p132)

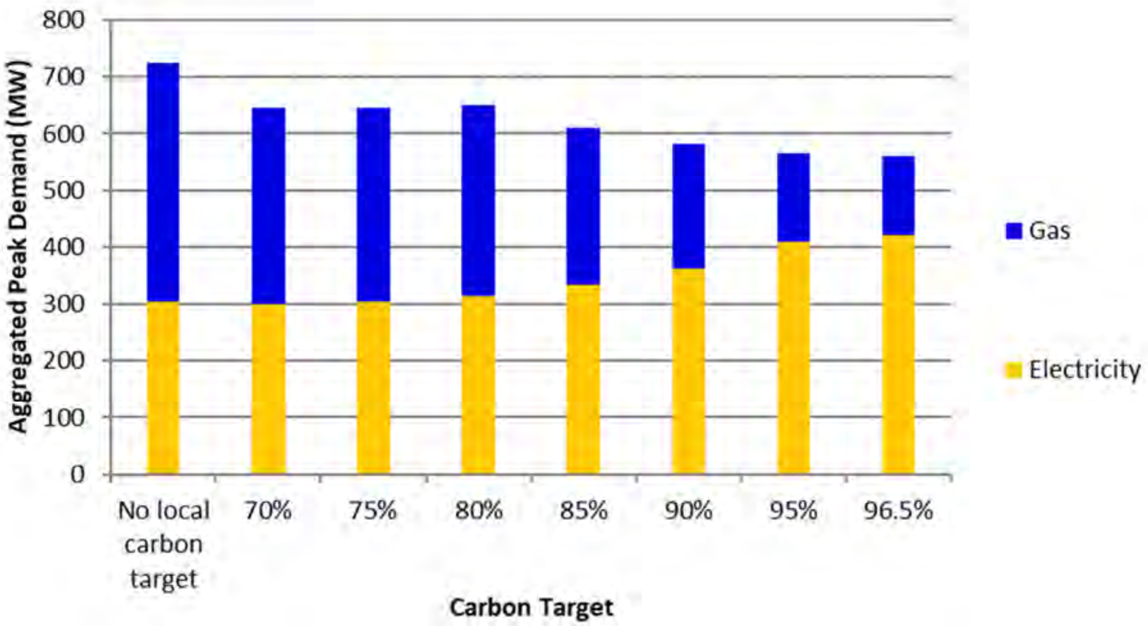


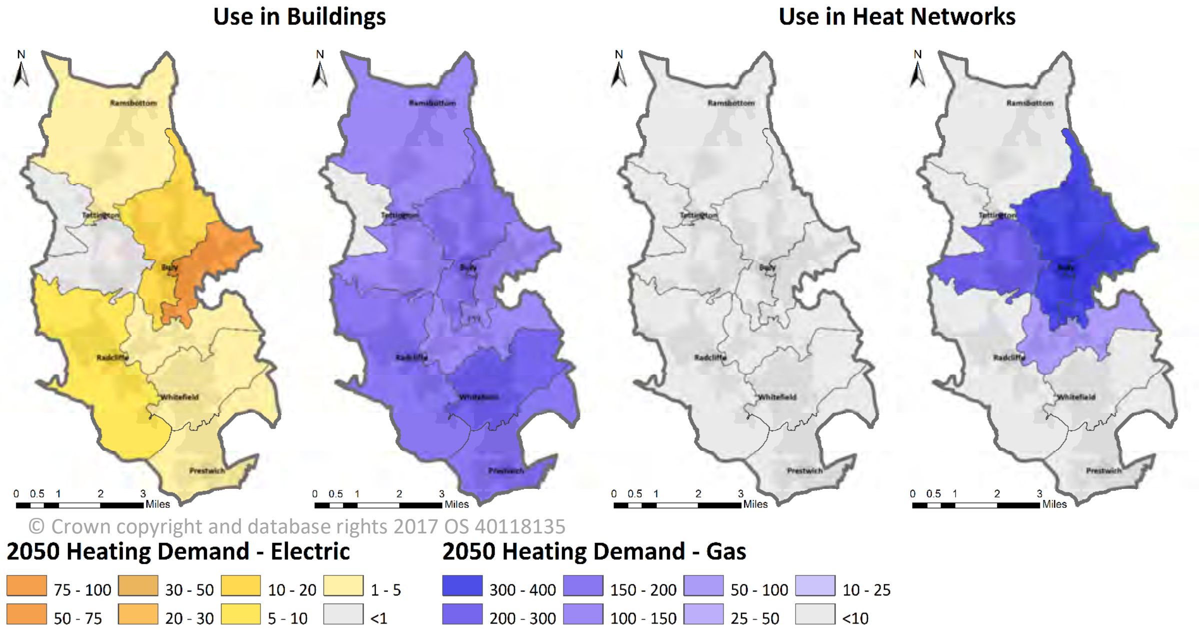
Figure 5-37 The variation in gas and electricity peak demands between carbon targets

Figure 5-37 shows how peak electricity and gas demand are modelled to change under the lowest cost plan to achieve each carbon target. As the carbon target increases peak gas demand falls significantly, and peak electricity demand is modelled to increase by a third.

Considering the results for the different scenarios spatially can show which areas of Bury were first or last to experience heating system change under the carbon targets.

When viewed one after the other, the changes become evident. As the carbon target increases from 80%, the shift from gas consumption to electricity consumption can clearly be seen. What is also clear is that while gas demand decreases in buildings, electricity consumption increases in both homes and energy centres. Only at the lowest carbon targets, where electricity is being produced in tandem with heat, does gas demand in energy centres make an appearance in and around Bury town.

With no local carbon target almost all buildings continue to be heated with conventional gas technology. A small number of homes and businesses are connected to a gas-fuelled heat network in Bury town centre and Radcliffe, which also provides some power (Figure 5-38).



Use in Buildings

Use in Heat Networks

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Figure 5-38 Energy used for heating in 2050 with no local carbon target

At a 70% target the results for space heating are almost identical. The only change is a 40% drop in electricity generation from Combined Heat and Power. At a 75% target the use of gas to generate electricity is scaled back a further 45%. This means some of the heat networks are no longer cost effective, leaving around 550 domestic properties on district heat. 3,350 homes previously on a heat network switch to an electric heat pump (Figure 5-39).

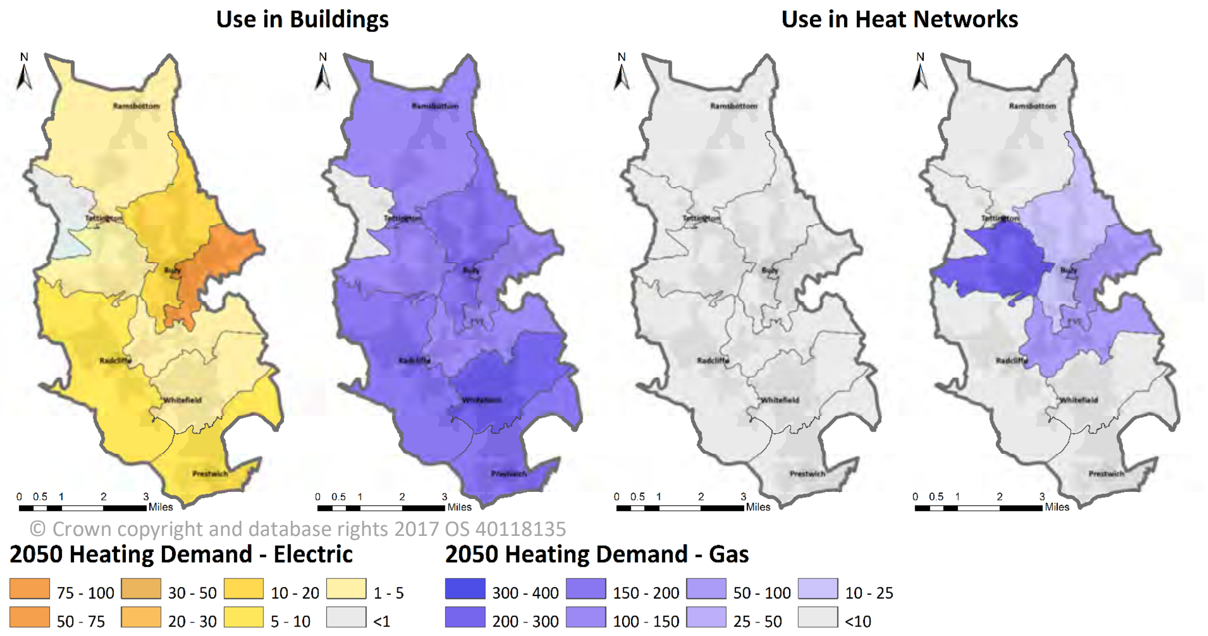

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Figure 5-39 Energy used for heating in 2050 under a 75% carbon target

Heating systems do not change between a 75% and 80% target. Instead the carbon saving is gained by further cutting back the use of gas to locally generate electricity. The electricity generated locally in energy centres is 83% lower than the previous target and is a 94% reduction from the no local carbon target scenario.

Going from 80% to 85% triggers significant domestic heating system change, with a number of new heat networks being established. Domestic district heat jumps from 550 homes to 24,200. 950 non-domestics also join the heat networks. In 2050 virtually all the heat in the networks is generated from large-scale electrical options (Figure 5-40)

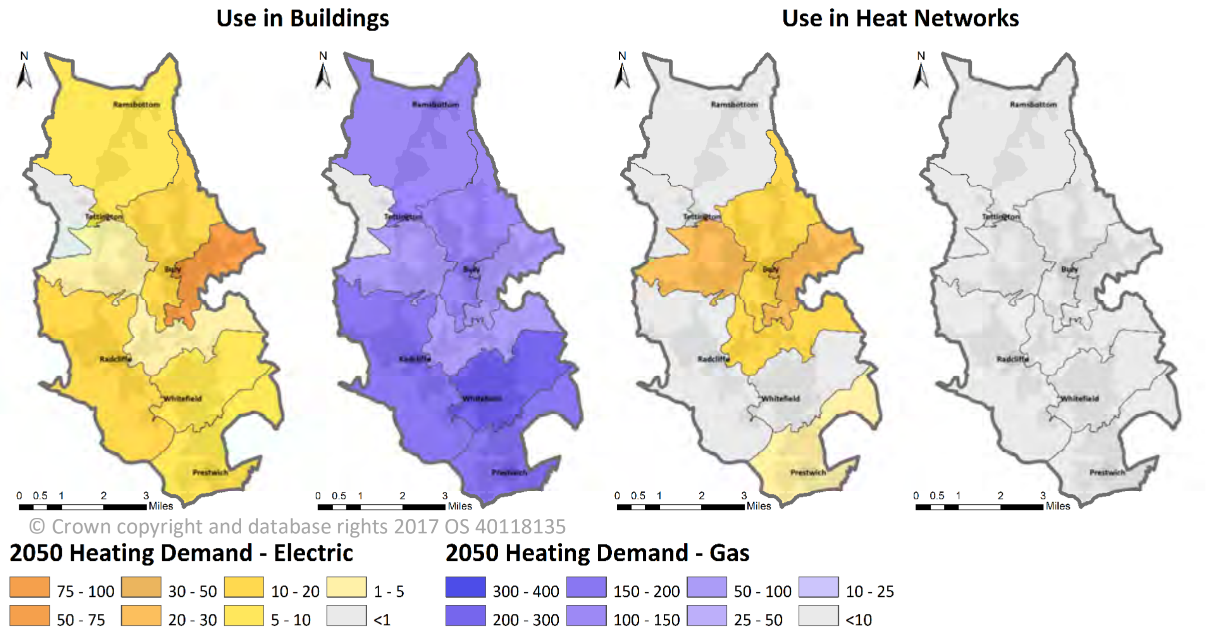

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Figure 5-40 Energy used for heating in 2050 under an 85% carbon target

At a 90% target, two thirds of domestic buildings have switched to low-carbon energy sources. This is the first point at which a major uptake of building-level electric options is seen - domestic electric heat pumps now provide heat for 28,000 homes. The number of domestic buildings connected to district heat increases to 38,300. 1,340 non-domestic buildings are also connected (Figure 5-41).

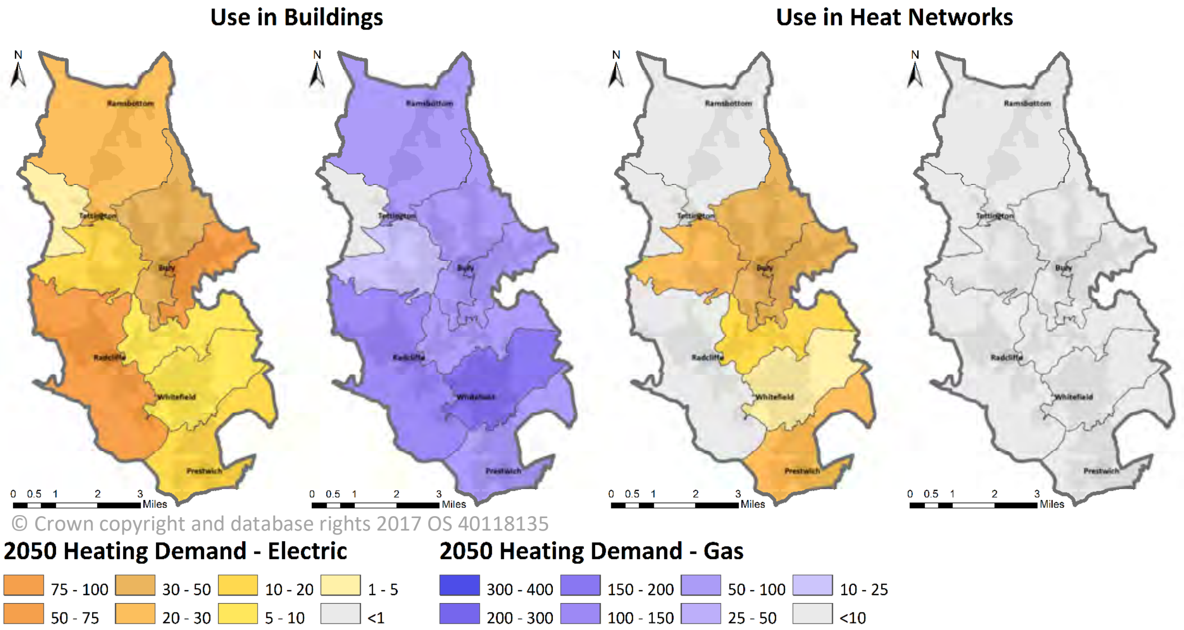

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Figure 5-41 Energy used for heating in 2050 under a 90% carbon target

To achieve 95% requires complete decarbonisation of the domestic building stock (Figure 5-42). The remaining gas is mainly in the non-domestic stock. 24,750 of the homes that were still on gas at a 90% target switch to a heat pump option. In total two-thirds of domestic buildings are on electric options, although 9,000 of these are hybrid heat pumps. A reduction in numbers of domestic connections to a heat network is mirrored by an increase in non-domestic connections, as the proportions of total heat network capacity shift in favour of non-domestics. Domestic insulation uptake also increases.

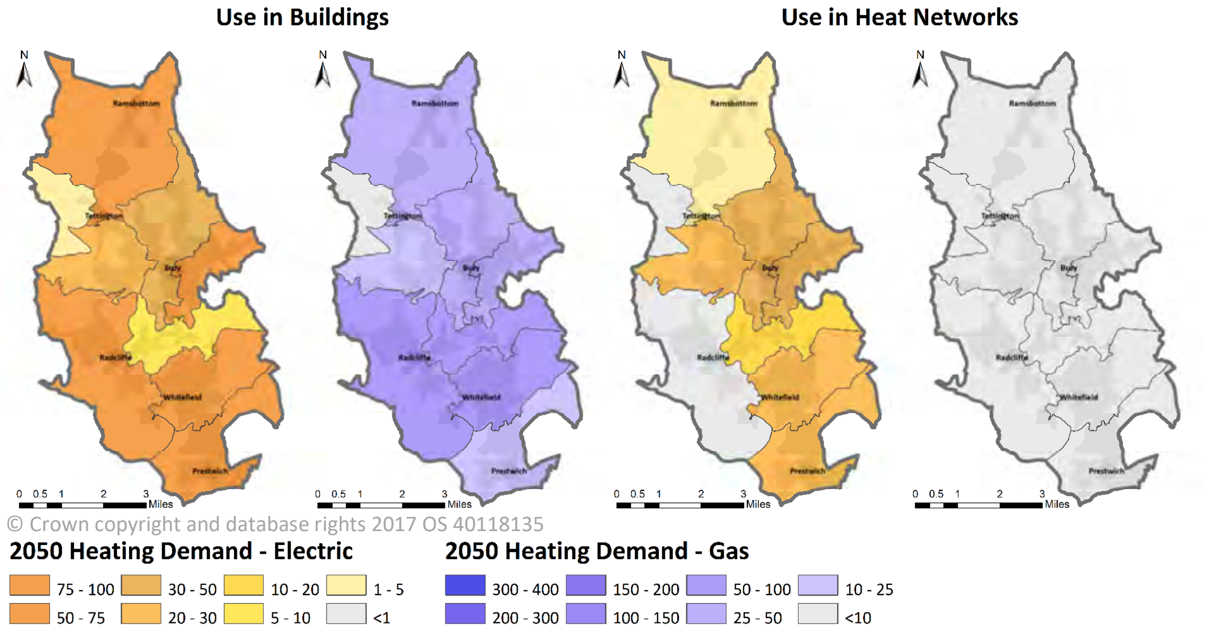

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Figure 5-42 Energy used for heating in 2050 under a 95% carbon target

To go from 95% to the modelled 97% maximum involves switching more non-domestics to a heat network. 6,400 non-domestic buildings are now connected to a heat network. Some large homes previously on hybrid heat pumps are also connected for the first time (Figure 5-43). This is reflected in the jump in costs - going from 95% to 97% costs as much as going from a 70% to 85% carbon reduction.

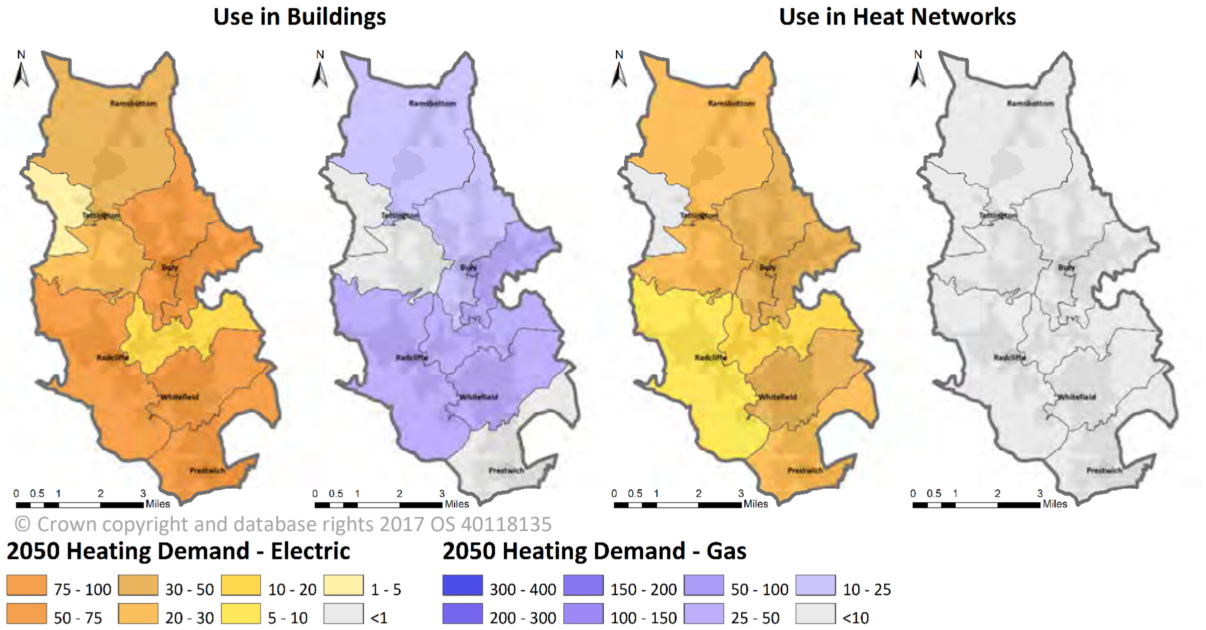

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Figure 5-43 Energy used for heating in 2050 under a 97% carbon target

Generally speaking, moving to a higher carbon target means transitioning more buildings, but not needing to change heating systems that have already transitioned to a low carbon option (Figure 5-44). There is a small amount of trade-off between electric heat pump solutions and district heat, but nothing to suggest that working towards a looser carbon target inhibits achieving a stricter target at a later date. Some solutions, such as ground source heat pumps, tend to remain unchanged above a certain carbon target. This is likely to be because of their suitability for one particular property type, in this example larger detached homes that are assumed to have a big enough garden and good access for installation.

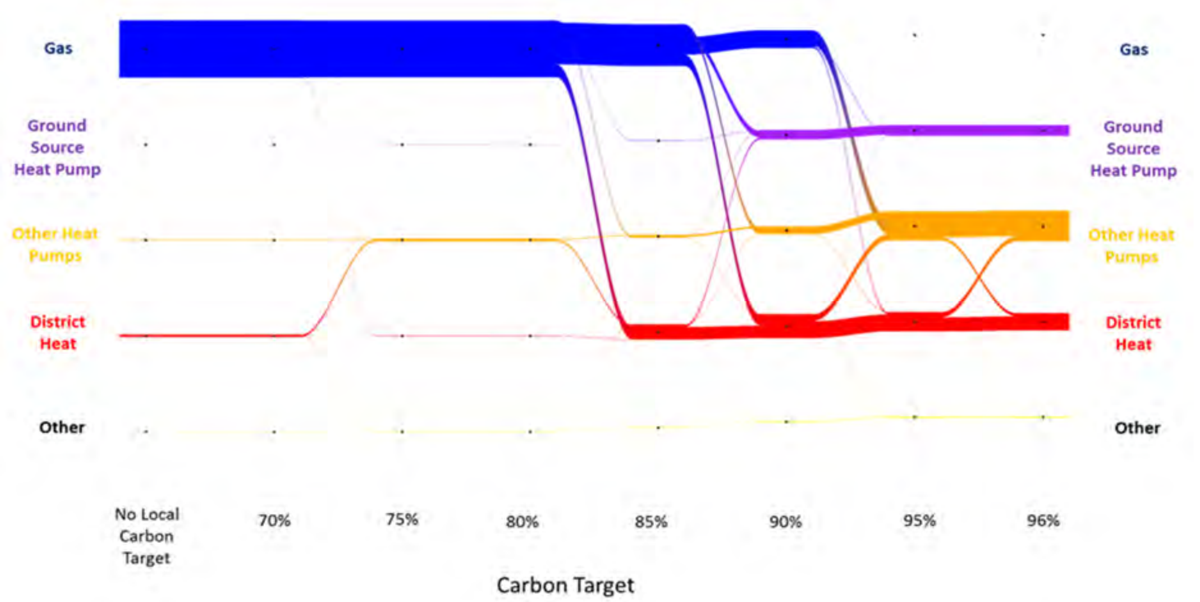


Figure 5-44 Flows between final heating systems for domestic buildings at different carbon targets

5.11.3 Key Findings

- At the lowest carbon targets, a number of smaller-scale, gas-fed heat networks are cost-effective.
- With a tighter limit on emissions the proportion of gas allowed in the solution decreases and the proportion of electricity increases.
- Large-scale heating system change is not required until Bury sets a carbon target of 85% or higher for in scope emissions.
- Above 85% the cost increases steeply – going from no local carbon target to 85% costs £232m, to reach 90% requires £570m.
- Generally speaking the low carbon option best suited for a building remains the same at a wide variety of carbon targets. Tighter carbon targets lead to more buildings moving to lower carbon heating systems, not using different decarbonisation options.

5.12 Maximum Carbon Reduction

Summary

This sensitivity tested a scenario where carbon was cut as quickly and completely as possible. In this scenario all low carbon heating systems were in place in transition one. Cutting the carbon as quickly as possible costs four times more than achieving the same reduction by 2050, and requires immediate network and heating system change.

5.12.1 Context

The carbon target sensitivity modelled different carbon reductions based on achieving 2050 carbon targets, focusing on the lowest-cost way to steadily cut carbon until the final 2050 carbon target.

Following discussion with stakeholders it was requested that an earlier carbon target be investigated, as Greater Manchester Combined Authority were exploring the possibility of decarbonising earlier than this. This sensitivity assessed how quickly Bury could cut its carbon emissions, what it would cost and how the changes would differ to those required for a 2050 carbon target.

5.12.2 Method

The model was setup with a high carbon price rather than a target. This meant the model would utilise every option available to decarbonise as soon as possible, regardless of the cost. This defines the steepest possible carbon reduction trajectory for Bury

5.12.3 Results

Although the Maximum Carbon Reduction scenario reaches the same annual emissions as a carbon target of 97% by 2050 (Figure 5-45), the total extra savings made between now and then are in the region of 4.3 Mt CO_2, and just under 9 Mt CO_2 compared to no local carbon target (Figure 5-46). Respectively these savings are equivalent to 6 and 11 years of current emissions.

Emissions from domestic building stock and energy centres are eliminated by 2030. At this point the remaining emissions come from non-domestics not suitable for low carbon heat and from imported national electricity. Further decrease in emissions beyond this point occurs as the grid decarbonises further.

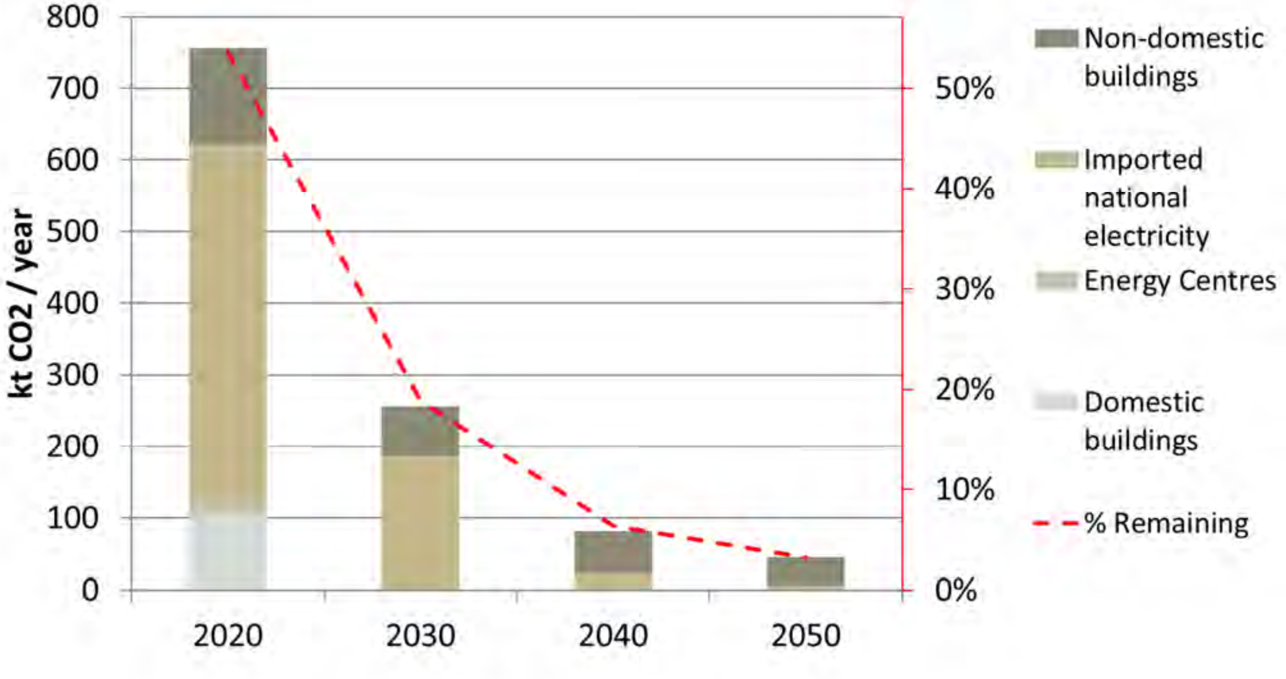


Figure 5-45 Emissions trajectory for Maximum Carbon Reduction

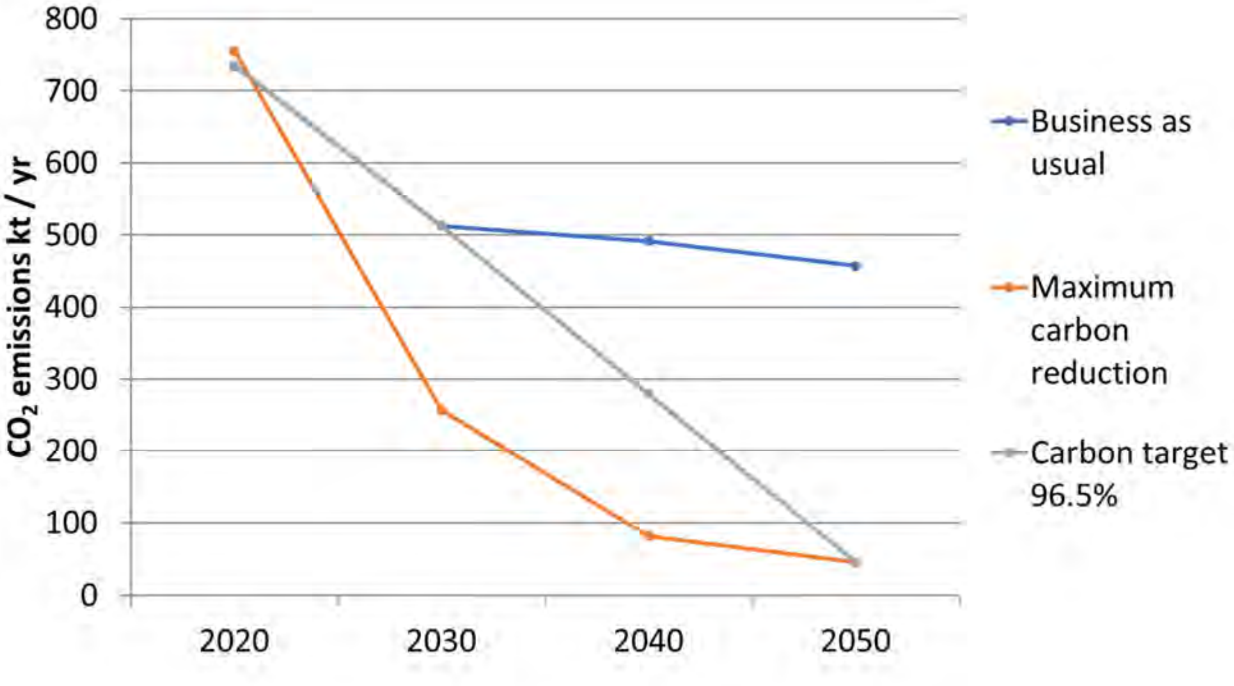


Figure 5-46 Comparison of the emissions from three scenarios

87% of non-domestic buildings that can switch to a heat network. This includes smaller floor areas that are marginal in other scenarios. The floor area that does not switch is that with lowest energy demands, and is constrained by some the modelled heat network infrastructure reaching its maximum size or capacity.

Domestic heating system results show virtually every building transitioning by 2030 and then remaining with the same system out to 2050 (Figure 5-47). This suggests that the most cost-effective way to decarbonise the homes is the same throughout the period. There is an approximate 40/60 split between district heat and electric heat pump solutions.

