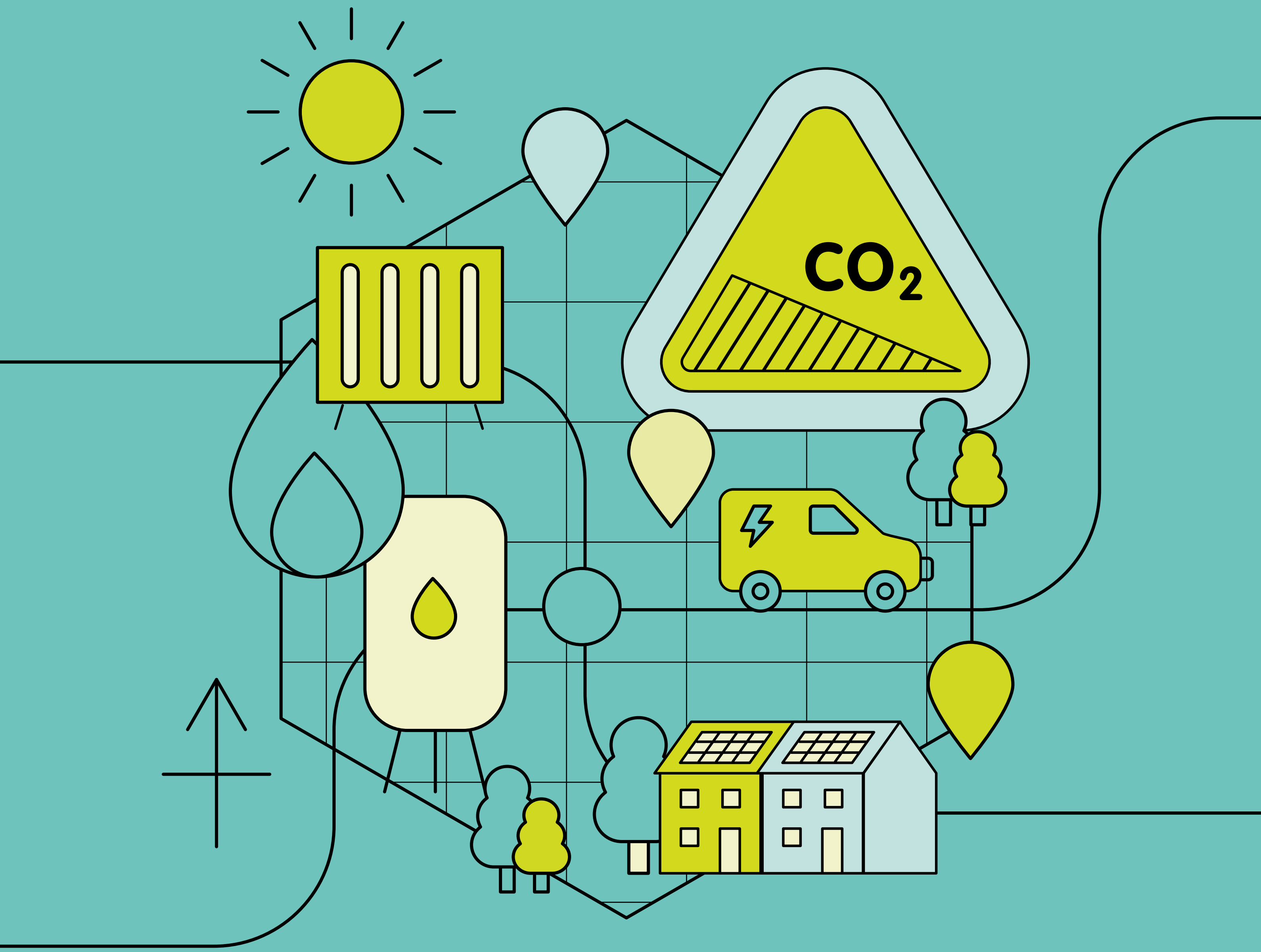
Energy Systems



Local Area Energy Planning:
Insights from three pilot local areas

energy technologies institute

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Acknowledgements

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- ETI industry and UK government members for their contributions and members of the Smart Systems and Heat programme strategic advisory group including Leeds City Council, Lancaster University, University College London and the Carbon Trust;
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"People, housing stock, energy networks and opportunities for change are all unique to an individual local area"

Local Area Energy Planning is vital to create resilient, local low carbon energy systems for the future, whilst also benefitting from the "Greatest industrial opportunity of our time" HM Government - The Clean Growth Strategy

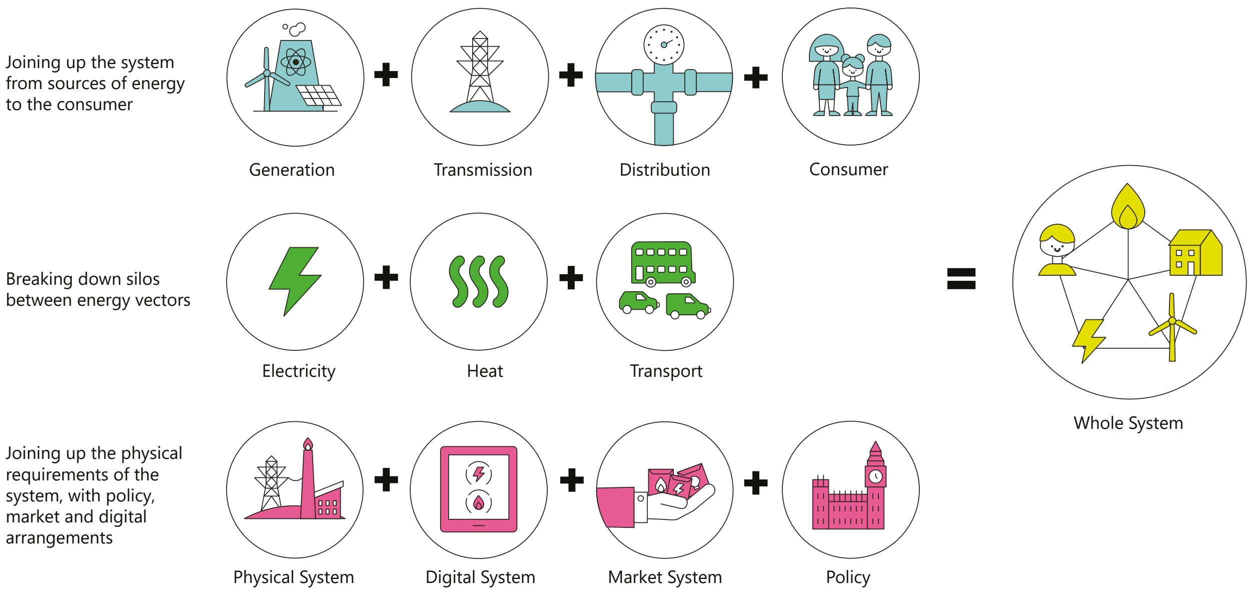
About Energy Systems Catapult

Energy Systems Catapult was set up to help navigate the transformation of the UK's energy system. We work across the energy sector to ensure businesses and consumers grasp the opportunities of the shift to a low carbon economy. The Catapult is an independent centre of excellence that bridges the gap between business, government, academia and research. We take a Whole Systems view of energy markets, helping us to identify and address innovation priorities and market barriers, in order to accelerate the decarbonisation of the energy system at the lowest cost.

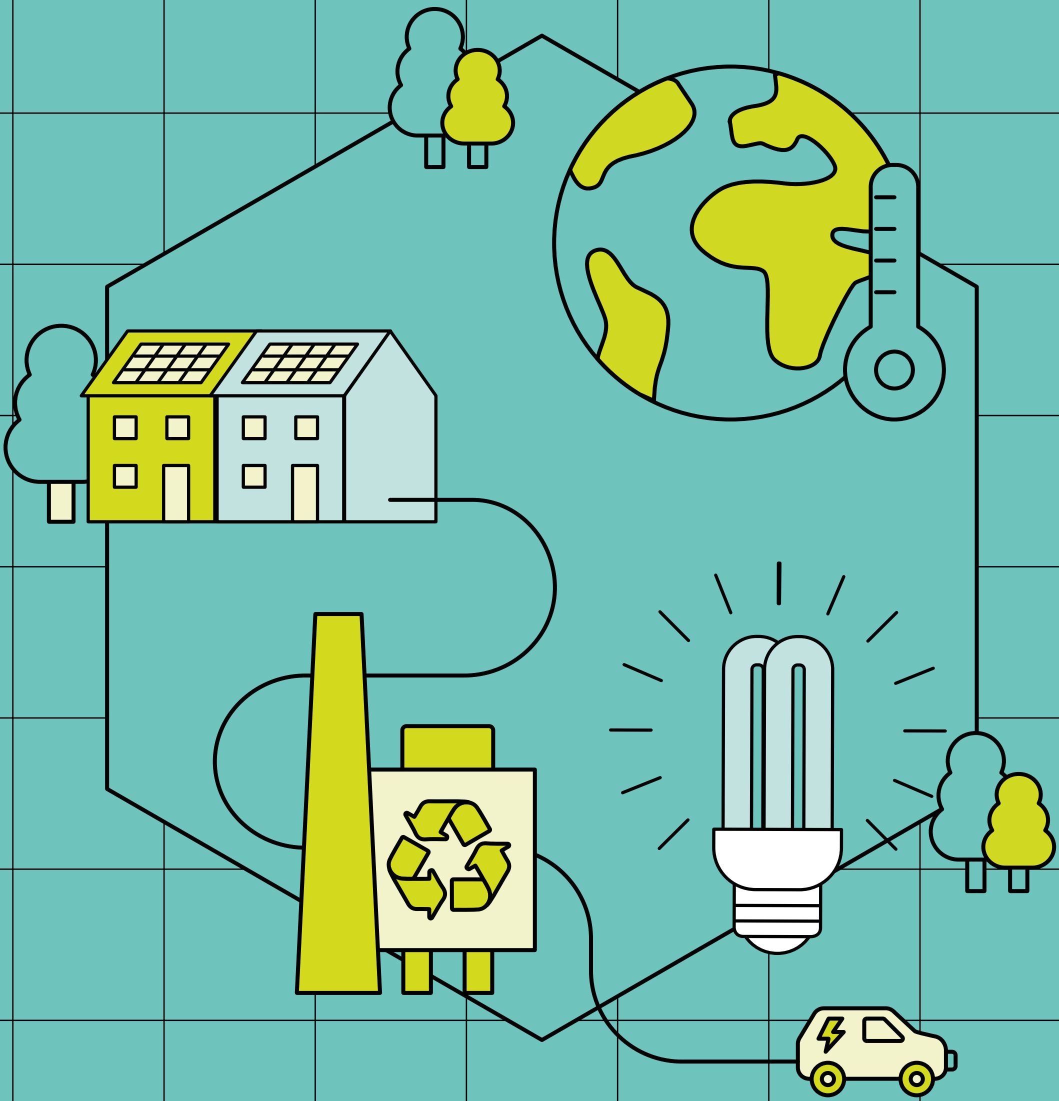
Our flagship Smart Systems and Heat (SSH) Programme works with government, local authorities, businesses and consumers to identify the most effective means of decarbonising the UK's 27 million homes. As part of the SSH Programme, the Catapult has worked with Newcastle City, Bridgend and GMCA councils to develop Local Area Energy Plans that define how each of these local authorities will transition to a low carbon future.

With 160+ staff based in our Birmingham headquarters with a variety of commercial, policy and technical backgrounds, we act as an 'impartial broker', helping to open up new markets and promote British skills and capabilities.

What is Whole Systems thinking?



Executive summary



Context

Energy is an essential part of national and local economies. It is required for everything from heating and lighting our homes and offices to transporting our goods and powering our industries. For the UK to reach its legally binding greenhouse gas emission reduction target of at least 80% by 2050, significant change is needed; both to our existing energy networks, and the heating systems and fabric of our homes and buildings.

National decisions and policies already have a direct impact on the options available both regionally and locally. For example, the rate of decarbonisation of national electricity generation will directly influence the carbon emissions associated with local electricity consumption.

Every local area is unique. Buildings, existing energy networks and people all vary between areas and the changes required to buildings and networks to effectively decarbonise our energy system will be specific to each area. Due to these local differences, it is not sensible to make all decisions at a national level. Forcing national solutions on local areas is likely to result in more expensive, less appropriate outcomes, and the decision on which solutions are best should be made at a local level.

Key findings

By achieving a low carbon economy we will create better places to live and work. Local Area Energy Planning provides the evidence, guidance and framework to enable the long-term transition to a low carbon energy system. It considers the unique characteristics of a local area and its existing energy system to guide the transition, aid decision making, prioritise resources, and support project and investment decisions.

Major changes to local energy networks and buildings will be needed to decarbonise heat, meet climate change goals and realise the benefits of low carbon transition. There will be significant benefits to be enjoyed from planning locally for this change, with decisions made now having a direct impact on future options. For example, extending a new or existing heat network could be more cost-effective than electrification of heating in individual homes. However, this will only be practical if the original network is designed to allow for future expansion. Planning for and executing these changes will take decades to complete. If the UK is to meet its 2050 carbon target, this process needs to start soon.

The change required to decarbonise will call for close coordination and decision making, involving different stakeholders at various scales. These include national and local government, network operators, energy providers, local communities and businesses as well as individual consumers. Any changes to a particular local area will need to be decided through a transparent, consensus-based process that includes all local stakeholders, including residents, businesses, local government, energy network operators and politicians. Currently, there is no structured planning process in place to manage this activity. 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.

Energy Systems Catapult has worked on three pilot local area studies exploring the decarbonisation of heat in buildings as part of the Energy Technologies Institute's Smart Systems and Heat (SSH) Programme. These are all able to achieve the near-complete decarbonisation of heat using existing technologies. The most cost-effective and desirable pathway for different local areas is influenced by a combination of factors, but all are heavily dependent on national energy system pathways – particularly the decarbonisation of national electricity supply.

There is no one size fits all solution and it will be important to retain optionality and flexibility in network and building choices as part of a Local Area Energy Planning process, supporting an affordable transition to low carbon heating. However, some common themes emerged from the pilot studies:

National policy

National government can enable local decarbonisation in several ways:

- A supportive policy and regulatory framework is needed for investment in future-proofed energy network infrastructure if this is to be planned, managed and delivered efficiently;
- Continued support for the vision to decarbonise national electricity generation by 2030 is required to achieve decarbonisation in local areas;
- Continued support for a wide range of different low carbon heating options, including heat networks, electrification, bio-fuel and hybrid solutions, is required.

Local planning

Local Area Energy Planning should include:

- Implementing a Whole Systems approach to aid an understanding of the options, inform the most appropriate combinations of network choices, fabric upgrades and heating systems in different places and allow more effective decision making;
- Setting clear local carbon budgets for emissions associated with buildings at levels above a 90% reduction on 1990 levels to support an acceleration in the decarbonisation of heat;
- Creating an open dialogue between key stakeholders, including local government and network operators, based on robust evidence to aid consensus-based decision making;
- Recognising there are just two windows of opportunity to change any individual heating system between now and 2050.

Local action

There are some local activities that could be undertaken immediately:

- Planning for the potential expansion of heat networks to connect existing homes and buildings over time;
- Planning and targeting domestic retrofit schemes;
- Delivery of new development to high standards of fabric energy efficiency and future-proofed to enable a transition to low carbon heating systems;
- Ensuring that sufficient skills and resources are available within local areas and network operators.

Development and demonstration

The following activities proved to be valuable across all local areas:

- Development and demonstration of integrated low carbon electric heating solutions;
- Development of smart heat storage solutions at domestic and network levels;
- Demonstration of hybrid heating systems as a potential transitional technology, particularly for hard to heat homes.

Data gathering

Improving knowledge of several areas would support the quality of Local Area Energy Planning:

- Investigation of the costs and impacts of low carbon gas, including hydrogen pathways, on local energy systems;
- Identifying sources of low carbon heat able to supply networks in local areas;
- Better understanding of the types and uses of non-domestic buildings and the options and costs to decarbonise them.

There is no single technology that can be used for cost-effective decarbonisation of heat. Commitment to a single decarbonisation pathway for domestic heat, such as the electrification of heat or repurposing of the gas grid for hydrogen, is considered a very high-risk strategy and unlikely to most cost-effectively meet the UK's 2050 energy and climate change goals.

Many of the technology building blocks needed to decarbonise heat already exist or are in development, and the integration of low carbon heating technology into more compelling customer propositions –including the development of new business models – represents a significant opportunity for innovation.

We have found that clean energy generation in local areas, such as combined heat and power generation and solar PV, alongside electricity storage, are likely to play a role in future local energy systems. However, local areas are expected to remain dependent on secure supplies of decarbonised national electricity by 2050.

Repurposing the gas grid for hydrogen is a potentially important and valuable option to decarbonise domestic heat, however, availability of data hasn't allowed this to be investigated in detail for the three local pilot study areas. Understanding the costs and impacts of a hydrogen pathway in different local areas is an important part of a structured approach to Local Area Energy Planning as well as in the context of national energy strategy.

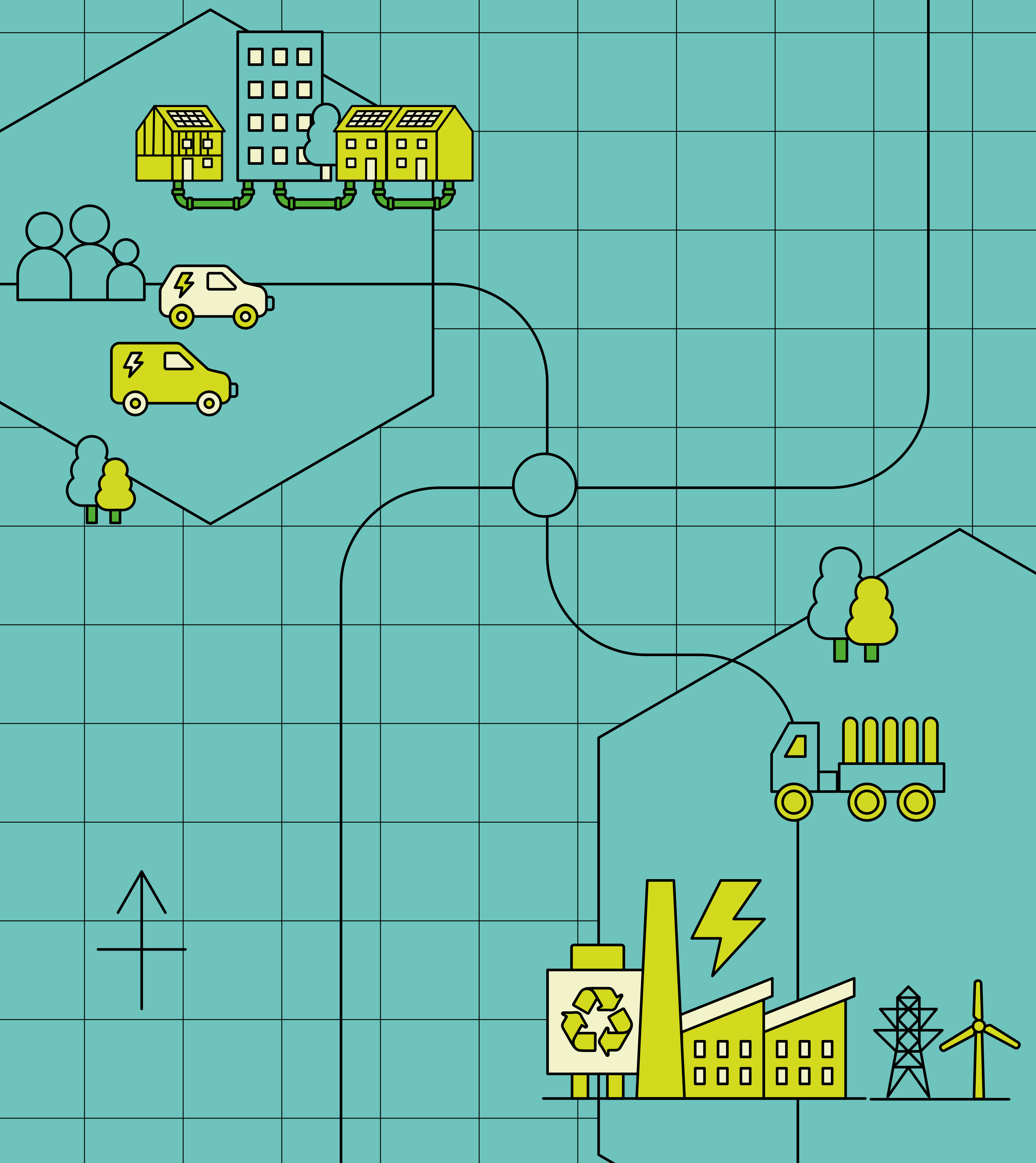
Decarbonisation of domestic heating will influence individual private homeowners who have the right to decide for themselves what changes they wish to make to their homes. To make changes to the way they heat their homes, homeowners must be provided with certainty that the choices they make will be supported in the long term with networks built and maintained to supply the energy they need, in sufficient quantities, at an acceptable cost.

The total system cost of energy, operating existing networks, changing heating systems and maintaining building fabric, even under business-as-usual, will be very significant (£6b-£12b for the pilot local areas). The additional costs of decarbonising local areas compared to business-as-usual are likely to be modest if well planned (12% average increase for our pilot studies). The cost of heat network development is likely to be one of the most significant factors in defining the least cost solution in any local area. National and local policies can help ensure that the impact on consumers, including the vulnerable, is well managed and the opportunities for UK industry can be realised.

Transitioning homes from natural gas to alternative low carbon heating solutions is likely to increase the cost of energy for heat and lead to varying impacts on consumers at different times during the transition. There is a key challenge in ensuring that these changes do not affect fuel poor households, who often live in the most inefficient houses and are most exposed to the impact of increased energy costs.

"A combination of technologies and networks will be needed to reduce the carbon emissions associated with heating"

1. Introduction



Energy is an essential part of national and local economies. It is required for everything from heating and lighting our homes and offices to transporting our goods and powering our industries. For the UK to decarbonise, significant change will be needed, both to the existing energy networks, as well as building heating systems and fabric.

Every local area is unique – buildings, existing energy networks and people all vary between areas – and the changes needed to decarbonise will be specific to each area. Such a significant transition will call for close coordination between many different stakeholders, including local and national government, network operators, energy providers, local communities and businesses, as well as individual consumers.

Currently, there is no structured planning process in place to manage this transition. In urban planning, "masterplans" establish a long-term view of how an urban area should be developed, providing a clear and consistent framework for change, rather than stipulating exactly what is going to be built where and when at a building-by-building level. To decarbonise the UK's energy system efficiently, and at least cost, Local Area Energy Planning can provide a similar long-term view for local energy systems.

Local Area Energy Planning can provide the evidence, guidance and framework to enable the long-term transition to a low carbon energy system. This can effectively consider the unique characteristics of a local area and its existing energy system to guide the transition, aid decision making, prioritise resources, and support project and investment decisions.