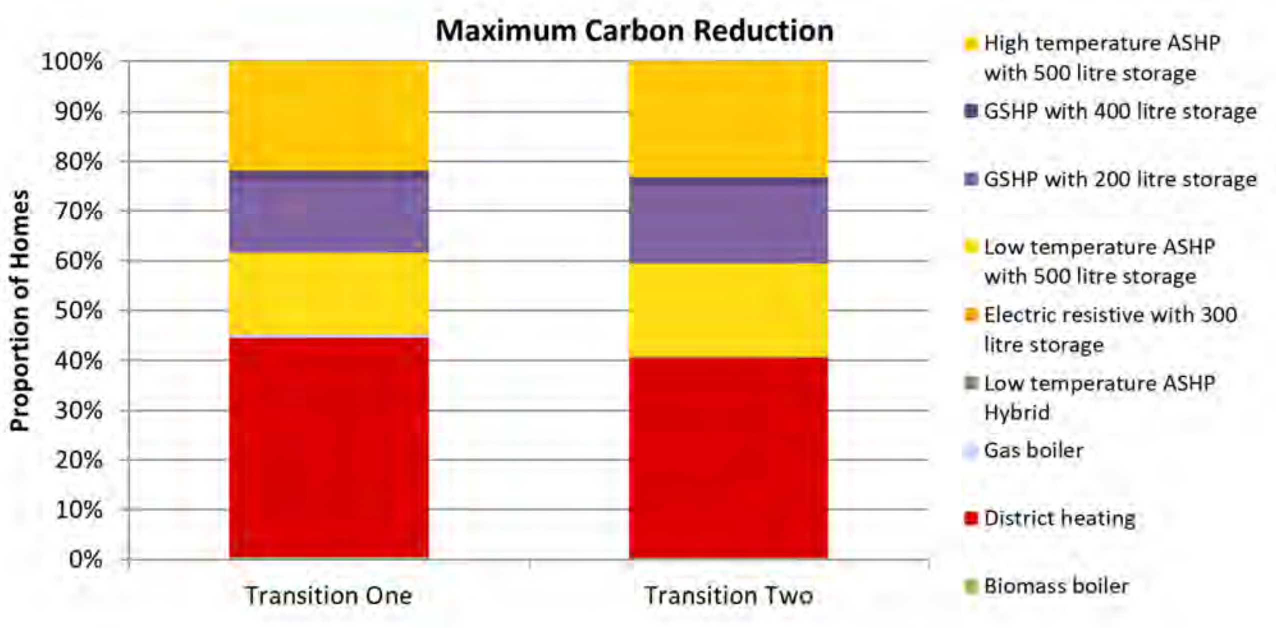
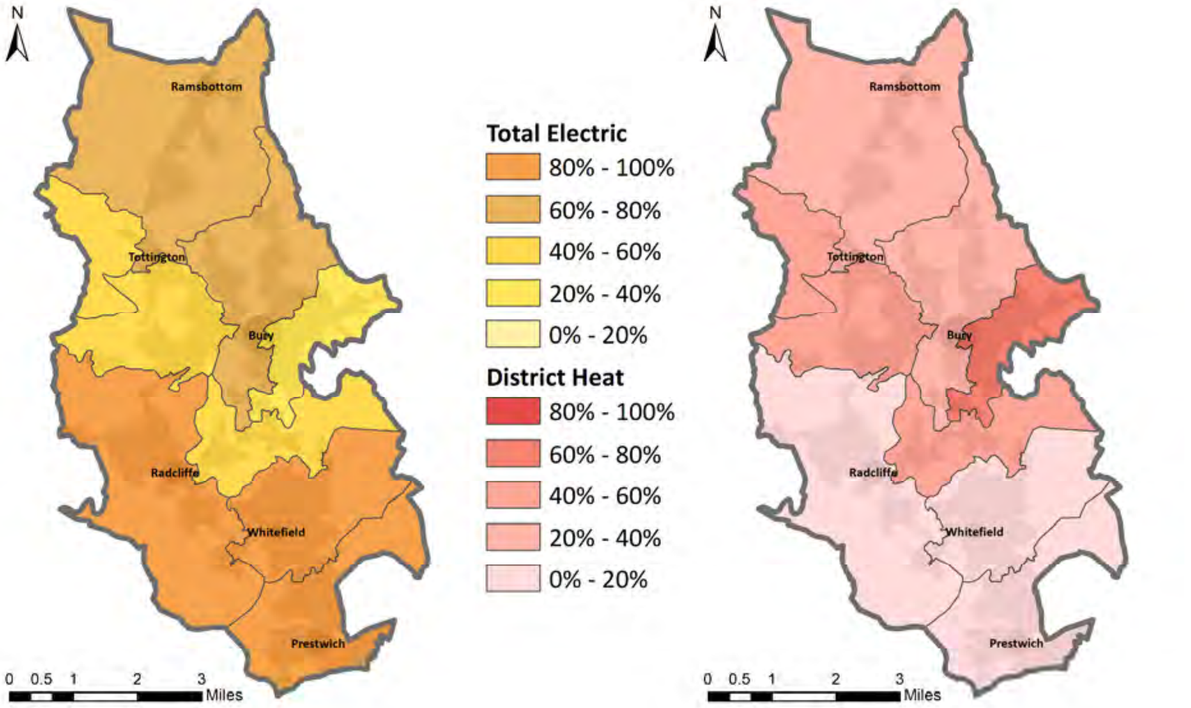


Figure 5-47 Domestic heating systems

High concentrations of district heat connections coincide with densely-populated areas in and around Bury town, while the south of Bury sees a far stronger uptake of heat pumps. This could be at least partially attributed to the greater proportion of semi-detached properties present in Whitefield and Prestwich. These areas are expensive for heat network construction and operation due to the larger distances between buildings when compared to more dense areas of housing, resulting in a lower heat demand per unit length of network.

Figure 5-48 Proportion of buildings going to a) district heat and b) heat pumps



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The switch to heat pumps and district heat means no gas only domestic heating systems remain. District heat is generated by large-scale heat pumps from the very start, breaking with the usual pattern of using gas-fuelled energy centres as a step to full decarbonisation. This means the emissions are associated with the imported national electricity. With the exception of some gas-fuelled combined heat and power generation in Bury town in the 2020s (Figure 5-50), energy centre gas capacity is then only kept on standby throughout the study period to provide heat for peak times, such as peak hours in midwinter.

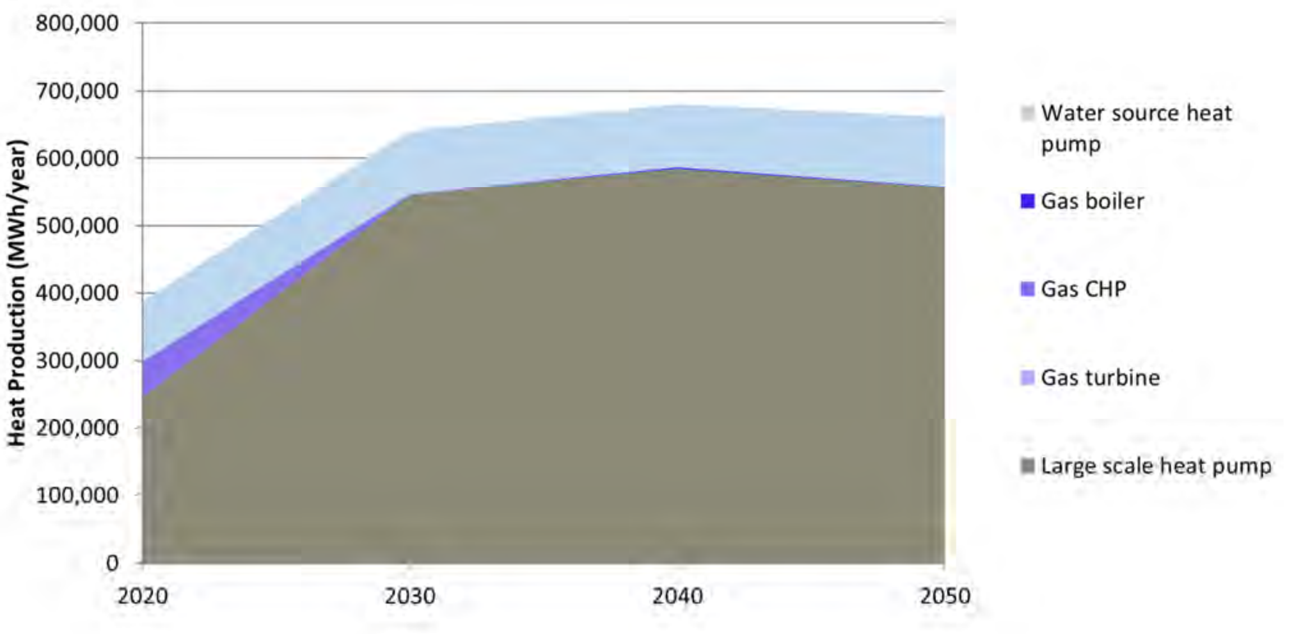

Figure 5-49 Heat production by Source

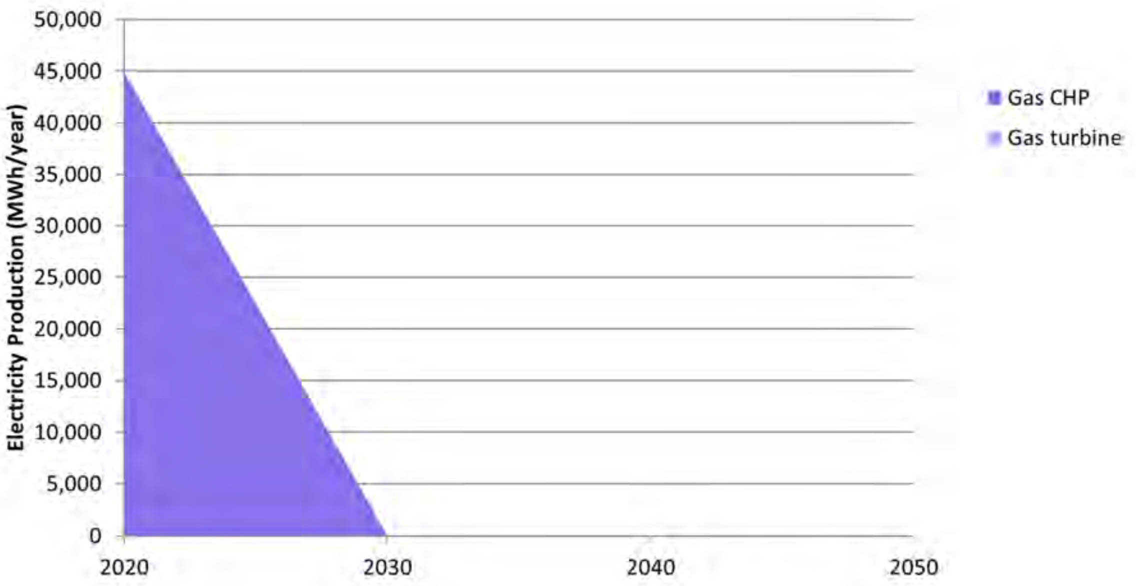

Figure 5-50 Electricity Production by Source

Compared to No Local Carbon Target the carbon max scenario costs £4,400m more (Figure 5-51). The equivalent 2050 carbon target costs £1,100m, so cutting the carbon earlier costs an extra £3,300m. This should be put in context of the extra carbon saved: 4.32MT is over 100 years of the 2050 emission level.

Both the heavy reliance on electricity throughout the study period and the early construction of heat networks contribute significantly to the extra costs of an earlier target (Figure 5-52). Constructing heat networks earlier costs more because the effect of discounting is less and the ongoing maintenance and operational costs are incurred for longer. Savings made on gas are not enough to offset the extra spend on electricity.

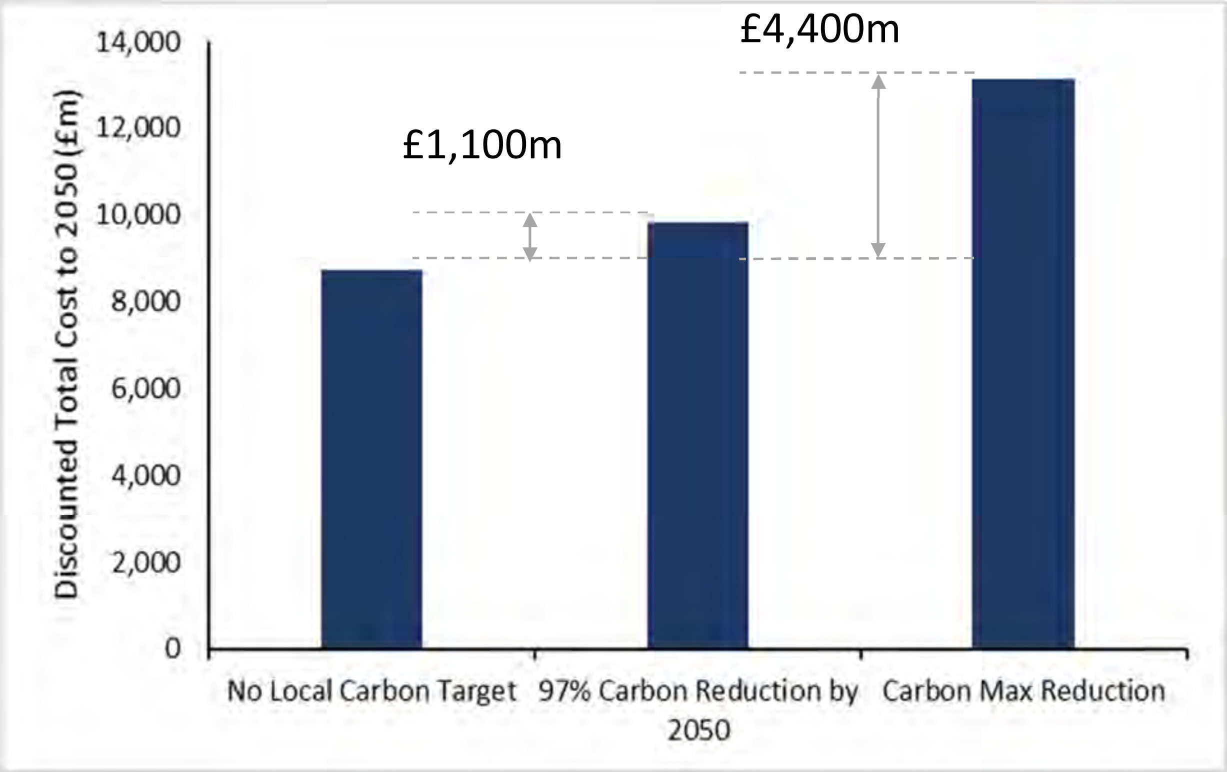

Figure 5-51 Comparison between the Total Cost of a 2050 and an earlier Carbon Target

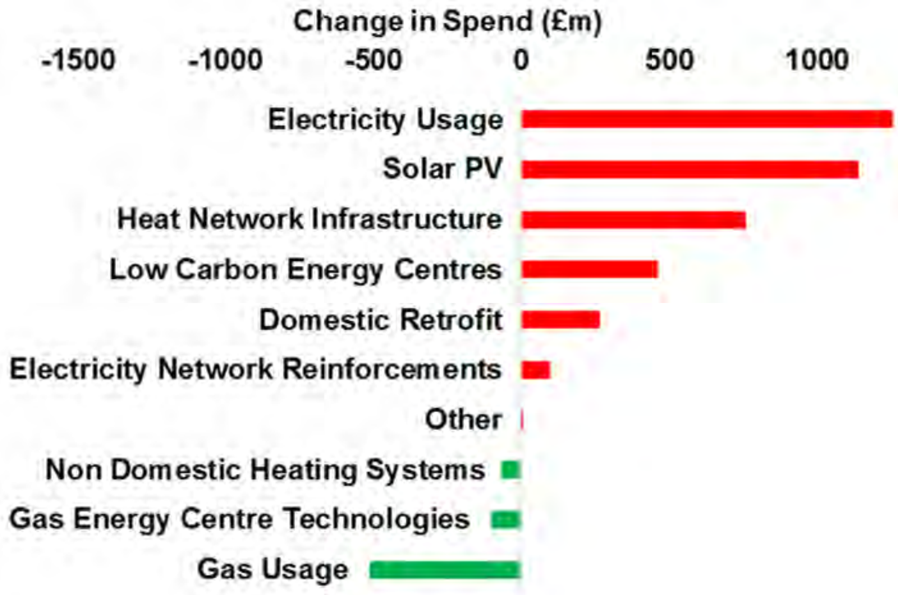

Figure 5-52 Extra spend by category for carbon max compared to a 2050 target

72% of domestic properties have solar photovoltaic installed by 2030, with most of the 220MW generation capacity installed in the 2020s. This capacity remains the same out to 2050. The Maximum Carbon

Reduction scenario shows that solar photovoltaic can contribute to cutting emissions when cost is not a factor.

5.12.4 Key Findings

- To achieve the maximum carbon reduction almost every building that can transition in Bury switches to a low-carbon heating system by 2030.
- This speed of network and building change is likely to pose significant practical difficulty.
- The earlier limit decreases the time available for test or demonstration. This gives less opportunity to explore consumer reaction to technologies before they are put in place.
- Gas use is limited to providing heat and some electricity in Bury town in 2020, plus a handful of non-domestic buildings that cannot transition to heat networks in the modelling. Beyond this, gas capacity remains in place purely for peaking loads in energy centres. Unlike other scenarios, gas is not used as a ‘step’ in district heat to large-scale heat pumps in later years, because the cuts to emissions have to be made as early as possible. This is done by transitioning virtually everything on to electricity by 2030, and then allowing grid decarbonisation to reduce the remaining emissions, with some support from local generation using PV.
- The highest extra spending is on imported national electricity, district heat networks and energy centres.
- Incentivising EPN to cut carbon at any cost as early as possible results in a £4.4bn increased spend over a no local target scenario where no action is taken. Some of the reasons for this include;
    - Switching to more expensive heating systems sooner, which use more expensive fuel for longer.
    - In general the technologies reduce in cost and increase in performance over time. Switching to some of them sooner means installing a more expensive and less efficient version.
    - A large spend on heat networks to decarbonise difficult non-domestic buildings.
    - Impacts of the need for earlier capital expenditure such that the beneficial influence of discounting on later expenditure is not realised.

5.13 Post Sensitivity Scenarios

Summary

Context (p133) - These scenarios represent the final modelling for Bury, including all data and model improvements.

Carbon Emissions (p134) – Scenarios with almost complete decarbonisation by 2050 and by 2040 were tested. The remaining carbon emission is in non-domestic buildings not considered suitable for heat networks and a small amount in imported grid electricity.

Domestic Heating Systems and Insulation (p137) – In 2050 approximately one third of homes are connected to heat networks and two thirds have electric heat pumps. Detached homes are served by Ground Source Heat Pumps, and larger homes may need a gas-electric hybrid. Under the 2040 target heating system change needs to occur earlier. There are areas of Bury where district heat is more cost effective. The model shows limited further insulation being installed with an earlier carbon target (p144).

Domestic PV and Batteries (p145) – By 2050 there is widespread PV deployment, and under the 2040 target it is deployed earlier to save carbon. Batteries are not shown to be cost effective.

Non-Domestic Heating Systems (p148) – all non-domestic buildings that are considered suitable are switched to heat networks.

Energy Networks (p150) – Gas demand falls considerably across Bury, but there is still some demand in all areas. Peak electricity demand increases, requiring significant network reinforcements. Heat network infrastructure is required across Bury, and is needed earlier under the 2040 target.

Energy Centres (p157) – In the early time periods gas CHP can be used as a cost-effective heat source, but the heat needs to be generated by electric heat pumps as the carbon target tightens. At peak winter times some gas technologies are still used.

Costs (p161) - The 2050 carbon target is modelled to cost £1,120m more than not having a local carbon target, an increase of 16%. The 2040 target is modelled to cost a further £960m more, an 86% higher spend on carbon reduction compared to the 2050 target. The main extra spend is on more electricity.

How to use low carbon gas (p163) – If there was an opportunity to use a small quantity of gas then it would be best used to reduce the level of heat network infrastructure required. This would be through the greater use of gas-electric hybrid heat pumps.

5.13.1 **Context**

The post sensitivity modelling reflects modifications based on the findings of the sensitivity scenarios, combined with further data and model enhancements that were possible during this time.

In addition, the carbon reduction ambitions of Bury Council were developed during the sensitivity runs. Bury Council joined the UK100 pledge, to '*have the ambition of making all our towns and cities across the UK 100% clean before 2050, in line with the commitments made nationally and internationally at the Paris Summit*.'

Following discussion with the key stakeholders it was agreed that there would be two main scenarios, one representing an almost complete decarbonisation (98% reduction) by 2050 and one reflecting an earlier carbon saving trajectory (Figure 5-53). It was agreed that this earlier trajectory would aim to minimise emissions by 2040. This differs from the previous maximum carbon reduction scenario, which aimed to minimise carbon immediately, and so was considered to be a more practical timescale. The scenarios were not completely zero carbon as the model shows a small emission remaining in the grid electricity and in non-domestics not suitable for heat networks. The 98% reduction achievable is greater than the 97% previously tested as updated data sets indicated lower emissions from some non-domestic buildings.

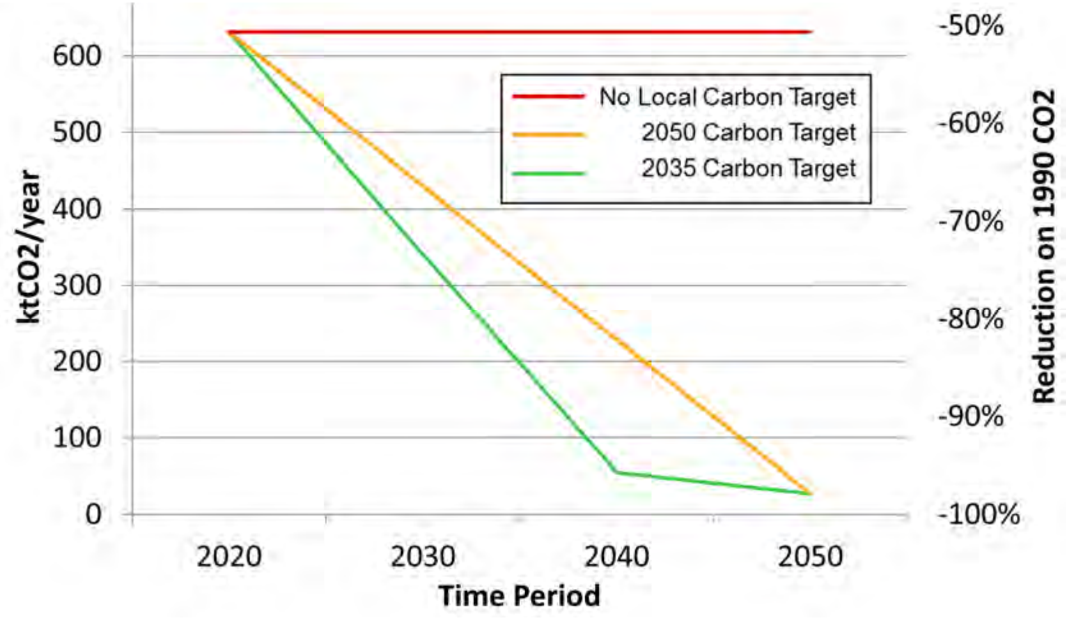

Figure 5-53 Carbon Emission Limits used in the Post Sensitivity Modelling

An additional piece of analysis was also performed to identify how and where in Bury a limited quantity of gas could be used in the future. This could be possible due to a lower carbon gas coming available or potentially space becoming available in the carbon budget through greater cuts in another sector.

5.13.2 Updates for the final scenarios

A number of model data and functionality improvements were made following the sensitivity scenarios. These included:

- Improving assumptions about typical height per storey of some non-domestic building types, to better represent their floor areas and hence energy demand estimates. This reduced the non-domestic demand considered not suitable for decarbonisation and so increased the maximum possible carbon saving for Bury.
- Updating electric vehicle charge profiles to better account for charging that may occur away from the home.
- Increasing the demand threshold at which a non-domestic building is connected to the high voltage (11kV) network rather than the low voltage (400V) network. This followed analysis of some additional data provided by Electricity North West.
- Improving the representation of PV and thermal storage.
- Updates to the water tank sizes allowed in flats following feedback from Arup.
- Changes to the technologies made available in energy centres following analysis of earlier runs and feedback from Arup.
- The inclusion of domestic batteries as an option and the deployment of insulation into houses most likely to be fuel poor, as agreed by the stakeholders following the sensitivity testing.

5.13.3 Results - Carbon Emissions

The three scenarios tested had different carbon limits defined in the model, which in turn led to different emissions profiles.

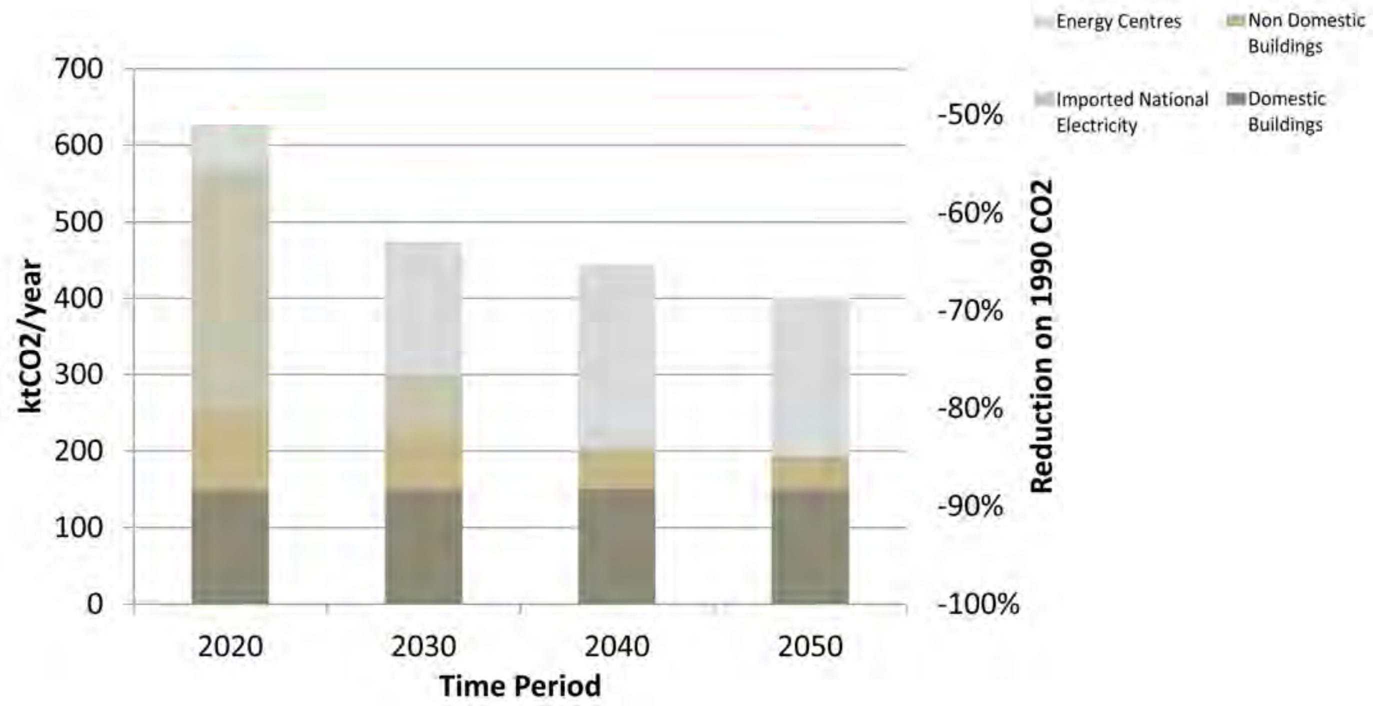

Figure 5-54 Modelled Emissions Profile for Bury with No Local Carbon Target

Figure 5-54 shows that even without a local carbon target we expect the emissions from Bury to fall. Without local action Bury would still benefit from national scale decarbonisation, such as in grid electricity. The modelling shows a 70% in scope emissions reduction from 1990 levels may be achievable, with the remaining emissions coming from gas fed heating systems.

National decarbonisation of generation will increase the cost of grid electricity, meaning that without a local carbon target there is increased incentive for local electricity generation though gas CHP. This increases the energy centre carbon emissions over time under this scenario.

In the 2050 target scenario the remaining emissions consist of a small amount in the grid electricity and some nondomestic buildings which are considered to be difficult to decarbonise and do not have low carbon options within EnergyPath Networks (Figure 5-55)

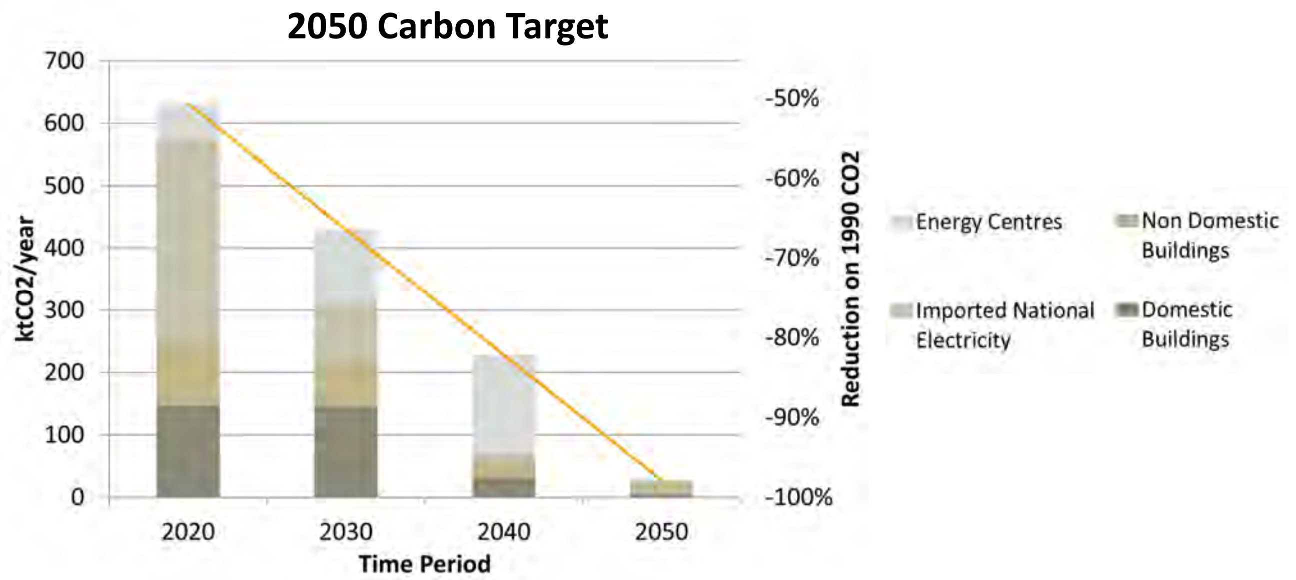

Figure 5-55 Modelled Carbon Emissions in the 2050 Target Run

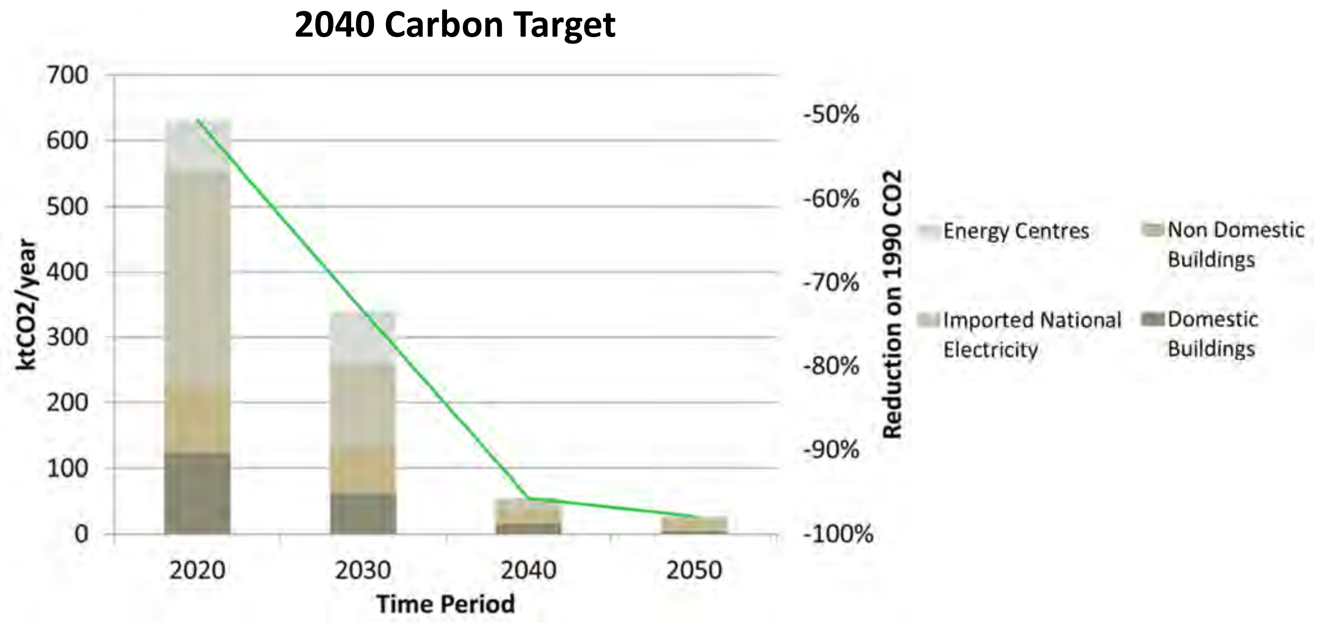

Figure 5-56 Modelled Carbon Emissions in the 2040 Target Scenario

Figure 5-56 shows the timings of emissions reduction under the earlier carbon target scenario. The 2050 emissions are the same as in the 2050 target scenario (a 98% reduction from 1990 levels) but by 2040 significant extra decarbonisation has occurred. The further reduction in emissions between 2040 and 2050 is due to further decarbonisation of national grid electricity.