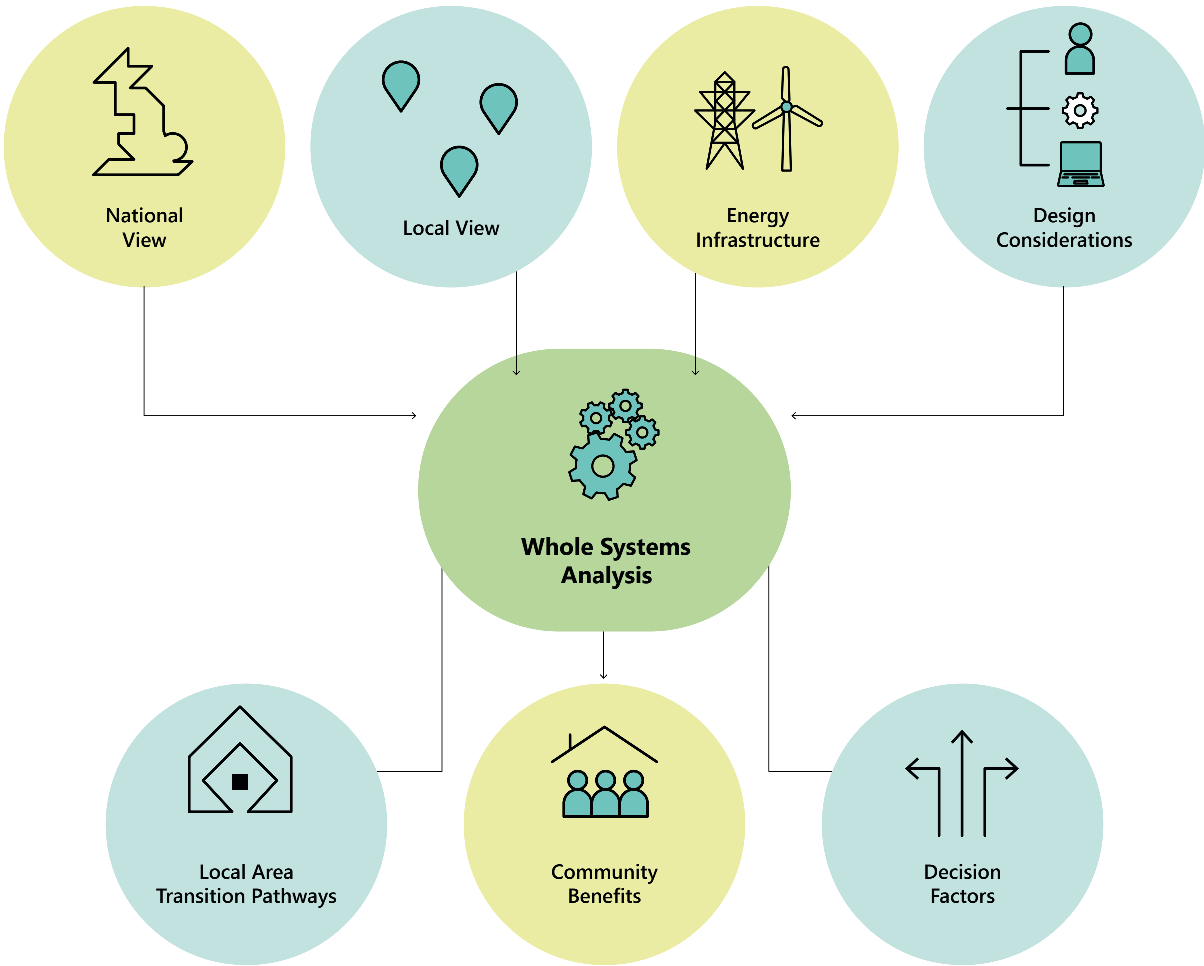
1.1 EnergyPath Networks

In order to investigate the lowest cost decarbonisation pathways in a local area and understand the form that a future Local Area Energy Planning process might take, the ETI has developed the EnergyPath Networks analysis framework (Figure 1) as part of the Smart Systems and Heat (SSH) Programme. This has been used by ESC in three pilot Local Area Energy Planning projects. It is underpinned by data from a range of sources, including publicly available data, information from partners in each of the local areas and ETI technology development projects, with additional inputs from the ETI's national Energy System Modelling Environment (ESME).

The framework can be used to explore different future scenarios by modifying the input data (for example the cost or carbon content of different sources of energy). Each set of input data will produce a different transition pathway. This document refers to a set of input data and the associated transition pathway as a scenario; these are not considered to be the correct solution for a local area but provide evidence to enable informed debate and decision making.

In all cases it is possible to include future development planned for the local area such as new housing, industrial or office buildings and the redevelopment of brown field sites or existing locations. In this way the influence of economic development on growth and the associated energy demands and network requirements are captured and incorporated into the energy planning process.

Figure 1: Overview of EnergyPath Networks



EnergyPath Networks is a Whole Systems optimisation analysis framework. It uses optimisation techniques within 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 the decarbonisation of heat and energy used by buildings at a local level. Whilst the influence of electric vehicle charging on electricity networks is considered, wider transport emissions are not. EnergyPath Networks outputs are used to explore options and aid consensus building with stakeholders and (in the future) local communities. This can allow informed and evidence-based decision making by key stakeholders.

The analyses are set in the context of national energy strategy and use scenarios created with input from local stakeholders, including:

- Integration and trade-off between gas, heat and power and their associated networks;
- Consideration of the energy supply chain, including energy production, storage and use with options to build, upgrade or decommission assets. This incorporates energy networks as well as building fabric and heating systems;
- The ability to understand 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 to single thousands of dwellings (potentially finer where required);

- Pathways produced showing changes in each decade up to 2050;
- Identifying the least cost decarbonisation measures, creating confidence in progressing in the near term, whilst providing a view out to 2050 to ensure long-term resilience when making near-term decisions to mitigate the risks of stranded assets;
- Identifying where further evidence is required to enable planning for the medium to long term.

1.2 Local pilot areas

The Catapult has worked with key stakeholders in three different local areas to pilot a Whole Systems approach to Local Area Energy Planning. The aim is to understand how a more effective Whole Systems approach might be undertaken. The initial focus has been on the challenge of decarbonising heat, to understand what types of information are needed to enable a mutual understanding of the options and how decisions might be made.

It has not been intended to define a single future pathway to decarbonise heat in a given local area that could be imposed. Rather, to enable the production of more robust evidence in the form of data and analyses that can help local stakeholders explore and understand the options, the robustness of solutions against different variables and the implications of different decisions. This can then enable a more effective Local Area Energy Planning process, supporting decision making at the right time and place in relation to building and energy networks.

The pilot projects worked with the following stakeholders in each area:

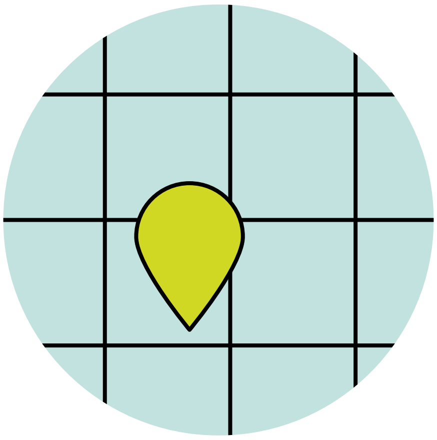
- Bury District Council, Greater Manchester Combined Authority, Electricity North West and Cadent;
- Bridgend County Borough Council, the Welsh Government, Western Power Distribution and Wales & West Utilities;
- Newcastle City Council, Northern Powergrid and Northern Gas Networks.

"A new gas boiler has a circa 15 year lifetime, meaning there are only one or two opportunities to replace it with a low carbon alternative before 2050"

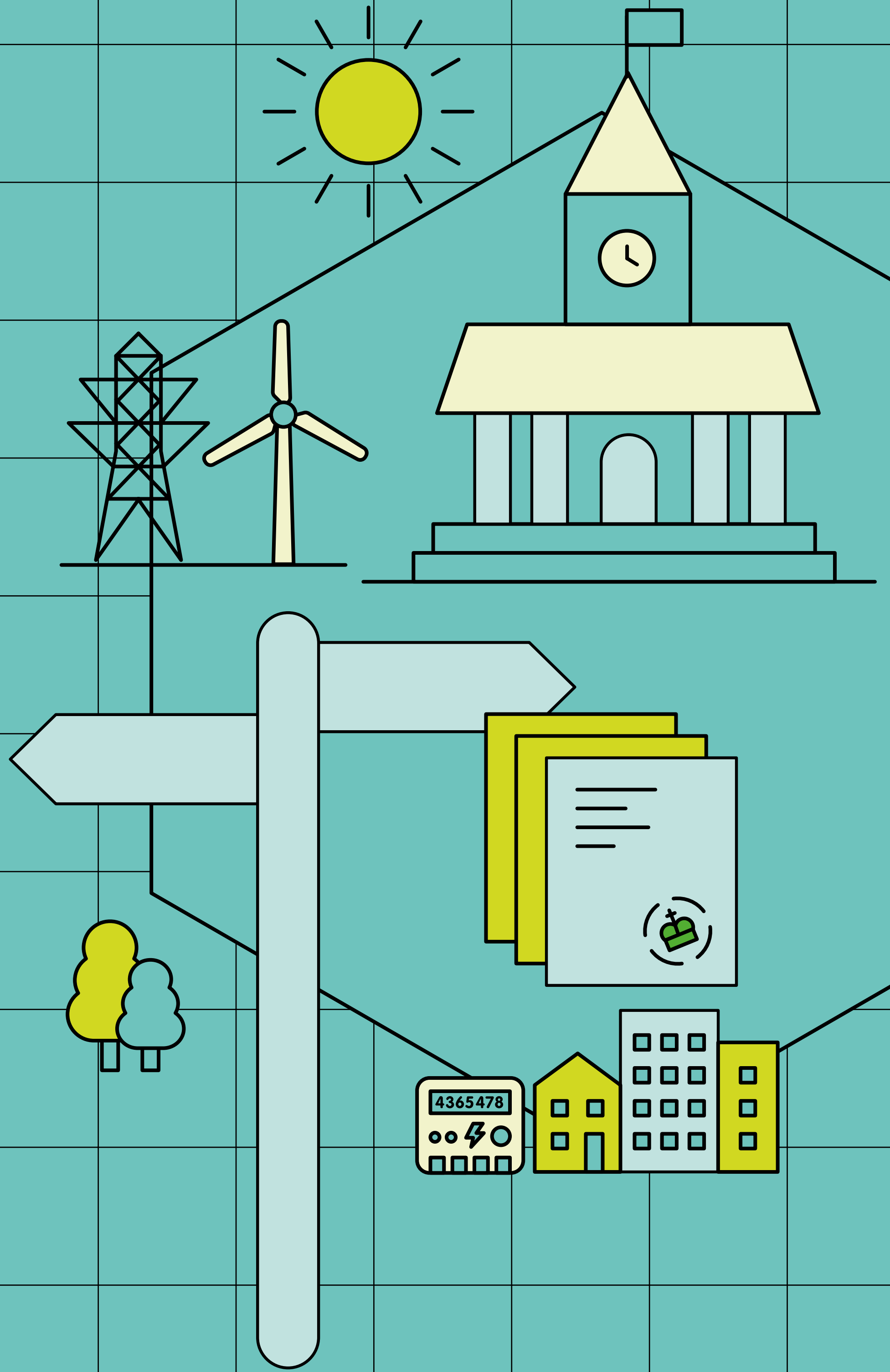
1.3 Report structure

This report discuses learnings from the three pilot studies along with any conclusions that have been reached. It is structured into the following key chapters:

- **Chapter 2** explores the importance of Local Area Energy Planning in decarbonising domestic heat and the rationale for an evidence-based, Whole Systems approach to support future network and building choices. It shows how local areas are all different and how evidence-based planning can inform the energy choices needed by the mid-2020s and beyond;
- **Chapter 3** focuses on the heating system and building options for the decarbonisation of heat, as well as important factors to consider when designing solutions;
- **Chapter 4** looks at the similarities and differences between solutions across local areas and how varying factors influence what is the most cost-effective combination of solutions. It highlights the importance of a diverse mix of heating system options and considers the implications for energy networks and their operators;
- **Chapter 5** considers the social dimension of Local Area Energy Planning and how local decision making, together with more effective Local Area Energy Planning, can inform future energy system designs and pathways to decarbonise heat. It also considers the factors that might affect local decision making and the opportunities for local action.



2. Importance of Local Area Energy Planning



2.1 Why is Local Area Energy Planning important for the decarbonisation of heat?

Evidence based Local Area Energy Planning provides the ability to develop robust plans for the transition of a local area's energy system, improving engagement, awareness of change and enabling decision making.

The ETI's SSH programme supported the development of future-proofed and economic local heating solutions for the UK, enabling us to tackle the decarbonisation challenge whilst providing solutions designed with consumers at the centre. From a systems perspective, the most cost-effective approach is to tackle the decarbonisation of power first, followed by the decarbonisation of heat, accompanied by the continual decarbonisation of the transport system.

In the UK, heating is the largest single user of energy and the largest emitter of greenhouse gases. Government figures show that heating accounts for around 45% of energy use. This is through a combination of space heating (the heating of rooms), the heating of water, the use of heat for cooking, as well as for industrial processes, making its decarbonisation very complicated. The production of heat accounts for around 30% of the UK's carbon emissions today. To meet the UK's climate change targets of reducing emissions by 80% of 1990 levels by 2050, we must decarbonise heat. Failure to do so will mean a failure to meet climate targets. Power is provided though national infrastructure and is most appropriately decarbonised at a national scale. In contrast, the provision of heat is delivered through local infrastructure, therefore decarbonisation should be managed at a local level.

Local Area Energy Planning can consider the key inherent characteristics of any given local area and from that establish the low carbon energy networks, building energy efficiency and heating systems needed to deliver local carbon targets. In the absence of a collective agreement on local energy system designs, there is a risk that solutions are developed independently and will inevitably lead to increased system costs. The timescales for network planning and the costs involved in network investment, when taken together, require coordinated action and an agreement on local area plans.

2.2 Why is a local approach needed?

For individual homeowners to make changes to the way they heat their homes, they must be provided with certainty that the choices they make will be supported in the long term with networks built and maintained to supply the energy they need, in sufficient quantities, at the time they need it, and at an acceptable cost.

Private owner occupiers who have the right to decide the changes they wish to make to their homes currently account for around 17.7m houses in the UK[1]. Decarbonisation of domestic heating will have a direct impact on them. Local Area Energy Planning can help to develop pathways that are attractive to local people and communities and can provide a mechanism for engaging different stakeholders in the development process. Any changes to a particular local area will need to be decided through a transparent, consensus-based process that includes local stakeholders, including residents, businesses, local government, energy network operators and politicians.

The people, housing stock, energy networks and opportunities for change are all unique to an individual local area.

Local Area Energy Planning is important in enabling the delivery of cost-effective local energy system designs because all areas are different, therefore a centrally planned solution is unlikely to be appropriate areas across all.

1 https://www.gov.uk/government/statistical-data-sets/live-tables-on-dwelling-stock-including-vacants

Decisions on the most appropriate networks for different areas cannot be made using simple metrics as multiple local factors can influence choices. For example, in a given spatial area many small demands could make transitioning homes from gas to a heat network technically feasible. However, the same total demand spread over a wider area could make heat networks less cost-effective from a systems perspective. Also, features of the current housing stock and electricity network may make low carbon electric heating solutions preferable in an area, even though it has a high heat density that might typically be considered well-suited to the development of a heat network, if considered in isolation. An example might be dense, thermally efficient and modern housing switching from electric storage heating to more efficient electric heat pumps. Lower levels of peak heat demand and the capacity of the local electricity network mean that only modest investment might be needed to reinforce electricity networks, giving much lower Whole Systems costs when compared to building and connecting these homes to a heat network.

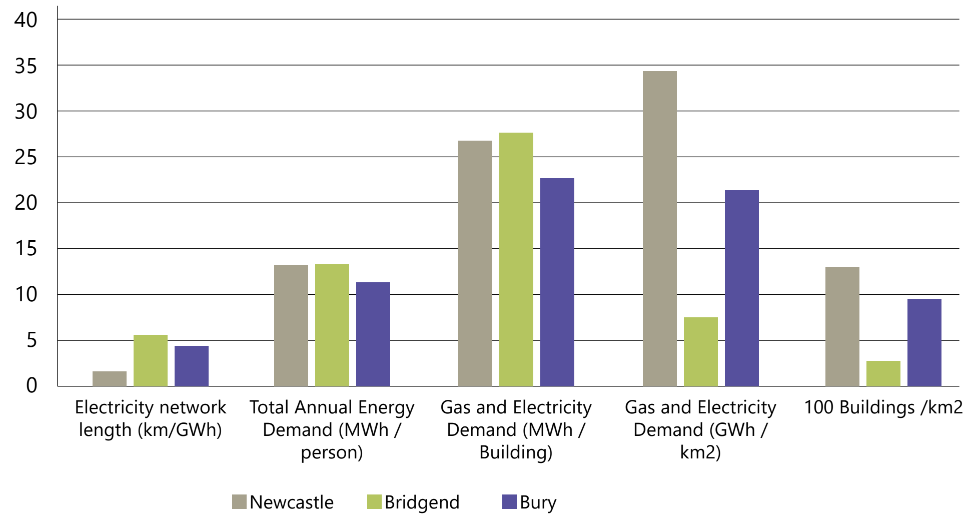
These distinct characteristics are evident in the three local authority areas with which the Catapult has been piloting a Local Area Energy Planning process and are summarised in Table 1.

Table 1: Characteristics of three study areas

Item	Newcastle	Bridgend	Bury
Area (km2)	113	255	99
Population	293,000	142,000	188,000
Domestic Buildings	127,000	62,000	83,000
Non-Domestic Buildings	18,800	5,600	9,500
Domestic Buildings Off Gas	10,470 (8%)	2,060 (3%)	2,420 (3%)
Electricity Network Length km	1,840	3,340	2,610
Number of HV Substations (33kV-11kV)	17	10	9
Number of LV Substations (11kV-400V)	769	759	570
Annual Gas Demand 2016 GWh	2,698	1,259	1,474
Annual Electricity Demand 2016 GWh	1,196	616	627
Annual Greenhouse Gas emissions ktCO2 2015	1,385	705	747

Since the areas have different population levels and varying numbers of buildings, it would be expected that they have different energy consumption and levels of carbon emissions. However, if the energy-related characteristics of the local areas are normalised by population or other factors, there are still significant differences in their normalised characteristics. Some examples are shown Figure 2.

Figure 2: Normalised characteristics for three different areas



Bury has less energy demand and carbon emissions per head of population than either Newcastle or Bridgend. This is related to how energy is used in the different local areas and is partially related to the types and volumes of industrial energy use. The spatial location and distance between buildings influences both the length of networks needed to deliver energy and the building density as shown in Figure 2. These influences are also shown in the energy density (Energy Demand / km^2).

The energy required to heat a building will depend on how it was constructed (related to building age), its type and size as well as how it has been modified over time. Comparison of the housing stock of the three local areas (Figure 3 - Figure 5) highlights significant differences in these characteristics. In general, the housing stock in Bridgend is younger and larger than that in either Bury or Newcastle. Newcastle has a much higher proportion of small flats than Bridgend and Bury.

Figure 3: Comparison of housing stock age in 3 different areas

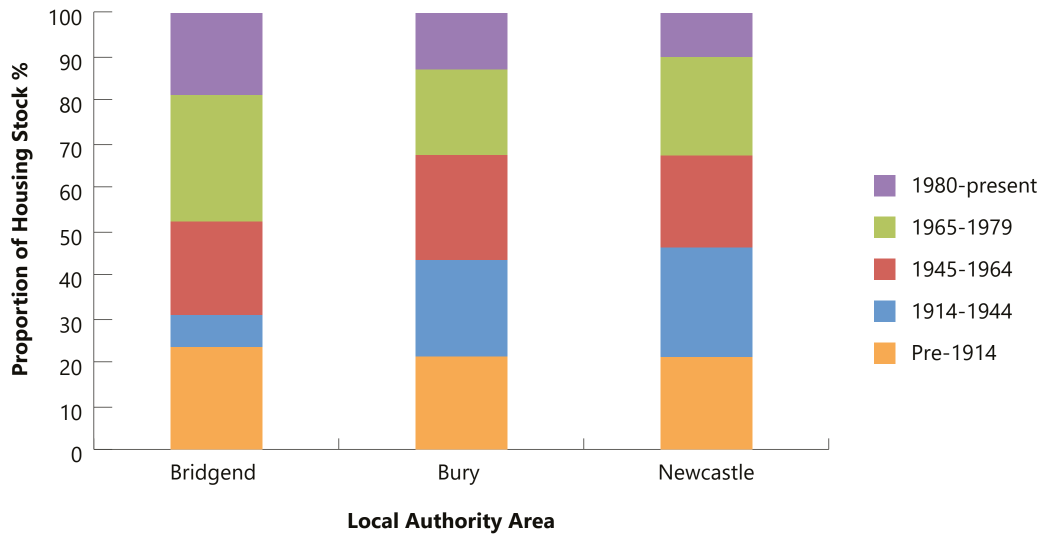


Figure 4: Comparison of housing stock type in 3 different areas

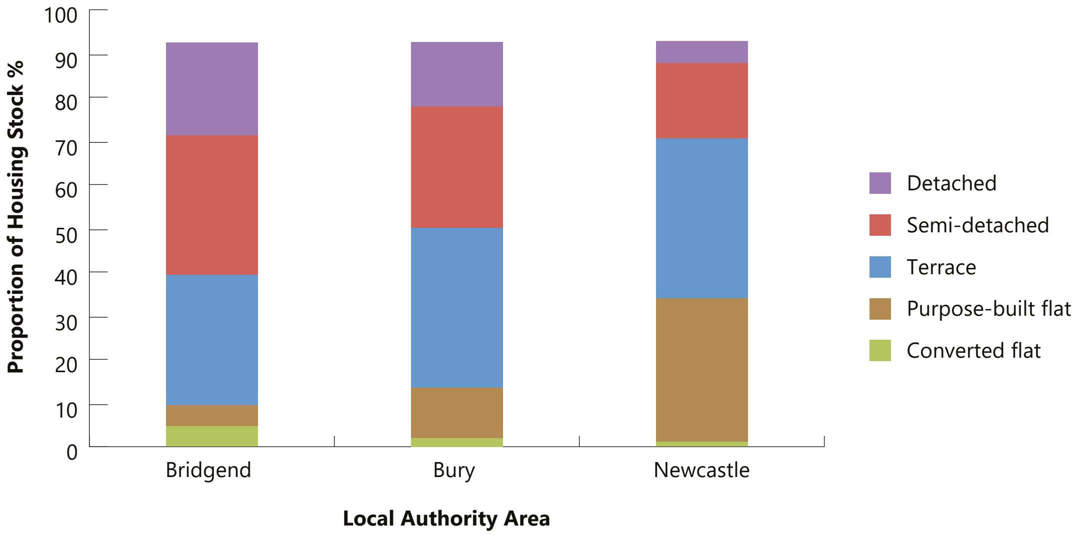
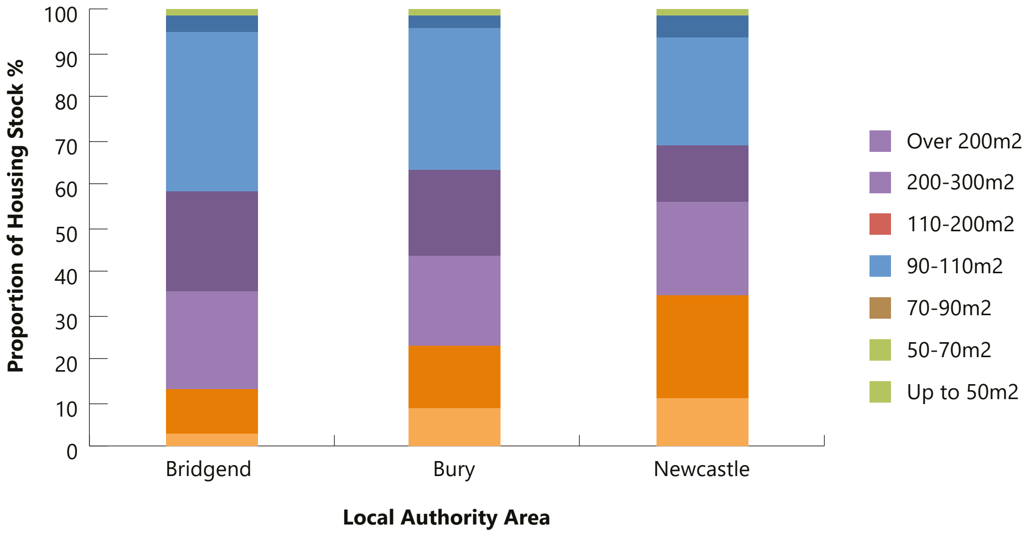


Figure 5: Comparison of housing stock floor area in 3 different areas

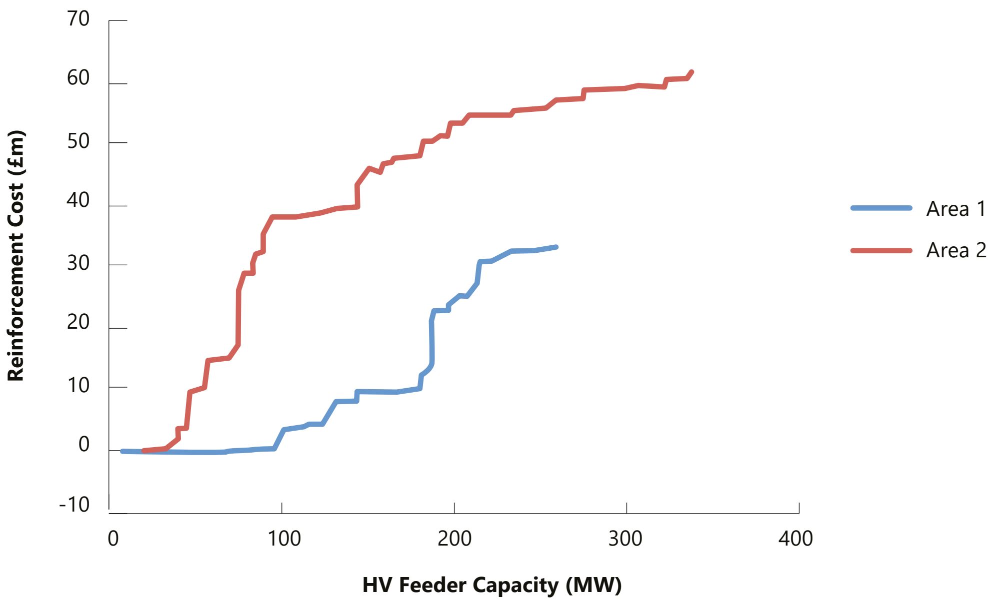


An example of how electricity network reinforcement costs can vary across local areas is given in Figure 6. This shows the estimated total cost of reinforcing high voltage (HV) feeders[2] in areas served by two different HV substations in Bridgend. Current network capacity is shown by the point at which cost is incurred to increase capacity. Two features are apparent:

1. Area 1 has nearly 100MW of current capacity compared to around 40MW of current capacity in area 2;

2. The estimated cost of increasing network capacity in area 2 is significantly higher than in area 1.

Figure 6: HV feeder network reinforcement cost curves for two areas in Bridgend



These differences are primarily due to the different network lengths in the two areas as well as other characteristics of the areas. Networks are significantly more expensive to reinforce in inner city areas where services are congested and greater disruption is caused.