The final 2050 view of Bury's energy system is very similar between the 2050 and 2040 carbon target scenarios. The timing of the changes to reach this point are different. In the following analysis anything that is different between the 2040 and 2050 scenarios will be highlighted, otherwise it should be assumed it is the same in both.

5.13.4 Domestic Heating Systems across Bury

With either carbon target, no domestic gas boilers are modelled to remain in Bury by 2050. Instead approximately a third of homes are connected to a district heat network and the other two thirds use an electric system (Figure 5-57).

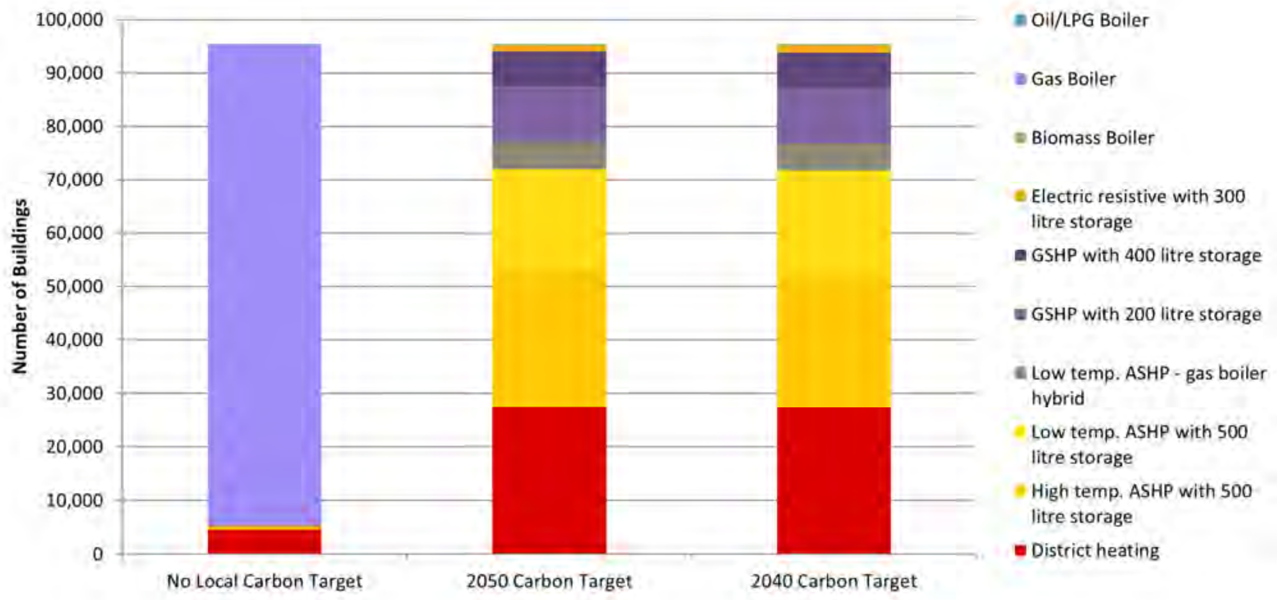

Figure 5-57 Domestic heating systems by 2050 (Transition 2)

The 2050 breakdown of heating systems is the same under both carbon trajectories.

Without a local carbon target the model shows that it is still cost effective for around 3,000 buildings to transition to district heat, making use of heat from gas CHP.

The modelled breakdown of heating systems under the 2050 scenario shows that significant change is not modelled to be required until transition two (i.e. the second end of life replacement), although there may be good practical reasons to do it sooner (Figure 5-58).

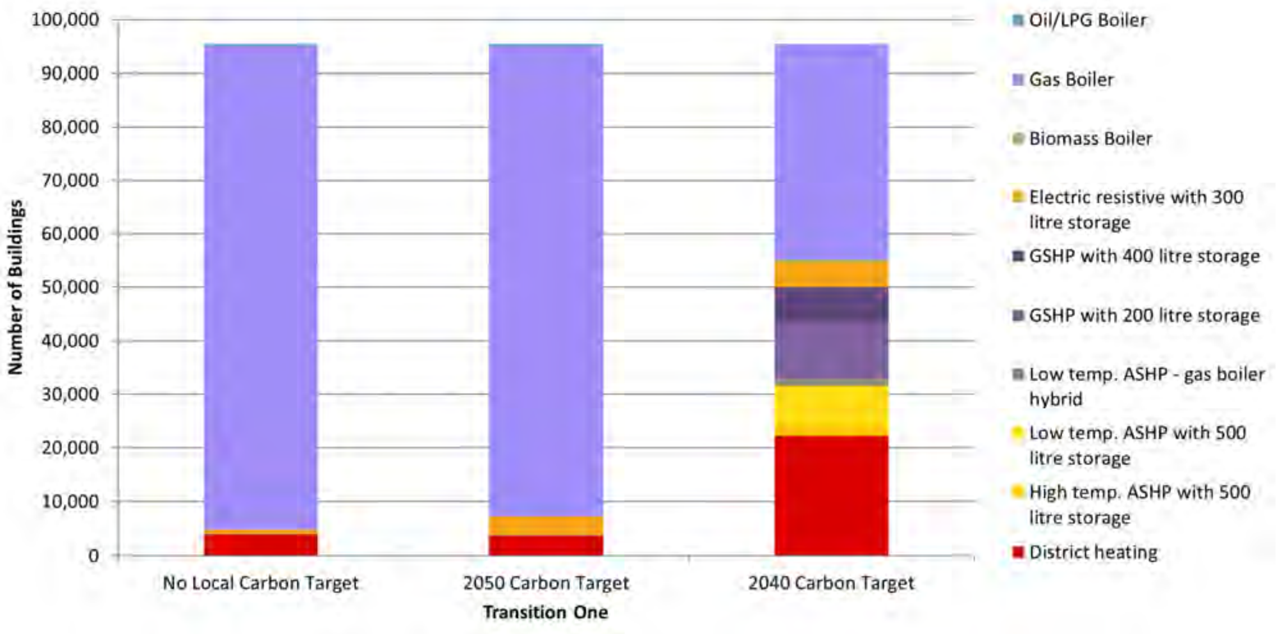

Figure 5-58 - Transition one heating systems

Under the 2040 scenario approximately half of domestic buildings have transitioned to a low carbon heating system by the first transition. Most of the district heat is in place by 2040.

The distribution of 2050 heating systems varies across Bury (Figure 5-59).

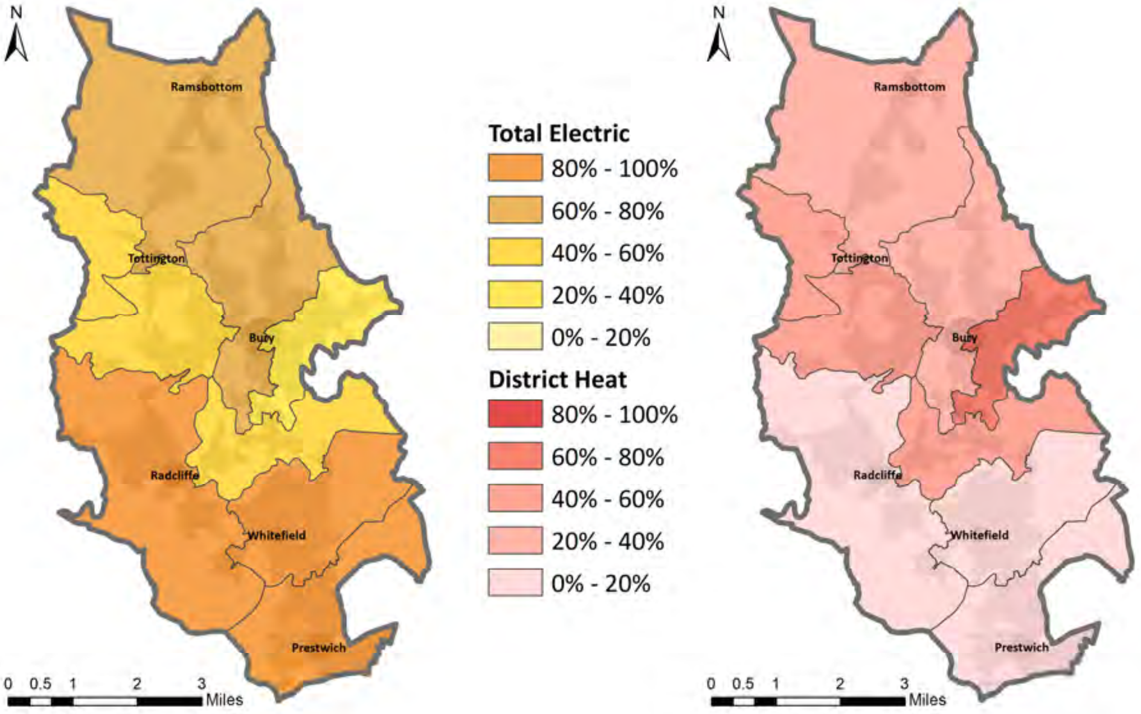

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Figure 5-59 Distribution of 2050 heating systems across Bury

The areas of greatest district heat deployment are in a central belt across Bury, with higher levels of electric heating system deployment in the north and south.

This distribution of heating systems across Bury is driven by several factors:

- Building and heat demand density in an area
- The cost of installing heat network infrastructure in an area
- Non-domestic building heat demands in that area
- Types of local domestic buildings
- Size of local domestic buildings

Within the areas the characteristics of the buildings influence the individual building heating system choice.

5.13.5 Domestic Heating Systems - Detached Buildings

In both carbon target scenarios detached buildings are modelled as best served by ground source heat pumps (GSHPs). There are 17,300 detached properties in Bury of which 98% are modelled as being served by a GSHP in 2050. The larger the building the more likely they are to need a GSHP with a 400 litre tank to meet demands (Table 5-15).

Table 5-15 Detached Houses - Influence of floor area on heating system

Floor Area (m^2)	Low Temp. ASHP with 500 litre Storage	GSHP with 200 litre Storage	GSHP with 400 litre Storage	District Heating	% by Floor Area
0 - 50	2			0.3	2
50 - 70			6		6
70 - 90		13			13
90 - 110		18	0.1	0.1	18
110 - 200		29	23	0.2	53
200 - 300			7		7
300 +			2		2
% by Heating System	2	60	38	1	

Ground Source Heat Pumps have a higher upfront cost in the model than other heat pump types due to the cost of installing groundloops, but they work at a greater efficiency due to having a higher temperature heat source. They become increasingly more cost effective on larger buildings, where there is greater energy use to cover their costs. Storage tank size increases with floor area.

5.13.6 Domestic Heating Systems - Smaller Non-Detached Buildings

For smaller (<110m^2) floor area houses that are not detached the choice of heating system is between air electric air source heat pumps and district heat, and the selected option varies by location in Bury. There are 55,000 homes which fit these criteria in Bury, making it the most common category of building.

80% of these buildings are modelled to use a heat pump in 2050. There are five areas in Bury where heat pumps are deployed to ~95% of these buildings (Figure 5-60), indicating areas where district heat is not a cost-effective option.

There are three areas where district heat options dominate for these buildings, shown in grey in Figure 5-60 below. The heat networks also serve large domestic and non-domestics in these areas.

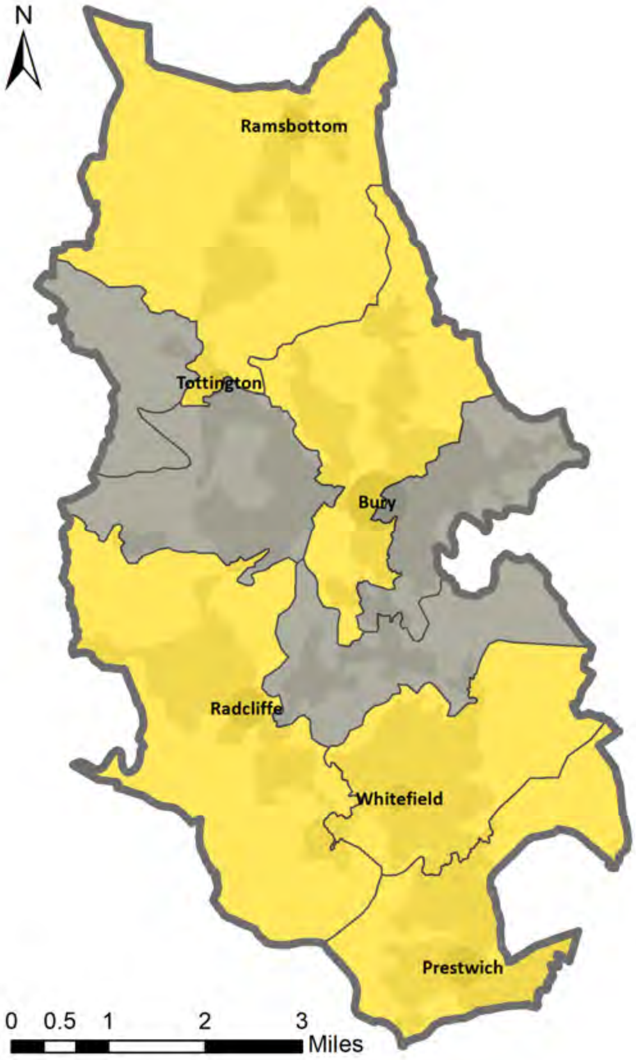

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Figure 5-60 - Areas of Bury where electric heat pump options dominate small non-detached buildings, shown in yellow

For the smaller properties that use heat pumps, the choice of heat pump is driven by their size and energy demands (Table 5-16).

Table 5-16 Heat pump choices for smaller non-detached homes by floor area

Floor Area (m^2)	% High-temp. ASHP with 500 litre Storage	%Low-temp. ASHP with 500 litre Storage
0 - 70	26	74
70 - 110	82	18

The smallest properties use low-temperature air source heat pumps (ASHPs), while 70-110m² floor area properties use high-temperature ASHPs.

The low temperature heat pumps are cheaper to deploy so are the most cost-effective choice if they are able to meet the heat demands of the property. In some cases, they may be able to meet demand in larger buildings if additional fabric retrofit is applied. However, installing a high temperature ASHP without applying retrofit is modelled as having lower total costs over the heating system lifetime.

There may be practical issues to overcome with installing 500 litre tanks in some properties of this size.

5.13.7 Domestic Heating Systems - Larger Non-Detached Buildings

For larger (> 100m^2) floor area non-detached buildings the choice is generally between gas-electric hybrid heat pumps and district heat options. Electric heat pumps without a gas hybrid element are generally not modelled as capable to meet the required peak demands for these buildings. There are 23,000 buildings in this category in Bury.

For the larger non-detached properties, the decision between district heat or hybrid heat pump is heavily influenced by location within Bury.

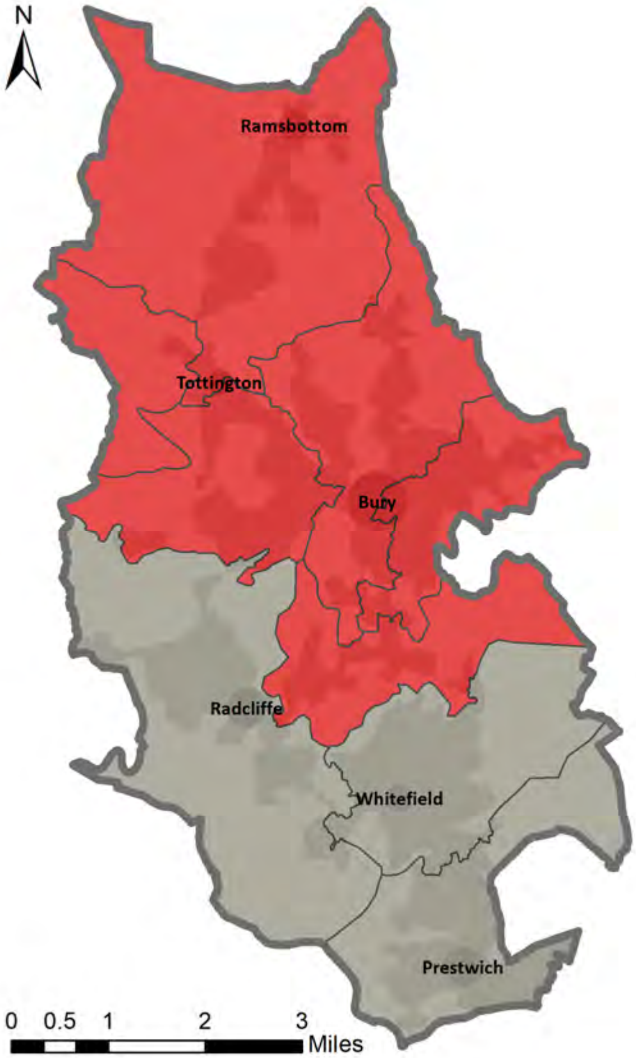

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Figure 5-61 - Areas of Bury dominated by Hybrids (grey) or District Heat (red) for the larger detached building types

In the red areas of Figure 5-61, 98% of the larger detached buildings use district heat to meet these demands. In the grey areas the majority of these buildings use hybrid heat pumps to meet their demands. The difference between areas of Bury is influenced by the suitability of the areas for district heat networks, and what other buildings in those areas may better suited to be connected to them.

On average, the hybrid heat pumps in Bury generate two thirds of their heat electrically (Figure 5-62), with gas generating 90% of the heat during the winter peak.

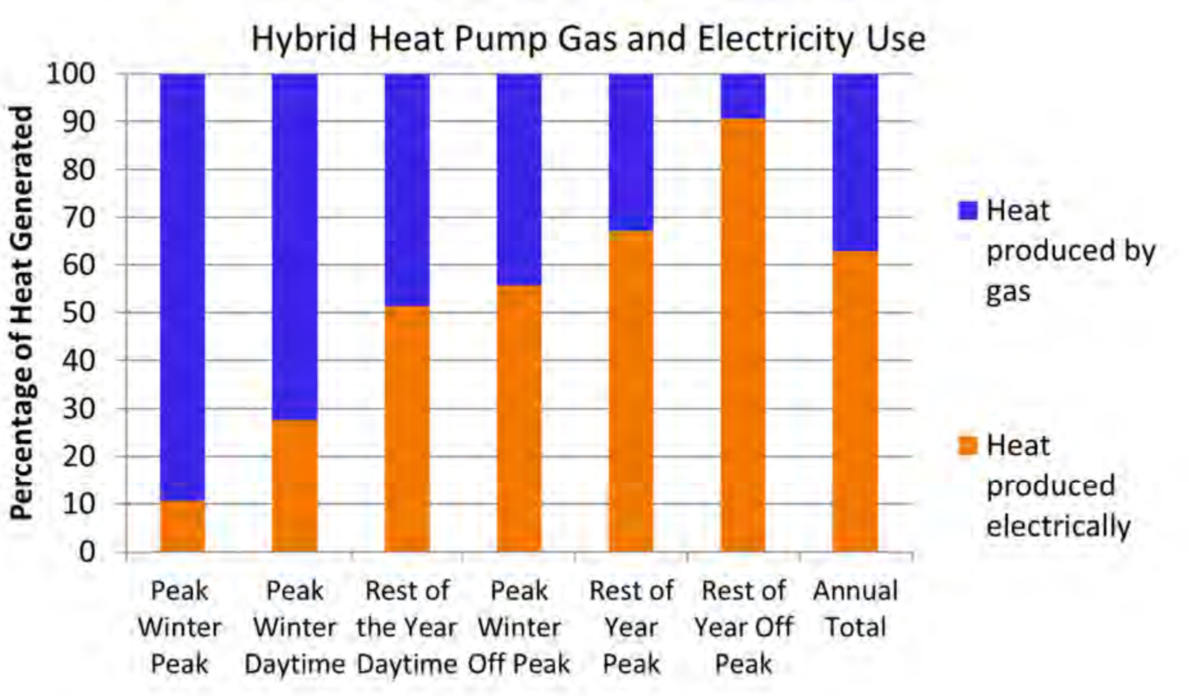

Figure 5-62 Average Breakdown of Gas and Electricity use by Hybrid Heat Pumps in Bury

5.13.8 Domestic Buildings - Additional Insulation

The modelling considers only a small amount of further insulation to be part of the most cost-effective way of reaching Bury's carbon target (Table 5-17, Table 5-18). By transition two up to 3,700 extra homes have insulation installed compared to the scenario without a carbon target. The majority of these are basic insulation measures, with the advanced measures shown as unlikely to be cost effective on a carbon saving basis.

Table 5-17 - Buildings modelled to gain insulation under the carbon target - transition one

	2050 Carbon Target	2040 Carbon Target
No difference	92,700	93,000
Further Basic Insulation	300	2,500
Further Advanced Insulation	0	0

Table 5-18 Buildings modelled to gain insulation under the carbon target - transition two

	2050 Carbon Target	2040 Carbon Target
No difference	92,700	92,800
Further Basic Insulation	2,700	3,500
Further Advanced Insulation	200	200

Applying further insulation at the same time as installing a low carbon heating system may allow a lower power system to be installed, and the resulting network impacts to be smaller. However the EPN building modelling suggests that generally it is cheaper to install a larger low carbon heating system than it is to pay for the smaller system plus the additional cost of insulation. Although the insulation may not be the most cost-effective method to save carbon, there are other good reasons for installation such as improvements in comfort and reduction in fuel poverty.

It should also be considered that at a national level reductions in demand due to insulation are required to reduce demand, allowing the electricity grid to be lower carbon at reduced cost. The carbon content of grid electricity derived from the ESME model (and used for this work) includes the influence of some national deployment of insulation.

The insulation is installed earlier and to a greater level in the 2040 target scenario. The number of buildings where the model considers further insulation to be cost effective for carbon saving is small, no more than 4% of buildings.

5.13.9 Domestic Buildings – Solar PV Deployment

In this final modelling by 2050 virtually all homes in Bury considered to have appropriate roofs have Solar PV installed. This occurs even without a local carbon target. In the No Local Carbon Target run and the 2050 Carbon Target, capacity remains the same at around 4 MW until 2040. However, in the 2040 Carbon Target installation begins in 2020 at around 25 MW. All three scenarios show around 220 MW installed in 2050. For the 2050 Target and No Local Target scenarios this equates to a carbon saving of around 44 kt CO_2 over the entire study period. At around 128 kt CO_2 saved, the 2040 Carbon target saves almost three times as much carbon over the study period. Figure 5-63 maps this deployment across Bury.

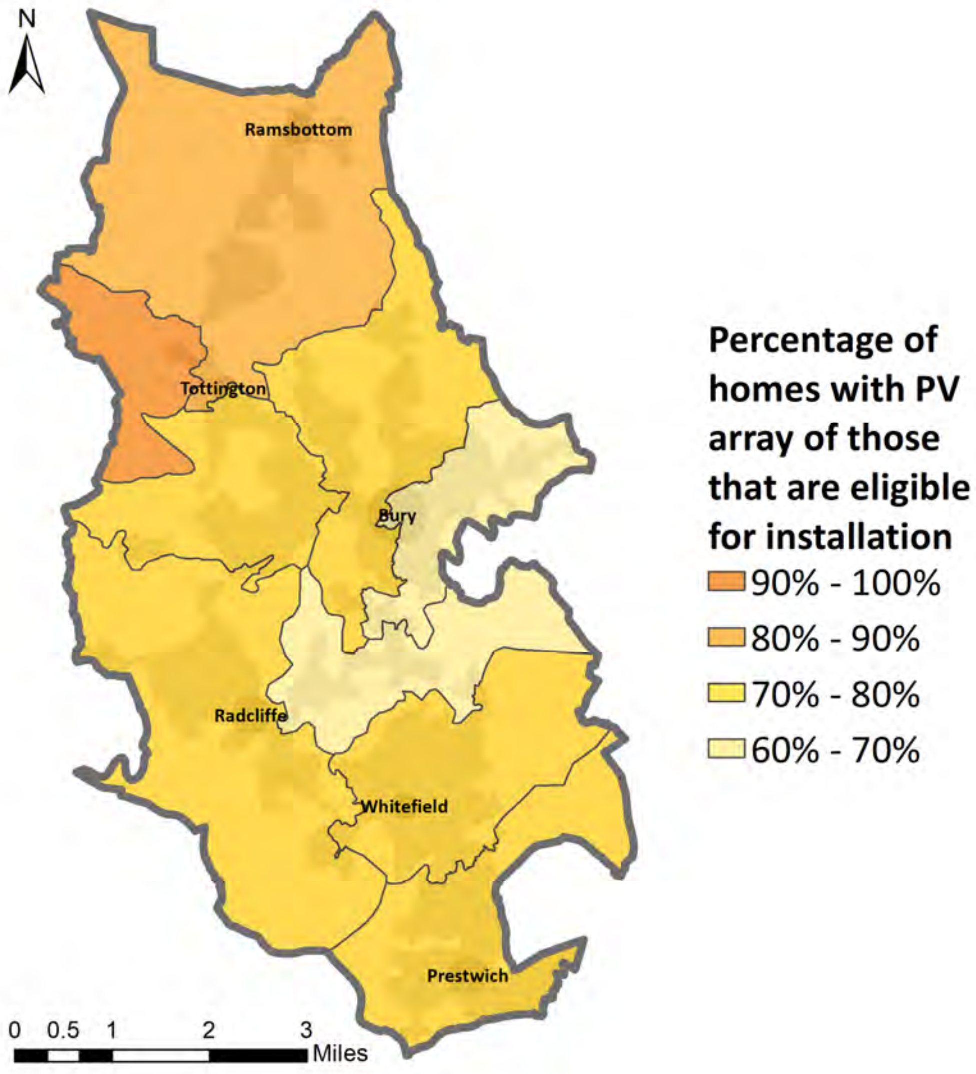

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Figure 5-63 2050 Solar PV deployment in final runs

EPN does not consider present day subsidies in the assessment of cost effectiveness, so the PV is not considered to be financially viable under present day conditions. However, under the 2050 carbon target, by 2040 the modelled increase in panel efficiency, reduction in panel costs and most importantly increase in grid electricity costs makes PV cost effective from this point forwards (Figure 5-64).

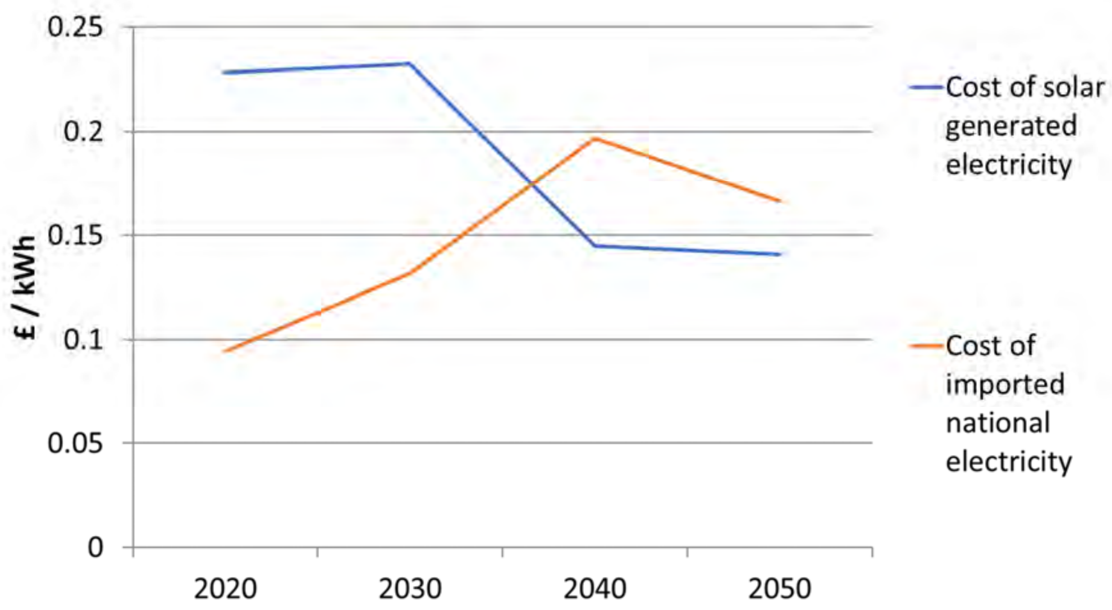

Figure 5-64 Relative costs of grid and domestic solar PV generated electricity by time period

Under the 2040 carbon target PV is modelled to be deployed earlier and used as a carbon saving measure, even when grid electricity would be cheaper.

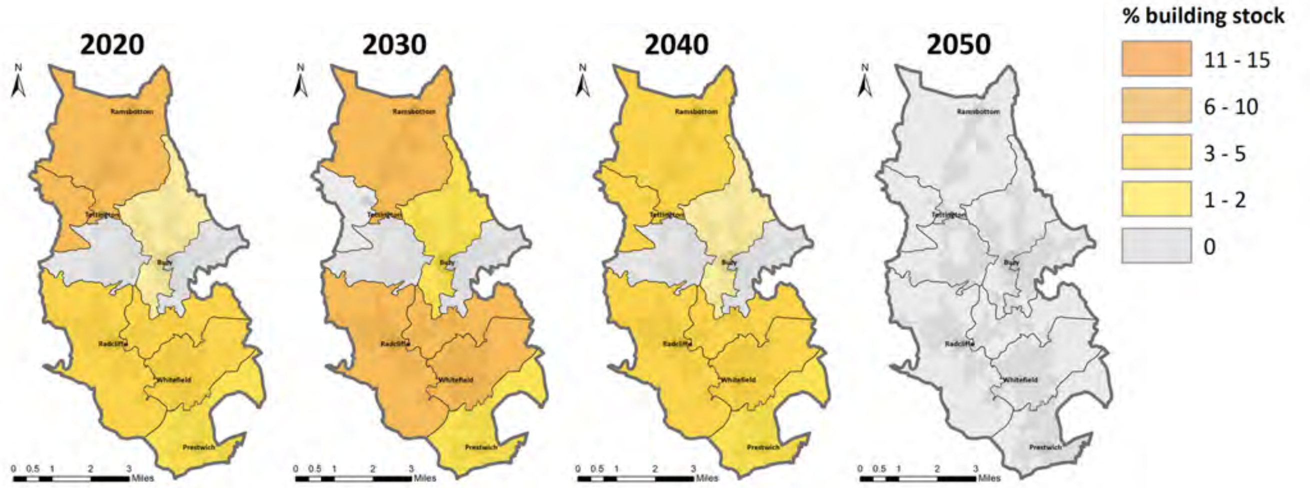

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Figure 5-65 Additional domestic PV deployment in 2040 target scenario compared to 2050 target and no local target scenarios

Figure 5-65 shows where in Bury PV would be best deployed earlier to save carbon, with the highest levels in the north and south of Bury. The location of PV installation is influenced local network conditions. By 2050 there is no difference in deployment to the other carbon target runs.

5.13.10 Domestic Buildings – Battery Deployment

Domestic battery options as tested in the battery sensitivity were given as an option in the final modelling, but were not found to be part of the most cost effective route to meeting the carbon targets.

The previous battery sensitivity indicated that domestic batteries could be of use for storing cheap electricity overnight and discharging it at times of higher cost during the day. They were not found to be a cost effective method of reducing network reinforcement.

In the final runs this timeshifting of demand was not found to be enough to make them cost effective. It is likely that the high deployment of PV reduces the incentive as this provides electricity at very low marginal cost during the daytime, which is when the batteries discharged under the sensitivity scenario.

5.13.11 Non Domestic Buildings

The decarbonisation of non-domestic buildings is required to enable Bury to meet the tighter carbon targets. Within this modelling work the low carbon option considered for non-domestic buildings currently heated using gas was connection to a district heat network. Not all non-domestic heat in the model is considered suitable for supply by a heat network: some heat demand in industry is considered used for industrial purposes rather than space heating, and therefore cannot be replace by a heat network and so remains on gas.

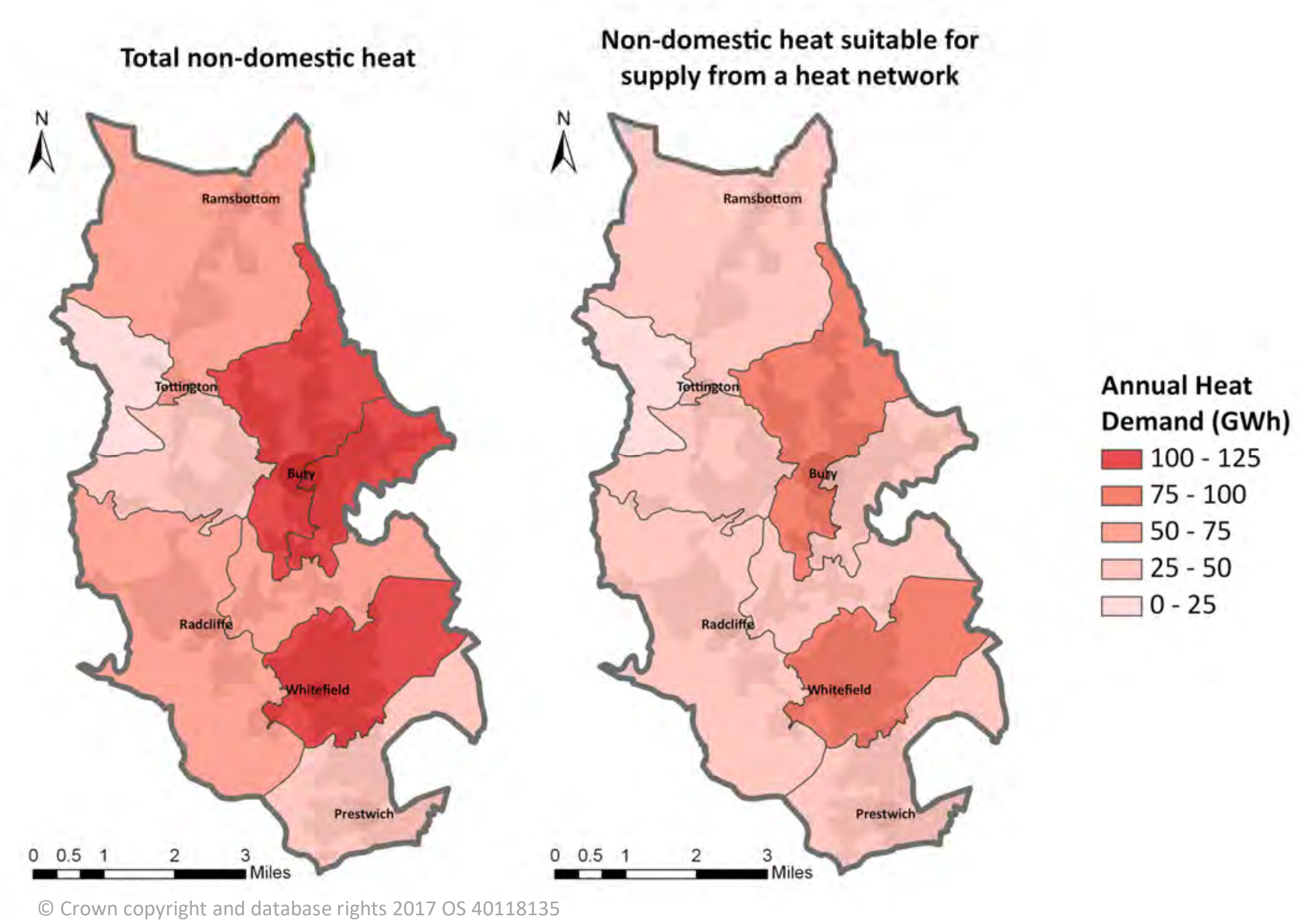

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Figure 5-66 Non-domestic heat demand in Bury and that suitable for heat network connection

Figure 5-66 illustrates that in Bury the greatest non-domestic heat demand is located in the more urban areas to the east. However, some of this heat is not suitable for heat network supply as it is considered to be used for industrial purposes rather than space heating.

Under both carbon targets virtually all suitable non-domestic floor area in Bury is supplied by a heat network in 2050.

- This consists of 66% of the non-domestic floor area in Bury.
- 24% of the non-domestic floor area in Bury is considered to be only suitable for gas heating due to the building use, and so does not have a low carbon option in the model.
- 10% of the floor area is modelled to already be electrically heated
- The remaining floor area is low demand and stays on gas due to constraints on heat network capacity

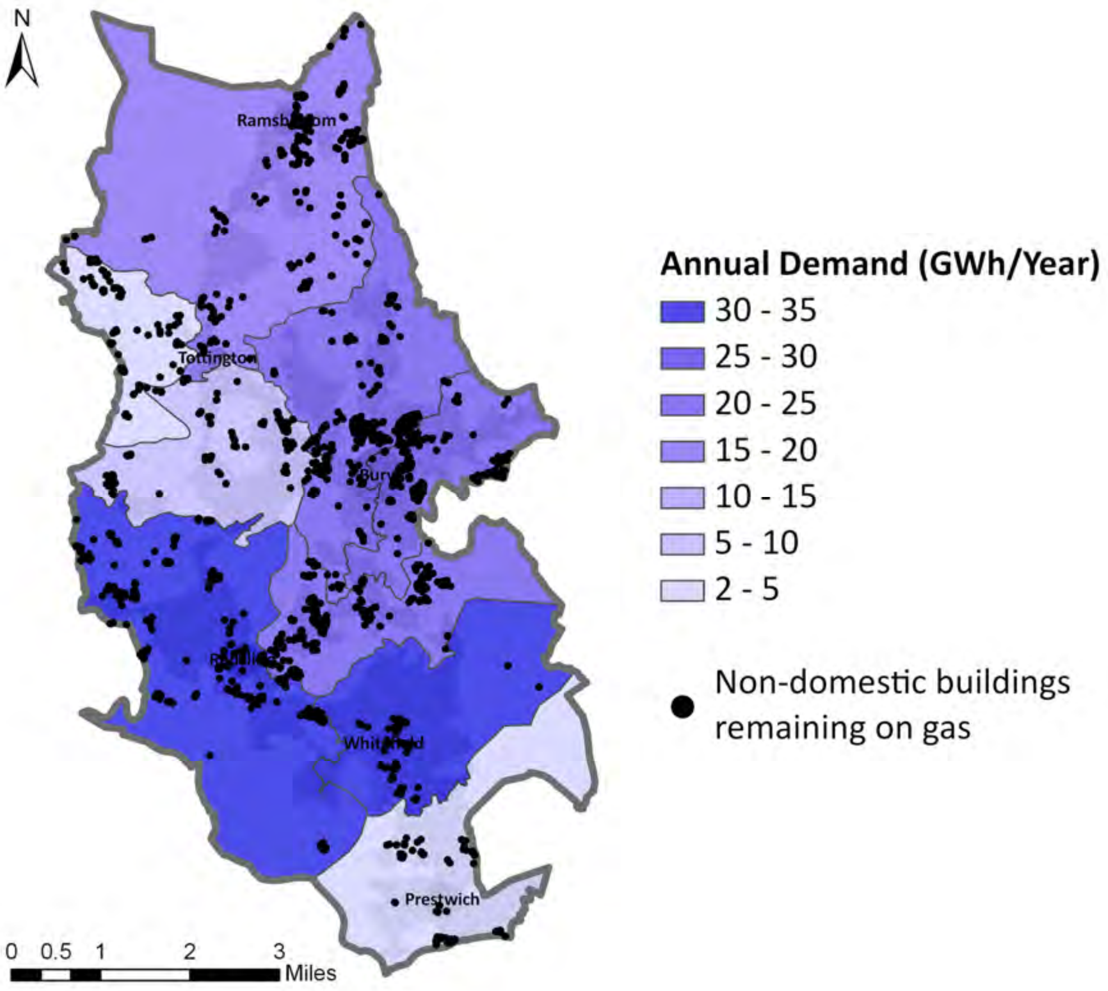

Figure 5-67 Non-domestic buildings remaining on gas in 2050

Figure 5-67 shows the locations of non-domestic buildings in Bury modelled to remain on gas.

Although some of these buildings are clustered, there are some distributed over the entirety of Bury. This, along with the use of hybrid heat pumps, implies that there will still be a requirement for gas network infrastructure to cover the majority of the area. This may be a challenge as the lower demands mean the network costs will be significantly higher per unit of energy delivered.

Our assumptions on which non-domestic buildings can move away from gas are cautious and based on limited data and so it may be worth collecting more data about individual buildings to assess their possibilities.

5.13.12 **Changes in Energy Networks**

Overall the modelling shows a shift in the energy vectors used to provide heat in Bury, shifting from gas to electricity (whether used at building scale or in district heat).

5.13.13 **Gas Network**

Annual gas demand is considered to fall rapidly under the 2040 carbon target (Figure 5-68). Under the 2050 carbon target it also falls to a low level, but the total use is still high in 2040 (Figure 5-69). With the 2050 carbon target there is significant use of gas in CHP in energy centres in 2040; these then become electric and so low carbon by 2050.

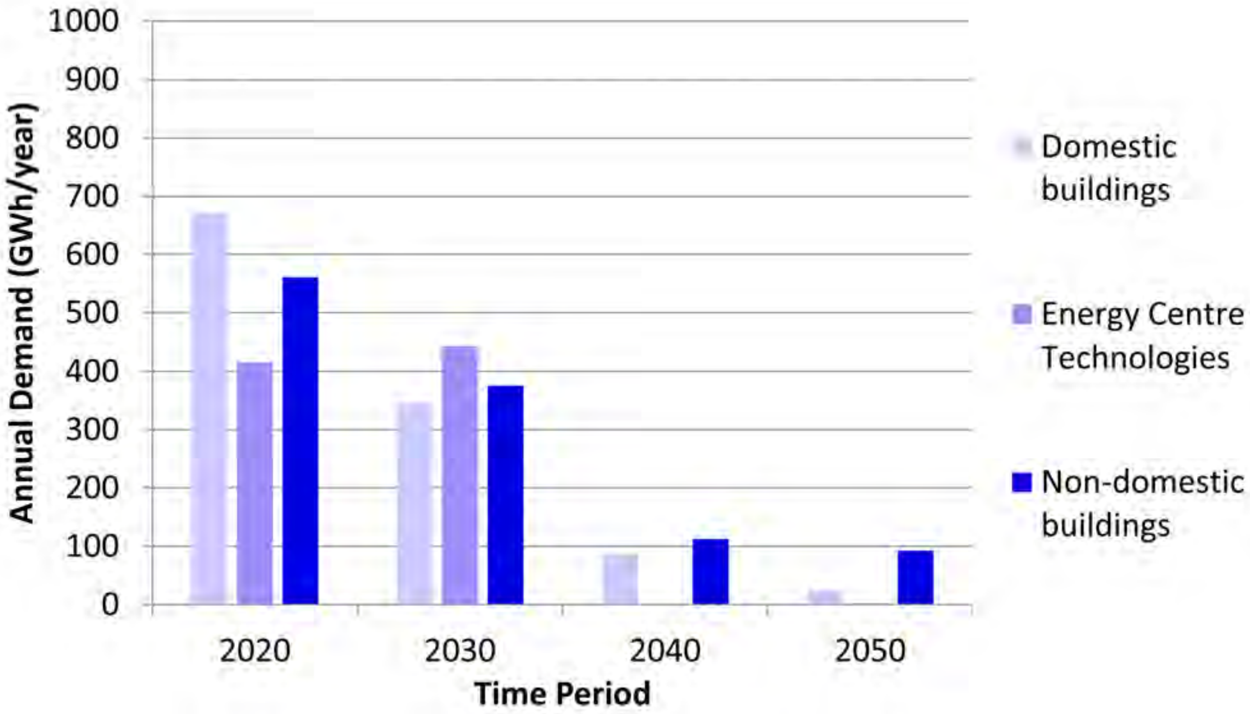

Figure 5-68 Annual Gas Demand under 2040 Target Scenario

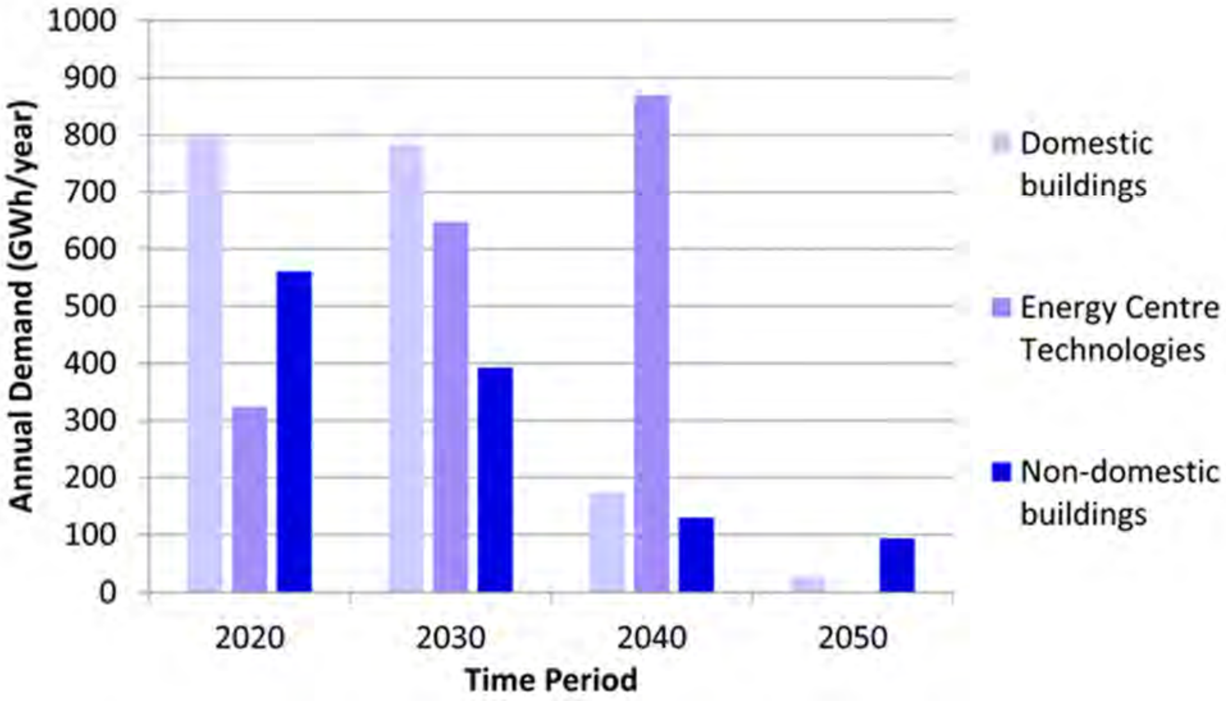

Figure 5-69 Annual Gas Demand under 2050 Target Scenario

Peak demand is the key factor for sizing a network, controlling the capacity of infrastructure required. Figure 5-70 maps the changes in peak gas demand between present day and 2050. The level of reduction in peak demand varies across Bury, but in all areas there is a significant drop.

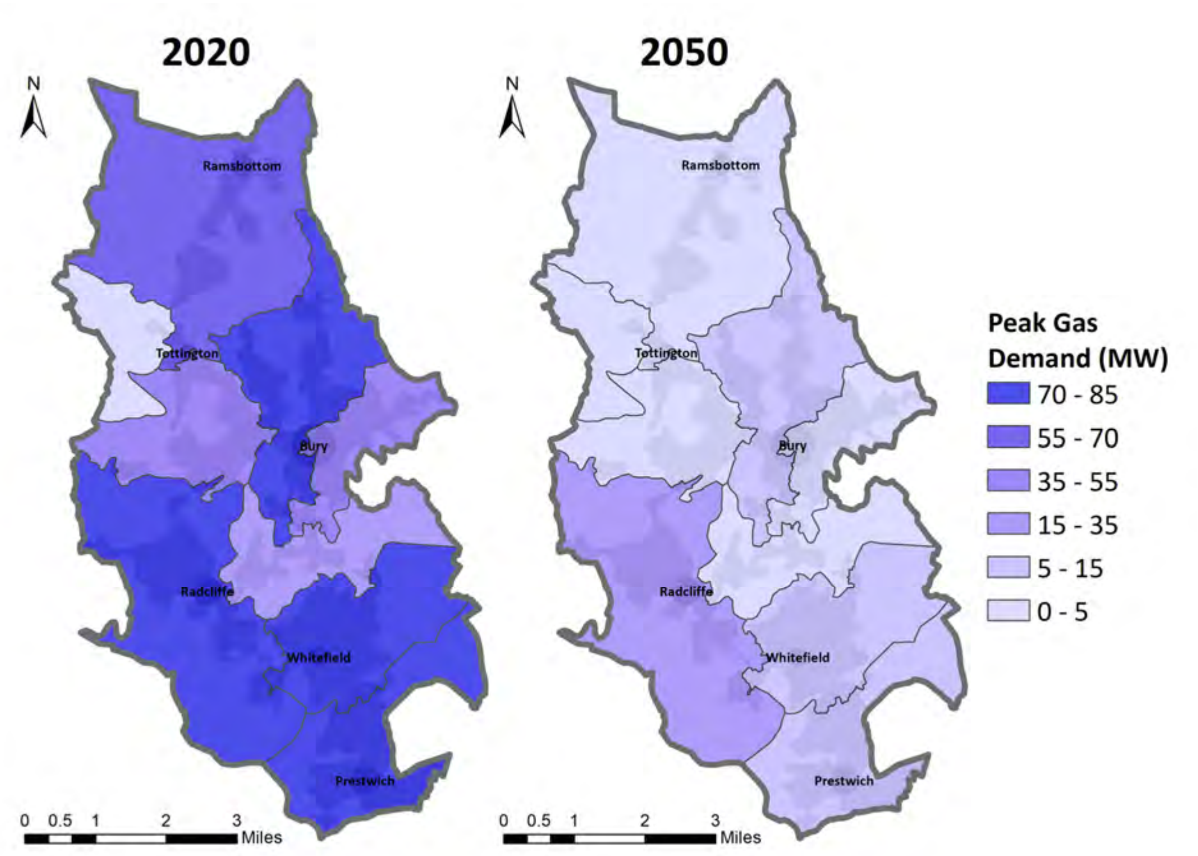

Figure 5-70 Changes in Peak Gas Demand (2050 Target)

Although the peak drop is significant there is still gas demand remaining across Bury. The results imply that it would not be possible to decommission large parts of the gas network.

5.13.14 Electricity Network

The lowest cost plan to meet the carbon targets for Bury involves significant electricity network reinforcement. The carbon targets require an increase in capacity of approximately one third by 2050 (Figure 5-71).

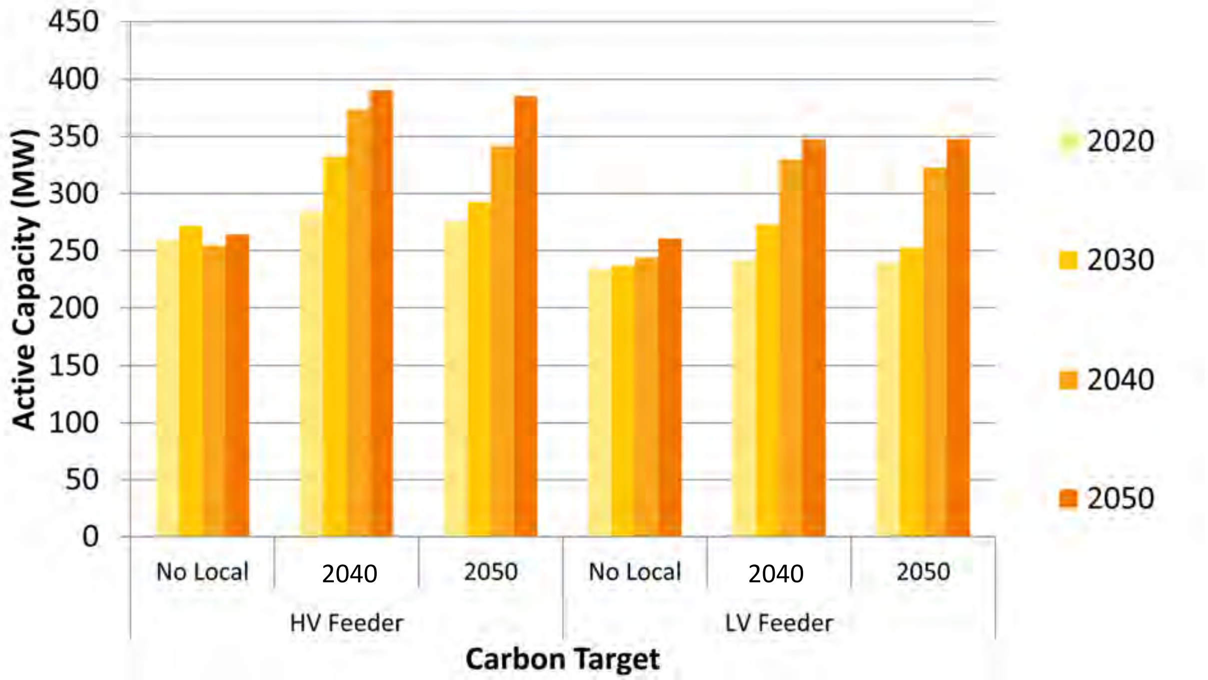

Figure 5-71 Required Electricity Network Capacities by Scenario and Time Period

Without a local carbon target there is still an increase to account for factors such as electric vehicle charging, PV uptake and an increase in non-domestic demands (e.g. due to greater cooling, IT equipment).

If aiming for a 2040 carbon target then by 2025 network reinforcement is widespread across Bury (Figure 5-72). For the 2050 target only two areas require reinforcement by this point.

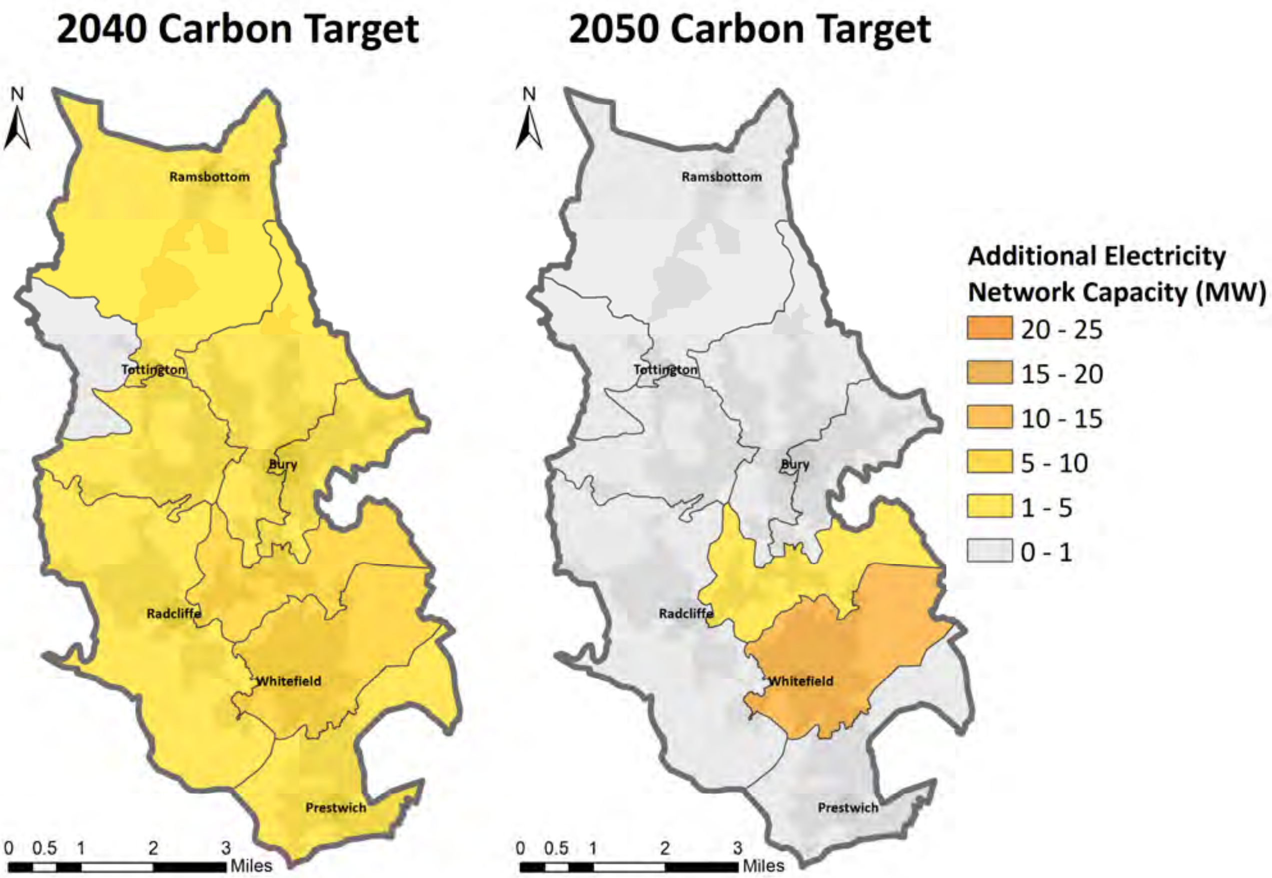

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Figure 5-72 Modelled Electricity Network Reinforcements deployed by 2025

By 2050 the pattern of network reinforcements required across Bury is the same under either carbon target (Figure 5-73), with the highest levels of network reinforcement required in the southern end of Bury – where there is high modelled deployment of individual electric heat pumps.

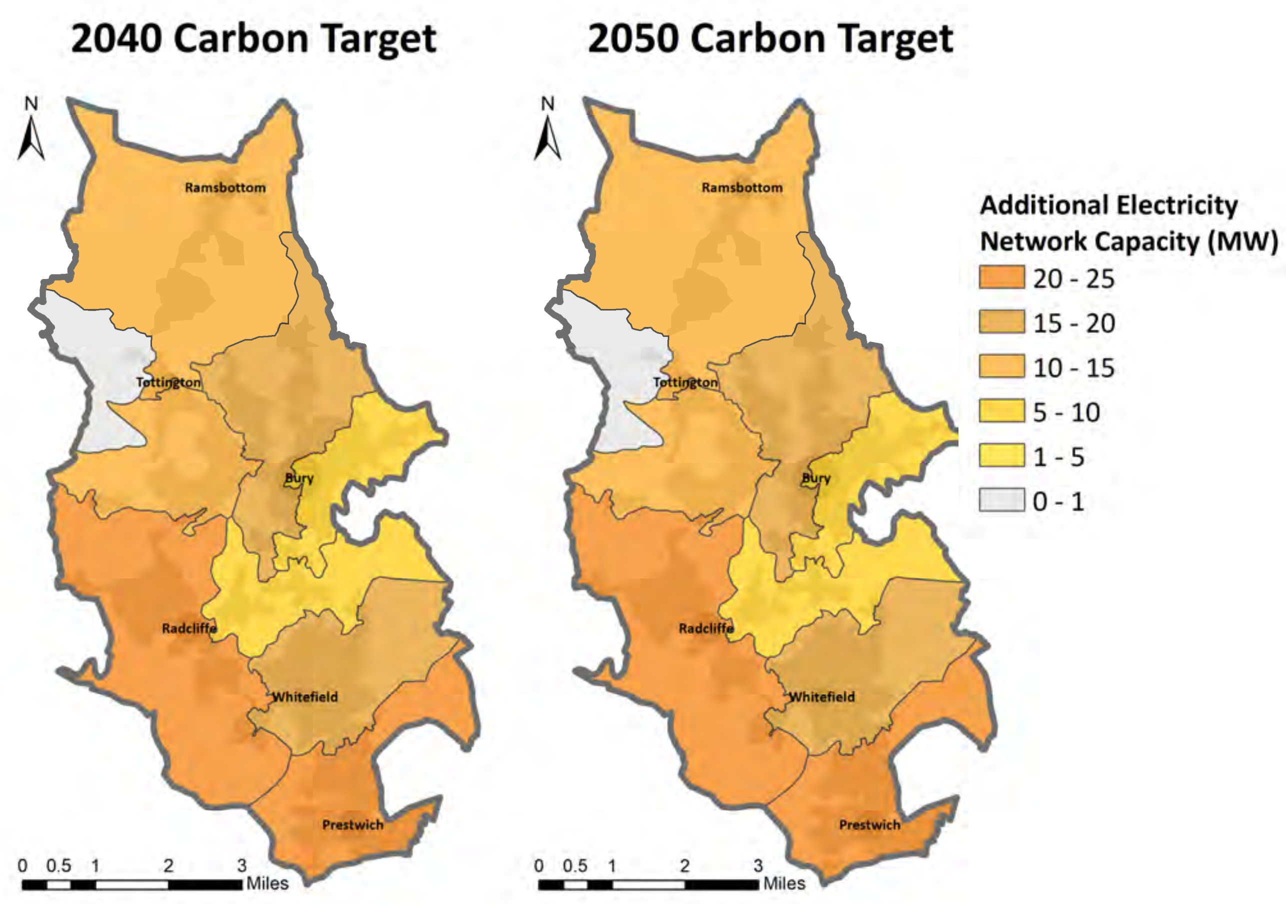

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Figure 5-73 - Modelled Electricity Network Reinforcements deployed by 2050

5.13.15 Heat Networks - Infrastructure

Heat network infrastructure is required to support domestic and non-domestic heat provision in the model. The heat network infrastructure delivers the heat from energy centres to properties, but gas or electricity networks are still required to deliver energy to energy centres.