Given the variations between and within local areas it is likely that the most appropriate low carbon technical solutions for each area will be different.

2 These are the wires which typically carry electricity at 11,000 volts in local electricity networks.

2.3 What national support is there for Local Area Energy Planning?

The UK Government, Scottish Government and Welsh Assembly Government all support the concept of local energy planning.

The Clean Growth Strategy[3] makes specific reference to local area land use planning and states that "moving to a productive low carbon economy cannot be achieved by central Government alone; it is a shared responsibility across the country. Local areas are best placed to drive emission reductions through their unique position of managing policy on land, buildings, water, waste and transport. They can embed low carbon measures in strategic plans across areas such as health and social care, transport and housing".

The Strategy adds that "many of our stakeholders have called on us to take a "Whole Systems approach to the decarbonisation of energy infrastructure systems. We agree with this principle and will position the UK as a leader in clean and efficient power, transport and heat through an integrated approach to decarbonising these increasing connected systems".

The Scottish Energy Strategy[4] (December 2017) sets a 2020 vision for energy in Scotland as "a flourishing, competitive local and national energy sector, delivering secure, affordable, clean energy for Scotland's households, communities and businesses." The vision is guided by three core principles namely: A Whole Systems view; an inclusive energy transition; and a smarter local energy model.

The Scottish Energy Strategy sets out its intent to develop a Local Energy System Position Paper in the near future, containing detailed principles such as local heat and energy efficiency strategies in use at a local level. This will create a strategy to guide investment in energy efficiency and heat decarbonisation and will be led by local authorities working closely with their communities. The intention is to set out a long-term prospectus for investment in new energy efficiency, district heating and other heat decarbonisation programmes.

'Energy Wales – A Low-carbon Transition'[5] was published by the Welsh Government in March 2012. The document makes references to a 'Whole Systems' transition to low carbon energy, covering electricity, heating and transport. The Environment (Wales) Act 2016[6] sets a minimum of 80% emission reduction by 2050. This will be achieved through the setting of interim targets for 2020, 2030 and 2040 and 5-yearly carbon budgets. The Welsh Government will be laying regulations around its interim targets and first two carbon budgets by the end of 2018, and shortly afterwards by publishing a Low-carbon Delivery Plan.

Across all pilot local areas there was some lack of confidence in central government's ability to lead the change to low carbon heating. There was also concern around policy makers and regulators' ability to make the changes required, to provide sufficient long-term stability for local stakeholders to plan, or for markets to be enabled in delivering the scale of change needed.

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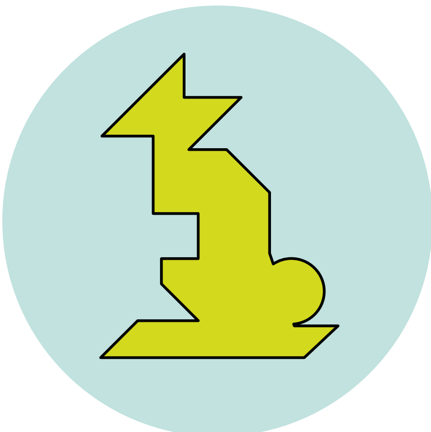
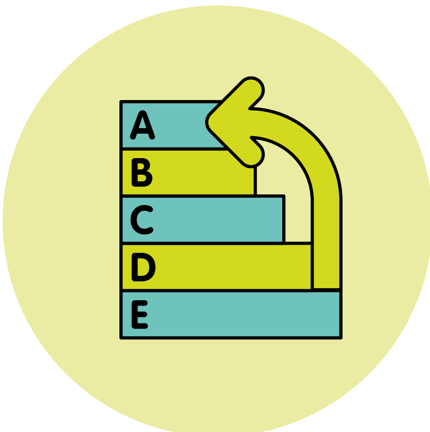
3 https://www.gov.uk/government/publications/clean-growth-strategy
4 http://www.gov.scot/Publications/2017/12/5661
5 http://gov.wales/topics/environmentcountryside/energy/energywales/?lang=en
6 http://gov.wales/topics/environmentcountryside/consmanagement/natural-resources-management/environment-act/?lang=en

Despite the high-level support for local area planning there is a barrier to achieving energy system change at a local level due to a lack of consistency in central government's national energy policy. Examples include the loss of the Department for Energy and Climate Change (there being now no stand-alone government department for energy or climate change); government back-tracks on commitments to zero carbon homes; the introduction of highly restrictive planning policies which have placed a fundamental brake on the future deployment of onshore wind in England (including barring access to Contracts for Difference for onshore wind); and the introduction of very supportive planning policies for unconventional gas extraction. Together with a strong continued priority in the delivery of housing infrastructure, these contribute to a lowering of the priority given to climate change action and decarbonisation and inhibit effective local policy making.

One of the main barriers to low carbon transition is that current local government structures and regulatory frameworks do not have a formal 'place' for the adoption of local energy strategies, unlike other spatial plans. This means there is no formal process to submit energy plans for approval and sponsoring local officers must try to gain consensus on a voluntary basis despite focus being much easier to achieve where councils are obliged to have formal processes, strategies and spatial plans.

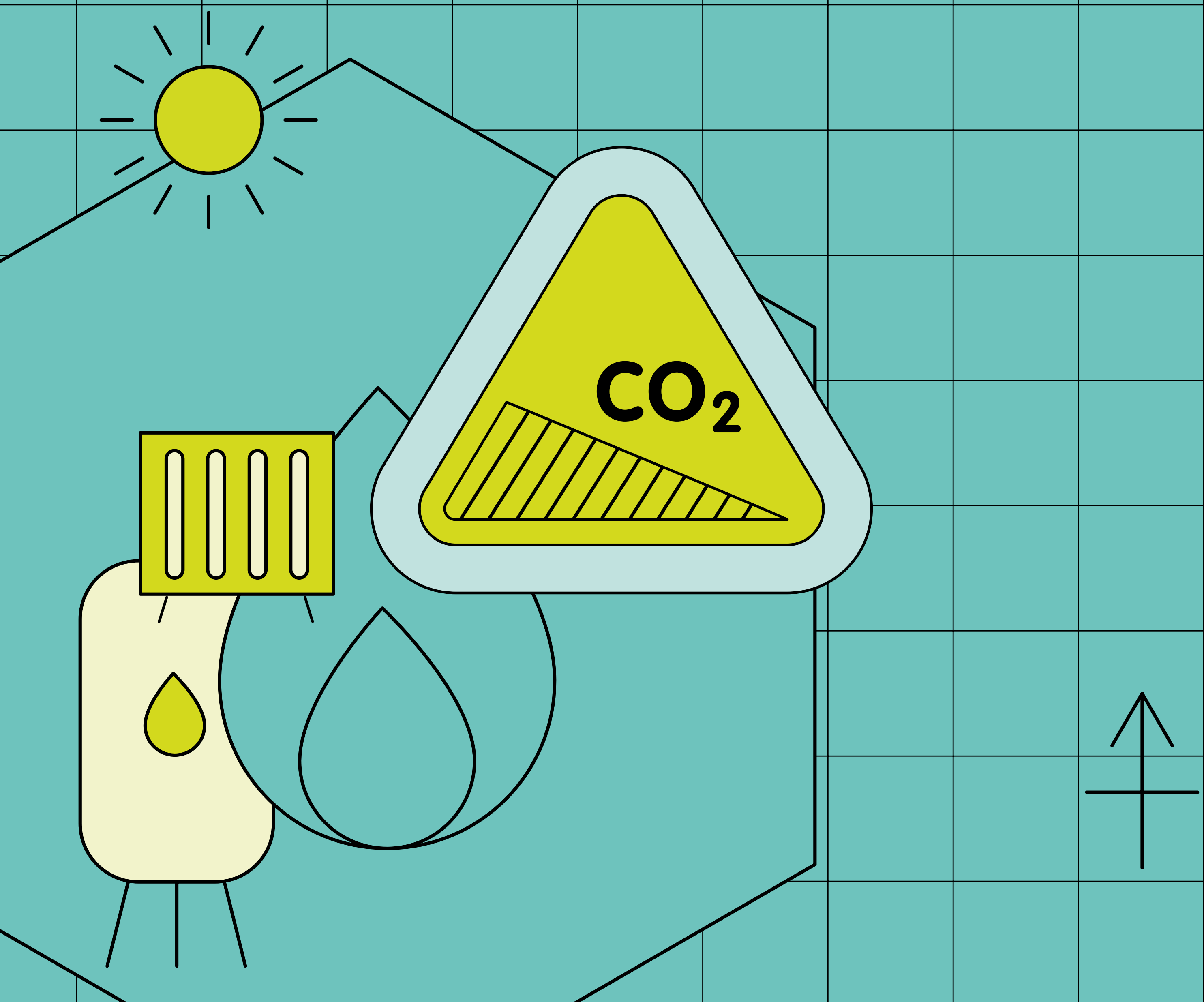
An example where clear local government responsibility has influenced action on energy is the 2015 fuel poverty strategy for the UK[7]. This has a target to "ensure that as many fuel poor homes in England as is reasonably practicable achieve a minimum energy efficiency rating of Band C by 2030". This requirement has a strong influence on local authority action to improve the thermal efficiency of fuel poor housing and drives action. Without similar requirements for the wider energy system, the agency of local authorities to achieve change is limited.





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

3. Options and choices to decarbonise heat



3.1 What are the current solutions for heating homes and buildings?

Virtually all buildings in the UK are connected to the electricity network and supplied with electricity that is predominantly generated at a national level, before it is transmitted to local areas. Natural gas and gas fired central heating systems dominate local energy systems across most of the UK, including our pilot study areas, and are used in homes for space heating and hot water. All local areas have a proportion of homes that are off-gas and supplied by either conventional electric heating, oil, or bio-fuel in different forms and Liquefied Petroleum Gas. Heat networks are being developed in many local areas, however they currently only connect a small proportion of homes in one of the three local pilot areas.

However, local energy systems are changing, with increasing levels of generation in the form of gas fired combined heat and power plants, in addition to the installation of solar photovoltaic (PV) and solar thermal systems. Government incentives in the form of the Renewable Heat Incentive, have also led to the replacement of some fossil fuel-powered heating systems, with alternatives such as biomass boilers and electric heat pumps.

The energy infrastructure for heating our homes and buildings in any given local area is interdependent on the energy infrastructure for transport and industry.

3.2 What is important in designing local solutions to decarbonise heat?

Different combinations of low carbon heating solutions can be deployed to decarbonise heat. The heating system choices made by consumers will have an impact on local energy networks.

EnergyPath Networks can be used to compare many possible future scenarios, complete with defined constraints, to investigate the lowest cost and least-risk pathway to decarbonise a given local area. For each scenario, a different combination of heating solutions will result. This allows uncertainty to be investigated by repeating the process many times using different input assumptions. These may include the cost or carbon content of energy imported to the study area, or the cost/efficiency of different technology options. It is then possible to identify the resulting heating solutions based on those input assumptions. An example is the connection of terraced houses in south-west Newcastle to a district heat network. This was selected under many scenarios and would appear a relatively low-regret option that would be a cost-effective decarbonisation route in nearly all futures.

However, there are significant consumer and commercial challenges in developing the heat network and securing consumer connections. Studies demonstrate people care more about their experience of using heat than how it is delivered and, for most people, low carbon heating systems are not currently an option they would consider[8]. The challenge of making low carbon solutions both attractive to consumers and economically viable for investors will be required for most of the decarbonisation options, even when they appear low regret from a techno-economic perspective. This chapter discusses the different technology options and choices in the context of the three pilot studies.

8 How can people get the heat they want at home, without the carbon? *Energy Technologies Institute (2018)*

There is strong evidence to suggest that a wide range of heating system options are needed to decarbonise heat in local areas

Our analysis found that no single solution was cost-effective in any local area. It has, however, identified some common themes across local areas regarding heating system options and cost-effective choices.

The typical lifetime of domestic heating systems means there are only two opportunities to change heating systems between now and 2050

The lifetime of a domestic gas boiler is typically 15 to 20 years. With only 32 years to 2050, the heating system in any house is only likely to be replaced twice in that time. Gas boilers being fitted today can be expected to still be in use as late as 2040. This would give a single opportunity to replace that heating system with a low carbon alternative before 2050.

Development and expansion of heat networks are a solution for built up, urban areas

In all cases we found that heat networks are part of the solution for built-up urban areas where the high heat density makes them a cost-effective decarbonisation solution under most future scenarios. These networks are expected to be built using gas fired combined heat and power to provide heat in early years. They will then need to switch to lower carbon heat provision to meet increasingly tight carbon emissions targets. These are likely to include large-scale heat pumps using low carbon electricity.

Electric heating solutions are more efficient in rural areas

Where housing is less dense it is likely that the most cost-effective route will be through the use of electric heat pumps to heat houses. The distances involved are too large to make heat networks cost-effective and, in areas off the gas grid, the electricity network may already have sufficient capacity to support heat pump loads if the current solution is electric resistive heating. Different heat pump solutions are likely to be appropriate for individual houses, with smaller properties using air source heat pumps while larger houses may require ground source heat pumps or high temperature air source heat pumps to deliver the power required on colder days.

Solutions for suburban areas are much more variable and subject to greater uncertainty

In these areas both electric and heat network solutions might be preferable, depending on the precise nature of the local area, its homes and buildings and the cost and performance of different solutions.

Smaller, better insulated homes are suitable for a wide range of low carbon heating solutions

Such homes have smaller energy demands and can be heated by lower power heating systems even on the coldest days. This allows a wide range of heating systems to be used with cheaper options generally preferred in our modelling. However, since the modelling takes a Whole Systems approach, more expensive building options might be selected if this allows for a lower Whole Systems cost.

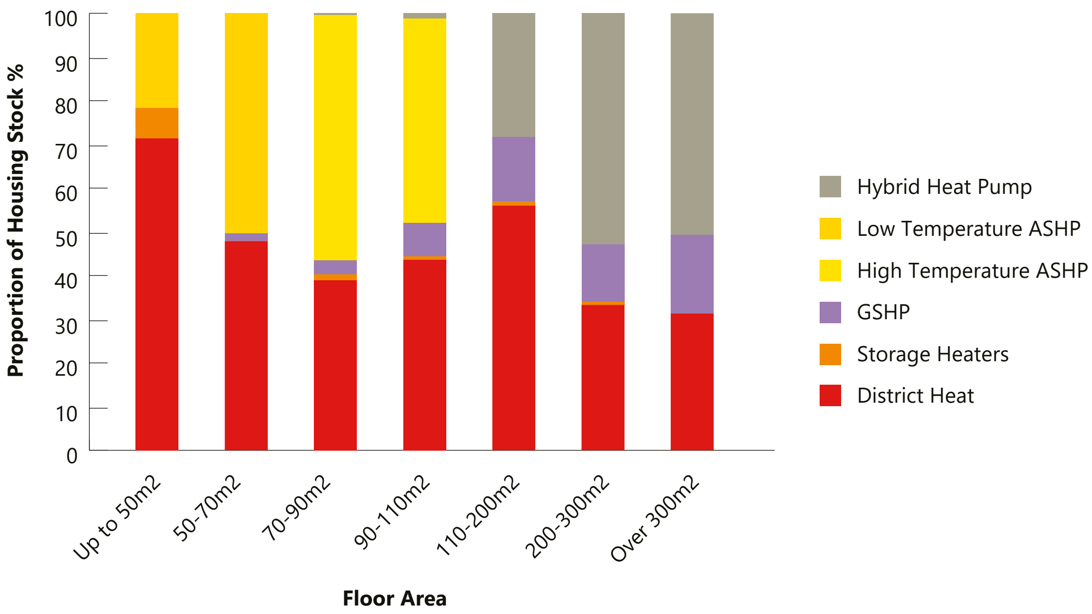
Larger, less thermally efficient homes are harder to heat with fewer low carbon options

In these cases, a heating system that delivers heat at high power levels is likely to be required. This limits the ability to use low temperature electric heat pumps in these homes. There were examples of 'hard to heat' buildings such as these in all pilot local areas.

Figure 7 provides an example of how the size of homes in Newcastle influenced the most cost effective electric heating solution. The larger homes could not be heated with Air Source Heat Pumps and require other heating systems with higher power outputs. In addition, low temperature Air Source Heat Pumps can be fitted to the smallest buildings whilst high temperature Air Source Heat Pumps should be fitted to slightly larger properties. Hybrid heating systems are utilised to meet the peak heat demand of the largest electrically heated homes.

It should be noted that lower power heating systems have the potential to be installed in larger homes but require more extensive improvements to thermal efficiency. There is expected to be a high cost associated with achieving good standards of thermal efficiency in most older buildings, therefore decarbonising incoming energy supply could be more cost-effective.

Figure 7: Example breakdown of selected heating system options by floor area for Newcastle[9]



Hybrid heating solution may be a valuable future option

Hybrid solutions can provide high power delivery of heat. This is likely to help consumer acceptance, as it has the potential to provide an equivalent experience to current gas boilers and heating systems. Hybrid solutions could therefore be valuable as a transition technology, allowing consumers to experience their homes being heated by heat pumps without significantly changing their current heat experience.

9 See Appendix 2 for details of different heating systems modelled.

Hybrid systems provide the flexibility to switch between gas and electricity use at different times and so manage peak network loads. However, hybrid heating systems are currently an expensive technology option and deliver limited carbon reduction benefits, whilst national electricity generation is still carbon intense. Post-grid decarbonisation it will not be possible to have a large number of hybrid heating systems and still meet ambitious 2050 carbon reduction targets. Much larger numbers are possible if emissions are allowable. Hybrid solutions are more likely to be viable if low carbon gas is available in the local area.

Based on the experience of the three pilot studies it is unlikely that local authorities will want to encourage widespread use of biomass for domestic heating

Space constraints for bio-fuel storage and delivery mean that biomass solutions are likely to only be practical for larger homes. Our modelling found bio-fuel heating solutions could be cost effective for some homes and areas if sufficient resource was available. In all local pilot areas, concern was raised by the local authority regarding the desirability and impact of switching from gas or oil to individual bio-fuel heating solutions, primarily:

- Air quality concerns. This was predominantly for urban and suburban areas, although fitting biomass boilers to houses in developments along the bottom of valleys in Bridgend was also questioned due to the risk of pollution being trapped in those areas;
- The future cost and availability of bio-fuel, which is likely to have high value in a future low carbon energy system due to its versatility. It can be used for a wide variety of purposes other than providing space heat, such as fuel for transport or for electricity generation with carbon capture and storage. This means there is a significant economic risk associated with encouraging home owners to consider switching to biomass for domestic heating.

3.3 What is important in designing low carbon electric heating solutions?

Electrification of heating can be an important part of affordable local energy systems. But electrification will not be suitable for all homes and will have different impacts across local areas.

Electrification of heating in combination with electrification of vehicles will create increasing pressures on the local electricity distribution networks and connections to houses.

The limitation on the deployment of electric heat pumps to large homes (see Figure 7) are partly a result of the maximum power assumed to be available to houses that are not currently electrically heated. A typical 230V domestic supply can provide a maximum of 18kW. Once the need to support other devices such as cookers and kettles is considered, a limit must be set for the maximum power that the heating system can draw with any individual device – typically restricted to 7.4kW. This limits the overall power available from any electric heating system. If a building requires high heat power to meet peak demand, it is likely that an electric heating system will have insufficient capacity due to this limit. Increasing the capacity of the electricity feed into individual buildings may be required for mass deployment of individual electric heat solutions.

A heat pump generally delivers more heat into a house than the amount of energy used to operate the pump. The ratio between the rate of heat delivery and the rate of energy consumption is the coefficient of performance. This will vary depending on the temperature of the heat source (outside air for an air source heat pump) and the temperature required from the heat pump to heat the house. Unfortunately, this number declines as the outside temperature drops and the heat pump must work harder to deliver the required output power. This means that heat pump performance is generally at its lowest on the coldest days when the most heat is required.

If the coefficient of performance of an air source heat pump is assumed to be no better than 1.5 on a cold winter day, the 7.4kW limit implies a maximum rate of heat delivery of 11kW. This is significantly below the maximum power of most current gas boilers.