By 2050 the peak heat network requirements are the same under both carbon targets (Figure 5-74)

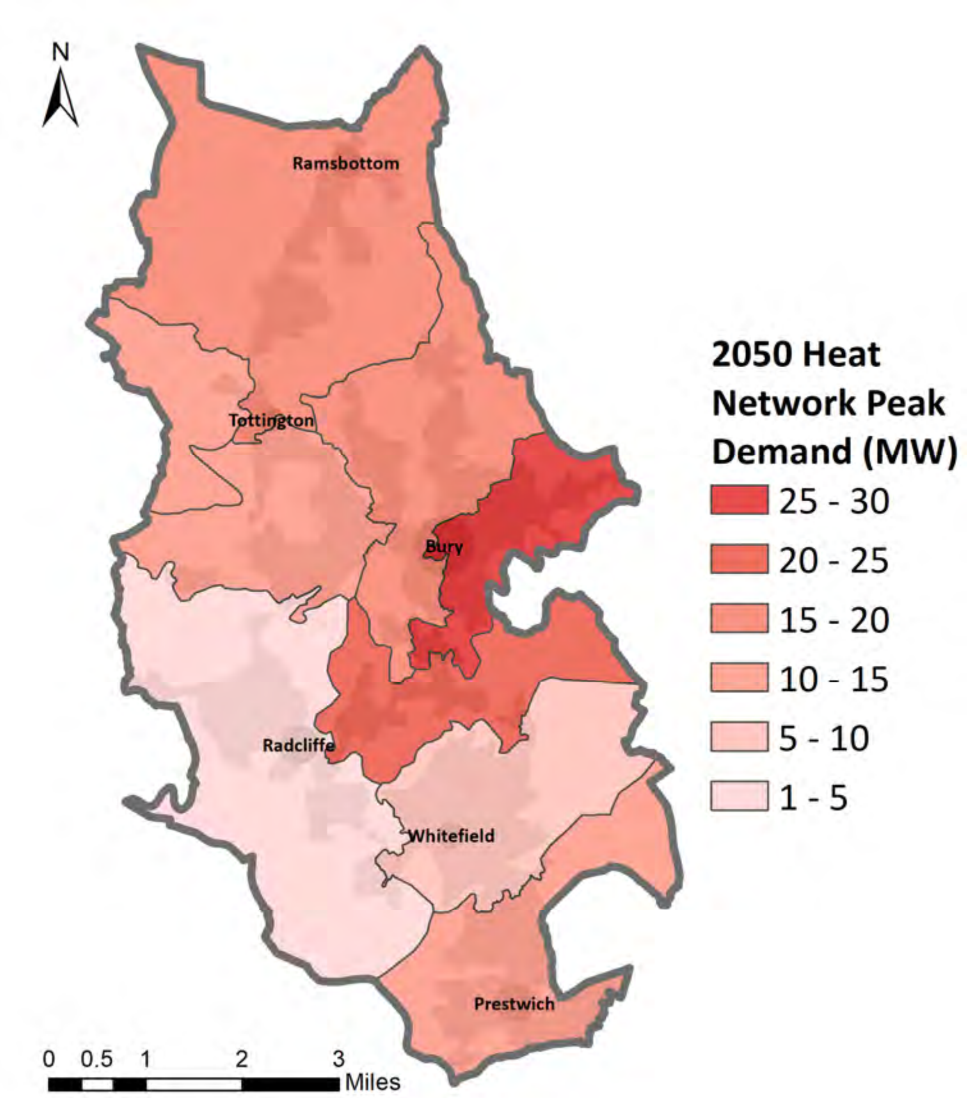

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Figure 5-74 Peak Heat Network Demands (2050) under both carbon targets

Figure 5-74 shows that the greatest peak heat network demands are in the east of Bury, in the area covering Bury town centre where there are large non-domestic demands. Figure 5-75 shows that although the final capacity is the same, under the 2040 target scenario the network infrastructure needs installing much sooner, with the majority of network construction occurring between 2025 and 2034. In contrast under the 2050 target most of the heat network reinforcement occurs between 2035 and 2044.

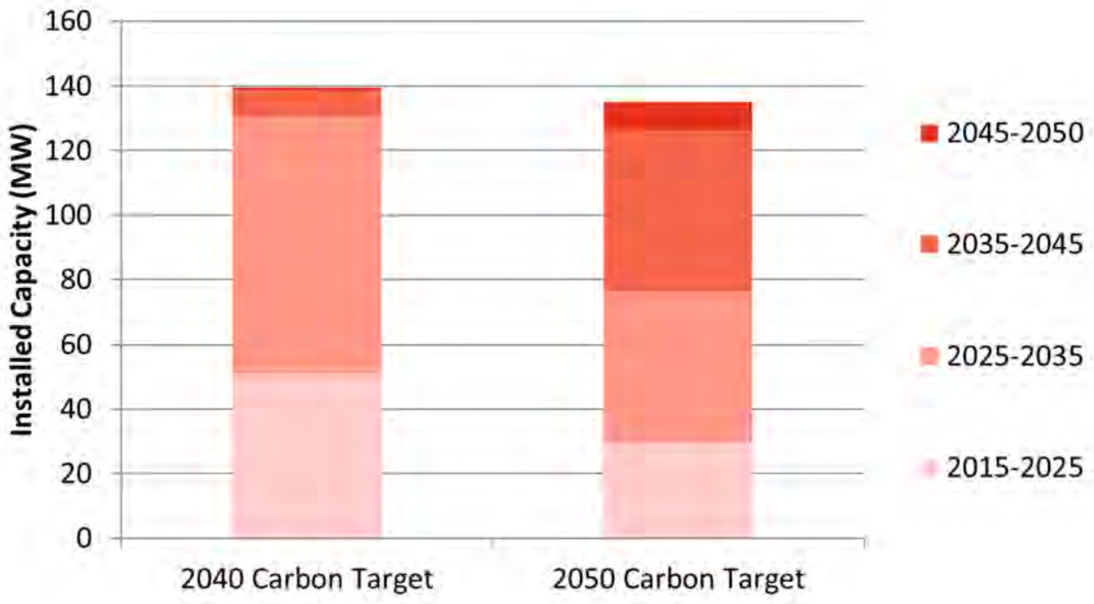

Figure 5-75 Timing of Heat Network Capacity by Carbon Target

5.13.16 Heat Networks – Energy Centres

Using the heat network infrastructure requires the development of energy centres to generate heat. To meet the final carbon targets requires this heat to be generated in a low carbon manner, but before this point there is scope to generate heat more cheaply using gas fired technologies.

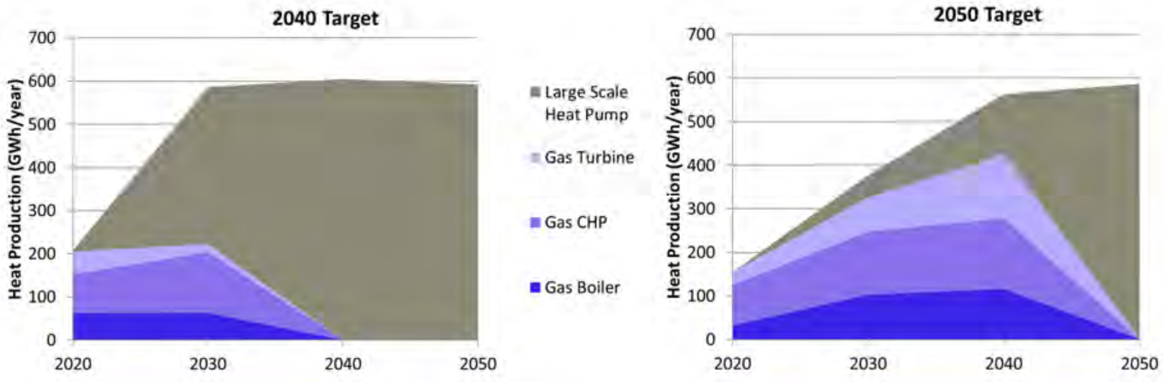

Figure 5-76 Annual heat production by technology and time period

Figure 5-76 shows that on an annual basis virtually all heat in the networks is produced by large scale electric heat pumps by 2050. Prior to this point there is some use of gas technologies, including CHP. These technologies are phased out sooner to meet the 2040 target than if Bury was following a 2050 target.

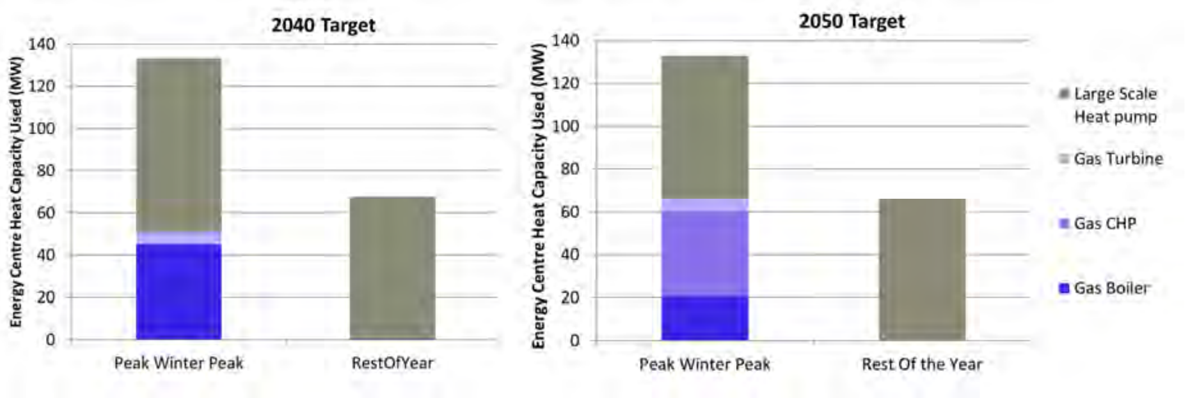

Figure 5-77 2050 Winter Peak Heat Production

Although on an annual basis the heat is generated from low carbon sources, at peak winter times the previously installed gas technologies are still required to meet demands, with gas boilers, turbines and CHPs used (Figure 5-77). As peak winter represents only the coldest few hours in a year the emissions produced from this gas deployment are not significant on an annual basis, and the fixed costs of maintaining the equipment are lower than the costs of installing a new low carbon option large enough for the winter peak. Under the 2050 target on the coldest winter days approximately half of peak network heat is generated using gas.

Figure 5-76 shows deployment of gas CHP technologies in the earlier time periods. Figure 5-78 shows the levels of electricity also generated from these technologies. This ability to also generate electricity helps increase the cost effectiveness of the technologies. The 2050 scenario has the highest levels of electricity generation between 2035 and 2045. Under the 2040 target the generation of electricity is more limited as the earlier carbon target does not allow as much gas usage. As more CHP can be used earlier under the 2050 carbon target scenario, then a greater proportion of the peak capacity in 2050 is CHP as the infrastructure is already in place. Under the 2040 scenario less CHP is built in earlier time periods so a greater proportion of the 2050 peak is provided by gas boilers instead.

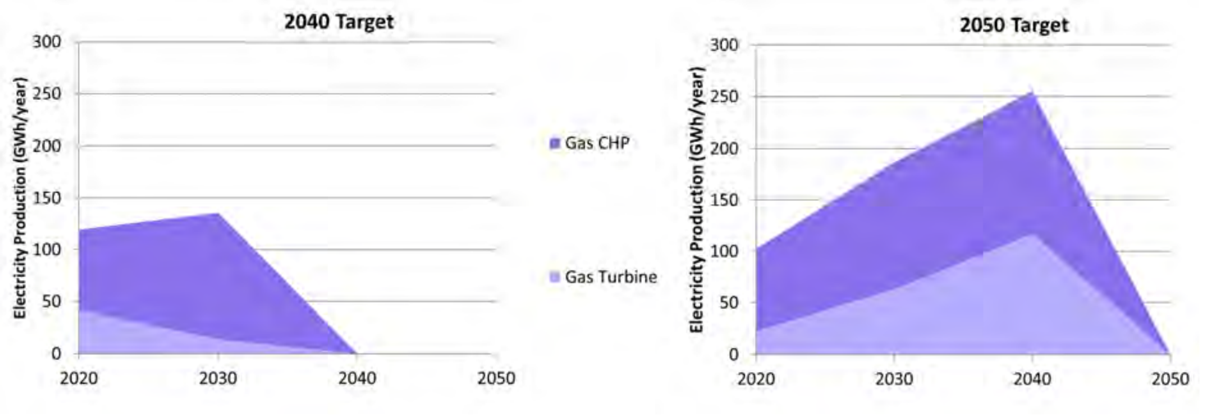

Figure 5-78 Energy Centre Electricity Production

5.13.17 Heat Networks – Thermal Storage

An engineering review of the initial modelling suggested thermal storage tanks should be given as an option for energy centres. This was reflected in the final modelling. The thermal storage tanks allow heat to be generated at times of day of lower cost or demand and then stored until the point in the day where costs or demand are greatest.

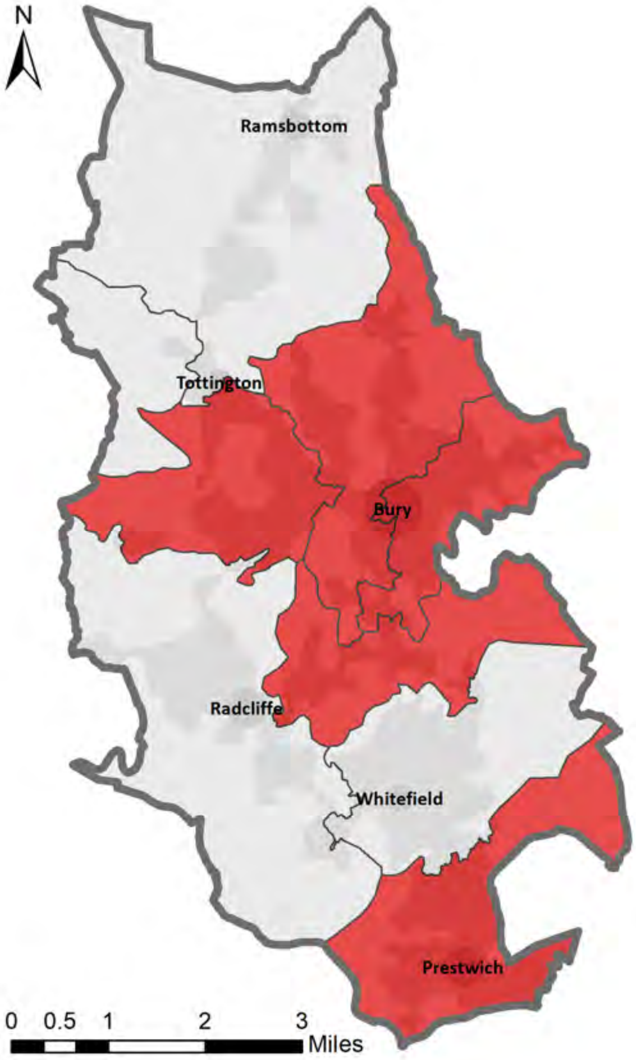

Figure 5-79 Areas of Bury (highlighted in red) where district heat thermal storage tanks were given as an option

In each of the areas highlighted in red in Figure 5-79 a 104 MWh tank was given as an option, as identified in the review. These areas were considered to be of a significant size and heat demand for storage tanks to be an option. These tanks would require a volume of 2,000 m^3 each. The modelling suggests that building up to 80% of this capacity would be cost effective for decarbonisation, with greater levels of capacity cost effective when a 2040 carbon target is followed rather than 2050 (Figure 5-80)

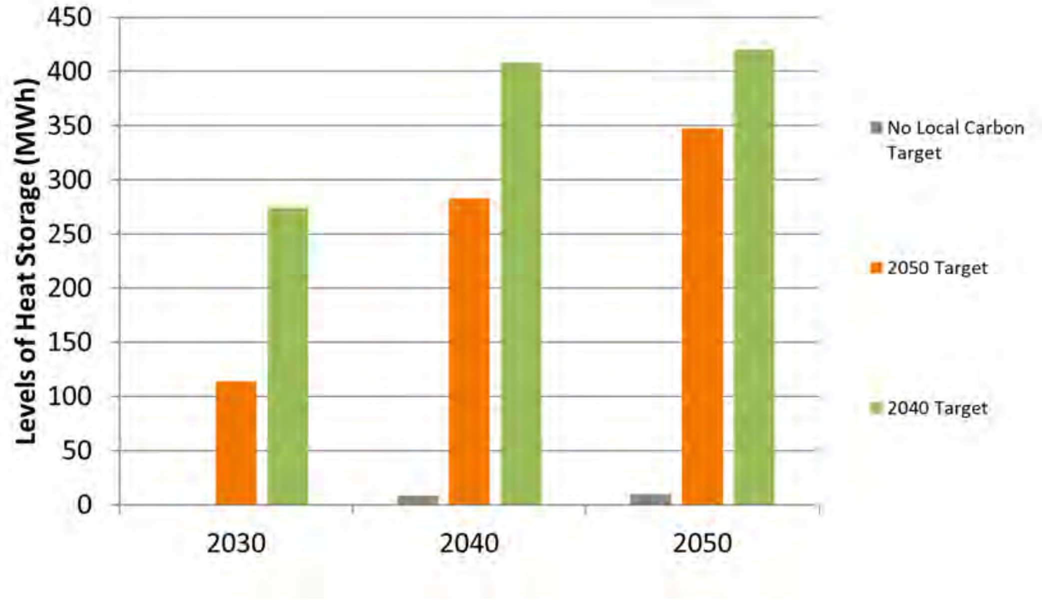

Figure 5-80 Deployed Heat Storage by Carbon Target

The modelling shows the thermal storage should be used to hold heat when it is generated electrically and when electricity is at its cheapest overnight, which can then be stored and discharged during the day when electricity is more expensive (Figure 5-81). In addition, discharging from the storage at peak times reduces the level of gas technologies needed to be available to meet the winter peak.

Figure 5-81 Charge and Discharge times for Thermal Storage

5.13.18 **Total Costs**

The modelled scenarios show that although the final 2050 situation is very similar under both carbon targets, under the 2040 target Bury's local energy system needs to change much sooner. These earlier changes come at a cost, with the more ambitious the carbon target the greater the costs of Bury's energy system between now and 2050.

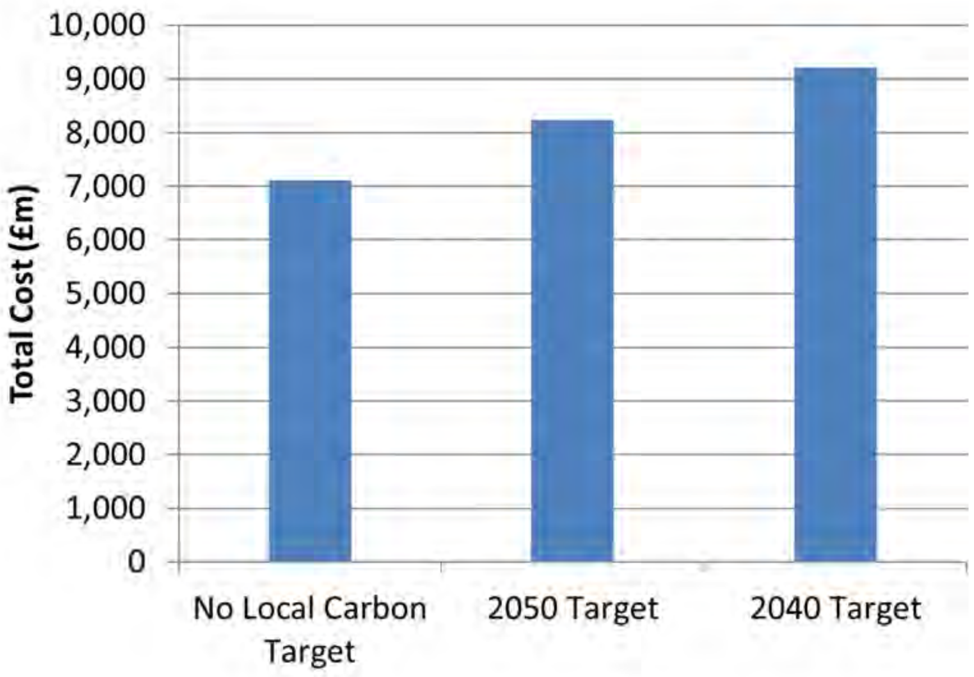

Figure 5-82 Total Energy System Cost under Each Carbon Target Scenario

Figure 5-82 shows the total system cost under each target. Without a local carbon target the model suggests that Bury's energy system would cost £7,110m between now and 2050. Aiming for the 2050 carbon target is modelled to cost £1,120m more, an increase of 16% over the baseline. The 2040 target is modelled to cost a further £960m more than the 2050 target, an 86% higher spend on carbon reduction compared to the 2050 target – but over the study period saves much more carbon - over 90 years of the 2050 emission level.

These costs assume perfect implementation of the energy system transition and have the potential to be higher given the practical challenges of implementing the changes required.

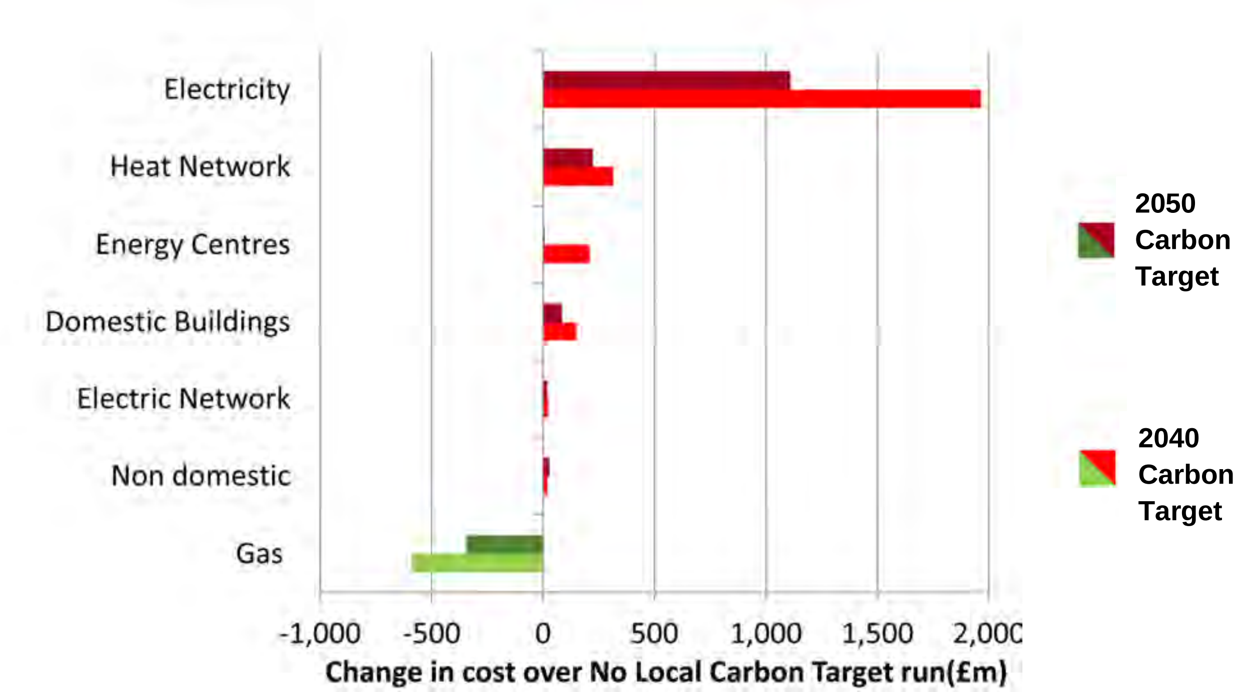

Figure 5-83 Cost Difference by Category for Carbon Target runs compared to No Local Carbon Targets

Figure 5-83 shows the cost difference compared to the scenario without a local carbon target, by category and carbon target. The 2040 carbon target requires higher spend on grid electricity used in heat pumps to generate heat in earlier time periods.

Although there is a saving on gas - £343m less spent on gas under the 2050 carbon target and £591m less spent on gas under the 2040 carbon target - the total spend on energy is still much higher, with almost £2,000m extra spend on electricity usage under the 2040 carbon target.

An earlier carbon target requires earlier spend on heat network infrastructure. This spend is higher because the effects of discounting are less and the ongoing fixed costs of maintenance are incurred for longer.

5.13.19 **Results – The influence of a low carbon gas**

This scenario was considered to identify where a limited quantity of gas could be best used in the future. This may be possible because of a limited quantity of low carbon gas becoming available (e.g. biomethane) or because greater reduction in carbon emissions elsewhere creates slack in the local carbon budget which then allows some residual gas usage in 2050 and beyond.

The scenario used allowed an extra 27kT of carbon emission in 2050. This value was found to allow some use of gas. It was analysed only to see how that gas was used, and not as a full modelled scenario for Bury.

Although the potential cost of the low carbon gas is not considered in this scenario, it suggests that if a small amount of low carbon gas was available then the most cost-effective option is to reduce the load on local heat networks, saving money on the network infrastructure.

This would be achieved by retrofitting some domestic properties with hybrid heat pumps rather than connecting them to a heat network. This occurs in three areas of Bury (Figure 5-84), where 6,600 domestic buildings that were modelled to be on heat networks are instead supplied by hybrid heat pumps. These buildings are larger, with floor areas over 110m^2 and so have higher demands. They are not well suited to supply from heat pumps without a hybrid element.

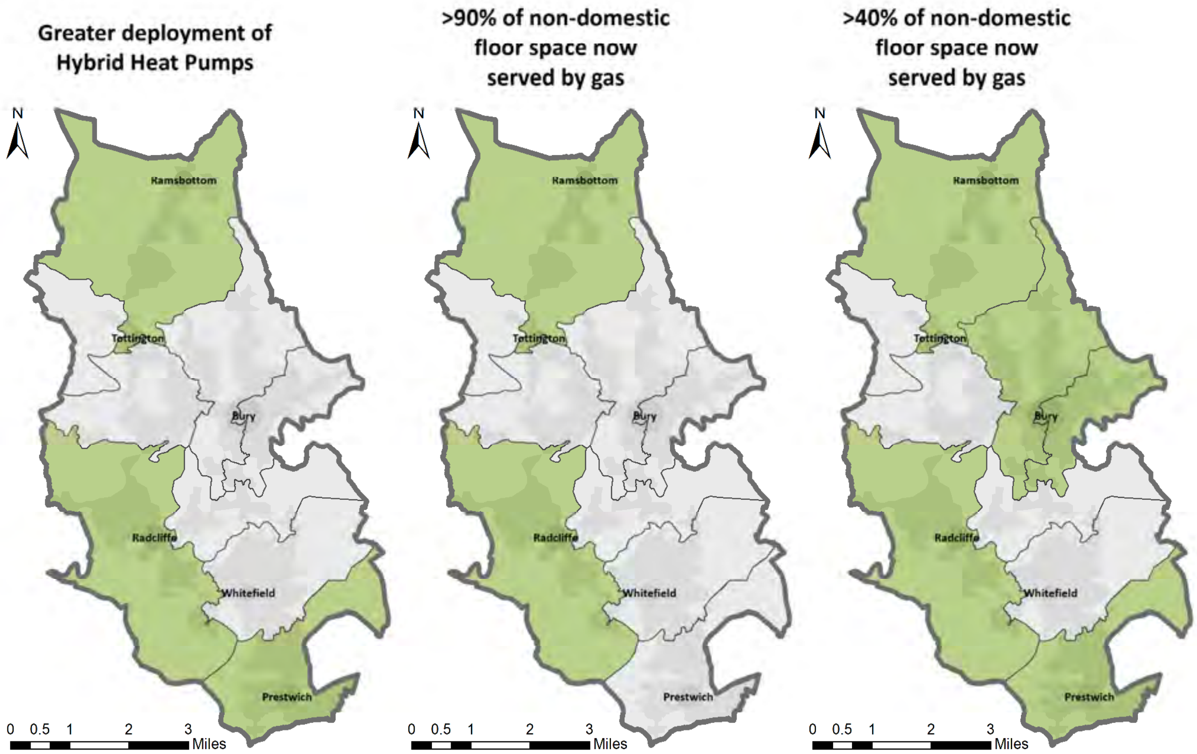

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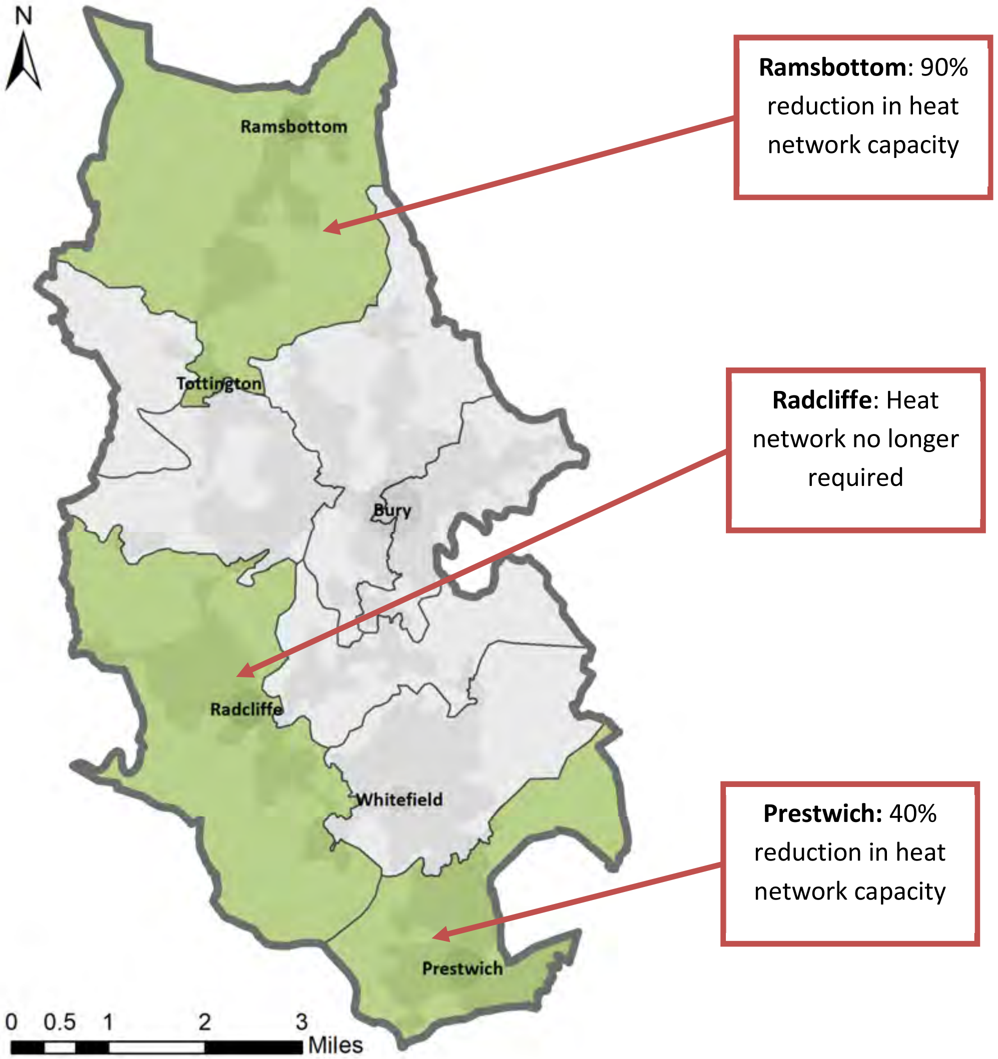
Figure 5-84 Areas of Bury (in green) where changes have occurred when some gas is available

The model shows that this additional use of hybrid heat pumps is a more cost-effective option than leaving more gas boilers in place.

The middle and right maps of Figure 5-84 also indicate areas where greater levels of non-domestic floorspace remain on gas heating systems. This also reduces the required capacity of heat network.

This use of gas allows the complete removal of heat networks from one area of Bury, and major reductions in capacity in two other areas (Figure 5-85).



Ramsbottom: 90% reduction in heat network capacity

Radcliffe: Heat network no longer required

Prestwich: 40% reduction in heat network capacity

Figure 5-85 Reductions in heat network capacity possible when gas is available

5.13.20 Key Findings

- By 2050 the plan to decarbonise is the same, regardless of whether the target is to achieve decarbonisation by 2050 or 2040.
- Under the 2040 target, heating systems and networks need to change earlier, at a greater cost. Widespread change needs to happen in the first transition, which implies little time to test or demonstrate approaches.
- The choice of heating system can be broken down by area of Bury, size of home and whether it is detached.
- Widespread solar PV deployment by 2050 saves money, and it can also be used as a method for saving carbon sooner.
- All non-domestic buildings that are considered suitable are switched to heat networks when tight carbon targets are set.
- Significant electricity network reinforcement will be required to support the increased electrification of heat supply.

6 Future Local Energy Scenarios and Network Choices

Section 5.13 set out the final stage of modelling for Bury. This represents the best detailed modelled representation of Bury's future energy system conducted in this project.

Between now and 2050 there is significant uncertainty in many factors that will influence the best options. It would clearly be a mistake to define a single complete plan now and attempt to follow it without responding to external factors and updating it for the future.

To start laying the foundations for change now it is necessary to identify options that are the most certain, or likely to be lowest regret. By generating broad themes for areas progress can begin to be made in the nearer term without yet having to commit to a definitive long term plan.

To generate this insight an analysis was performed looking at all the modelled scenarios for Bury. The sensitivity work tested changing many external factors, so findings that were consistent throughout all of these can be considered relatively low risk.

6.1 Heating System Certainty

Figure 6-2 and Figure 6-6 show the distribution in types of heating system by area and scenario. The final modelling scenarios are shown separately to the range of sensitivity values. The final scenarios include data changes and have used a tighter carbon target and so are not directly comparable to the previous modelling. The sensitivity range includes all the Monte Carlo simulations (see p89).

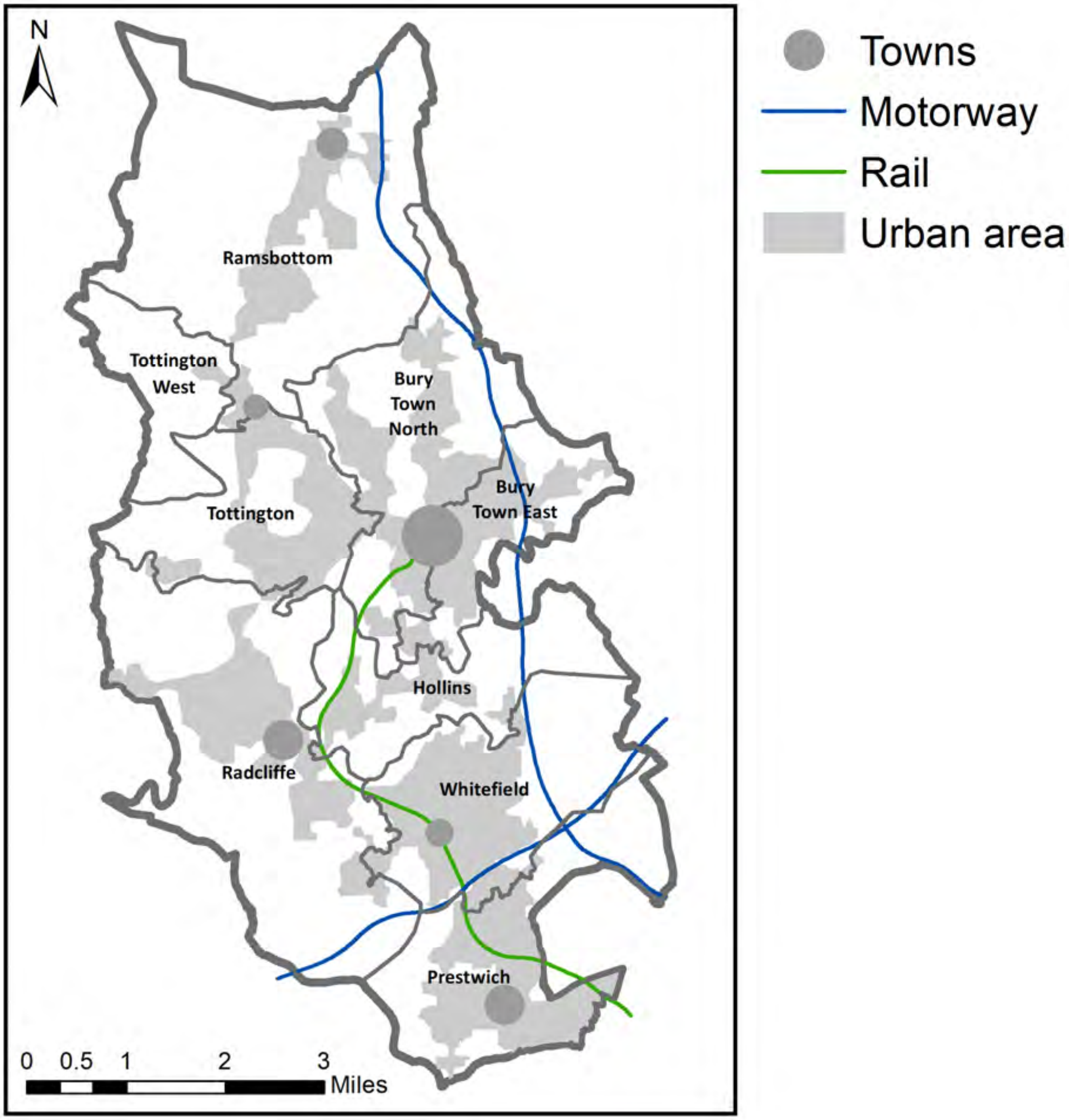


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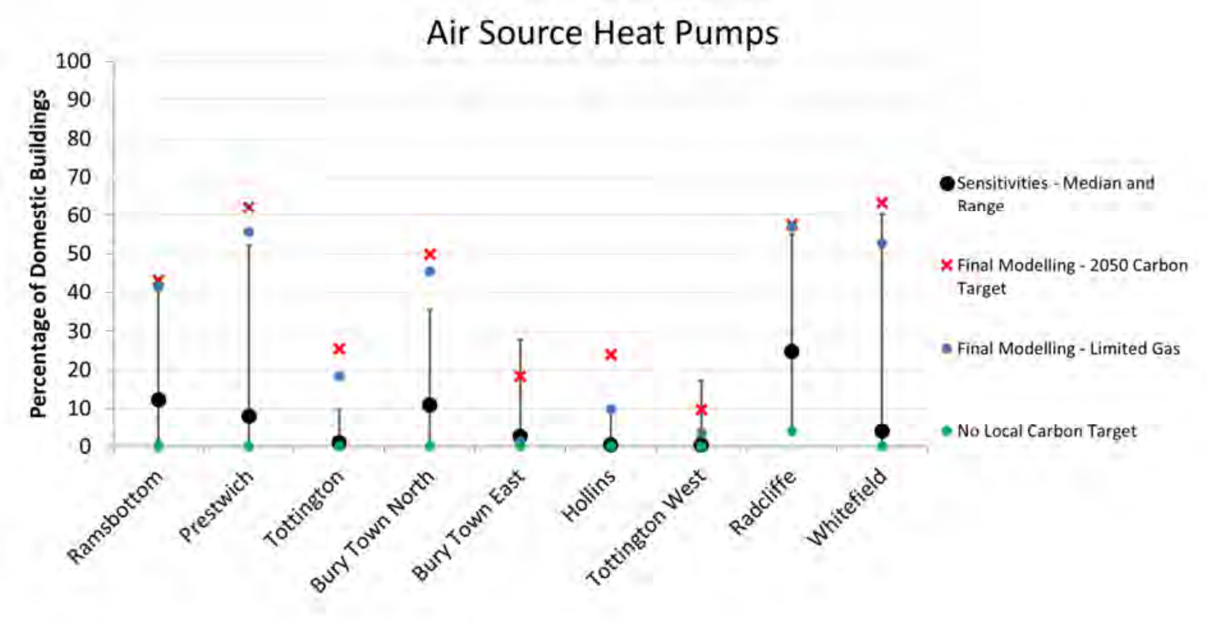
Figure 6-1 Location of analysis areas used in comparison graphs

Figure 6-2 to Figure 6-7



show the variation in uptake for different heating systems across Bury in 2050.

The graphs indicate the range of uptake values across scenarios. The black bars show the range of values across the sensitivity and Monte Carlo analysis, with the circle indicating the median or middle value of uptake across the scenarios. The final modelling runs are marked separately.

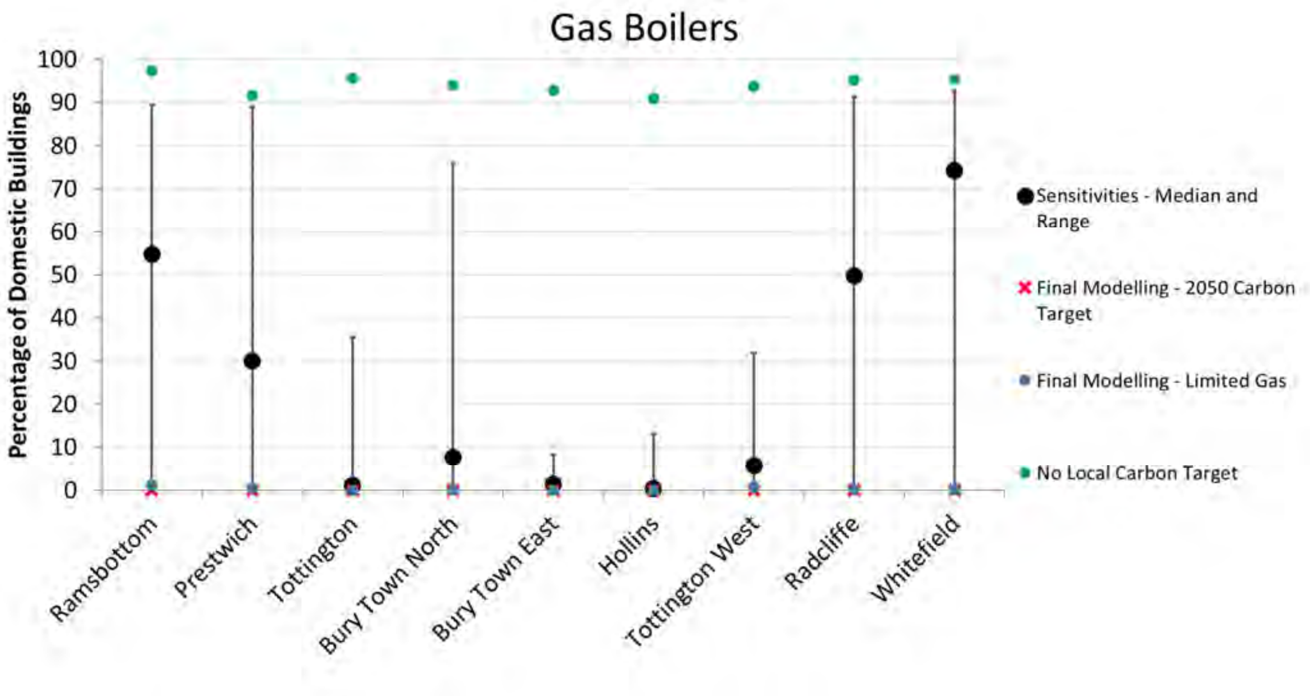


Figure 6-2 Range of uptake of Gas Boilers by area

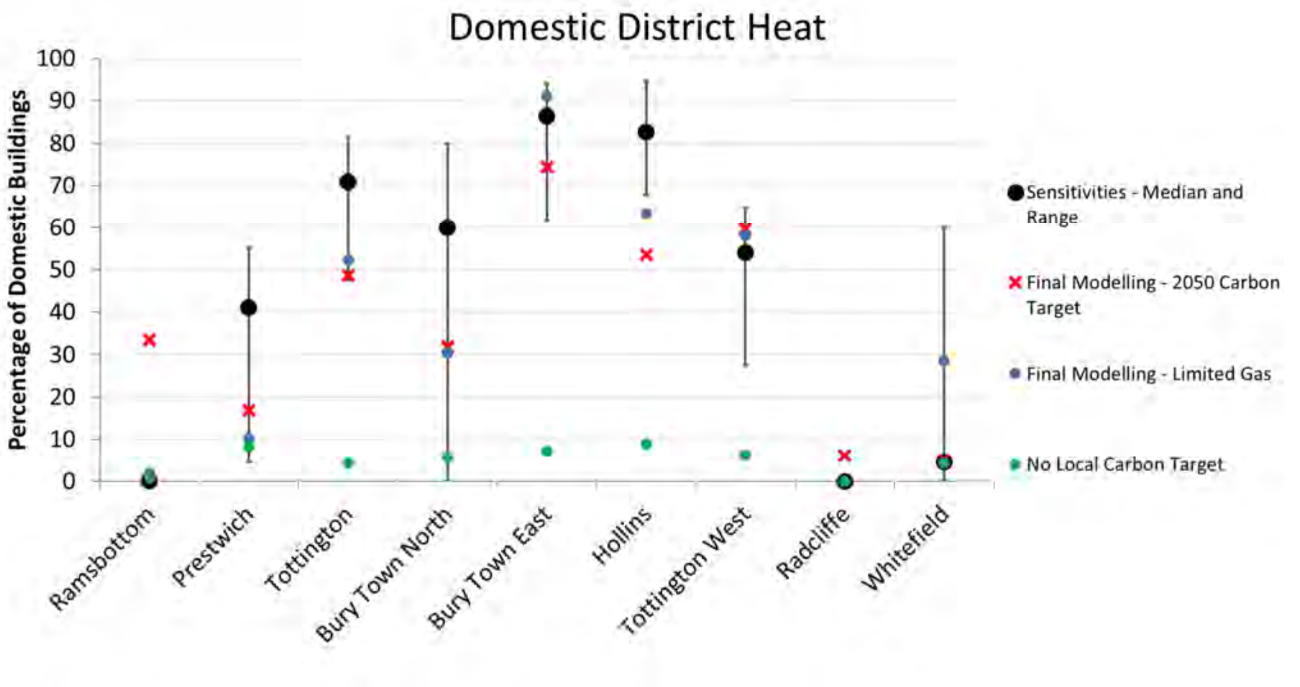


Figure 6-3 Range of uptake of Domestic District Heat by area

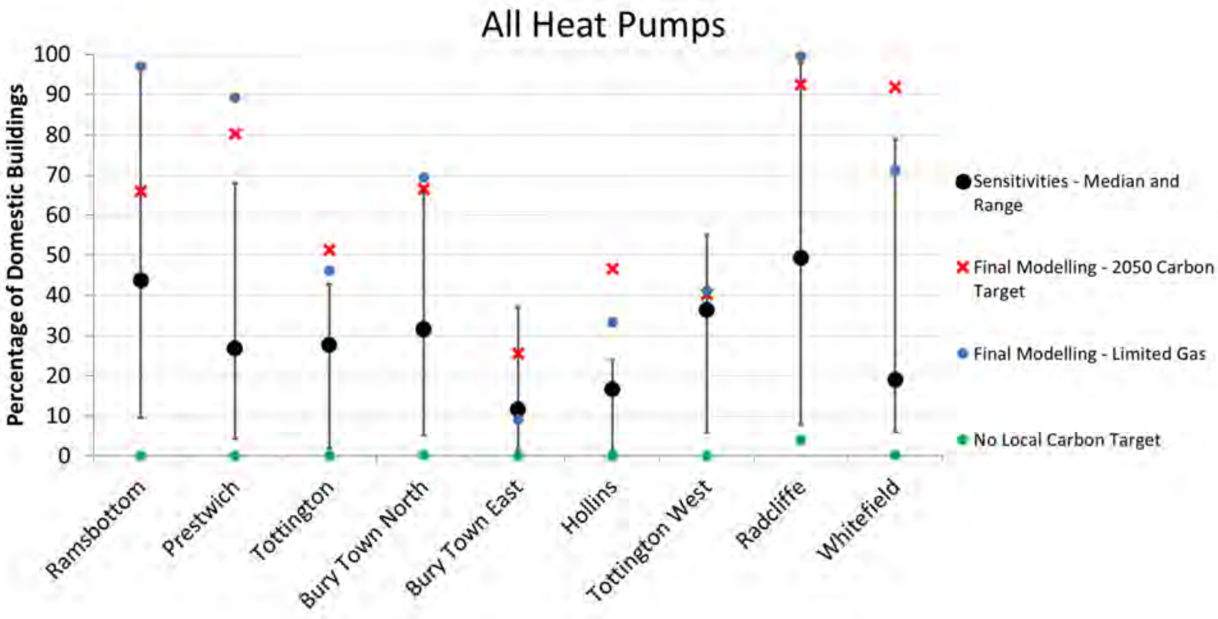


Figure 6-4 Range of uptake of all Electric Heat Pumps by area

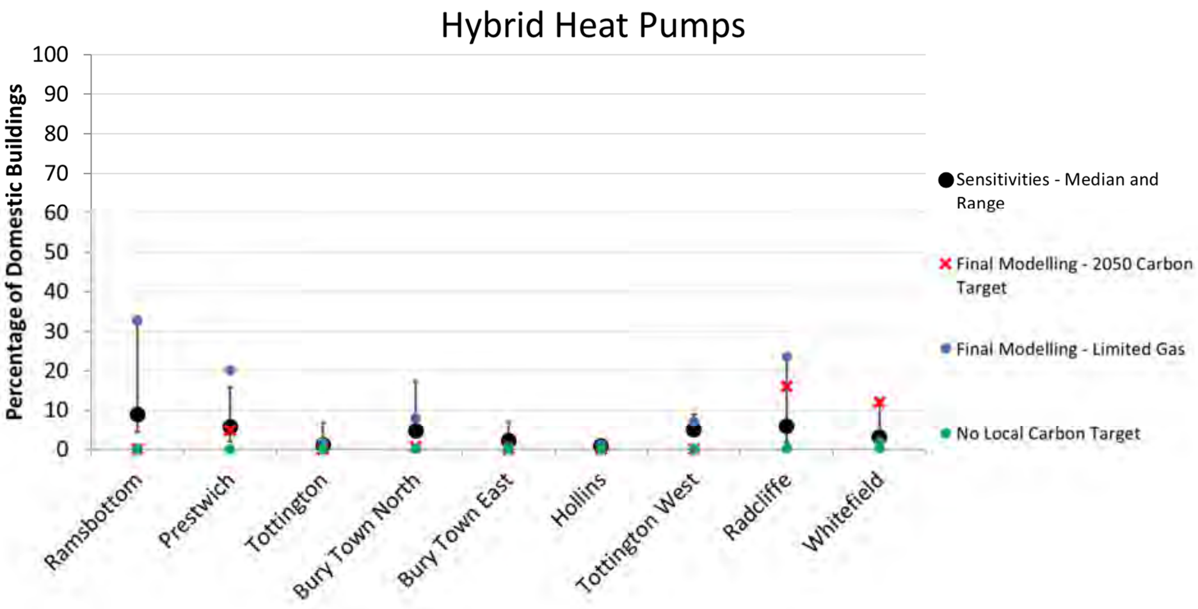


Figure 6-5 Range of uptake of Gas/Electric Hybrid Heat Pumps by area

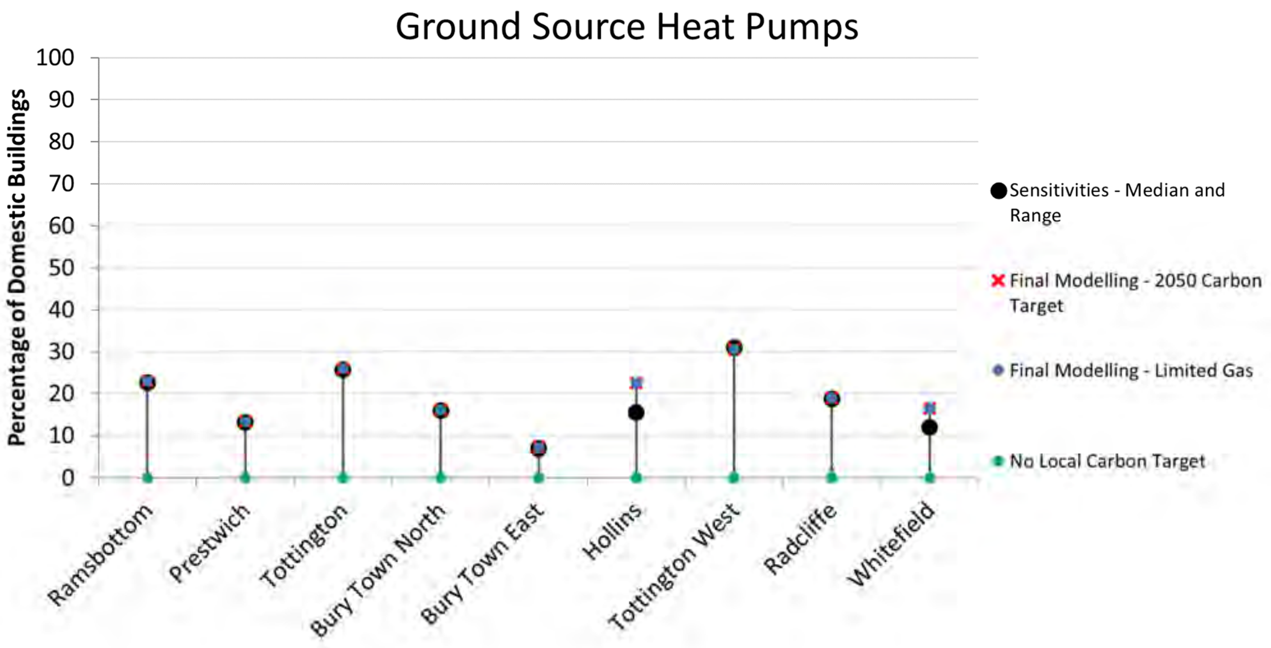


Figure 6-6 Range of uptake of Ground Source Heat Pumps by area

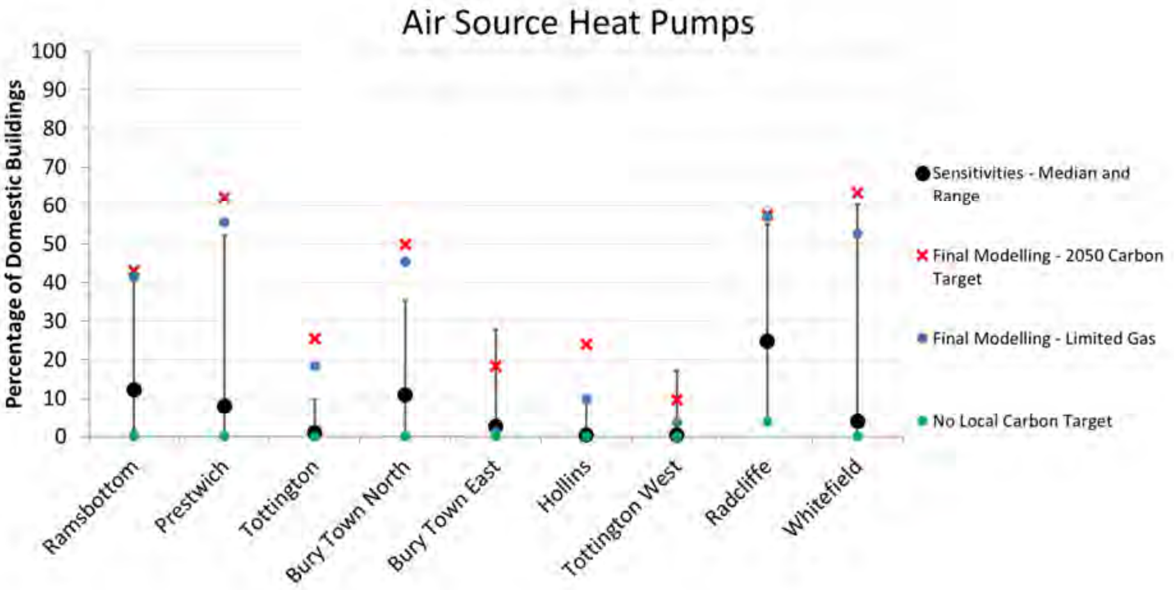
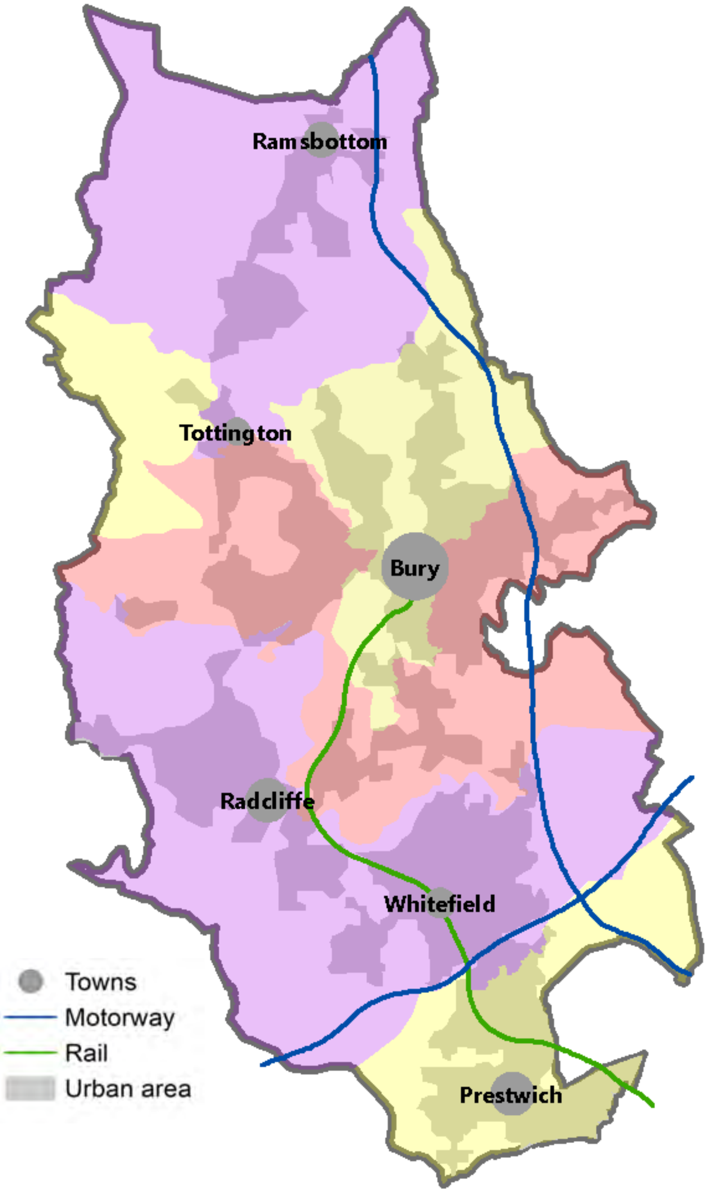


Figure 6-7 Range of uptake of Air Source Heat Pumps by area

6.2 Area by Area Influences on Network

The analysis of the consistency of heating system choice in areas across Bury allows the identification of themes for network choice in areas of Bury. Three main themes for areas of Bury have been identified (Figure 6-8)



District Heat Dominated

Tottington, Hollins, Bury Town East

Electric/District Heat mix

Tottington West, Bury Town North, Prestwich

Electric/Gas mix

Ramsbottom, Radcliffe, Whitefield

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Figure 6-8 Network Themes for Areas of Bury

The themes represent the most common modelled domestic heating systems for these areas. Inside each area there are different sets of contributing factors. The results can be broken down further by building type within the areas, for example the previous discussion in section 5.13.4.

The analysis areas are derived from the areas modelled as served by different HV substations. They are modellings unit rather than on the ground constraints and so should not be considered hard boundaries.

6.2.1 District Heat Dominated

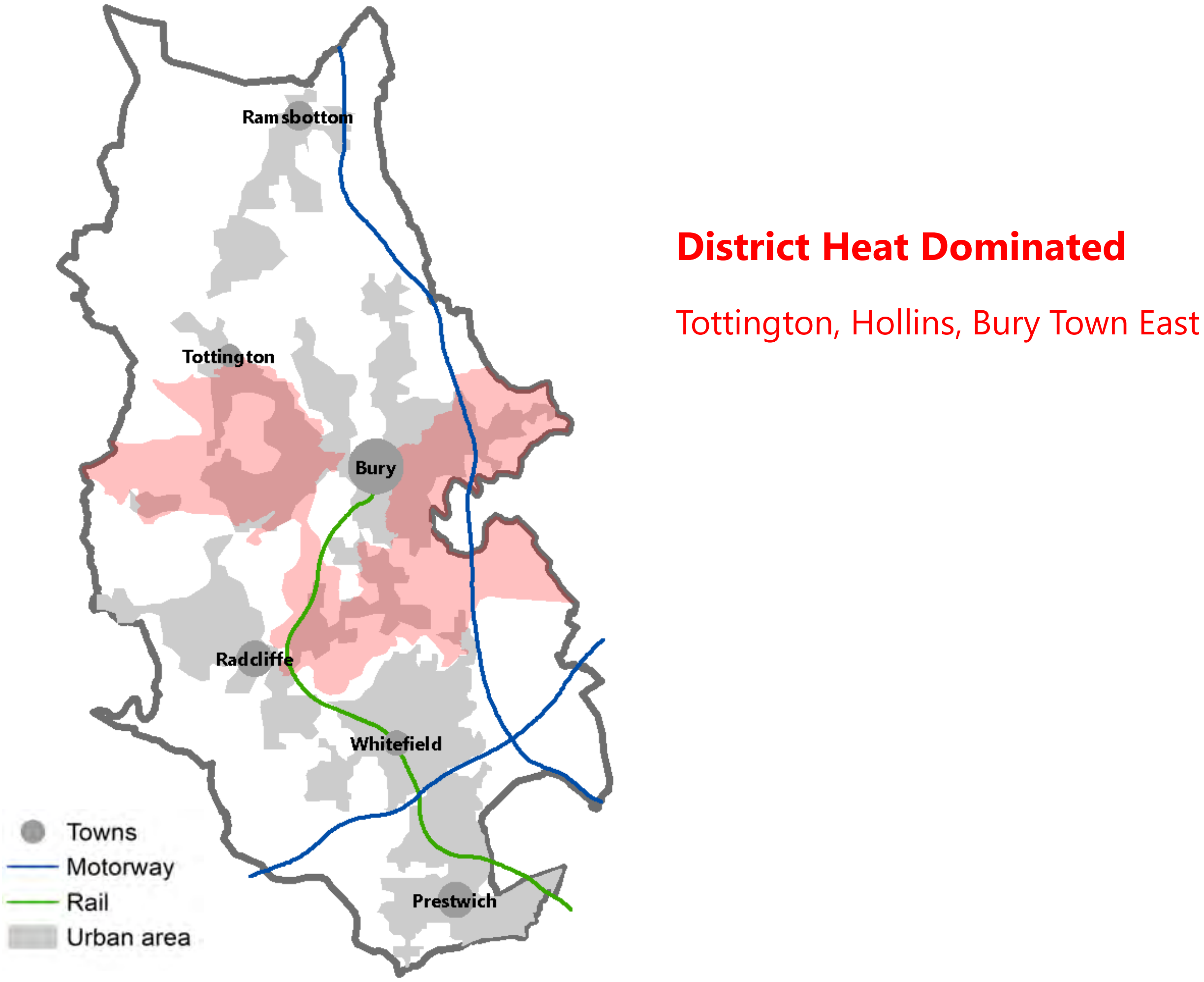

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Figure 6-9 District Heat Dominated Areas of Bury

The areas of Bury shown in Figure 6-9 are consistently shown to be areas cost effectively transitioning to heat networks across a wide range of model scenarios.