Combining these factors suggests there are four important areas for research and development to support future electrification of heating. This can establish solutions able to meet needs of consumers whilst informing network planning and choices before they are deployed at scale:

1. Heat storage that works in 'real world' domestic situations. Our analysis suggests that a useable storage of 24kWh, with the ability to charge at 11kW and discharge at 6kW, would allow most buildings to meet target temperatures with a low temperature air source heat pump on peak days. Consideration would need to be given to the space needed in homes and the efficiency of both charge and discharge, as well as the rate of heat loss while energy is stored;

2. Options to cost-effectively upgrade the electricity supply in existing homes to allow electric vehicle charging and electric heat systems with an input power of greater than 7.4kW;

3. Development of heating control systems that exploit the thermal mass of the home so that pre-heating can allow thermal comfort to be achieved in all buildings without the need for high peak power demands. This type of control may need to consider groups of buildings on the same low voltage feeders, as well as individual buildings;

4. Development of higher performance electric heat pumps with performance levels similar to that of ground source heat pumps. Our analysis found that if the coefficient performance of an air source heat pump or other electric heating solution (currently assumed as 1.5) could be raised to the equivalent of a ground source heat pump on a cold winter day (2.1) for an additional fixed cost of £1,100 or less, combined with an increase in variable cost of £380/kW (installed power output) or less, then electric air source heat pumps could be cost effective for deployment in a much wider range of homes.

3.4 What is important in designing future heat networks?

Development and expansion of heat networks to connect homes and buildings can be an important part of a cost-effective solution to decarbonise heating. Development and retrofitting existing homes to heat networks is not suitable in all areas and retrofitting even a small proportion of existing homes would represent major infrastructure investment and disruption, requiring effecting planning and coordination,

In all the pilot study areas, the connection of a significant proportion of existing homes to a heat network was found to be the lowest-cost solution to decarbonise heat and meet ambitious local carbon targets (see Figure 13). These proportions are often very different to national studies that do not account for local factors[10 11]. Since only three local areas have been studied it is not possible to establish whether aggregating local solutions across the whole of the UK would result in similar results to those produced by national studies.

However, most of the proposed heat networks would not be commercially viable in the current market and are unlikely to be able to find the capital investment required to build them. This largely relates to the level of connections that are required to make a scheme viable. If the target market for a new heat network is existing homes that are currently heated with gas boilers, it is hard to conceive a way that sufficient numbers of private owner-occupiers could be persuaded to switch en mass under current market conditions. The options for how this might be achieved have been explored in other parts of the Smart Systems and Heat programme[12].

Analysis showed that the total local energy system cost was most strongly influenced by the cost of building new heat networks. Reducing the cost of building, operating and maintaining heat networks could have a dramatic influence on their commercial viability and significantly reduce the cost of decarbonising heat in buildings. The ETI has identified opportunities to achieve this[13].

Once the initial investment in establishing a heat network in a local area has been made, planning for the future development and expansion of this network to connect more buildings is often found to be a cost-effective route to decarbonising homes and buildings. If it is likely that a planned heat network could be extended, the initial design and planning activity should be based on this extension taking place, ensuring the original network is future-proofed to allow its value to be maximised over its lifespan. Low utilisation of heat networks results in higher-per-unit costs for delivered heat, as the cost of building and maintaining the networks is spread over a smaller number of customers. Once a commitment has been made to invest in developing heat networks, exploitation of the asset is vital, if customer bills are to be minimised.

Detailed design considerations may also have an influence on the practicality of retrofitting heat networks into existing homes. For example, there may be challenges in connecting terraces that have been converted into flats to heat networks due to problems with installing Heat Interface Units (HIUs) and pipework for upstairs flats. HIUs might need to be installed in other properties to allow a ground floor connection point to the heat network. This would result in potential ownership and maintenance responsibility issues in privately rented and owned flats.

10 National Comprehensive Assessment of the Potential for Combined Heat and Power and District Heating and Cooling in the UK, *Ricardo Energy and Environment (2015)*

11 Cost analysis of future heat infrastructure options , *Element Energy for National Infrastructure Commission (2018)*

12 http://www.eti.co.uk/insights/domestic-energy-services

13 http://www.eti.co.uk/programmes/energy-storage-distribution/heat-infrastructure-development

3.5 What heat sources might be used for heat networks?

It is likely that heat networks will initially be powered using gas technologies that will then be replaced with lower carbon alternatives to achieve carbon targets.

3.5.1 Role of gas fired combined heat and power (CHP)

Local gas fired combined heat and power plants (CHP) can provide an affordable source of low carbon heating for heat networks and local electricity generation within local areas during the transition. They are generally replaced in later years with lower carbon solutions in our modelling. There are several reasons why CHP might be a key part of the transition pathway:

- As national electricity generation de carbonises the plants can provide electricity at lower cost than importing nationally generated electricity, if the local carbon target allows sufficient headroom;
- The plants are valuable for providing heat and electricity at times of peak demand during winter;
- Gas CHP plants are generally cheaper to build and operate than low carbon heat sources for heat networks, such as large-scale heat pumps.

There is a risk that such plants will produce higher carbon energy (heat and electricity) than that produced using national generation from a decarbonised grid. With no legal restrictions on individual carbon producers, or no carbon price, this risk will increase over time under current market conditions and regulations.

> "By targeting house retrofits, we can support the cost-effective decarbonisation of local areas"

3.5.2 Zero carbon heat for heat networks

To meet tighter carbon targets, alternatives to gas fired heat will need to be found for heat networks in the longer term. Across the local pilot areas, identifying suitable and sufficiently large quantities of zero carbon heat for heat networks will be needed to allow local areas to achieve long-term decarbonisation ambitions at least cost.

Some of the associated challenges and opportunities can be understood, using the Newcastle pilot as a case study. With restrictions in place with respect to individual electric heating systems, the EnergyPath Networks analysis can be used to estimate that around 700,000 MWh/year of zero carbon heat in heat networks could be needed by 2050 to meet demand in Newcastle. In addition, a small amount of heat (600 MWh/year) from gas fired boilers and combined heat and power is likely to be needed to meet peak demand on cold days.

Whilst the River Tyne was identified as an option for use with large scale water source heat pumps, this resource will need to be shared with Gateshead, and was identified by DECC[14] as in the lowest band in terms of available heat when compared to other rivers in the UK. Within EnergyPath Networks around 60,000MWh/year is provided by water source heat pumps in Newcastle. For Newcastle to meet its 100% renewable city ambition, the remaining 640,000MWh/year will need to be provided by alternative zero carbon sources if district heating is to supply a significant proportion of Newcastle's homes by 2050. Methods to produce this heat will need to be identified, but possible options include:

- Local gas-powered combined heat and power combined with carbon capture and storage;
- Heat from small modular reactors;
- Development of large scale heat pumps, deployed at sufficient scale to meet the demand using nationally generated low carbon electricity;
- Use of electric boilers to provide resistive heat from nationally generated low carbon electricity.

If the heat provided by large scale heat pumps is replaced by heat produced by bio-fuel, the additional annual emissions are estimated to be 26 ktCO_2. This would result in emissions of more than 2.5 times those achieved by assuming that zero carbon heat is available.

If large scale heat pumps make up a significant proportion of heat for heat networks, then research to establish the locations and magnitudes of heat sources in local areas would be valuable for energy planning purposes. For the most promising heat sources, further analysis should be completed to identify the options for exploitation, any limitations or constraints, and the associated costs.

Heat sources that could be researched include but are not limited to: Waste water/sewage, heat in tunnels of underground railways, coastal heat, ground heat, industrial heat sources, ground or mine water and electricity substation heat.

14 https://www.gov.uk/government/publications/water-source-heat-map

3.6 What is the role of heat storage?

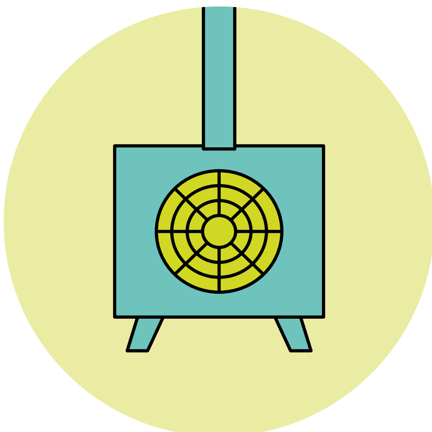
Domestic heat storage is a valuable part of future local energy systems and a common feature of future decarbonisation pathways for local areas in all the scenarios we investigated.

Considerable energy is currently stored in gas networks due to the influence of pressure. At times of peak demand, pressure in the network is allowed to fall to maintain supplies. As we move away from using gas for heating, this peak demand must be met in other ways. One option is store energy in individual homes as heat.

There are several benefits to domestic heat storage as part of future local energy system designs, including:

- Allowing heating systems with lower power demands to meet peak heat demand requirements by 'topping up' heat as it is generated;
- Allowing hot water demands to be met using systems with low power outputs, such as Air Source Heat Pumps;
- Reducing network capacity requirements by allowing some load shifting away from periods of peak demand.

However, there are challenges associated with integrating heat storage into existing homes as many homeowners have removed hot water tanks and installed a combi-boiler. For example, the English Housing Survey[15] shows that 54% of homes had a combi-boiler in 2016, with this figure rising by around 2% a year since 2001. Such consumers often place a high value on the space that has been made available 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),[16] it is clear that the options for using space for domestic heat storage are likely to be heavily dependent on local factors.



15 https://www.gov.uk/government/statistics/english-housing-survey-2016-to-2017-headline-report
16 https://www.ons.gov.uk/peoplepopulationandcommunity/housing/bulletins/housepricestatisticsforsmallareas/yearendingseptember2017

3.7 What is the value of improving the energy efficiency of existing homes through fabric retrofit?

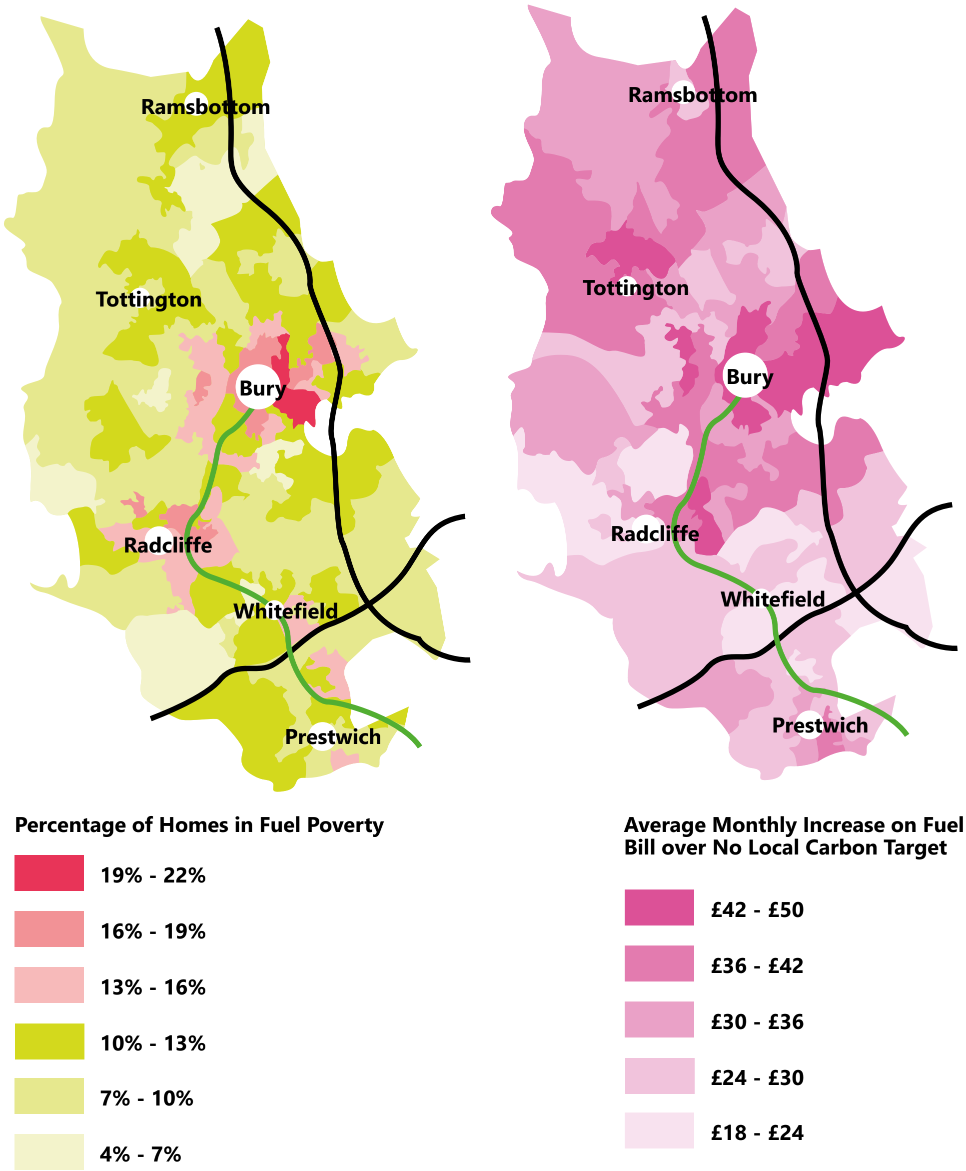
Targeted retrofit improving the energy efficiency of existing homes is an important part of a cost-effective transition to decarbonise heat in local areas and can provide a range of wider benefits.

The English Housing Survey[17] shows that 68% of homes with cavity walls are filled, 37% of houses have 200mm or more of loft insulation and 83% of homes have double glazing. Our analysis has found that low cost fabric retrofit measures such as cavity wall and loft insulation should be prioritised at the remaining homes that have not yet been retrofitted. These measures are often economically viable and will pay for themselves regardless of whether a carbon target has been set. More expensive insulation measures such as solid wall insulation do not save sufficient energy to justify their higher cost, however it should be recognised that other factors, such as health and fuel poverty, could turn more expensive retrofit measures into attractive options.

With an analysis performed at a household level, homes where delivered energy costs have changed (either reduced or increased) can be mapped to see how the location of these homes correlate with fuel poor areas (Figure 8). This type of analysis can then be used to help target retrofit programmes.

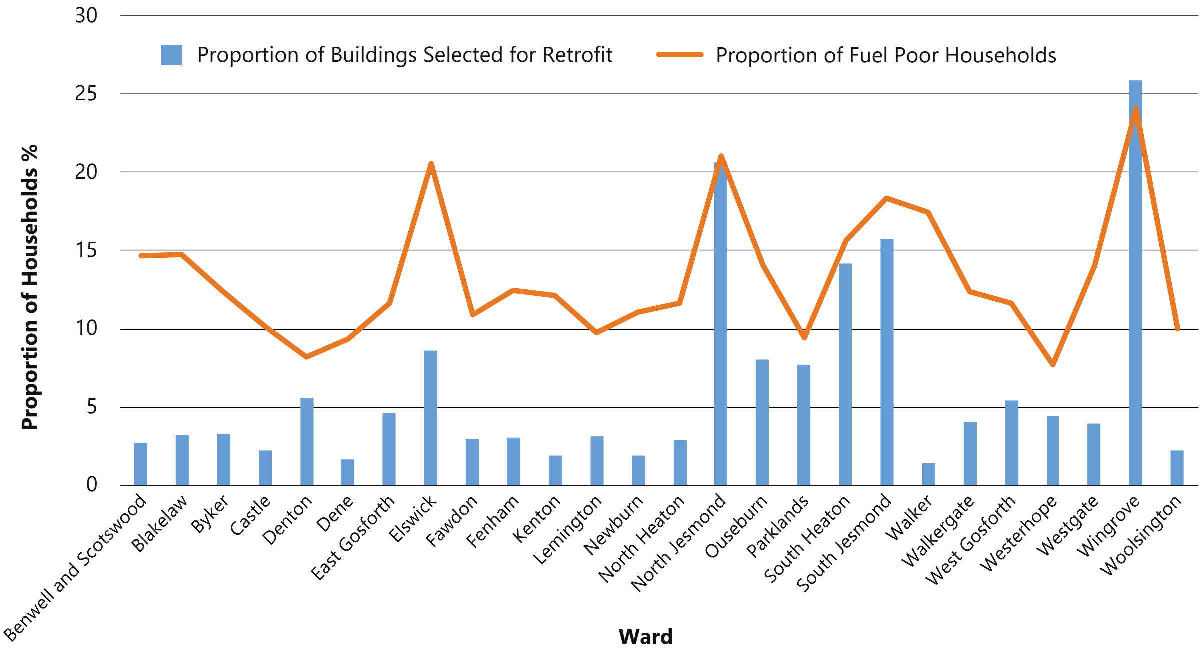
17 https://www.gov.uk/government/statistics/english-housing-survey-2016-to-2017-headline-report

Figure 8: Maps of fuel bill changes and fuel poverty for Bury



In all local pilot areas some level of fabric retrofit was found to be a cost-effective part of future pathways, even under business as usual with no local action or targets to reduce carbon emissions. This low-cost fabric retrofit generally aligns with areas that have the highest levels of fuel poverty, suggesting that targeted deployment of cavity and loft insulation could be effective in addressing fuel poverty (see Figure 9). Calculation details are given in Appendix 1.

Figure 9: Fuel poverty and low cost retrofit for Newcastle

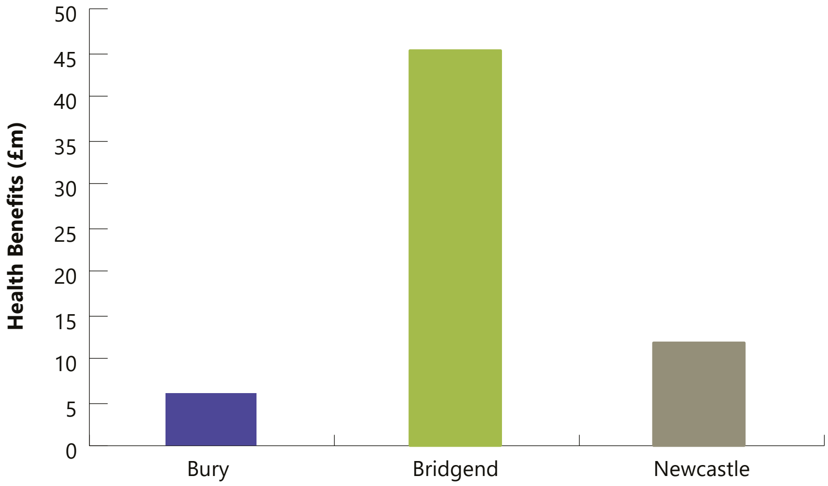


Decarbonisation will lead to improvements to housing stock, such as improved building insulation and more energy efficient and lower carbon heating. This could have additional benefits, through an increased level of comfort due to housing that is warmer and less damp. Air quality in the house should also be better as fossil fuels will not be directly used in the home. These factors should help to improve the health of residents who have existing medical conditions such as respiratory, cardio-vascular and circulatory problems, and also help to prevent new cases developing. These health benefits can be quantified using domestic energy savings as a result of retrofit or heating system interventions[18]. Details of the methodology are given in the appendix.

18 Any energy savings as a result of solar PV installations are not accounted for in this calculation as these will translate to health benefits via comfort taking, not due to increased energy efficiency.

These benefits are shown in Figure 10.

Figure 10: Estimated monetary value of health benefits of transition in three local areas



Despite these wider benefits, current costs mean that private owner-occupiers are unlikely to install expensive measures such as solid wall insulation due to both cost and disruption. Significant reductions in cost, or new business models, will be required for these types of measures to achieve wide-scale uptake.[19]

"Decarbonising domestic heat is cheaper than other areas of the energy system such as heavy duty transport, aviation or shipping"

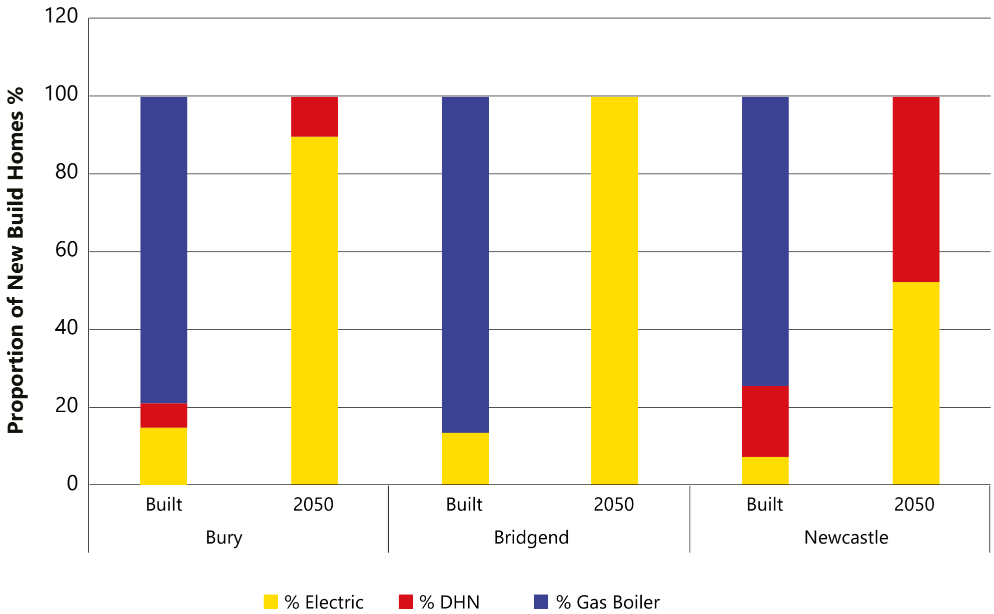
19 For a more detailed discussion of some of the issues see: Housing Retrofits – A New Start, *Energy Technologies Institute (2016).*

3.8 What does this mean for new homes and developments in a local area?

New development offers an opportunity to build homes that are energy efficient and either fitted with, or future-proofed for low carbon heating systems.

Our analysis found that new homes built with gas heating systems will ultimately need to switch to alternative low carbon heating systems to meet 2050 carbon targets (Figure 11). Since new homes built to current building regulations are well-insulated, they can be heated with lower power heating systems than many older houses. We found that new homes across the three pilot local areas transitioned predominantly from high efficiency gas fired central heating to electric heat pump solutions, however a significant proportion of dense new developments in urban areas such as Newcastle transitioned from gas to heat networks as the least cost pathway. It should be noted, however, that the modelling undertaken assumed that all new builds achieve the thermal performance intended by building regulations and that heating systems were sized appropriately in all cases. There is significant evidence of a 'performance gap' between building standards and achieved levels of thermal efficiency[20] and boilers are often over-sized, resulting in them operating at part power, which lowers efficiency.

Figure 11: Heating systems fitted to new build homes when built and retrofitted to meet a 2050 carbon target



Ensuring new homes and buildings are ready for transition to future low carbon heating systems could substantially reduce future costs and disruption to consumers. Establishing which heating systems are most likely to be appropriate in a particular area should be part of a wider Local Area Energy Planning process to ensure these choices are appropriate for the wider future energy network infrastructure.

20 Building Performance Evaluation Programme: Findings from domestic projects, Making reality match design, *Innovate UK (2016).*

Local authorities can find it difficult to enforce local planning requirements that exceed current building regulations, as developers argue that such houses are more expensive to build, and this extra cost cannot be realised in the marketplace, making developments unviable. If local authorities have new build requirements that assist their low carbon ambitions they risk being unable to attract investments for development to their area. This commercial pressure is also reflected in paragraph 173 of the current National Planning Policy Framework (NPPF), which states that:

“Pursuing sustainable development requires careful attention to viability and costs in plan making and decision taking. The plan should be deliverable. Therefore, the sites and scale of development identified in the plan should not be subject to such a scale of obligations and policy burdens that their ability to be developed viably is threatened. To ensure viability, the costs of any requirements likely to be applied to development, such as requirements for affordable housing, standards, infrastructure contributions or other requirements should, when taking account of the normal cost of development and mitigation, provide competitive returns to a willing landowner and willing developer to enable the development to be deliverable.”