In these areas there are **never less than 60%** of domestic buildings modelled as being on district heat. The uptake was modelled as lowest when electricity prices were low – as discussed in the energy costs sensitivity (p80). Uptake was also at the lower end in the final model scenarios. In these scenarios the almost complete decarbonisation of Bury requires all suitable non-domestic buildings to join the heat network. The network capacity is used to serve those rather than as many domestics.

Considering all the model scenarios together district heat is **usually deployed to 75-80%** of the domestic buildings in these areas and there was **at most 88%** district heat deployment, when electricity prices were scaled highest. The buildings in these areas not chosen for district heat show high levels of Ground Source Heat Pump (GSHP) deployment. Usually 17-18% are modelled as best served by a ground source heat pump, with a range of 8% when electricity prices are highest (section 5.6.3) to 19% under the Clockwork national policy scenario (see section 5.5). 19% of buildings in these areas are detached, so under Clockwork virtually every detached building has a GSHP.

There is no single factor to explain the high relative uptake of district heat in this area compared to the rest of Bury. In general, across the highlighted areas homes are in the smaller to mid-range floor bands (50-110 m^2). There is a higher housing density, which leads to lower heat network infrastructure costs per household and higher network efficiencies.

Other influencing but less consistent factors are property types and ages, the non-domestic loads present and their suitability for district heat, and the relative costs of installing heat network capacity compared to reinforcing electricity networks.

The model findings are based on a combination of these factors relative to other areas of Bury.

6.2.2 Combination of Electrification and District Heating

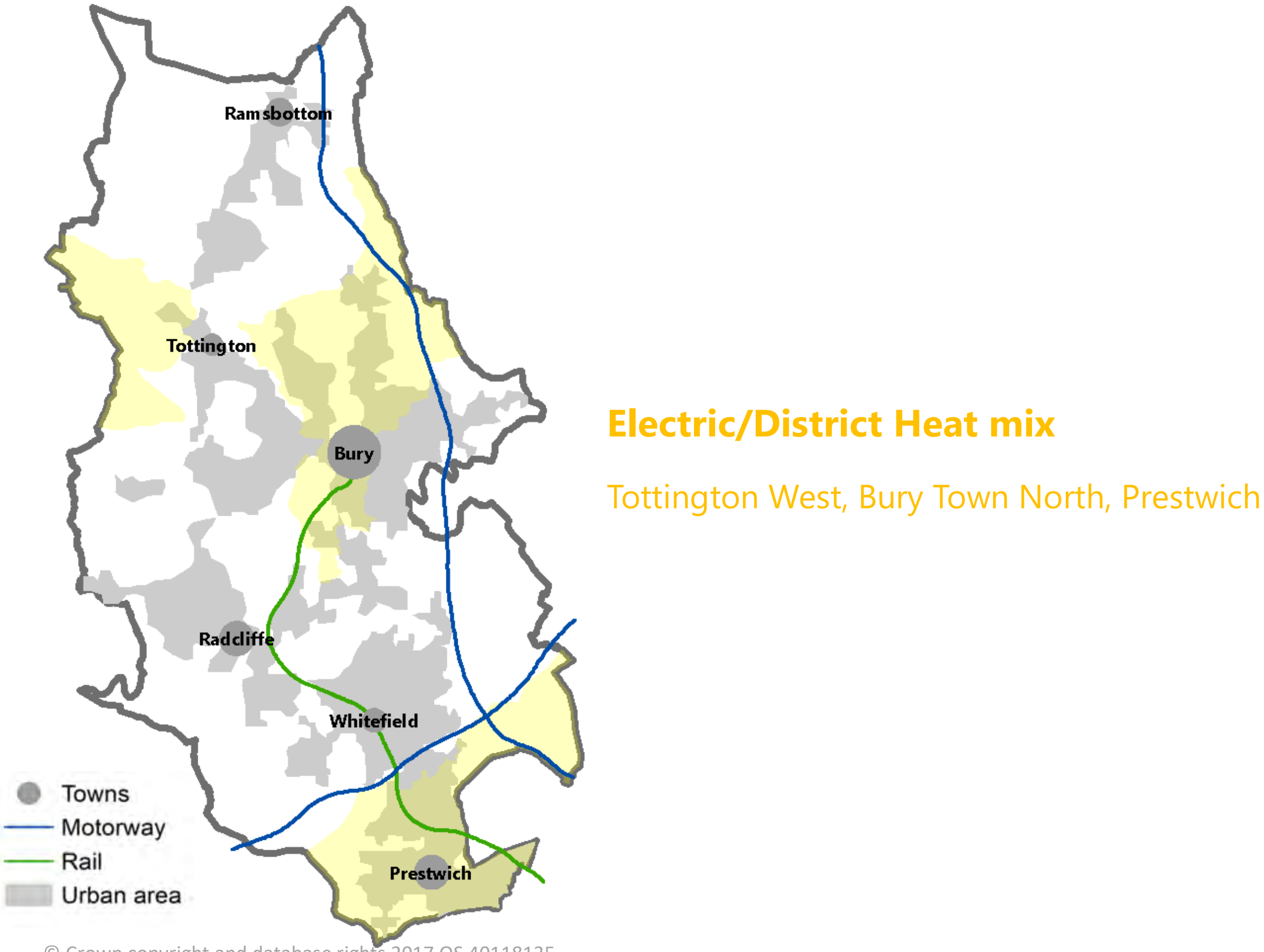

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Figure 6-10 Electric/District Heat Mix Areas of Bury

When considering all the model scenarios these identified areas are shown to be best served by a mixture of electric heating systems and district heat. The choice between them is shown to be highly sensitive to building type and changes in the scenario.

Usually in these areas electric heating sysytems are deployed to **26-35%** of the domestic buildings and district heat is deployed to **46-56%** of the domestic buildings.

There were **never less than 21%** of domestic buildings modelled as having electric heating and, similar to elsewhere, this was lowest when electricity prices were high. Under this scenario 55% of homes were on district heat.

There was one exceptional scenario where only 4% of domestic buildings modelled as being on district heat: this was when electricity prices were low.

The highest electric heating system uptake is 76%, under the final 2050 carbon target run. It was high under this scenario because domestic district heat uptake was low – 24% - probably because more non-domestics were required to join the network, leaving less capacity for domestics.The highest district heat uptake was 65%, when electricity prices were high. This scenario had 21% on electric heating systems.The area west of Tottington showed a small uptake of biomass boilers, averaging around 3.5%. This area is characterised by larger properties, with high demands, but low density meaning high network lengths and so high reinforcement costs. There was only a small amount of biomass modelled as available to Bury so biomass boilers could never be widespread.

There is no single factor that explains the heating system choices in these areas, although it is clear that electricity costs have a large influence in the decision, particularly in the more northerly areas. Across the three areas there are generally mixed property types and ages and both electricity network reinforcement and heat network build costs are relatively high. Other factors that have an influence but are not consistent across the areas include building density and floor areas.

6.2.3 Combination of Electric Heating and Gas Boilers

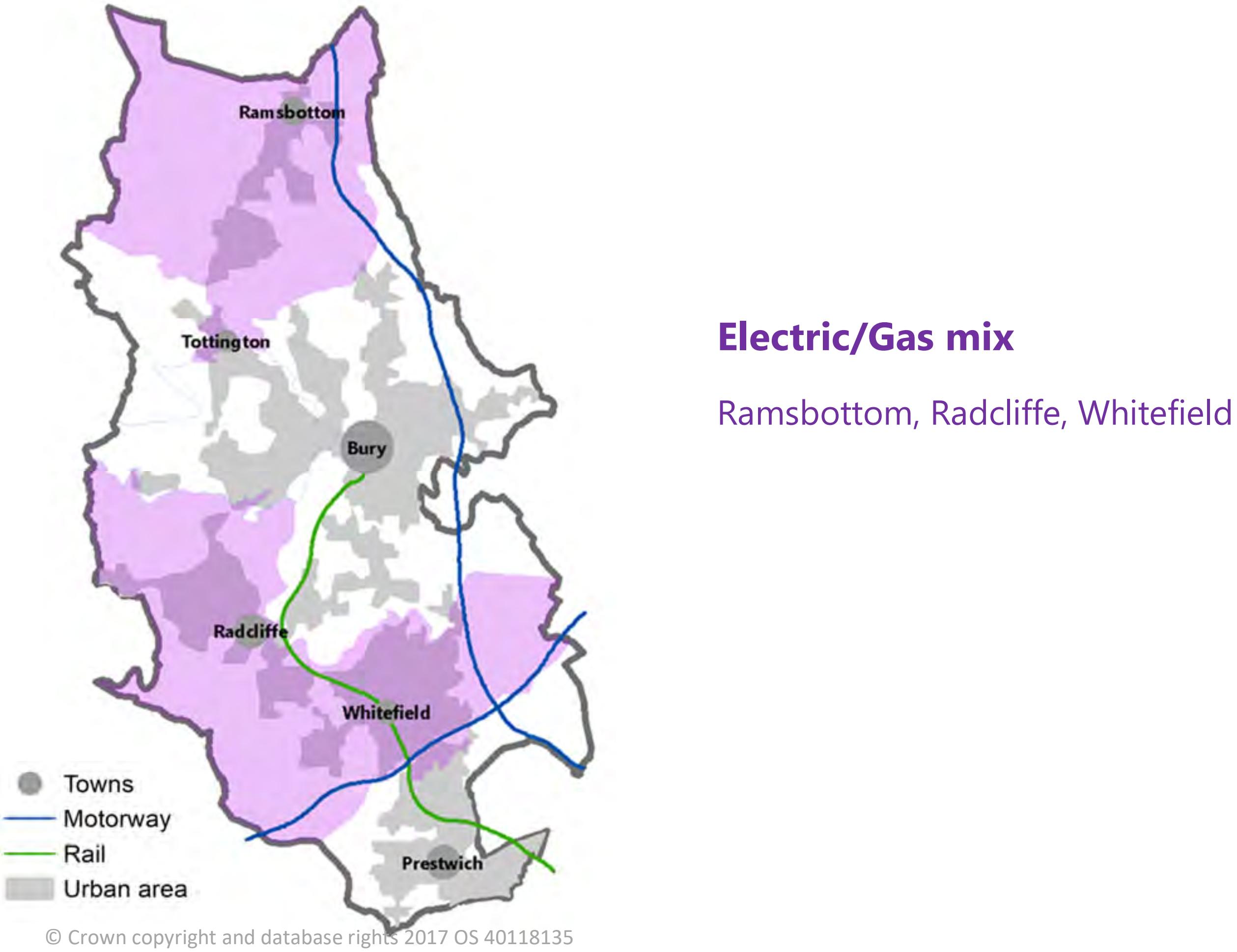

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Figure 6-11 Electric/Gas mix Areas of Bury

These areas of Bury have been identified as likely to be the hardest to decarbonise given the modelled options. Looking across all the scenarios tested with a 90% carbon target then usually 56-63% of the buildings in these areas remain on gas boilers. The lowest gas boiler uptake with this carbon target was 43%, and the highest was 66%. These both occurred in the Monte Carlo analysis testing different technology costs (section 5.7).

In the final modelled scenarios, that target complete decarbonisation, gas boilers are not possible. Instead there is 85-90% deployment of electric options, and 10-20% of homes are served by gas/electric hybrid heat pumps.

These areas are shown by the model to be the most expensive and hardest to decarbonise, hence gas boilers are modelled if possible. If complete decarbonisation is necessary, and no lower carbon gas options are available then they can be served by electric heat pump options, but these are expensive.

If there was a way of keeping many of the buildings in these areas on a gas based heating system then that would be a sensible way forward – either through a lower carbon gas source or creating space in the carbon budget to allow greater natural gas usage. There are a number of factors that make these areas the hardest to heat in a low carbon manner.

In Ramsbottom there are:

- Relatively old and large buildings compared to the rest of Bury, giving the highest annual energy demands per property in Bury.
- Low linear heat density (heat demand per length of network required) despite the large per-building demands, making network infrastructure expensive.

The Radcliffe area has:

- Fairly typical building size, ages and demands for Bury.
- Still a low linear heat density per network length.

The Whitefield area is also fairly typical for the rest of Bury. Under the highest electricity prices it has up to 50% district heat deployment, so in relative terms the network costs are less prohibitive than in other areas identified as hard to decarbonise, but still high compared to Bury as a whole.

6.2.4 Local Energy System Data Dashboard

Bury Council have been provided with a data dashboard that allows the identification of modelled heating systems in different areas by characteristics including building type and age. This allows greater insight into the particular types of building within an area that should be targeted. The area fact files (p183) also provide further insight into the results by area.

7 Conclusion

To enable a cost effective low carbon transition, more advanced local area energy planning can help to identify the right technologies in the rights place, at the right time. This project has piloted such a process using EnergyPath Networks to build a whole system model of the local energy system in Bury and investigate possible future local energy scenarios engaging key stakeholders including local government electricity and gas distribution network operators.

It provides a robust evidence base to inform a Local Area Energy Strategy and corresponding action for Bury and the foundation for a long term whole system approach to local area energy planning across buildings and networks across Greater Manchester. It also provides valuable data and insight to support the identification and development of future projects.

- **By 2050 Bury can reduce its building emissions by 98% from 1990 levels.** A 95% reduction could be achieved by 2040.
- **These carbon savings would not come easily.** Significant change to domestic heating systems across Bury would be required, swapping gas boilers for a variety of electric heating and district heat systems. Except at the winter peak or in the early time periods, the heat for the heat networks needs to be produced in a low carbon manner, requiring either the use of large scale electric heat pumps or alternative significant low carbon heat sources to be identified.
- **There are limited windows of opportunity to replace domestic heating systems.** Heating systems are naturally replaced at the end of their lifetimes, giving, maybe, only two opportunities to replace between now and 2050.
- **If Greater Manchester and Bury aim for a more ambitious carbon target of nearly zero carbon by 2050 then low carbon heating needs to accelerate. Heating systems need to become low carbon at the earliest opportunity** i.e. gas boilers being replaced in the next couple of years need to begin to switch to low carbon options, otherwise the target will become unachievable.
- **For some areas and homes in Bury, if lower carbon gas is not available it is clear that electric heating is a cost effective way to decarbonise**, with the choice of system determined from the size and type of the building.
- **For other areas there is the potential to have a lower cost solution using district heating networks.** The modelling shows that in these areas the choice between heat pumps or district heat is very sensitive to the cost of grid electricity and the cost of installing heat network infrastructure, specifically the pipes in the ground.
- **There is significant uncertainty today in the future costs of both electric heating systems including heat pumps and heat networks.** Development and demonstration of integrated solutions able to meet the needs of homes and consumers is needed to inform major infrastructure choices for some areas of Bury.
- **Decarbonising non-domestic buildings is necessary.** Non-domestic buildings vary more than domestics and the available data is poorer. The possible heating and building fabric changes are more complex and so they are more difficult to model. The evidence suggests that where they

currently use gas boilers they should instead be joined to heat networks, where they can provide anchor loads that normally peak at a different time to the domestics.

- **Some non-domestics are modelled to use heat industrially and so are difficult to switch to a low carbon source.** In this work they account for most of the remaining 2050 emissions. To accurately plan for the future, better data is required about key non-domestic heat users. This project can identify areas most worth targeting, but it is likely that more data will need to be collected on all aspects of non-domestic buildings in Bury.

- **Local renewable energy generation can play an important role.** Increasing uptake of Solar PV could play a role in reducing carbon and can be a cost effective local energy system design. Battery storage may be a cost effective option if there is a large enough variation in electricity prices throughout the day.

- **Meeting carbon targets will come at a cost.** The total cost of a local energy system is large between now and 2050. Meeting a 2050 carbon target [55]was modelled to cost an extra £1,120m[56], but this is just 16% extra compared to not having a carbon target. Cutting carbon sooner will cost more. Aiming for a 2040 rather than 2050 carbon target costs an extra £960m, although it brings much lower total emissions over the period.

7.1 Wider Context

7.1.1 Consumers

It is important to consider constraints that are not assessed by EnergyPath Networks (such as consumer, policy, commercial, skills and supply chain aspects), since they can have a significant impact on the decarbonisation process. These will be discussed in the LAES. However, the analysis presented in this report has led to several consumer-related questions and opportunities that are note-worthy:

- **Most consumers are not currently familiar with the transitional technologies discussed in this report.** For example, the "Energy and Climate Change Public Attitude Tracker"[57] suggests that around 37% of UK residents are aware of ASHPs. Currently the majority of properties have gas boilers. The remaining household heating systems are predominantly split between electric heating systems, oil & LPG boilers. Consumers understand these technologies and the commercial arrangements involved in buying and operating one. A wide range of heating system and retrofit options will be required to be able to make the largest carbon reductions so **organisations will need to develop corresponding products and services that individuals want to use.**

- **Many consumers will value the sunk cost of their current heating system that is not at end of life – even if a new system would save them money overall.** The analysis in this report assumes that heating systems will only be replaced at their end of life, giving two opportunities for change.

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[55] A 98% reduction in in-scope emissions from 1990 levels. In-scope emissions are those relating to buildings. Transport emissions are not included, although electric vehicle charging at home is in scope.

[56] Discounted costs

[57] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/678077/BEIS_Public_Attitudes_Tracker_-_Wave_24_Summary_Report.pdf

However, this could be influenced by new policies or business models such as "Heat as a Service"[58].

- **Even familiar technologies cannot be assumed to be easy to implement.** For example, many building fabric retrofit measures are not high on consumers' wish lists. Thought will need to be given on how to encourage residents to take up insulation when they have been settled in their homes for a number of years and are not making any other home improvements. Some Local Authorities have struggled to sign residents up for insulation measures, even when those measures are free.
- **Transitional technologies could help to tackle some of these consumer issues**. For example, hybrid heat pumps would allow consumers:
  - Time to get used to operating new heat pump technologies whilst having the gas boiler back-up to deliver heat in peak times.
  - Back-up for times when the heat pump is not able to deliver sufficient heat to meet demand, for example when the weather is very cold.
  - To avoid giving up space for a hot water tank. The viability of using domestic electric heat pumps depends critically on the ability to use them in conjunction with heat storage, which may not be agreeable to consumers that do not currently have a hot water tank.

  EnergyPath Networks does not recognise these benefits and simply sees hybrids as more expensive systems. Therefore, the model will only choose them in properties where thermal efficiency is poor and demand cannot be met by a standard heat pump. **For this reason, it is important to consider hybrids in general "electric" areas** from the analysis**.** Both standard and hybrid heat pumps will require effective control systems and strategies to be competitive with other options and to realise their potential benefits to network operators.
- **The relative future costs of fuels, heating systems and fabric retrofit options closely influence which options are likely to be preferable.** The cheapest option is not necessarily the "right" solution in reality. For example, installing a powerful heat pump with a hot water tank may be cheaper than improving building performance. However, consumers may object if this involves reinstalling a hot water tank and digging up a driveway to increase the capacity of the electricity feed into the building.
- **The level and cost of network new build and reinforcement and the opportunities for solar PV and battery storage are projected to be different depending on location, demonstrating why local area energy planning is needed to manage the process.** If network costs are allocated only to the people connected to the parts of the network where costs accrue then there are likely to be large variations in energy bills. Whilst network costs are already socialised for gas and electricity networks this is not true for heat networks. **Consideration will need to be given to how heat network costs are socialised across the local area.**

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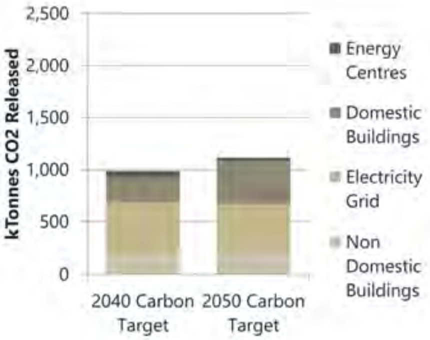
[58] "Heat as a Service" is a potential business model whereby consumers paying for a warm home rather than kWh of fuel. This definition is a work in progress that will be updated by the Energy Systems Catapult following consumer responses to trials in the Winter of 2017-18

Appendices

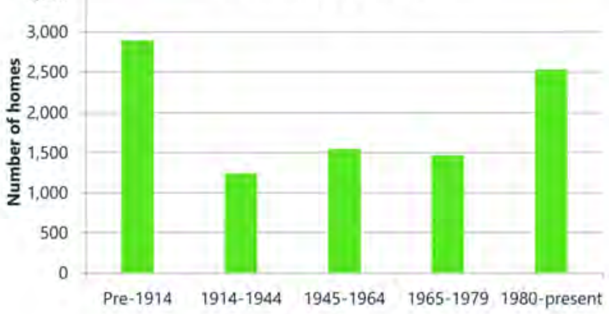
8 Appendix A - Area Fact Files

Ramsbottom Analysis Area Fact File

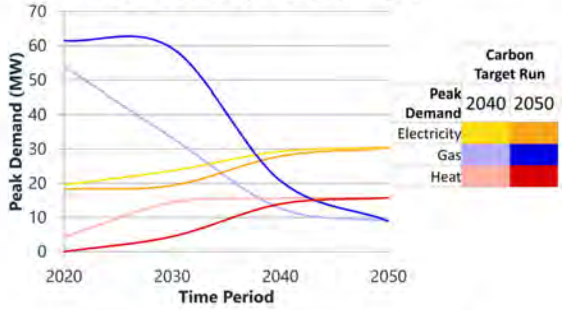
This is the northernmost analysis area of Bury and is the largest by area. The majority of this area is located to the east of the M66 as it merges into the A56 heading north. This is one of the 3 areas identified as an ideal location for a limited amount of low carbon gas to be used in hybrid heat pumps.



Property Age



Peak Network Demand



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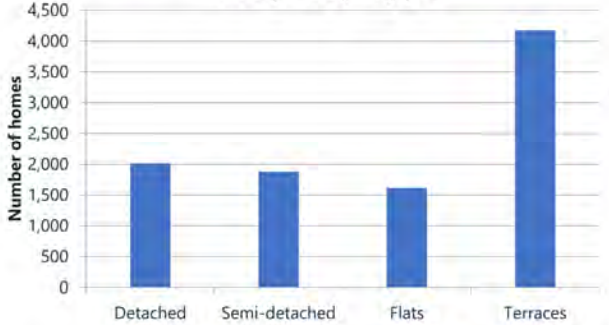
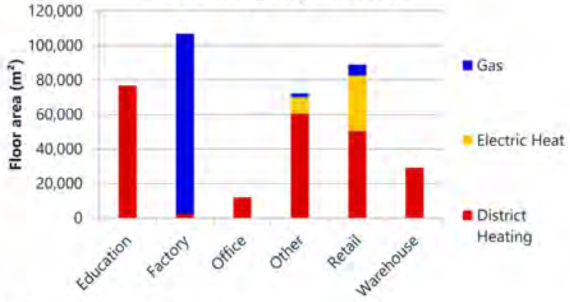
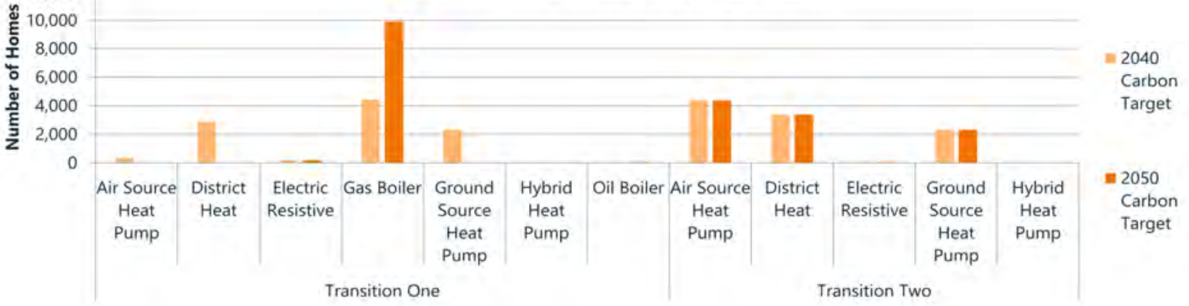


2050 Non-Domestic Building Heating Systems



Domestic Heating Systems



Tottington Analysis Area Fact File

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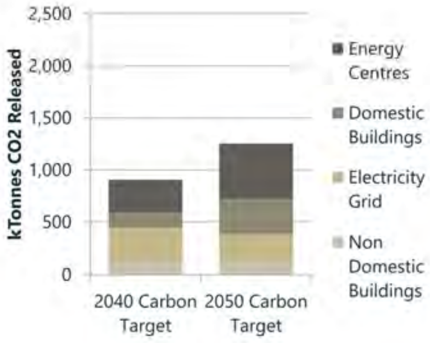
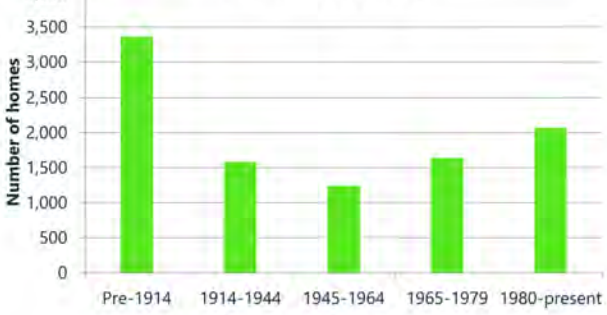
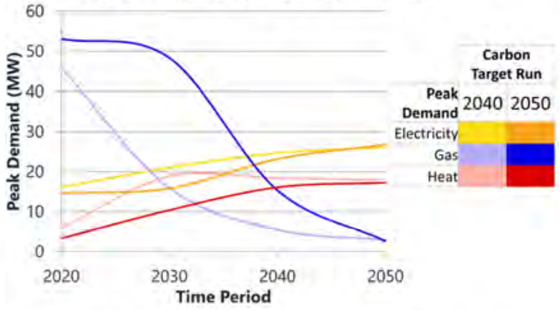
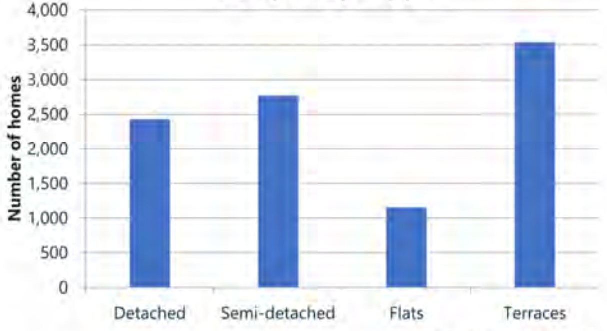
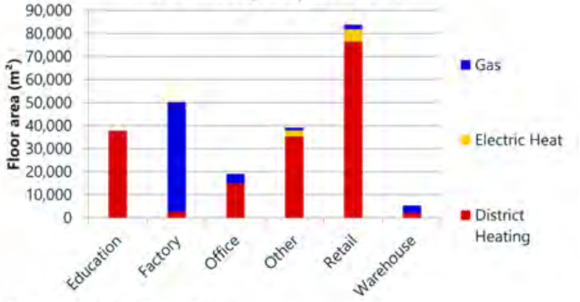
This analysis area sits to the east of Bury town centre, above the A58, and stretches as far as Tottington and Ainsworth.

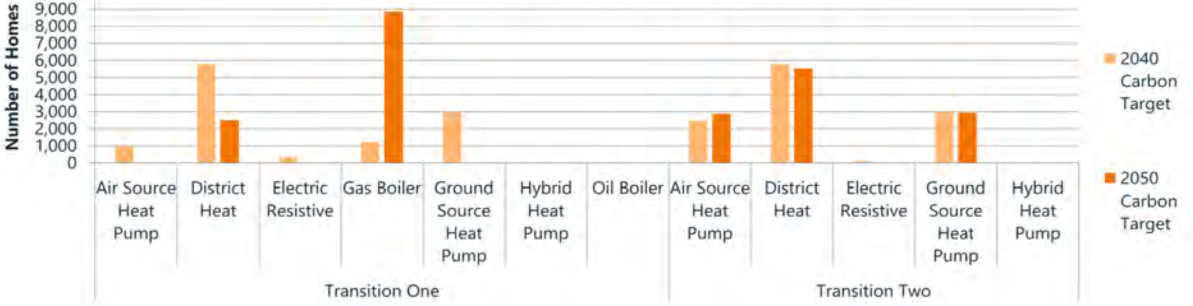



Property Age


Peak Network Demand


Property Type


2050 Non-Domestic Building Heating Systems


Domestic Heating Systems

Bury Town North Analysis Area Fact File

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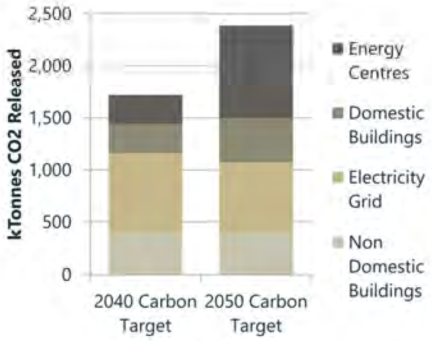
Sitting north of Bury town centre, this analysis area covers the surrounding areas of the M66.



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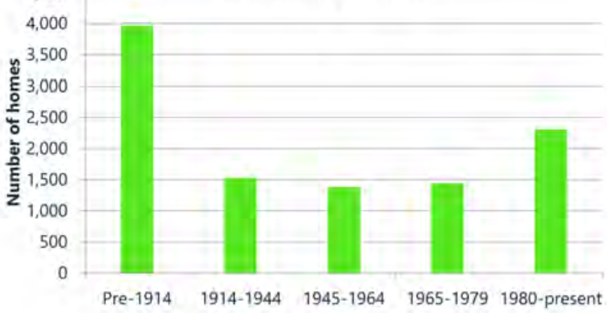
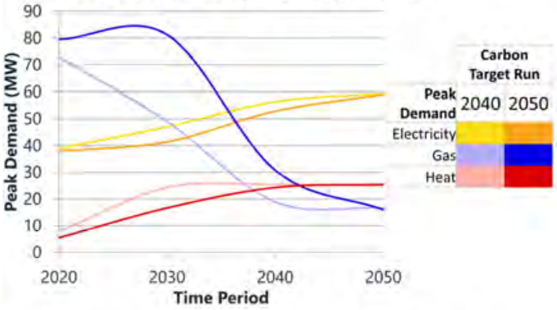


Peak Network Demand



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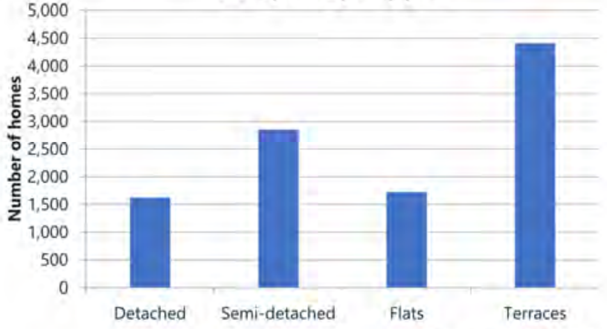

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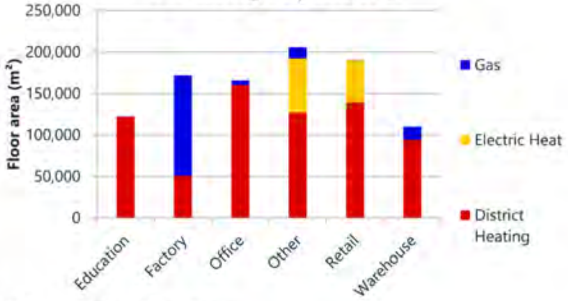
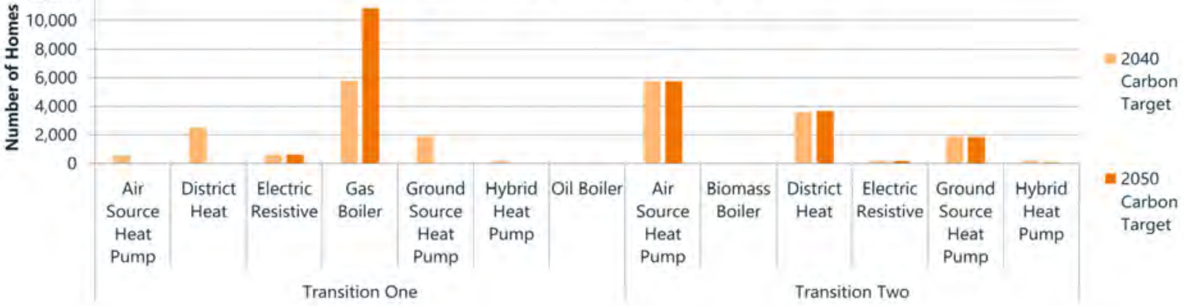


Domestic Heating Systems



Bury Town East Analysis Area Fact File

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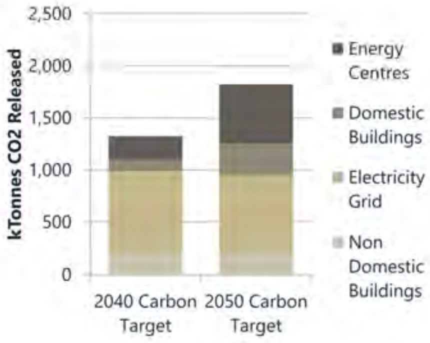
The most eastern part of Bury, this analysis area covers the eastern part of the town centre and the green belt area north of the A58 as it makes its way towards Rochdale.



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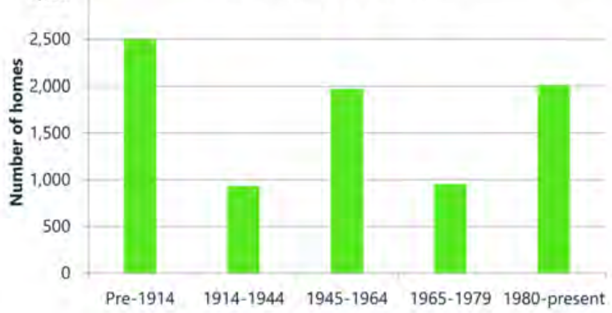

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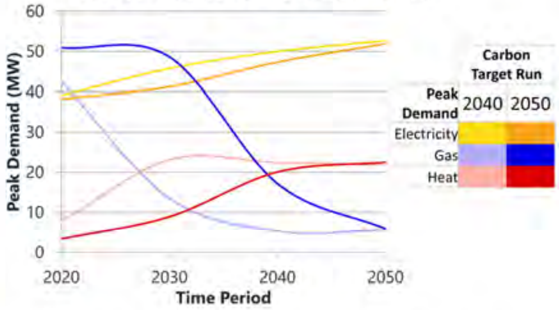

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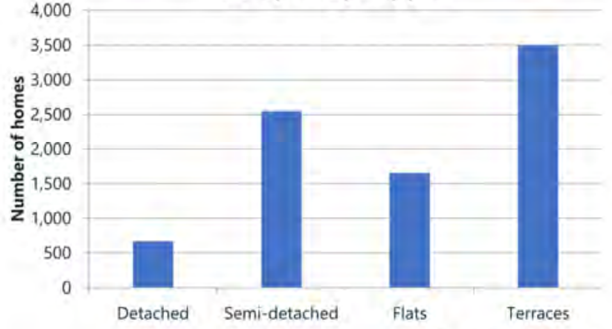

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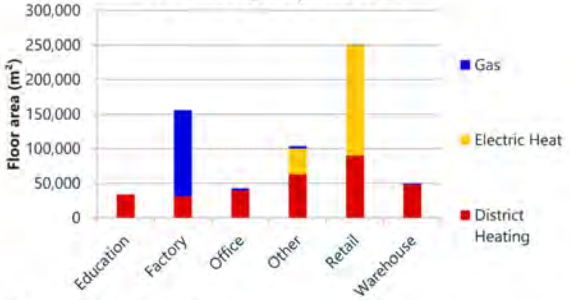
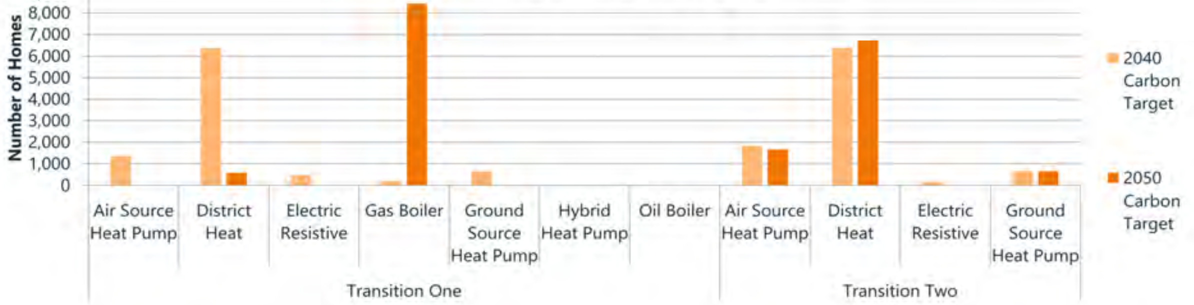


Domestic Heating Systems



Hollins Analysis Area Fact File

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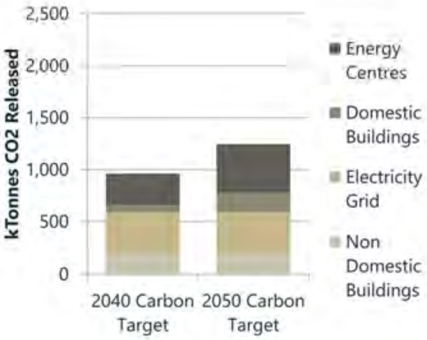
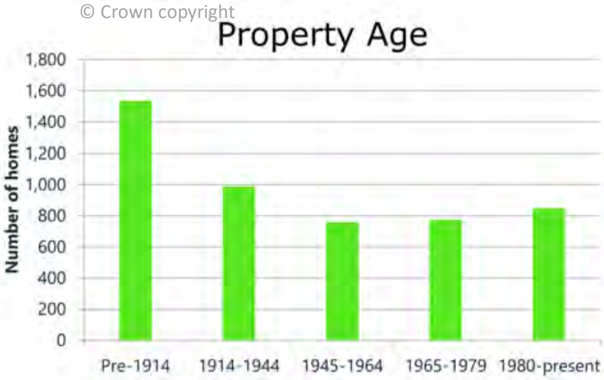
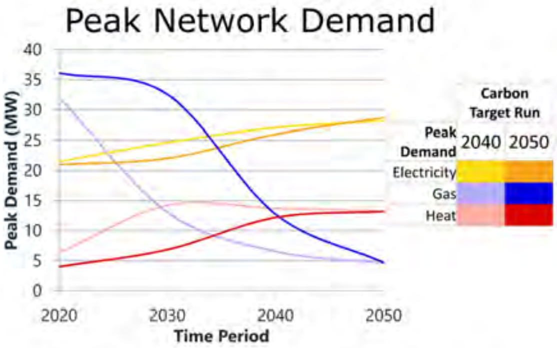
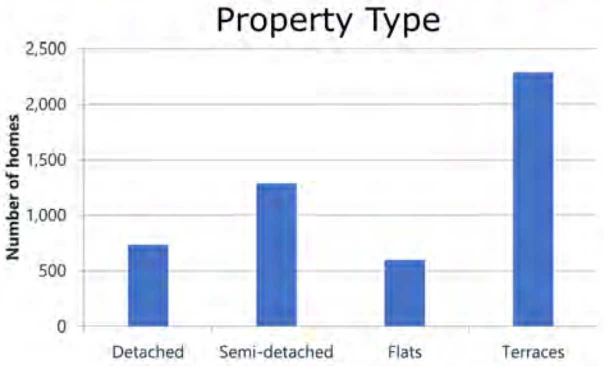
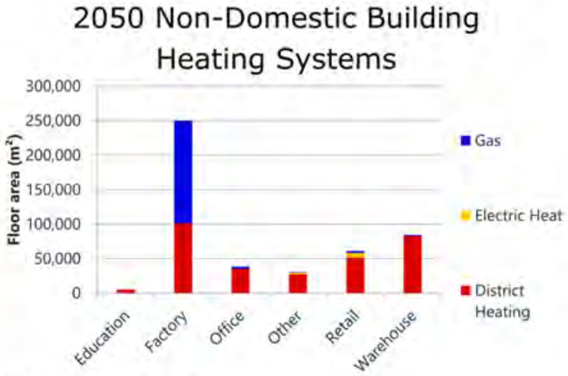
Again separated by the M66, this analysis area contains a large area of the south of Bury town centre alongside a large area of greenbelt east of the motorway.

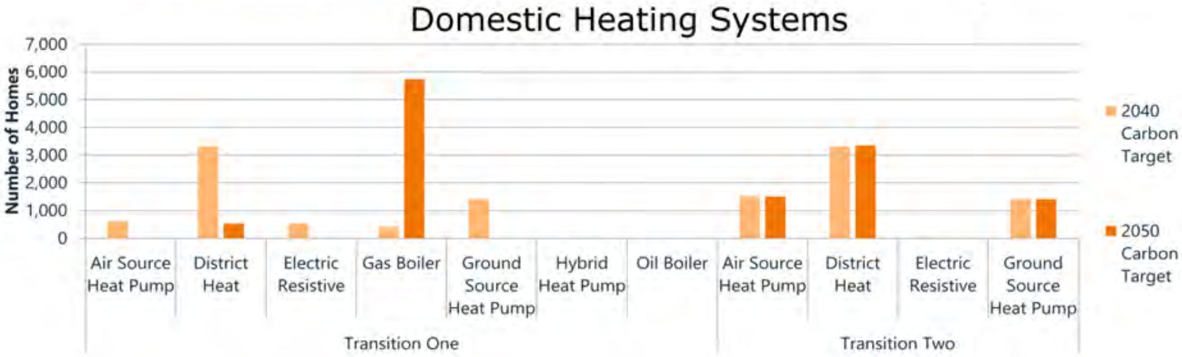






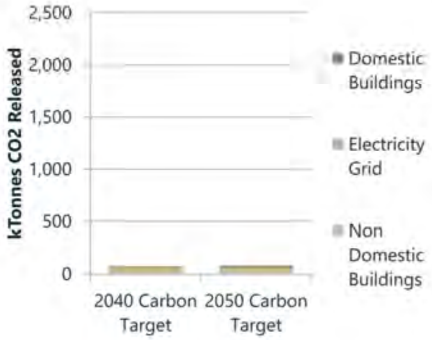


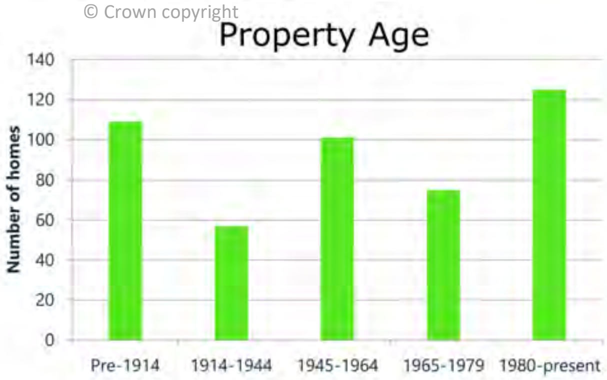


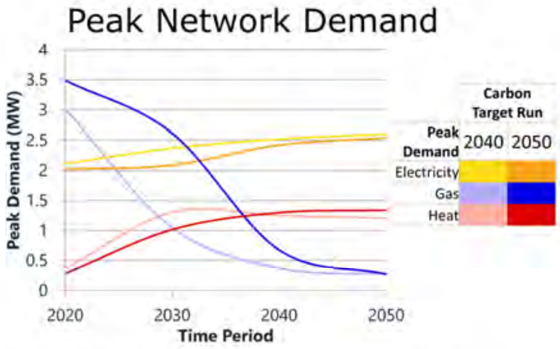


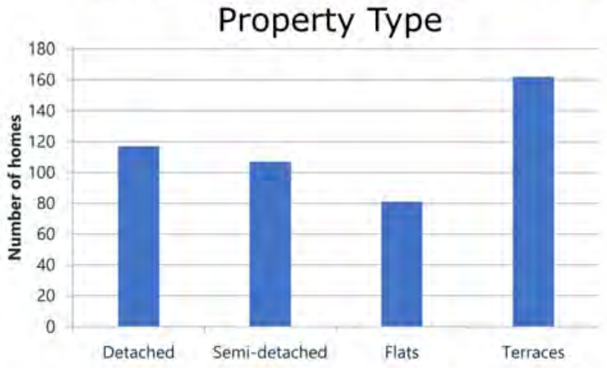
Tottington West Analysis Area Fact File

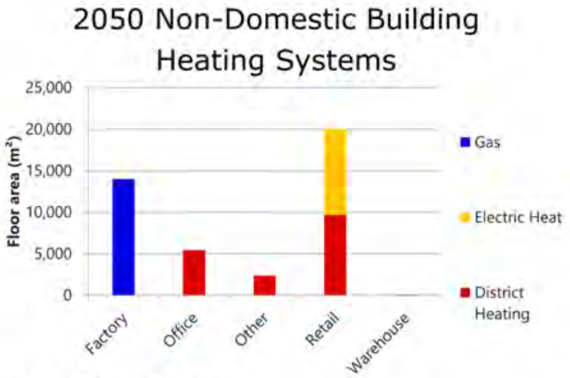
The smallest analysis area by both size and number of properties, this analysis area covers a rural area on Bury's border between Blackburn and Bolton.

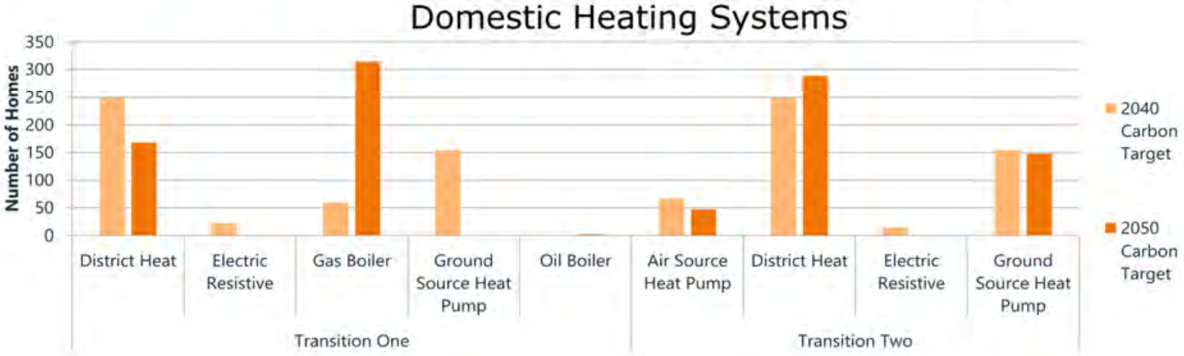












Radcliffe Analysis Area Fact File

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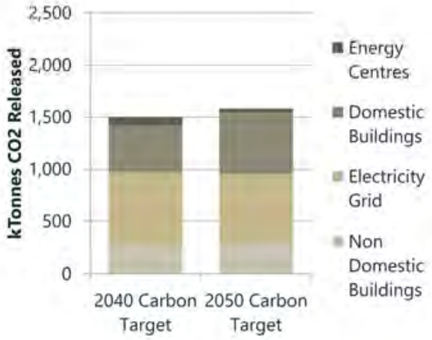
The second largest analysis area by size, this covers a large rural region stretching from the A58 down to the M60. This is one of the 3 areas identified as an ideal location for a limited amount of low carbon gas to be used in hybrid heat pumps.



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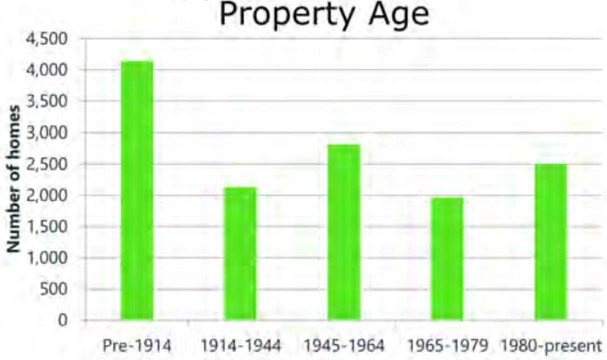
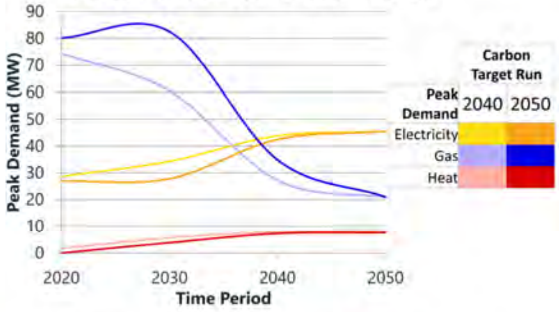


Peak Network Demand



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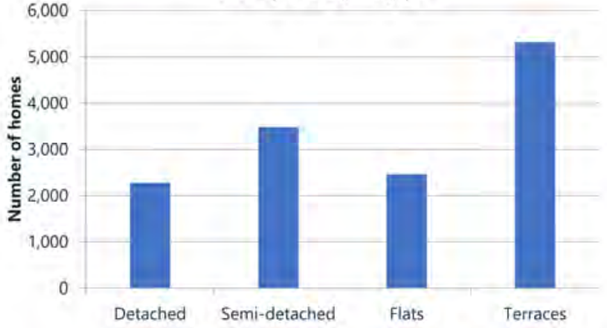
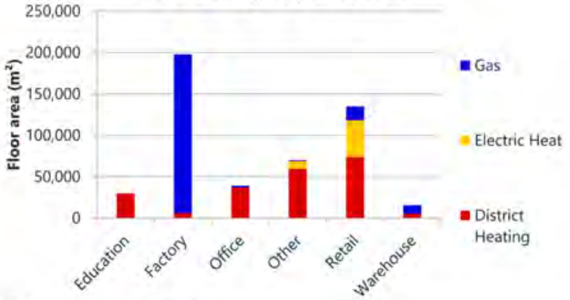
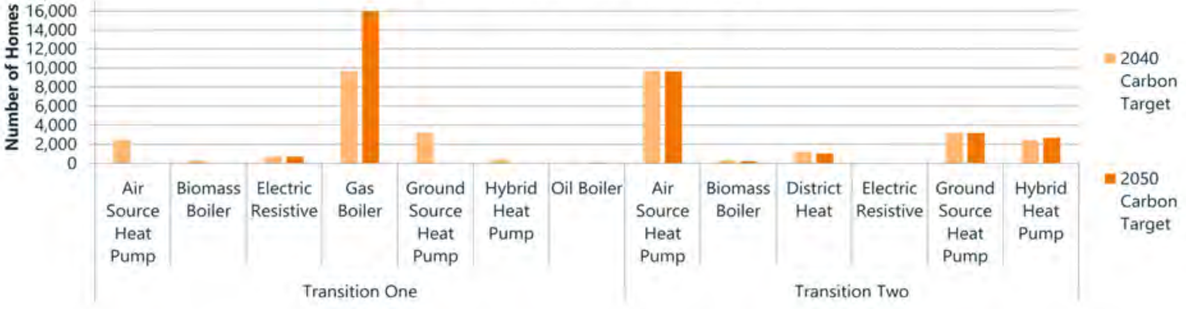


2050 Non-Domestic Building Heating Systems

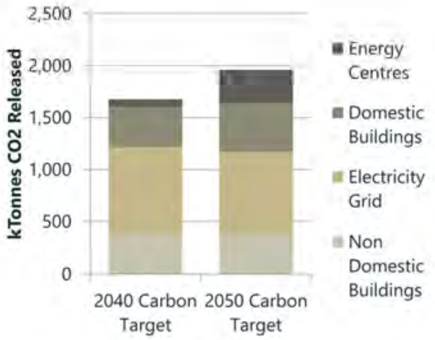


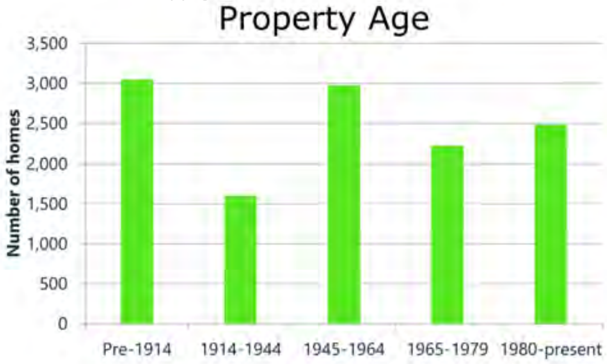
Domestic Heating Systems



Whitefield Analysis Area Fact File

This covers a large semi-rural area sitting between Bury and the M66.

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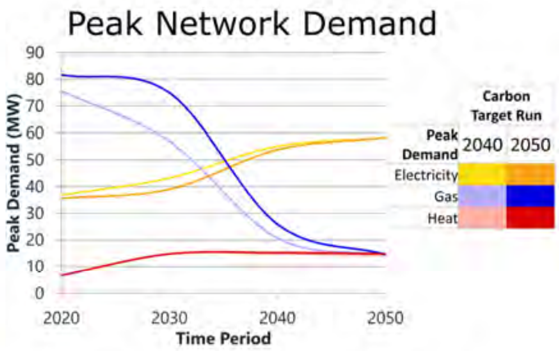
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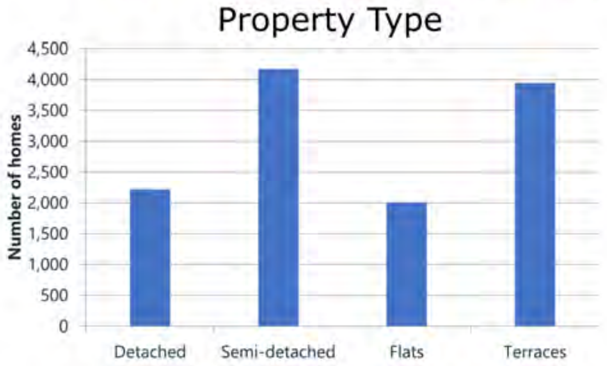
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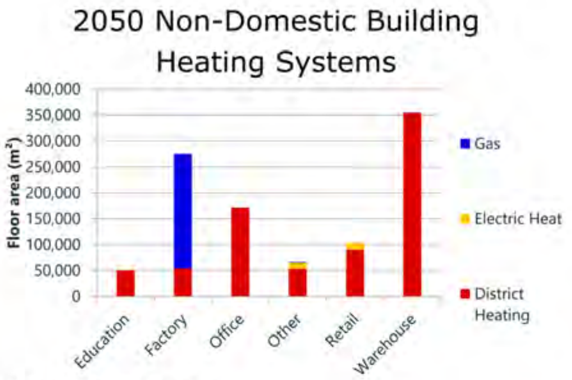
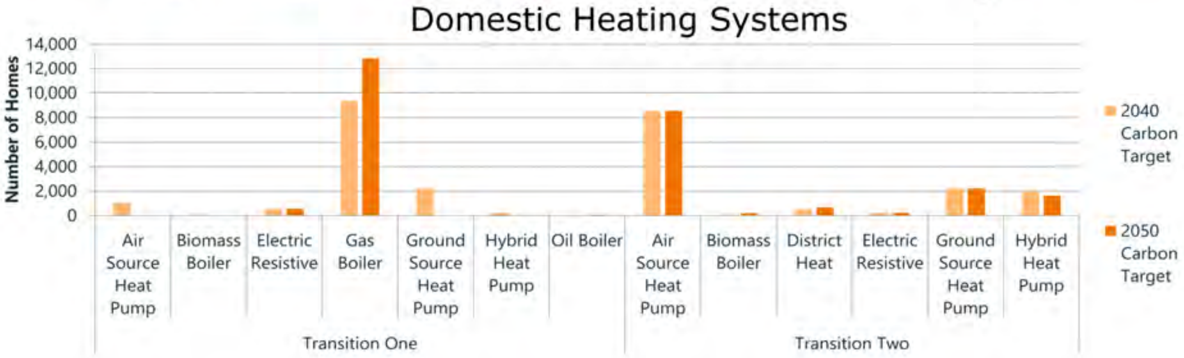

2050 Non-Domestic Building Heating Systems


Domestic Heating Systems

Prestwich Analysis Area Fact File

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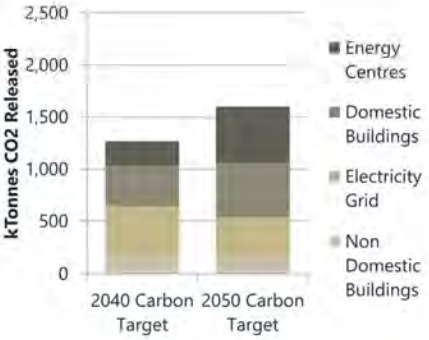
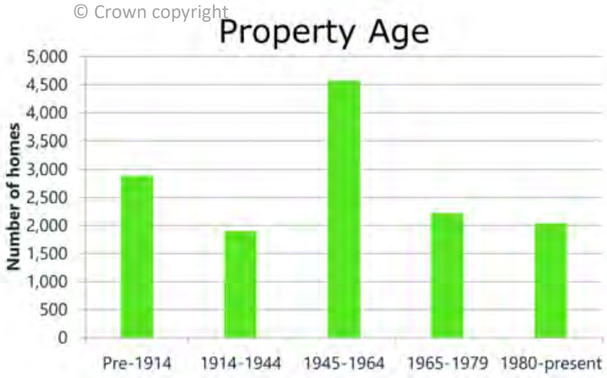
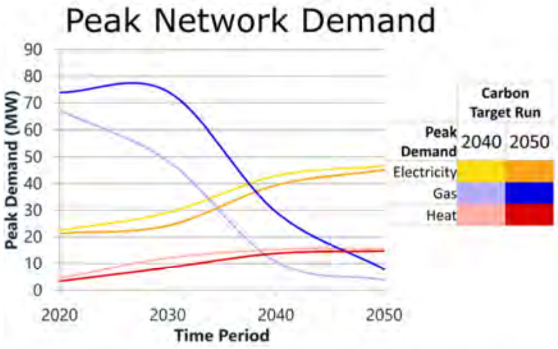
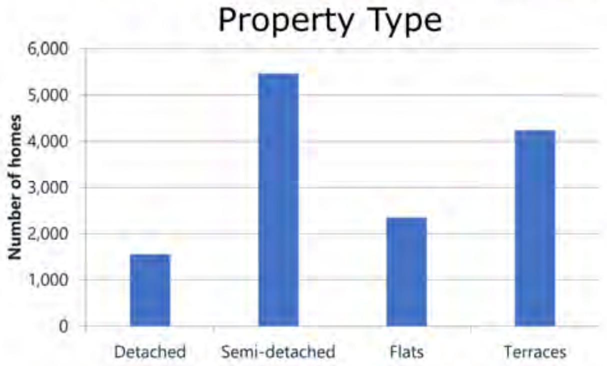
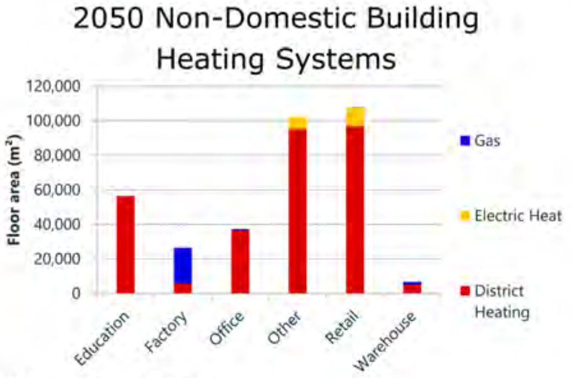
Sitting below the M60, this analysis area is the southern most part of Bury and the closest to Manchester city centre. This is one of the 3 areas identified as an ideal location for a limited amount of low carbon gas to be used in hybrid heat pumps.

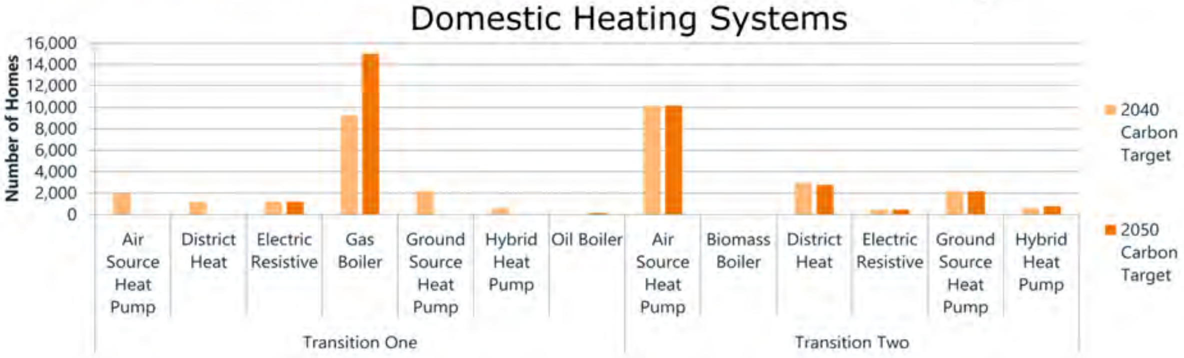












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Title:		Bury Local Area Energy Planning - Evidence Base
ETI Project Number:		SS9007
EEC Project Number:		ESC00049
Version:		Version 3.0
Status*:		Final
Restrictions**:		Public
Completion Date:		May 2018
Author		David Lee
Reviewer		Richard Halsey
Approver: (Approval Denoted by Signature)		Emma Harrison

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Revision History

Date	Version	Comments
21/03/18	0.1	For first ESC review
06/04/18	0.2	For second ESC review
18/04/18	0.3	For KSG review
08/05/18	0.4	For final ESC review
23/05/18	1.0	Final
29/06/18	2.0	After ETI review
13/07/18	3.0	Following further ETI comments

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