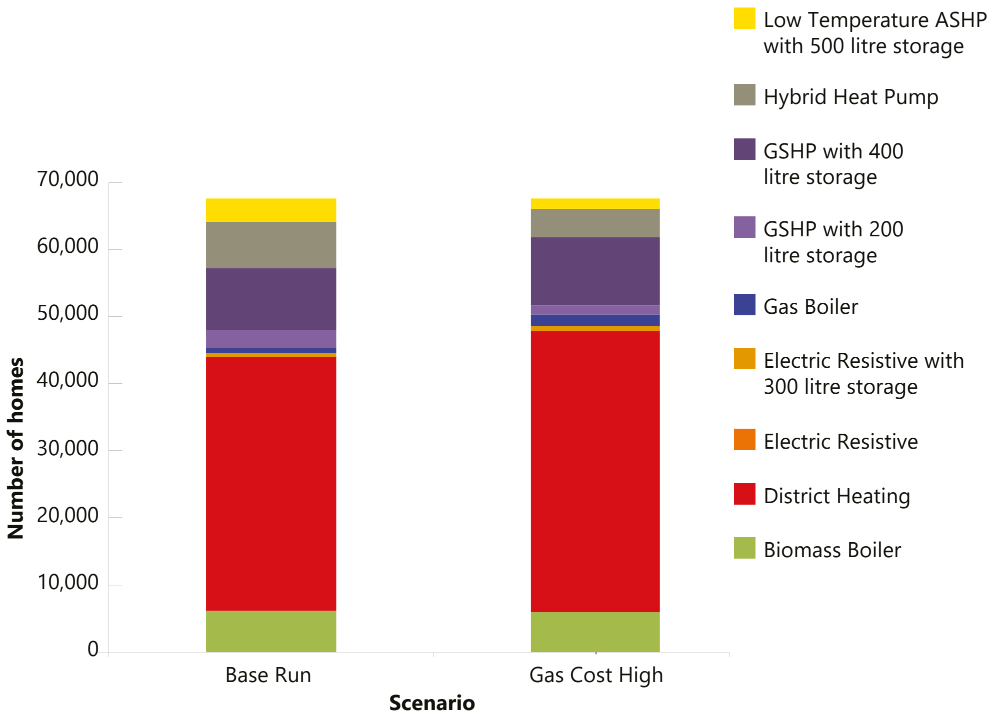
Similar considerations are included in the current (May 2018) Draft Planning Practice Guidance[21] which is part of the NPPF consultation. This states that “Plans should be informed by evidence of infrastructure and affordable housing need and an assessment of viability that takes into account all relevant policies, local, and national standards including for developer contributions. Viability assessment should not compromise the quality of development but should ensure that policies are realistic and the total cumulative cost of all relevant policies is not of a scale that will make development unviable.”

21 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/687239/Draft_planning_practice_guidance.pdf

3.9 What does this mean for non-domestic buildings?

Commercial and public buildings often have considerable energy demands and can have a significant influence on the least cost decarbonisation options for their local areas. For example, they can act as anchor loads to support the development of heat networks. In addition, we found that their high energy demands mean that the least-cost pathway for decarbonisation can be heavily influenced by the relative costs of different fuels. As part of the Bridgend study, the influence of changing future gas costs was explored. With higher gas prices, the least-cost solution was to switch non-domestic buildings to use a heat network connection. This enabled the connection of a larger number of domestic buildings to heat networks rather than switching to electric heat solutions. Furthermore, the reduced CO_2 emissions from non-domestic buildings allowed more domestic buildings to continue using gas boilers (Figure 12).

Figure 12: Comparison of domestic heating system solutions in Bridgend with different gas costs



To develop a credible strategy to decarbonise non-domestic buildings in a local area, a detailed knowledge of the buildings, energy uses and dominant heating systems is needed. This enables an analysis of the available options for different buildings to be performed and decarbonisation strategies to be developed. The future energy use of these buildings under different scenarios also needs to be considered. This includes aspects such as building refurbishment, change of use, fabric retrofit and change of heating system to heat pumps or district heat connection. The importance of considering the options for decarbonisation of non-domestic buildings can be seen in Table 2, which demonstrates that these emissions make up around 50% of all building emissions in Greater Manchester.

The nature of the non-domestic building stock makes this analysis extremely challenging. Due to the wide range of construction ages and types of non-domestic buildings it is not possible to classify them into archetypes of similar energy performance as can be done for domestic buildings. The thermal efficiency of all houses built under a particular set of building regulations are assumed to be of the standard implied by those building regulations. For example, the energy performance of all houses built between 1965 and 1979 can be reasonably estimated, based on the size of the buildings and the building construction required by building regulations used at that time. In contrast, non-domestic buildings of a similar age could have been built using a wide variety of techniques, depending on the use originally intended and requirements of the original developer. Since that time, the use of the building may have changed significantly and modifications could have been undertaken to update the building for these alternative uses.

Within the three local pilot areas an attempt was made to understand the current use of each non-domestic building. This analysis was based on a variety of data sources that often conflicted, and assumptions were made as to which source was most appropriate for a set of circumstances. The results of this classification have not been verified in detail and are likely to include errors.

The data sources used included Ordnance Survey and Valuation Office Agency data for building size and current use. The CARB2 project run by University College London (UCL)[22] and standard Chartered Institution of Building Services Engineers (CIBSE) energy benchmarks[23] were used to estimate current energy demand. Other sources of these types of benchmarking data are also available[24]. In addition, Display Energy Certificates and local authority-held data on public building energy use can prove valuable to help identify buildings that might act as suitable anchor loads for heat networks (see section 5.8).

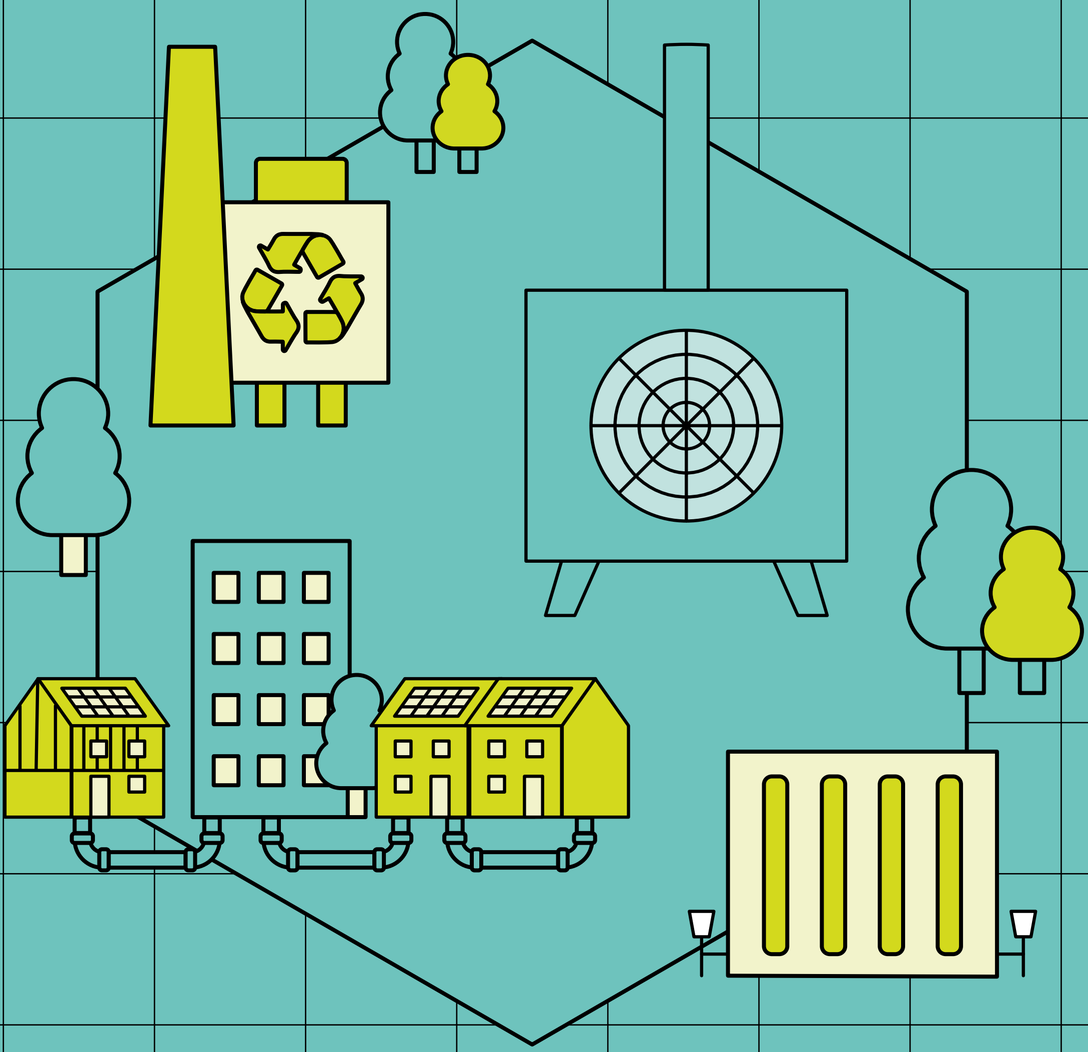
The influence of using local authority buildings as anchor loads to encourage heat network growth was shown in the Newcastle study, where including the planned Civic Quarter heat network in the analysis resulted in a significant number of additional domestic buildings being connected in the modelling under a variety of scenarios. Depending on the scenario modelled, the minimum number of connected domestic buildings was 250, with a maximum of around 2,000 and an average of 1,000 connected.

22 http://www.ucl.ac.uk/energy-models/models/carb2

23 The Chartered Institution of Building Services Engineers*: Energy benchmarks (TM46: 2008)*

24 Energy Consumption Guide 19: Energy Use in Offices (ECON 19), *Action Energy (2003).*

4. Low-carbon pathways for local areas

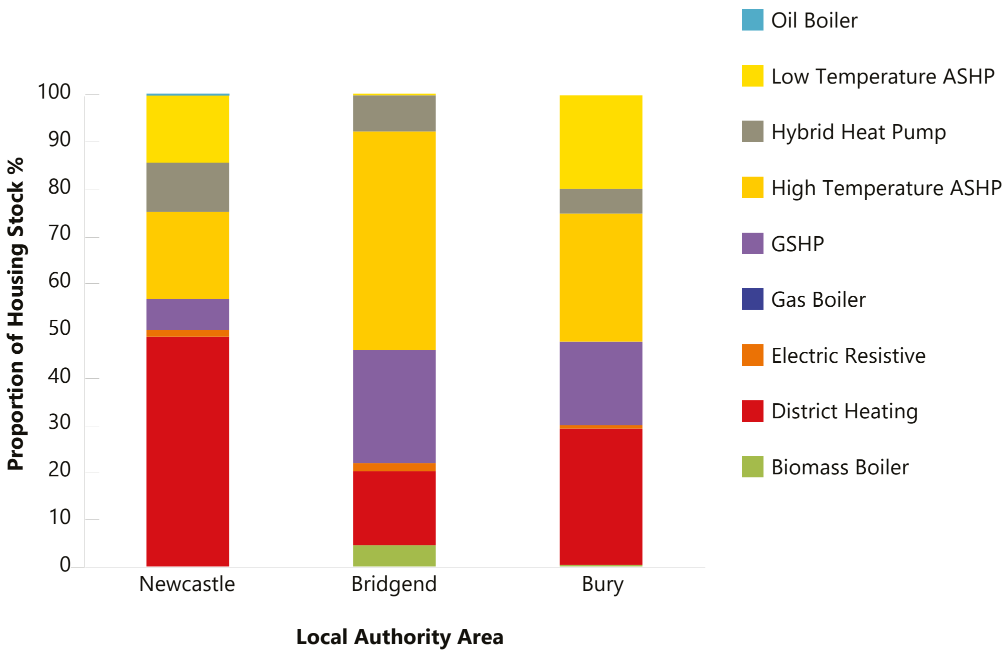


4.1 How do local pathways to decarbonise heat compare?

There is no single solution for reducing the carbon emissions associated with heating. A combination of technologies and networks will be needed.

Our analysis found that in all cases, a wide variety of heating solutions are required to achieve a least-cost decarbonisation pathway. These include both heat networks and a variety of individual electric heat solutions. The proportion of different solutions selected to achieve the least-cost solution varies depending on the characteristics of the local area (Figure 13)[25]. For Newcastle, almost 50% of homes are considered cost-effective if connected to heat networks whilst in Bury, the figure is less than 30%. In Bridgend, just over 15% of homes are connected to a heat network in 2050.

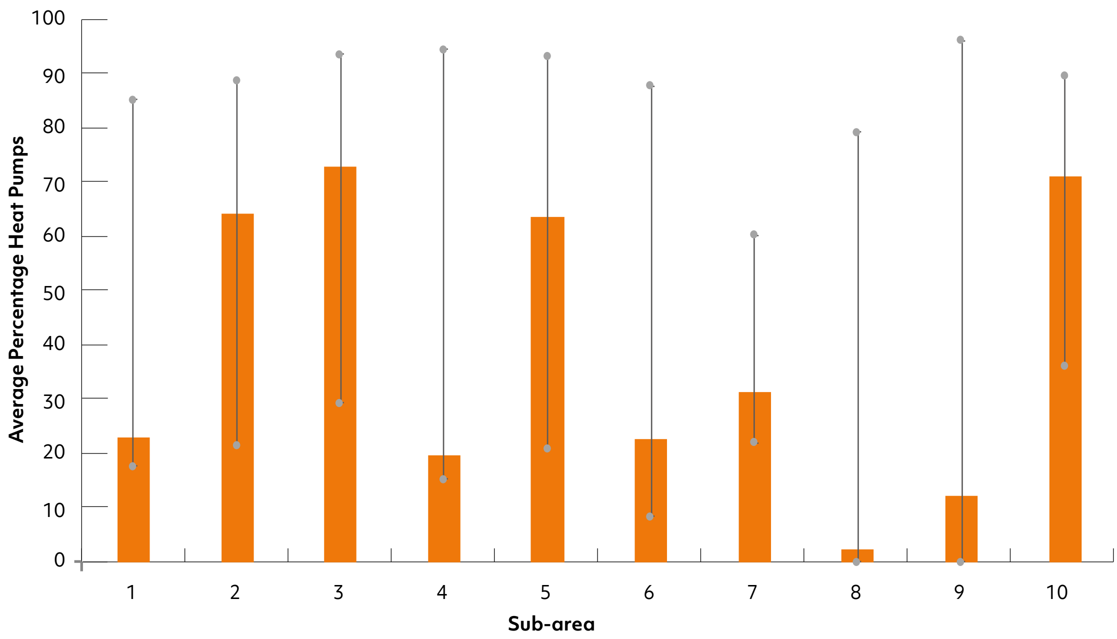
Figure 13: Proportion of different domestic heating solutions installed by 2050



25 For each of the study areas the EPN analysis framework has been run over 100 times with different input assumptions. The comparisons provided in this chapter are for a single run for each area and represent the final set of input parameters and assumptions for each local area which were developed with local stakeholders during the process of developing a local area energy strategy.

If a solution is selected in a given area under a wide variety of different assumptions, this solution will be more robust to uncertainty than those that are only selected under specific scenarios. By looking at the range of heating solutions selected for different parts of a study area, across a wide variety of input scenarios, it is possible to identify target areas (Figure 14) for different domestic heating solutions. Within EnergyPath Networks, the study area is broken down into sub-areas; each of which has its own pathway. In this case, analysis areas 2, 3, 5 and 10 always have a significant number of heat pumps selected under a wide variety of possible future scenarios.

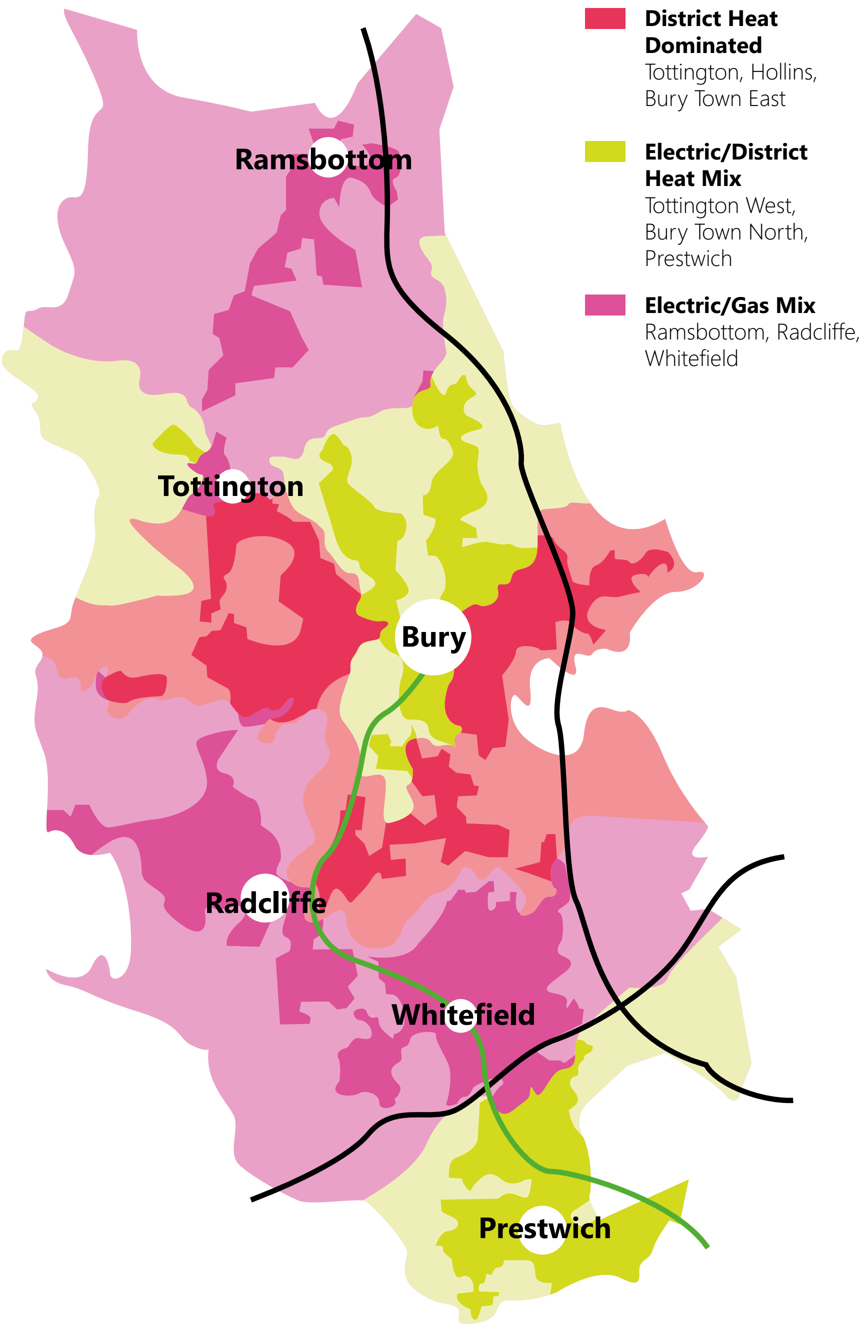
Figure 14: Ranges and average numbers of heat pumps selected for different scenarios in the Bridgend study



A similar analysis for heat networks enables the identification of areas where the development and expansion of heat networks is more likely to be cost-effective. Areas where there is greater uncertainty on network infrastructure and heating systems across the range of scenarios, can also be identified. Figure 15 shows an example for Bury where heat dominated, electric/district heat mix and electric/gas mix areas are identified. The electric/gas mix areas are those that are best suited to continuing to use gas if low carbon gas is available, or there is sufficient headroom in the carbon budget to allow gas heating systems to remain.

It might be expected that there would be common factors associated with target network choices when considering the three study areas. However, in practice, different factors explained the most cost-effective network choices in the different areas. For example, in Bridgend, the choice as to whether an area was best suited to district or electric heat solutions was closely related to the heat demand per unit land area (GWh / km^2). Places with high heat density were better suited to district heat and areas with low heat density were better suited to electric solutions. In contrast, heat density did not entirely explain the choice between district heat and electric solutions for Bury. In this case, some areas with high heat density were identified as better suited to electric heating solutions. This was due to the relative costs of electricity network reinforcement and the development of heat networks as well as the mix of property types in different areas.

Figure 15: Energy network target areas for Bury local authority area



4.2 What is the impact on the total system cost in a local area?

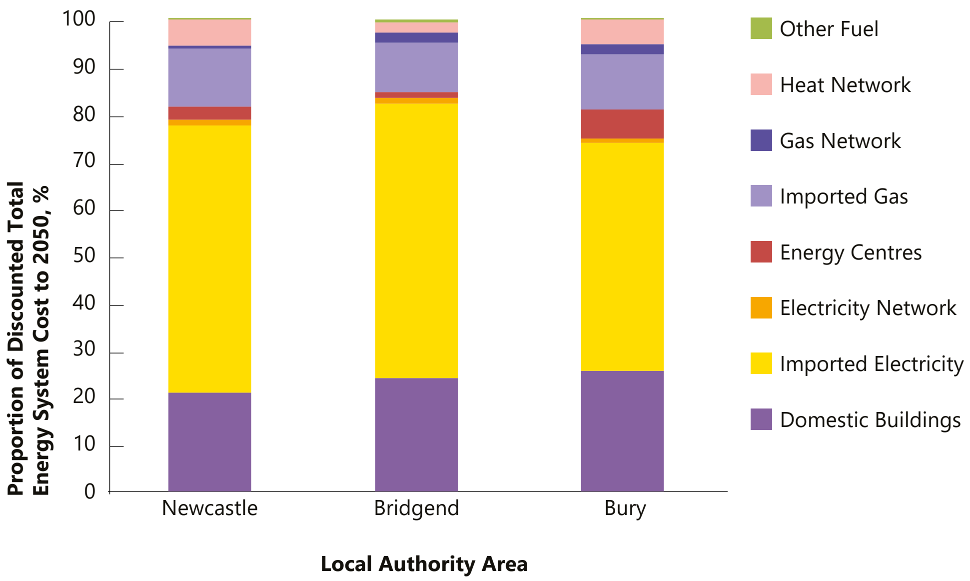
The Whole Systems cost – including new investment in and operation and maintenance of buildings, the networks that serve them and the energy used between now and 2050 – represents billions of pounds of spending over the next 30 years in each local area, regardless of decarbonisation.

Achieving the least-cost and most desirable solution to decarbonise heat will require network choices on the future energy infrastructure needed in local areas.

The economic impact of the decarbonisation pathways differed between the three local areas in our studies. Low-carbon energy system designs that are able to meet ambitious local carbon targets and decarbonise heat can be delivered for a less than a 12% increase in cost compared to a 'do-nothing' scenario. This additional cost will deliver benefits in both health and air quality, although our analysis found the cost of decarbonisation to be higher than the benefits realised. The cost of carbon required to match the costs of decarbonisation, minus the air quality and health benefits it is expected to bring, varies depending on the local area. To break even on a decarbonisation investment, the required cost of carbon for the three study areas was estimated to be **between 2,900 and 6,400 £/tonne**, based on the total increase in cost and the total carbon saved to 2050.

Figure 16 shows a breakdown of the estimated total energy system cost to 2050 for the three different local areas[26]. Future costs are discounted to 2015[27].

Figure 16: Total energy system costs to 2050 for different local areas



26 The total systems costs presented include network reinforcement, energy network/infrastructure new build and operation, changes to individual homes (including heating system changes and fabric retrofit) and the cost of the energy consumed

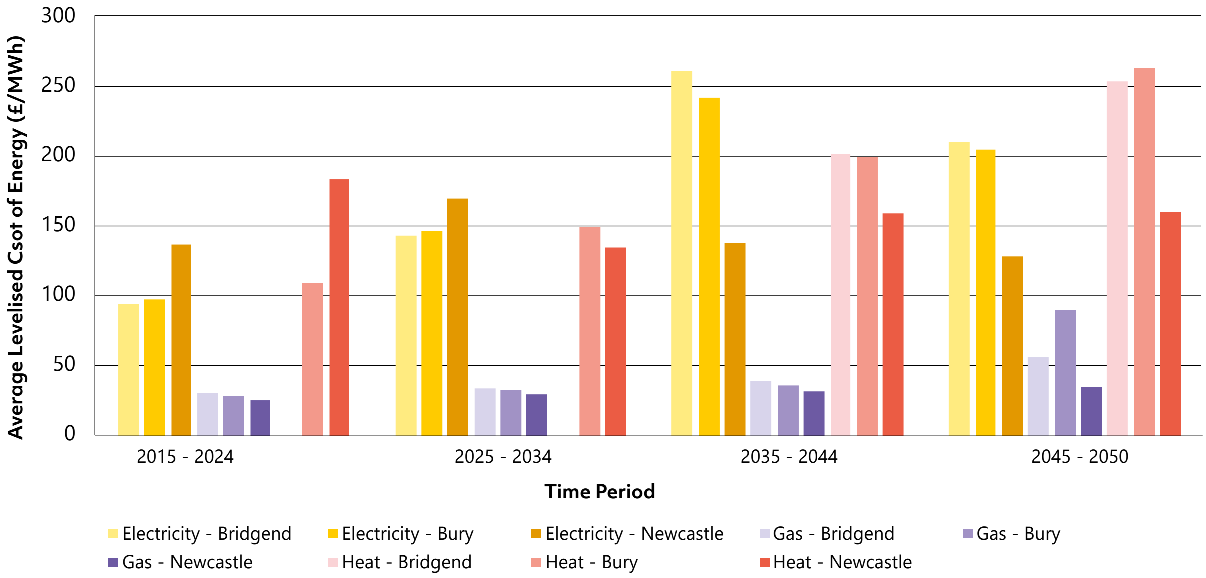
27 Discounting is a process that accounts for costs and benefits with different time spans to be compared on a present value basis. This is considered as the value of money will vary over time, where due to factors such as inflation, a £ today is worth more than it would be in a years' time

The proportion of the total cost spent on different aspects of the local energy system is broadly similar across the three pilot local areas[28]. In all cases, the largest proportion is spent on importing electricity into the local area from the National Grid.

A comparison of the levelised costs of delivered energy for the different local areas is shown in Figure 17 (for the calculation methodology see Appendix 1: Methodologies and Assumptions for Benefit Assumptions). The costs are different for each local area. This is a result of the differences between local areas, in terms of current and future energy demands and energy networks.

It should be noted that the cost of gas is still significantly lower than other energy forms in all time periods. This has implications for the delivery of decarbonisation in a free market without a carbon tax.

Figure 17: Example levelised costs of delivered energy for 3 different local areas



28 For each of the study areas the EPN analysis framework has been run over 100 times with different input assumptions. The comparisons provided in this chapter are for a single run for each area and represent the final set of input parameters and assumptions for each local area which were developed with local stakeholders during the process of developing a local area energy strategy.

4.3 What is the potential impact of local leadership and target-setting on carbon emissions?

Decarbonisation of heat from energy used in buildings is expected to be cheaper than other areas of the energy system such as heavy duty transport, aviation and shipping.

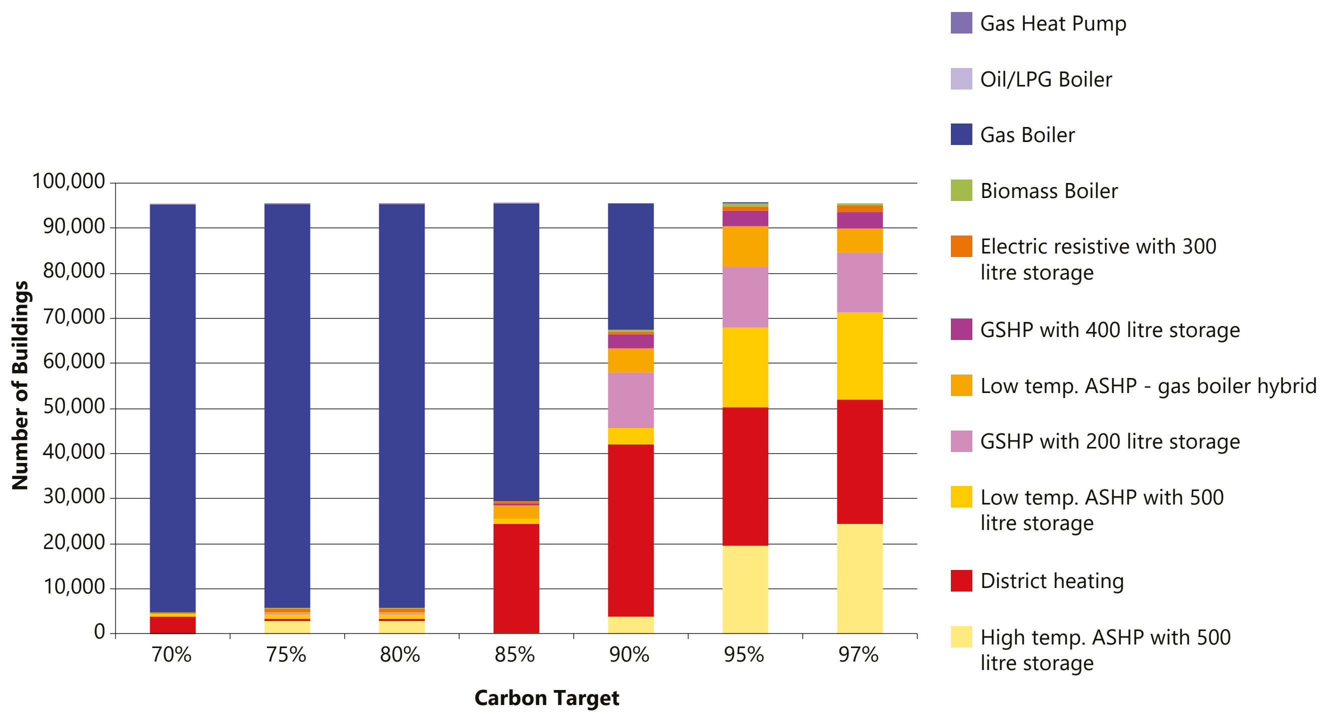
In its 2017 Report to Parliament,[29] the Committee on Climate Change stated its belief that emissions from buildings need to "fall by around 20% between 2016 and 2030, with options developed to allow near-zero emissions by 2050". This implies that setting a target of 80% reduction for emissions associated with buildings will not achieve the overall levels of reduction required.

Our work has found that translating national policy directly into an 80% local carbon reduction target for buildings will stimulate very limited change to domestic heating systems, with most homes retaining gas boilers. This is due to an assumption that national electricity generation will decarbonise regardless of local action. Along with other reductions seen in local emissions since 1990, this is sufficient to provide most of the 80% reduction in building emissions. Setting an 80% emissions reduction target for the buildings in Newcastle resulted in around 65% of homes keeping gas boilers. Similarly, an 80% local carbon reduction target for Bury resulted in over 90% of homes retaining gas boilers in 2050.

The level of change required is heavily influenced by the level of decarbonisation ambition.

Figure 18 shows the influence of a tightening carbon target on the types of domestic heating systems that could be required in Bury. At an 80% or less reduction, the change is achieved through decarbonisation of national electricity generation. It is only beyond this point that significant local change is required.

Figure 18: Influence of local carbon target on heating system deployment in Bury

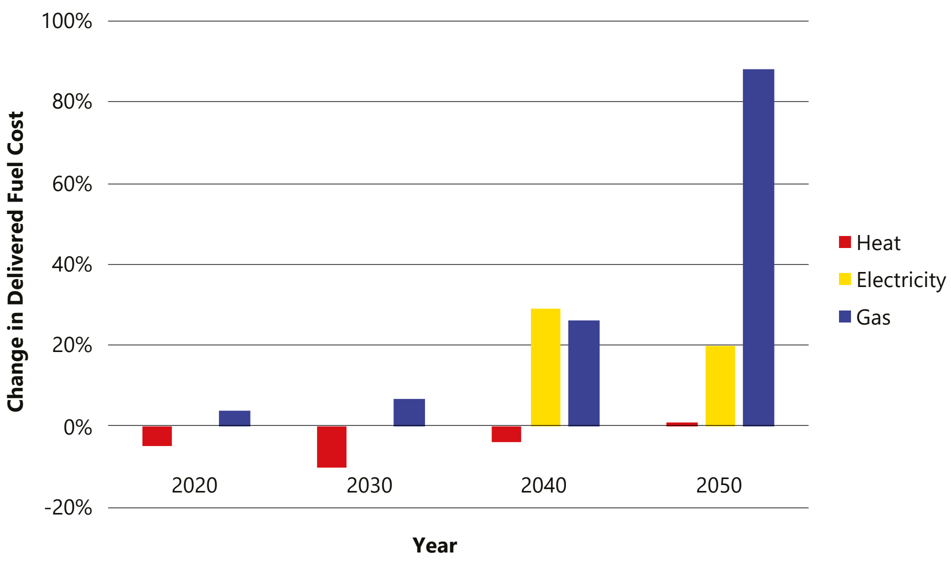


29 https://www.theccc.org.uk/publication/2017-report-to-parliament-meeting-carbon-budgets-closing-the-policy-gap/

If a lower reduction is targeted it is likely that the scale of change required could be achieved by using hybrid heat pumps, possibly in combination with a limited supply of low carbon gas. There are risks, however, that a later switch to a tighter target might then be more expensive, due to inappropriate investments to meet an earlier target. In addition, a late change may leave insufficient time to plan and implement the scale of change required.

As the types of heating systems used changes with tightening carbon targets, the amount of energy passed through different networks changes. Tighter carbon targets lead to less utilisation of the gas network and increasing demands placed on electricity and heat networks. This shift of demand between networks influences the cost of delivered energy, as the cost of building and maintaining the networks is spread over different quantities of energy. For example, Figure 19 compares delivered fuel costs for two runs of EPN for Bridgend. One scenario did not have a local carbon target, whilst the other did. The cost of delivering heat through heat networks decreases due to increased asset utilisation, whilst the cost of delivering gas increases significantly, as a large network is maintained with much lower levels of gas delivered such that the cost of network maintenance per unit of energy delivered is considerably increased.

Figure 19: Change of delivered fuel cost when a carbon target is set. Positive values indicate increased cost with a carbon target30



30 These bars represent the change from predicted future costs in delivered energy cost for each year which results from setting a carbon target.

4.3.1 Local targets and priorities

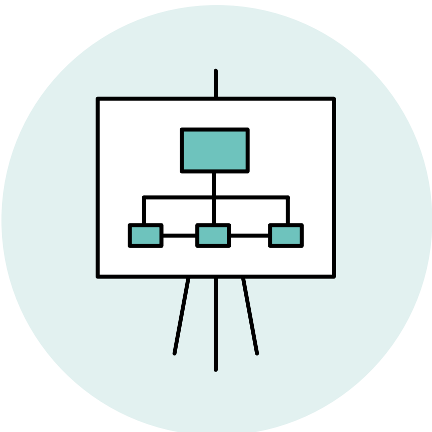
Local government support and definition of clear visions and ambition for change can drive local action for a low carbon future in the absence of statutory obligation.

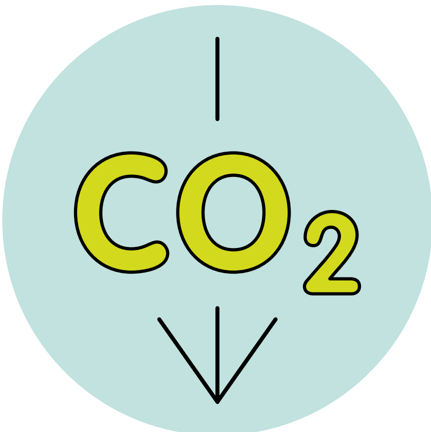
Around 70 local authorities in the UK have signed up to use 100% clean energy by 2050 as part of the 'UK100 network' – reflecting leadership on climate change and clean energy. During the projects in both Newcastle and Bury, the local authorities both adopted the target of being 100% clean energy cities by 2050. This had an influence on both the carbon targets used in the EPN modelling and the perception of the value of the outputs of the local area energy strategy development process.

Once these types of pledges have been made, public focus inevitably shifts to how they might be met. This will require knowledge of the options that are available locally and the implications of choosing from those different options. For example, within the modelling completed for Bury (when commercial and industrial new builds were included), the original carbon trajectory could not be met in early years. This implies that there is benefit in building efficiently for the short term to save energy and carbon and to make future long-term targets easier to achieve. Similarly, within Newcastle, modelling a linear reduction from current emission levels to the 2050 target was not achievable for the domestic buildings, as there are limited opportunities for the decarbonisation of buildings until the electricity grid decarbonises.

A process of evidence-based Local Area Energy Planning could help inform decisions on the overall level of emissions reductions to be targeted for buildings between now and 2050, in the context of national carbon budgets. Some initial local actions for change are discussed in section 5.8.

It should be noted that local authority officers can find it hard to sell decarbonisation strategies and commitments to local politicians as the problem can seem remote and long term. Focus is often on more immediate concerns. Central government encouragement of local areas to adopt similar pledges (either through a provision of funding or expertise) could be a powerful enabler for local areas to engage more actively with Local Area Energy Planning.

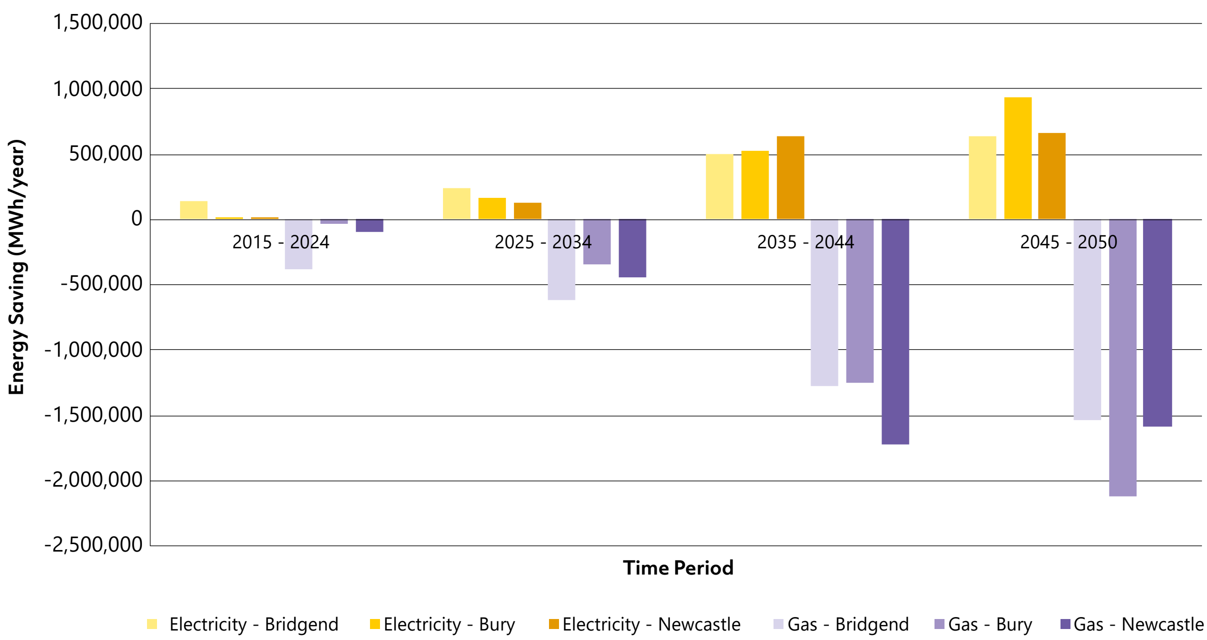




4.4 What are the implications for networks?

The decarbonisation of heating is likely to result in significant changes to the types of energy used in a local area. Figure 20 shows an example of gas savings and increased electricity demand for three pilot study areas. The rate of decarbonisation will have strong influence over these trajectories, with faster decarbonisation leading to bigger reductions of gas use in earlier years.

Figure 20: Example of annual energy savings resulting from decarbonisation for three different local areas



Considerable investment will be needed in energy networks as energy demands change to achieve low carbon ambitions.

Our analysis of the pilot local areas estimated that the additional discounted capital investment required in electricity networks to support the decarbonisation of heat is around £14m for Newcastle, £21m in Bridgend and £11m in Bury. If these investment requirements are replicated across the whole area served by a network operator, significant resources will be required for street-by-street network analysis, reinforcement planning and action.

In addition, planning of large-scale network projects is essential to ensure positive outcomes – projects can take 10 years to plan and implement. Facing the scale of change suggested, this poses a significant challenge, if all local areas will need sufficient time to plan and deliver the changes required to meet their own local goals. For example, GMCA has proposed ambitious early decarbonisation goals with Greater Manchester's date for achieving carbon neutrality brought forward by at least a decade to 2040[31]. This means that the time available to plan and reduce risk is limited if projects are to be completed on time.

31 https://www.greatermanchester-ca.gov.uk/news/article/290/green_summit_heralds_bold_green_future_for_greater_manchester

For Local Area Energy Planning to effectively support the decarbonisation of heat and enable the network choices and investment needed, it will require the support and involvement of network operators in providing data, participating in stakeholder meetings and discussions and providing valuable feedback on modelling approach, future local energy scenarios and system designs. If a Whole Systems approach to Local Area Energy Planning is to be scaled-up across the UK, the support and resources needed from network operators could be considerable.

4.4.1 Regulatory Influences

Gas and electricity network operators currently work in a highly regulated environment. Strategic network investment without a specific customer can only happen if it is contained within the license agreement. This allows for a degree of network investment if there is a clear, current or future need. Network operators are legally obliged to provide a service if it is requested. For domestic properties, the cost cannot be passed directly to the homeowner if the request is for a supply of less than 18kW.

Planning for the low carbon transition needs to be conducted over long time horizons. However, network operators are licenced for eight-year periods with a reduction to five-year periods proposed under the next round of price controls for the network companies running the gas and electricity transmission and distribution networks (RIIO-2[32]). This means that network planning and investment decisions are focused on shorter periods, limiting the ability of network operators to plan and budget for longer term, large scale network transitions. Whilst network operators are interested in longer term strategies, it is difficult for these to be enacted within the current regulatory framework, where planning and execution at the level required risks being indefinitely postponed. It can be hard for network operators to consider longer term, Whole Systems network development under a regulatory framework that focuses on short term delivery to the exclusion of longer term considerations.

The license periods for gas and electricity network operators are staggered by two years. Combined with short license periods, this limits the ability for different network operators in a local area to plan collaboratively from a Whole Systems perspective. In addition, the area boundaries covered by the various gas and electricity network operators are not aligned, requiring each operator to work with several others.

If Local Area Energy Planning outputs are to be used by network operators as part of their submission to Ofgem under RIIO for investment allowances, this implies a need for studies to be aligned to windows of time when operators are developing and submitting their license renewals. There is a risk that either opportunities to include local energy strategies will be missed, or that strategy work will be cyclical to fit with network operator renewal timescales. This cyclical nature of events is more likely if DNOs are funding the work. If work is led by local authorities and has regular renewals/updates, this is less likely to happen. In this case, the latest versions of local government plans for the whole DNO area could be brought into DNO discussions with Ofgem when required. Ofgem is currently (May 2018) consulting on the RIIO-2 framework[31.] This provides an opportunity to consider how network operators might best engage with Local Area Energy Planning.

32 https://www.ofgem.gov.uk/publications-and-updates/riio-2-framework-consultation

4.4.2 The value of Whole Systems approaches

The pilot studies have clearly indicated the value of taking a Whole Systems approach to energy planning so the trade-offs between options can be understood. Network operators have, traditionally, only been concerned with managing their own assets in isolation. For Whole Systems Local Area Energy Planning to be conducted across many areas, it would be valuable for network operators to have a deeper knowledge of the wider energy system and the interactions between different parts. This would allow them to be more proactive in developing solutions that have the best outcomes for society.

In the pilot studies it was noted that network operators were still inclined to consider how different options might impact their network, rather than considering the wider benefits of those options. From a consumer perspective, the best option for network operator investments might not be investment in network assets. For example, spending money on improving the thermal performance of houses might prevent the need for network reinforcement, while reducing consumer bills. Ofgem is considering a requirement for network operators to consider these factors under RIIO2[33].

For non-strategic network investments, each distribution network operator has a procedure that must be followed by anyone wishing to apply for a new connection or an increase in connection capacity.

A typical process includes:

1. Application form – including details of the number and type of buildings, the electrical devices within them and their expected network loads;
2. Design and quotation – with quotations valid for 30 days;
3. Customer acceptance and payment;
4. Wayleaves[34] and legal process;
5. Construction.

Whilst the process can work well for specific property developments, it is hard to imagine how it might be used for large-scale schemes such as the deployment of heat pumps across whole city districts. If each property is considered as an individual project that is handled alone then excess or insufficient additional capacity may be planned for any given timescale. There will also be an excessive administrative burden and network reinforcement activities will be piecemeal rather than planned or enacted in a way that minimises the cost to consumers. Network reinforcement planned and enacted at a larger scale is more likely to achieve better outcomes at lower cost. Adopting a transparent, consensus-based process of Local Area Energy Planning, that includes all local stakeholders such as residents, businesses, local government, energy network operators and politicians, should reduce the risks associated with network planning. It could provide individual home owners with confidence that the choices they make will be supported in the long-term with networks built and maintained to supply the energy they need, in sufficient quantities, at an acceptable cost.

Changes will be required to network operator license conditions to enable and encourage the adoption of this approach.

33 For example, as outlined in the recent RIIO-2 consultation Ofgem flagged the need to support the delivery of "Whole Systems outcomes" and for more extensive stakeholder engagement with consumer, user groups and others, both of which align closely with the way EPN has been developed and how it has been applied in practice. https://www.ofgem.gov.uk/system/files/docs/2018/03/riio2_march_consultation_document_final_v1.pdf

34 A right of way granted by a landowner, generally in exchange for payment and typically for purposes such as the erection of telegraph wires or laying of pipes.

4.4.3 Timing of changes to networks

Due to the size of the networks they manage, and the level of change likely to be required, it is reasonable to expect that the transition will be phased to minimise and manage disruption to local areas and consumers.

Based on current network planning approaches, it is possible that such phasing would not align with the ambitions and commitments of the local areas to act on climate change. For example, Cadent considers that the deployment of hydrogen in the gas network across the North West would spread out from coastal areas in north Cheshire, where there are hydrogen production facilities and stores for CO_2. It anticipates that hydrogen would initially be supplied to the Liverpool area before it would be piped inland to central Manchester. It is likely to be a significant time before this hydrogen network would be extended northwards to Bury, and could therefore delay the decarbonisation of heat in the area, or lead to the adoption of alternative options, which could prove more expensive for residents and businesses.

4.4.4 Risk of disruption caused by the changes to networks

The pathways to decarbonise heat in each local area are likely to require significant work to energy networks and associated disruption to homes, people and businesses, including:

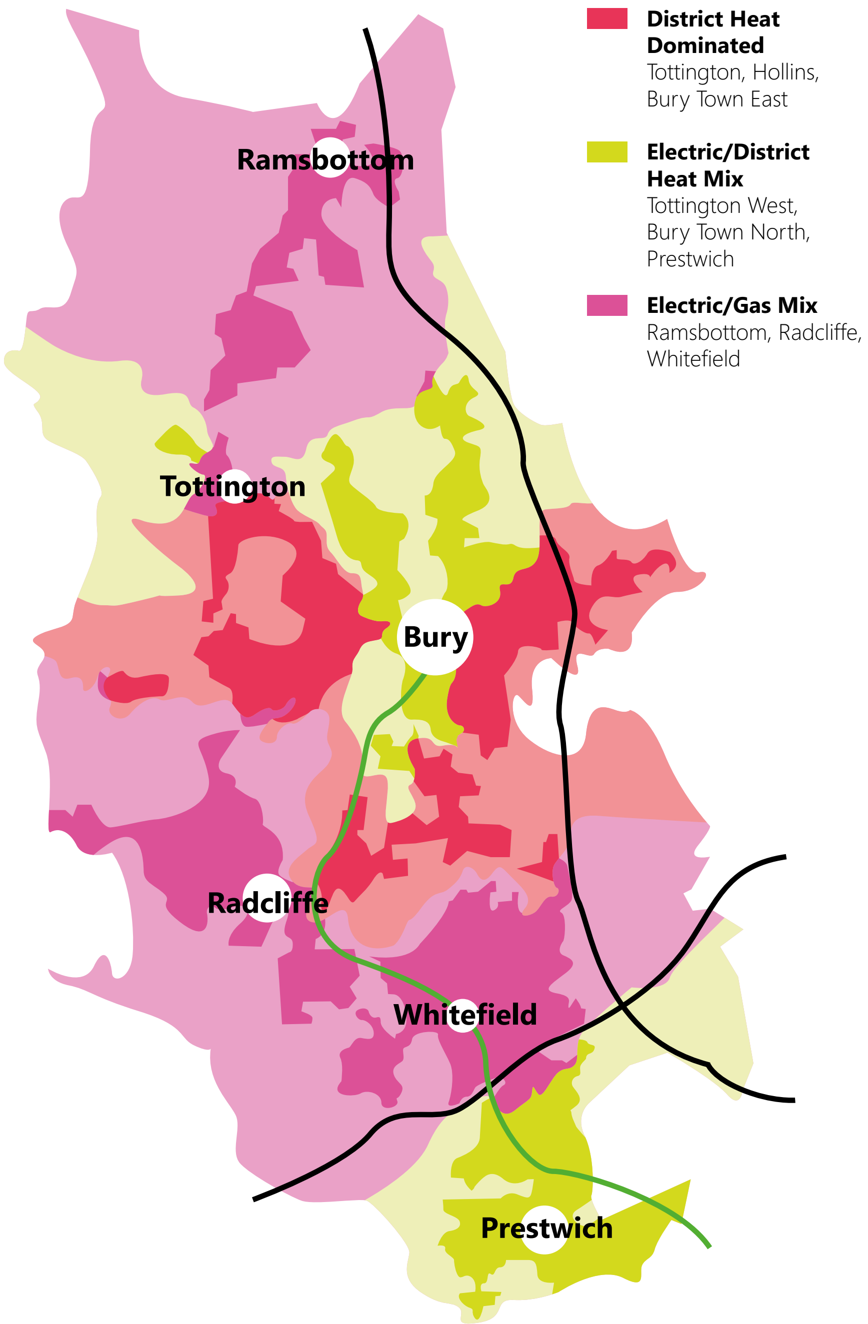
- Building heat networks;
- Reinforcing electricity networks;
- Repurposing and/or decommissioning gas networks.

These are all likely to require roadworks across wide areas and have significant impact on local transport, causing wide-scale disruption and potentially short term negative economic impact. These impacts will need to be investigated, understood and mitigated where possible.

4.4.5 The role of the gas network and low carbon gas

The UK has a world-class gas grid infrastructure, with over 80% of properties using gas to provide their heating and cooking needs. 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. In addition, 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 sites. The potential for a lower-carbon gas utilising the existing infrastructure is therefore appealing.

The Bury analysis highlighted that some areas are harder to transition than others. It suggested that if a limited volume of low carbon gas was available in a local area, it should be targeted to these areas to gain the maximum benefit from a Whole Systems perspective (see Figure 15).



There are many options available for producing low carbon gas, including landfill gas, sewage gas, anaerobic digestion of wet waste and gas produced directly from biomass.

Not all the available biomass resource should be expected to be converted into biogas. Biomass is an extremely valuable resource due to its versatility and is likely to be in demand for central power generation with CCS (to create negative emissions) and for conversion to transport fuels (where there are limited practical options for decarbonisation of fuels for aviation and heavy duty vehicles). Similarly, any low carbon gas produced is likely to have significant value in the wider energy system for transport or industrial heat, meaning the gas network would have to be maintained despite delivering much lower quantities of energy. It is hard to predict the likelihood and magnitude of these influences. When considered together, low carbon gas may prove to be too expensive to be a viable option for domestic heating.

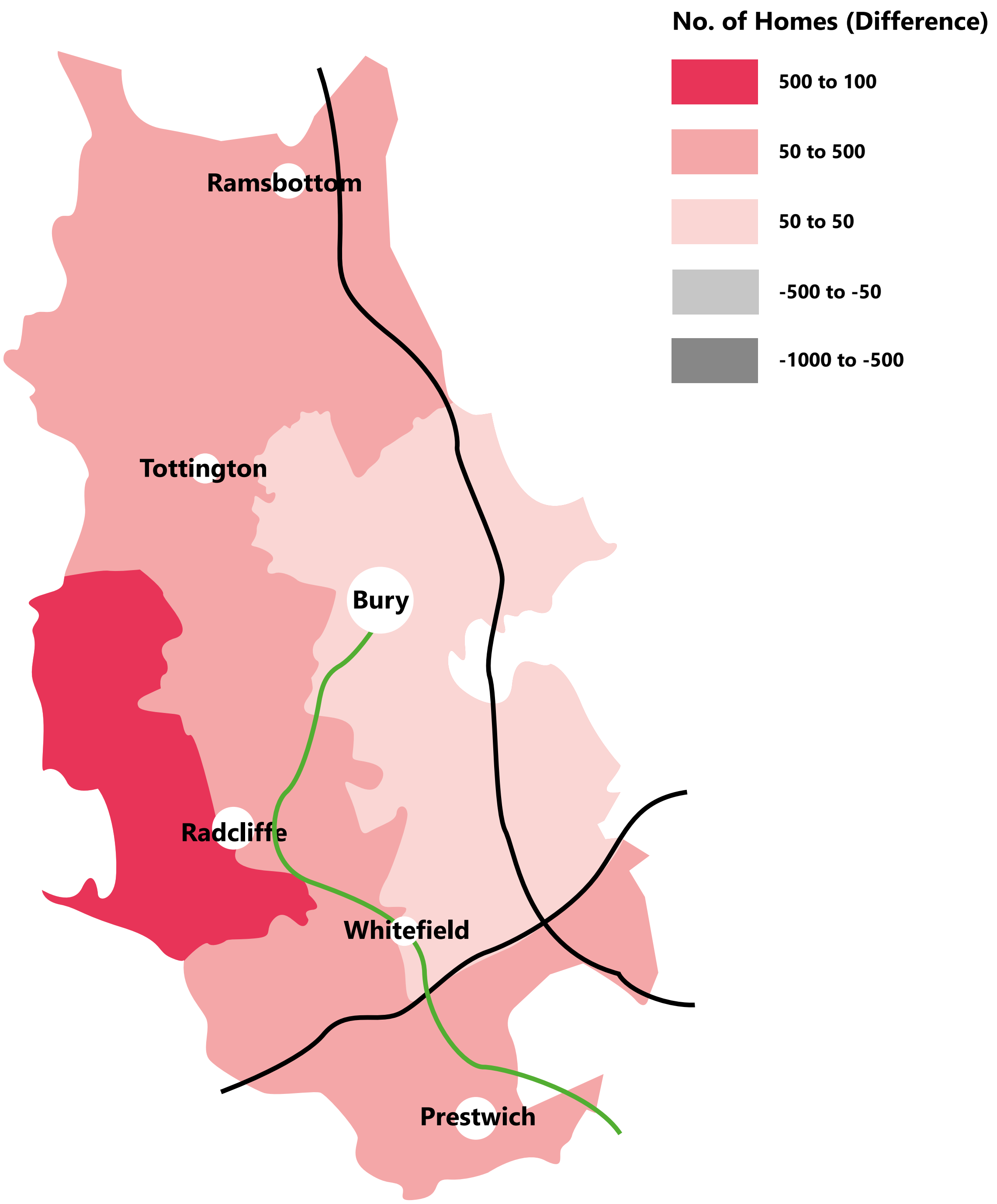
If sufficient volumes of low carbon gas could be delivered, this may provide an alternative option to providing heat through heat networks or individual electric solutions. An option could be to use heat pump technology to meet the base load, hybridised with a gas boiler to meet peak demand. Air Source Heat Pump gas boiler hybrid technologies are already available commercially and are offered as an option within EnergyPath Networks. They can be sized to meet the heat demands of all buildings. However, they cannot be used in sufficient quantities whilst burning natural gas without exceeding a tight emissions constraint. Using low carbon gas would, however, enable their use whilst still operating within a tight constraint.

An alternative method for achieving a lower carbon gas would be to blend it with hydrogen. This could be implemented at a level where it would still be compatible with current domestic heating systems. The maximum hydrogen blend that could be mixed with natural gas, without requiring changes to gas boilers, is 20% by volume[35]. When considering this option, it is important to remember that 20% hydrogen by volume is only 7% in energy. If hydrogen still has some embedded carbon due to the production method, the impacts of the blend will inevitably be small. An analysis using a high-hydrogen gas blend for Bury highlights the areas where moving away from gas boilers is most difficult. When low carbon gas is available, buildings in these areas are able to continue using gas boilers, as shown in Figure 21.

"Energy demands are changing. To achieve low carbon ambitions significant investment in energy networks is needed"

35 https://hydeploy.co.uk/

Figure 21: Buildings in Bury that remain on gas boilers when low carbon gas is available compared to a scenario when it is not available



An alternative option could be use of the gas distribution network to provide hydrogen for heating systems. This has been researched within the H21 project led by Northern Gas Networks[36]. This project looked in detail at Leeds but also considers the implications and options for a wider roll-out across the UK. In addition, it identifies a series of further research and development projects which should be conducted to improve our understanding of the options available and their practicality under real-world constraints. When the pilot projects were initiated, little data was available for the production of low carbon hydrogen and the costs of re purposing the gas network for hydrogen. Since the H21 project was published, further work has been conducted and EnergyPath Networks is able to consider the option of using hydrogen for heat, which could form an important part of scaling up a Whole Systems approach to Local Area Energy Planning and informing long term network choices.

In all study areas the local gas network operator was interested in the options for use of low carbon gas. To understand and assess this, several pieces of information are required:

1. The volume of low carbon gas available to the study area;
2. The timescales at which different volumes of gas will be available;
3. The cost of producing low carbon gas;
4. The carbon content of the gas;
5. Whether the gas is mixed with natural gas or substitutes it.

None of the gas network operators involved in the pilot studies could provide all of this information.

36 https://www.northerngasnetworks.co.uk/wp-content/uploads/2017/04/H21-Report-Interactive-PDF-July-2016.compressed.pdf

4.4.6 Optimising the value of planned or previous network investments be optimised

Previous or future planned investments may provide an opportunity for energy system change. For example, current electricity network operator practice is to fit large 300m^2 feeders when replacing LV network assets. Areas where this has occurred are much better suited to large-scale use of electric heat solutions compared to areas where traditional practice was to fit the smallest feeder that would meet predicted demand with an associated headroom.

4.5 What are the benefits of open data driven approaches?

There are several areas where lack of data and information is a considerable barrier to making informed decisions and initiating action towards a low carbon transition.

A lack of data gives a high degree of uncertainty in the assessment of future options, leading to a reluctance to pursue actions that might result in inappropriate investment decisions and stranded assets.

In some cases, data might be available but is held by different stakeholders who can be reluctant to share it for commercial or privacy reasons (e.g. customer connection data which can be valuable in understanding how demands are applied to networks in a Whole Systems analysis). Ofgem prefers to define principles that encourage data sharing rather than mandating what should be shared, and different network operators have their own policies around what data they are prepared to share.

In some cases, such as various heat pump trials, data is dispersed (The Customer Led Network Revolution led by Northern Powergrid, the Freedom project led by Wales and West Utilities in conjunction with Western Power Distribution and the NEDO project co-ordinated by GMCA). In all cases, while detailed reports might be published, the underlying data is not publicly available. This decreases the ability to collate information from all trials and achieve maximum benefit.

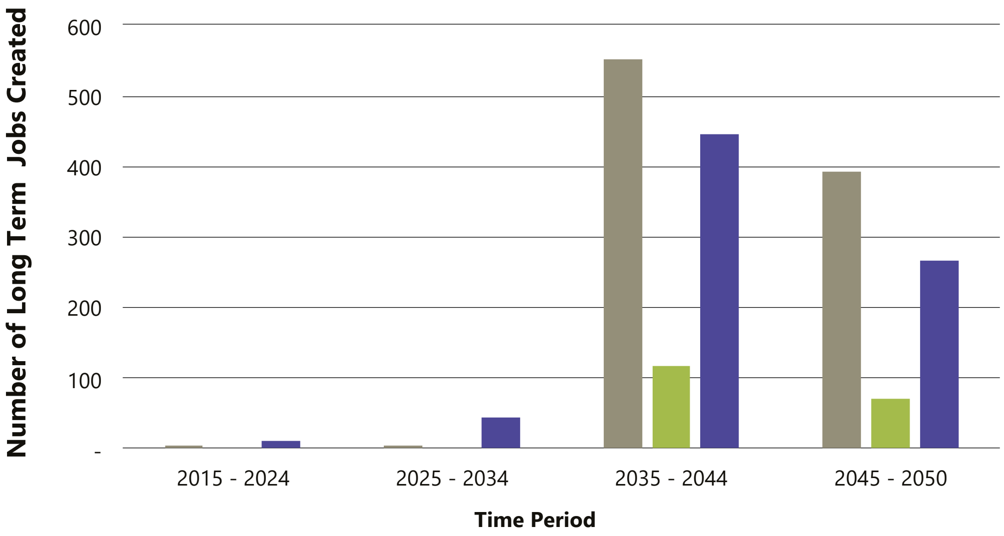
Local authorities could begin to fill the data gap over time by taking advantage of ongoing and future infrastructure projects in their local area and compiling survey data, as well as detailed records of new installations, replacements or maintenance on local utilities. This would help to develop a good understanding of the installed infrastructure along potential heat network routes. They could also build relationships with large energy consumers in the local area and promote detailed record keeping of energy usage.

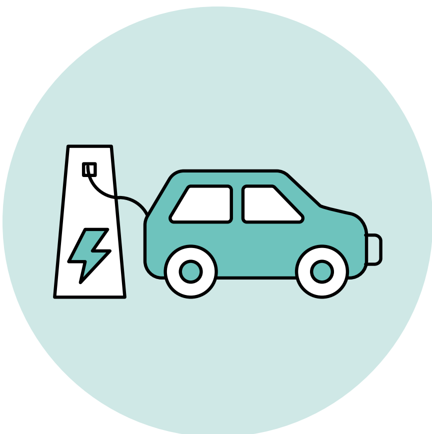
4.6 What are the wider benefits of a local approach to decarbonising heat?

As discussed in section 3.7, improvements to the thermal efficiency of homes have the potential to realise benefits in terms of improved health and reduced fuel poverty. Reducing the amount of gas burnt in boilers may also generate improved air quality benefits in urban areas.

Investments associated with a low carbon transition will create jobs for both domestic installations and new energy networks/reinforcements, as well as additional maintenance jobs. The estimated number of additional long-term jobs created in each local area is different, as shown in Figure 22. These are additional jobs created through investment in decarbonisation that would not exist under 'business as usual'. Most jobs are created in later years when the pace of change is greater. These jobs are mainly split between work on networks and on domestic buildings, as shown in Figure 23.

Figure 22: Estimate of long term local jobs created in three local areas





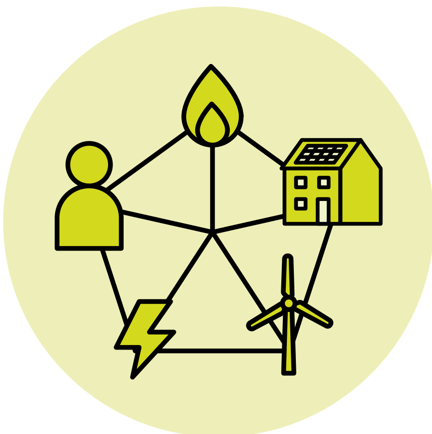
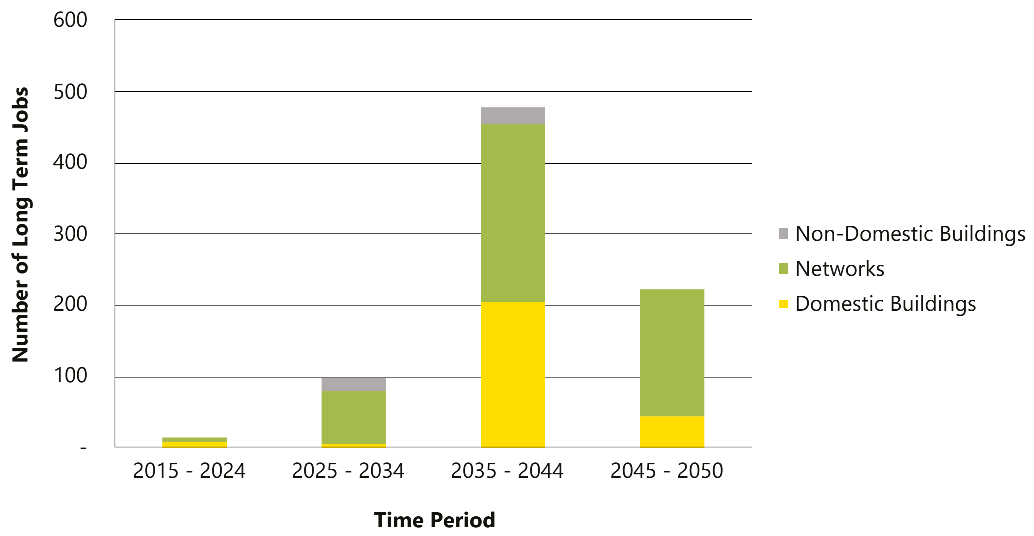


Figure 23: Breakdown of predicted long term jobs for Bury



“A lack of data and information presents a barrier to making informed decisions and progressing the low carbon transition”

5. Social dimension of Local Area Energy Planning

Making decisions is a social, not a technical process.

Change cannot be enforced in a democratic society. Individual private homeowners have the right to decide what changes they wish to make to their homes for themselves. Any changes to how homes are heated will need to be decided through a transparent, consensus-based process that includes all local stakeholders, including residents, businesses, energy network operators and politicians. For individual homeowners to make changes to the way they heat their homes, they must be provided with confidence that the choices they make will be supported in the long-term through supply of the energy they need, in sufficient quantities, at an acceptable cost.

The pilot projects intended to start the process of exploring what this consensus-based process might look like, the types of information required to enable a mutual understanding of the options and how decisions might be made. The EnergyPath Networks Analysis Framework was developed to support this exploration. It was not intended to provide a single future pathway that could be imposed on residents. Rather, to enable the production of data and analyses that can help local stakeholders explore and understand the technical options, the robustness of solutions to various scenarios, and the implications of different decisions.

Local governments are an obvious choice to lead Local Area Energy Planning as they are led by democratically elected representatives and have a desire to meet the best interests of their residents.

Local areas have different demographics in different areas. These will require individual engagement strategies. For example, in Bridgend, an area of new housing exists to the east of the town centre that is predominantly occupied by young families and is located close to new industrial areas. This contrasts with the Porthcawl, area where the housing stock is older, and the population is predominantly ageing, retired and more affluent.

Much of the previous material presented relates to the characteristics of local areas, the technical data and mathematical process used to develop evidence that could be used to support local decision-making around local energy systems. However, making those decisions is a social, not a technical process. All decision-making situations are affected by different stakeholders with a variety of personalities and individual factors influencing their decisions. It is therefore not possible to define a rigorous process to be followed in all situations. This section draws out common themes and differences from decision-making undertaken across the three pilot studies.

The pilot studies used an evolving social process, working with key local stakeholders to develop a local area energy strategy for each of the three local authorities. Local network operators and devolved government partners (Greater Manchester Combined Authority for Bury and Welsh Government for Bridgend) have been involved in this process, and the resulting strategies reflect their interests and concerns. There will be benefits to be gained from wider consultation and engagement with residents when developing local area energy strategies, in a similar way to those currently adopted for development planning.

5.1 What are the barriers to a local approach?

There are many barriers to achieving a low carbon transition in local areas. Research conducted by the Town and County Planning Association (TCPA)[37] presented the following conclusions:

1. Climate change has been de-prioritised as a significant local planning policy issue;
2. National policy regarding viability prevents the delivery of key actions;
3. Evidence gathering, methodologies and policy making for matters such as flood risk are far more sophisticated than the equivalent for climate mitigation or any aspect of adaptation;
4. Climate change-related policy in Local Plans is generally short term and not sufficiently 'future facing' to deal with climate risk;
5. The duty to co-operate among LPAs is overwhelmingly focused upon housing growth, with little or no emphasis placed on cross-boundary climate change issues.

Many of these issues have been experienced in the pilot studies, whilst other factors identified are discussed below.

5.1.1 Local government skills and resources

Lack of skills and resources within local authorities present a barrier to the development and implementation of Local Area Energy Plans.

A questionnaire sent to local authorities as part of the Smart Systems and Heat programme identified that:

- Only 33% of respondents identified that their planning authority had the skills to effectively plan for local area energy provision;
- Only 17% of respondents identified that their authority has the resources available to effectively plan for local energy provision.

The consensus amongst the responders was that:

- National planning policy needs to be strengthened to effectively deliver Local Area Energy Planning;
- The split between planning and building regulation control makes it difficult to impose comprehensive low carbon energy solutions;
- There is a lack of local authority resources to deliver Local Area Energy Planning;
- Resources are severely stretched (staff and funding), meaning there would need to be a statutory requirement for the delivery of Local Area Energy Planning to achieve the traction and deployment required.

Some respondents also identified that the requirement to deliver housing is taking precedence over the need to reduce emissions from those new developments. This highlights the competing priorities in the wider planning system and is discussed further in section 3.8.

37 Planning for the Climate Challenge – Understanding the Performance of English Local Plans, *Town and County Planning Association* (2016)

5.2 What is the right scale in adopting a local approach to decarbonise heat?

Decisions related to energy must be made at varying scales and involve different stakeholders.

There is a significant challenge with decision-making across scales and the relationships between local, regional and national priorities and agencies. These are exacerbated by the large number of stakeholders who must make decisions in order for common action to occur. Examples include:

- Reflecting national carbon targets in corresponding regional and local carbon targets;
- Decisions influencing the technologies used to generate electricity at a national scale and their influence on local carbon emissions;
- Decisions made by distribution network operators that influence the choices available at a local level;
- The priorities and powers of devolved governments and combined authorities, and their influence on local authority decision making.

In addition, different stakeholders act across a variety of scales. For example, an electricity network operator is responsible for an area covering many cities and different local authorities whilst a heat network operator will be considering small areas within individual cities and local authority areas.

5.3 How do local government structures influence local decision-making?

Local areas have different governance structures regarding decision-making.

These also influence the availability of funding sources for local action, depending on whether responsibility is held centrally, regionally or locally.

In some cases, such as Newcastle, all decisions and responsibilities currently lie with the council. In other cases, such as Bury, some decisions and responsibilities lie with the combined authority, of which the council is a member. Each combined authority has a different set of roles and responsibilities depending on their individual devolution deal with central government. There is no common template for how these relationships might influence responsibilities and decision-making in any combined authority. In the cases of Wales and Scotland, different powers and responsibilities have been devolved to the regional governments and this will influence their interactions with local councils.

5.4 How should emission reduction targets for decarbonising heat be shared?

Setting carbon targets is a complex area that requires decision-making across scales.

The potential interactions between different levels of government in setting carbon targets are shown in Figure 24. There is no national regulation requiring carbon target setting, or action at a local scale. There are also questions around how to ensure the sum of any voluntary local and regional targets is sufficient to make up the national target.

In addition to the need for local and regional interaction with national government, there are questions around what is the 'fair share' for any local area. Areas that have suffered loss of heavy industry since 1990 may have significantly more carbon headroom available than areas where industry has remained. When considering emissions from the 10 local authorities that make up Greater Manchester Combined Authority, different targets would appear to be appropriate.

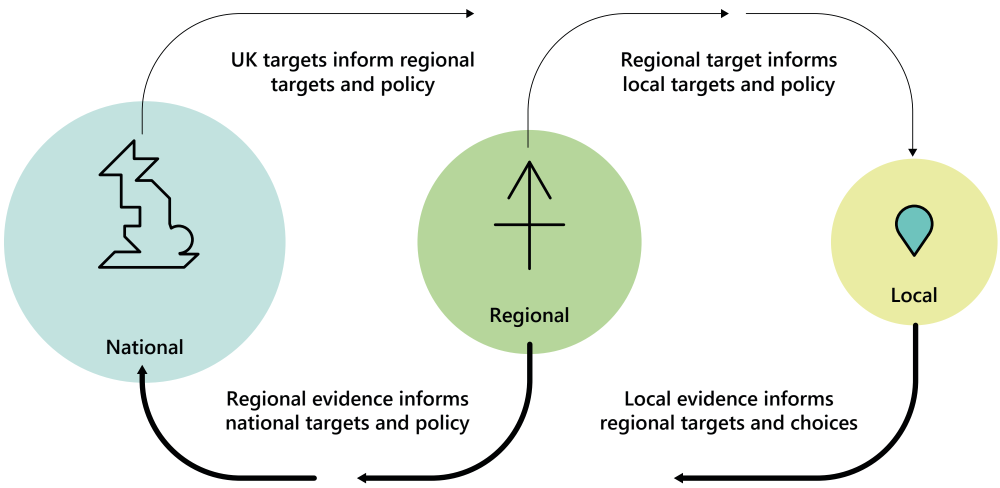
Bury has the lowest industrial and commercial emissions (as a percentage of all building emissions) of all councils within the authority (Table 2). This is partly due to the closure of several industrial sites within Bury. It might, therefore, be reasonable for Bury to target higher emissions reductions (from 1990 levels) than other areas that have higher industrial and commercial emissions as it is easier for Bury to meet a reduction target than other areas. It could be argued that Bury should take a larger proportion of the total combined authority emissions reduction target than its 'fair share'. Alternatively, it could be argued that Bury should be allowed greater emissions headroom to allow the opportunity for greater economic growth to replace previously lost industries in the area.

Table 2: Proportion of emission sources for local authorities in Greater Manchester[38]

	Percentage of LA emissions	
Second Tier Authority	Industrial and Commercial	Domestic
Bolton	46%	54%
Bury	41%	59%
Manchester	59%	41%
Oldham	43%	57%
Rochdale	50%	50%
Salford	48%	52%
Stockport	42%	58%
Tameside	46%	54%
Trafford	68%	32%
Wigan	48%	52%

38 https://www.gov.uk/government/collections/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics

Figure 24: Relationship between local, regional and national government

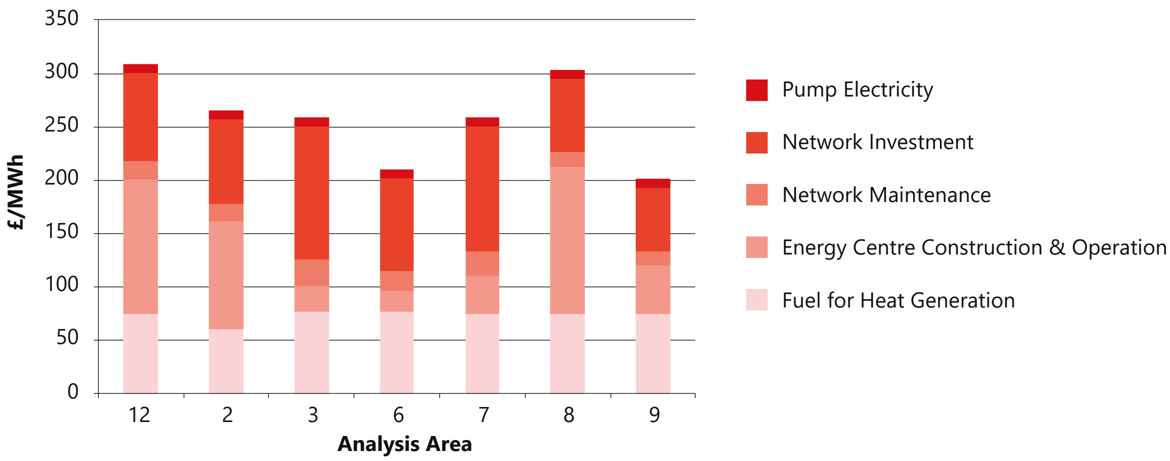


5.5 How should costs be shared?

Our analysis has found that the costs of transition are not uniform across a local area.

Figure 25 demonstrates how the different components of the total cost of delivering heat could change depending on the local area, with the most expensive area being 50% more expensive than the cheapest.

Figure 25: Delivered heat cost for heat networks across different areas of Bridgend



There are questions around how costs for both buildings and networks should be distributed between different energy users. The current arrangement socialises costs for gas and electricity networks so that investments in one part of a network are paid for by customers across a much wider area. There is no similar mechanism to socialise heat network costs across an area wider than that served by the network itself. The problems of socialising costs are equally acute for investments in private housing. For example, the Feed In Tariff for solar PV[39] is funded by all electricity bill payers but has predominantly benefitted more affluent owner-occupiers who are, effectively, being funded by those least able to pay for higher energy costs.

39 A subsidy paid to owners of solar panels based on the electricity they generate.

There are also problems associated with paying the costs of gas network maintenance with reducing gas demand as customers switch to alternative low carbon heating systems. This can be seen in the estimated total gas costs for Bury, where in one scenario demand is estimated to decrease from 1,680MWh/year in 2020 to just 120MWh/year in 2050. The result is that, whilst raw gas cost is forecast to increase by 23%, the cost of delivered gas increases by three as the gas network operation and maintenance costs are spread over a much smaller quantity.

Inconsistency between the tax regimes for different energy networks can distort their competitive position. For example, heat networks are disadvantaged compared to other energy networks due to a requirement to pay business rates, which does not apply to gas and electricity network operators.

Costs often accrue to different stakeholders compared to those who benefit from particular choices.

For example, installing heat storage into homes may reduce the need for network reinforcement. This increases homeowner costs whilst reducing network operator costs.

"Energy system decisions should be made across varying scales and involve different stakeholders"

5.6 How can the interests of different stakeholders be aligned?

One stakeholder's decisions can impact other stakeholders.

Whilst Local Area Energy Planning is considered an important enabler for decarbonising heat and delivering low carbon future energy systems, local governments are not directly responsible for or directly involved in most aspects of energy generation, distribution and supply in their local area. Decisions on these factors will be dependent on a variety of stakeholders, and there are several areas where the decisions of one stakeholder can impact other stakeholders:

- Homeowners may be reluctant to change from using a gas boiler to heat their home if they are not confident that the fuel and energy network required for the alternative system (e.g. switching to a heat network) will be both available and reasonably priced in the long term;
- A local area plan may designate one area as particularly suitable for electric heat solutions, but this could depend on the network operator agreeing to reinforce the network in that area. This decision would also influence the viability of the gas network in that area, which may then be decommissioned, whilst some gas uses are not ready or able to switch to an alternative energy source;
- A decision to repurpose the gas grid to hydrogen could require all connected customers to modify or update their gas appliances;
- Non-domestic decisions can drive domestic options. Since many non-domestic buildings have large heat demands and are professionally managed, they have strong incentives to use the least-cost solution. Such buildings may therefore remain on gas boilers, forcing domestic energy users to switch to low carbon heat solutions if emission reduction targets are to be met;
- Gas network operators are currently legally obliged to provide new network connections if requested. This may prove unhelpful in the context of a local area energy strategy that is expecting certain areas to move away from using gas heating solutions;
- The license periods for gas and electricity network operators are staggered by two years. With license periods of eight years this limits the ability for different network operators in an area to plan collaboratively from a Whole Systems perspective. In addition, the boundaries of the areas covered by the gas and electricity network operators are not aligned, meaning that each operator will have to work with several others.

5.7 What are the common themes related to the social dimension of more effective Local Area Energy Planning?

The process undertaken in the pilot studies has identified common themes related to the social dimension of Local Area Energy Planning:

- The local government is keen to be involved in energy related decisions because they understand the wider influence of energy in people lives in their communities;
- Local government has limited powers and resources with relation to energy, with no statutory obligation to conduct energy planning. Effective planning will require significant expertise, which is not widely available within local authorities;
- It is hard for local government to make the business case for energy planning and projects that come from that planning process. It is difficult to quantify the wider benefits reliably and the direct financial benefits of a scheme may be insufficient to justify investment;
- It is often difficult for local stakeholders to engage with energy system modelling and analysis in the early stages of exploration. Model outputs feel remote and are hard to relate to their knowledge of the local area;
- There is a significant challenge with decision-making across scales and the relationships between local, regional and national priorities and agencies. These are exacerbated by the large number of stakeholders who must make decisions in order for common action to occur. In addition, different stakeholders act across varying scales. For example, an electricity network operator is responsible for an area covering many cities and different local authorities whilst a heat network operator will be considering small areas within individual cities and local authority areas;
- Network operators are interested in understanding options and pathways at a local authority scale, but this only relates to a small portion of the network they manage. It is not clear how operators might engage with the process across multiple local areas or integrate the outcomes into their own planning processes;
- Local councillors are interested in pathways at a detailed level. For example, what does it mean for residents in a ward? This can lead to a lack of interest in, and engagement with, the wider aspects of a strategy. It also suggests that it will be hard to achieve stakeholder engagement with centrally planned, top down solutions;
- Network operators understand the need to engage with local stakeholders and are encouraged to do so under RIIO. However, there is only a requirement to demonstrate engagement and the scale and type of engagement are not specified. It may not be reasonable or practical to expect that network operators could engage in detail with all the local authorities in their network area;
- The EnergyPath Networks analysis was used to identify key themes for each local area. These were then used to encourage discussion between the local stakeholders to help identify actions that were of interest and where stakeholders felt they had agency to act. The process of using model outputs as a common evidence base for local discussion and decision making appears valuable in terms of achieving common understanding and goals;

- In the current policy and regulatory environment, it can be hard for a local authority to achieve significant energy related change as they do not have a remit to engage with energy beyond considering their own estates and the requirement to reduce fuel poverty;

- There is often a desire to identify low-risk projects that can be funded and brought forward in the short term as a shorter planning timeframe helps to manage uncertainty. Whilst these projects demonstrate commitment, there is a risk that they will not fit well into a longer-term strategy for the whole energy system if they have been developed in isolation;

- Many decarbonisation projects are unlikely to be commercially viable for the private sector. Whilst local authorities have opportunities to borrow capital at low interest rates, they have significantly constrained budgets, whilst many can only support investments that will make a financial return;

- The scale of change required to fully decarbonise the buildings in a local area is sufficiently large that many stakeholders consider the challenge as unaffordable. This leads to a desire to find cheaper and easier solutions and a desire to postpone action.

5.8 What are the opportunities for direct local action?

There are few areas where a local authority can have a direct influence on future carbon emissions.

Local authorities currently have some powers and the ability to directly influence future carbon emissions in new builds. New build emissions are estimated to be less than 0.5% of total UK domestic emissions based on building around 200,000 units annually. Improving the performance of these buildings will not address the larger problem of reducing emissions from existing housing stock, but should be considered as part of an overall strategy as:

- These buildings can be expected to be in existence for decades and still be emitters in the future. If planned government build rates continue to 2050 then all the buildings completed between now and 2050 could make up over 30% of the total 2050 stock;

- Demolition and replacement of older buildings means that new builds will become an increasing proportion of the total stock;

- New buildings could be made ready for future low carbon heating systems so that transitioning them can happen at a lower cost and inconvenience to residents;

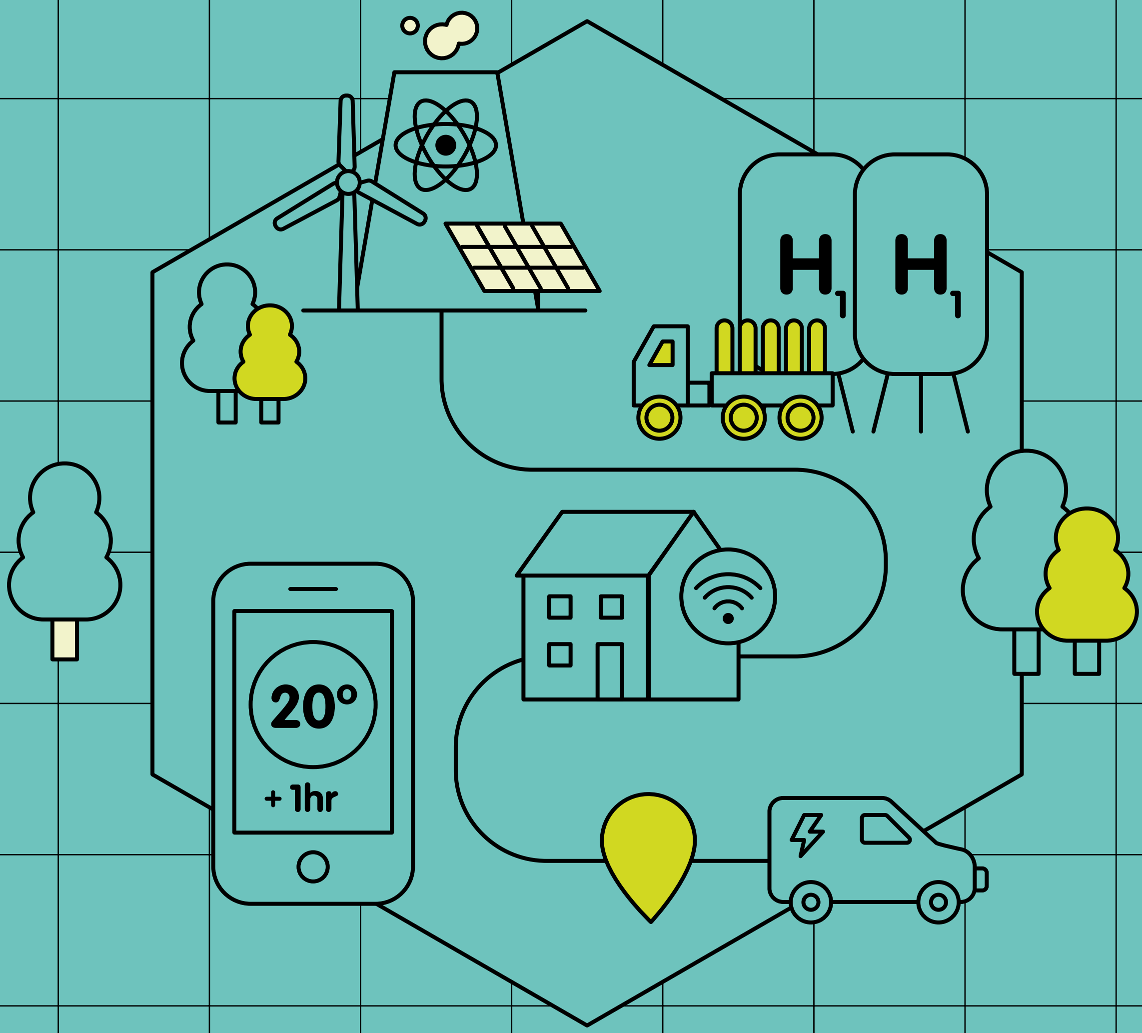
- Fitting low carbon systems to these buildings could encourage take up in older buildings if they are perceived as a newer, better technology.

Some of the challenges associated with defining new build specifications are discussed in section 3.8.

Secondly, local authorities can also directly influence emissions from their own buildings (both public buildings and social housing), through investment in improved thermal efficiency and low carbon heating or generation systems.

Thirdly, larger local authority-owned buildings (such as leisure centres, offices and libraries) may also be suitable as anchor loads for heat networks. Providing significant heat demand by connecting buildings over which a local authority has control, local authorities can help make heat network schemes viable.

6. Conclusions



6.1 Places

- Every local area is unique – buildings, existing energy networks and people all vary across areas – and the changes required to reduce carbon emissions will be specific to each area
- Local decision making will require:
    - Consideration of the local building stock;
    - Inclusion of the spatial characteristics of a local area and the existing energy networks;
    - Consideration of future development plans, including new domestic and non-domestic buildings and their associated energy demands;
    - A multi-solution approach that includes interactions between different energy networks across the local area.

6.2 Technologies

- A wide range of heating system options are required to enable the deepest carbon reductions. Individual electric heating systems, heat networks and low carbon gas are all likely to play a prominent role in a low carbon heat solution.
- The mix of these solutions will be unique to each local area. It is not possible to define simple metrics that allow choices to be made quickly and easily, with the least-cost solutions for suburban areas being particularly hard to define.
- Gas combined heat and power (CHP) for heat networks and air source heat pump-gas boiler-hybrid heating systems in individual homes could be valuable transition technologies.
- It is unlikely that local government will wish to encourage widespread use of biofuel, including use of biomass boilers, for domestic heating.
- Heat storage is likely to be a valuable component of future heating solutions, both at a domestic scale and in association with heat networks.
- Identifying the sources of low carbon heat that could be used for heat networks in a local area will be critical to developing networks that can deliver significant carbon reductions.

6.3 Networks

- Significant resources will be required from network operators if they are to engage effectively in the sort of transparent, consensus-based Local Area Energy Planning process that will be required to meet ambitious carbon reduction targets. Consideration should be given to how planning for wider-scale domestic retrofit schemes might be conducted more effectively to reduce administration and expensive incremental network reinforcement.
- Regulation will need to change to allow wide-scale schemes to be planned, managed and enacted efficiently. Ofgem should consider:
    - How to encourage Local Area Energy Planning to achieve a more integrated and co-ordinated approach to network development that engages a range of stakeholders to make decisions;
    - How the planning framework can be aligned with network operator regulated planning cycles;

  - How network operators can be incentivised to make the data they hold more readily available to enable an effective Whole Systems planning process;

- Whole Systems analyses which consider interactions between a variety of energy networks will be critical to identifying the most appropriate solutions for different areas;

- Heat pump trials have generally avoided clustering to reduce network reinforcement requirements. A better understanding of the influence of clustering on networks would be useful. Initially this could be through network modelling, prior to a large-scale trial.

6.4 Opportunities and barriers

- Lack of skills and resources within local government is a barrier to development and action of Local Area Energy Plans.

- New development offers an opportunity to build houses that are highly energy efficient and fitted with low carbon heating systems.

- New developments built with gas central heating should be 'future-proofed' to allow a cost-effective switch to low carbon heating systems.

- There are several areas where lack of information is a considerable barrier to making informed decisions and initiating action for a low carbon transition.

- In adopting a Whole Systems approach to Local Area Energy Planning it can be difficult to align the interests of different stakeholders, especially as costs often accrue to stakeholders who may not benefit from particular choices. For example, fitting larger heat storage tanks in domestic buildings might reduce the requirement for electricity network reinforcement. This would save the network operator costs at the expensive of householder cost and convenience. How costs and benefits are divided will be critical to achieving a fair solution.

- It is unclear how network operators can plan and invest in the levels of network change required whilst working within restricted license periods.

- There is no formal process to undertake Local Area Energy Planning or ensure such plans are adopted within local government.

- Available subsidies can drive short term decision-making without considering how these choices might fit into a longer term, area-wide strategy that considers the whole energy system.

6.5 Local area planning process

- Local governments are an obvious choice to drive Local Area Energy Planning as they are led by democratically elected representatives and have a desire to meet the best interests of their residents.

- Local governments have limited powers and resources in relation to energy, with no statutory obligation to conduct energy planning.

- Decisions related to energy must be made at varying scales and involve different stakeholders.

- There is a significant challenge with decision making across scales and the relationships between local, regional and national priorities and agencies.

- A process of exploring future local energy scenarios to produce a common, robust evidence-base for local discussion and decision making appears valuable in terms of achieving common understandings and goals.

- The scale of change required to fully decarbonise buildings in a local area is sufficiently large that many stakeholders consider the challenge as unaffordable. This leads to a desire to find cheaper and easier solutions and a desire to postpone action.

6.6 Economic and social impact

- It is expected that replacing natural gas with low carbon energy sources, when combined with the required network changes, will increase the cost of energy for heat.

- The overall energy demand is expected to reduce due to efficient electric heat pumps displacing gas boilers. This change is expected to be insufficient to offset the increased cost of low carbon energy, compared to natural gas.

- To break-even on decarbonisation investment, the cost of carbon for the three study areas was estimated to need to be **between 2,900 and 6,400 £/tonne** based on the total increase in cost and the total carbon saved to 2050.

- Investments associated with the transition will create jobs for domestic installations, new energy networks build and network reinforcements, as well as additional maintenance jobs.

- Some improvements in local air quality can be expected from a switch away from gas boilers.

- Improvements in housing stock as part of decarbonisation should result in health benefits, such as warmer and less damp housing.

- A key challenge is ensuring that the cost of decarbonisation is mitigated for fuel poor households who often live in the most inefficient houses and will therefore suffer most from increased energy costs.

Appendix 1: Methodologies and assumptions for benefit calculations

A variety of economic costs and benefits are expected to be realised from the decarbonisation of local energy systems. Analysis using EnergyPath Networks has adopted an approach of comparing the costs and benefits of achieving a local carbon target with a counterfactual when no local carbon target is set. This business-as-usual scenario consists of modelling exactly the same dataset but with no carbon target set for the local area (decarbonisation of the national energy supply still occurs in this scenario). In all cases, a range of different scenarios can be analysed to give an indication of the uncertainty associated with the calculations.

The methodology developed takes output data directly from EnergyPath Networks and calculates indicative costs and benefits using HM Treasury (HMT) Green Book and Inter-departmental Analysts Group (IAG) guidance where appropriate.[40,41] By using data directly from EnergyPath Networks, it ensures that the accompanying cost-benefit analysis is consistent with all assumptions made in developing the technical aspects of the local area energy strategy.

As values of costs or benefits in the future are not representative of their worth in the present day (due to inflation etc.) all future costs and benefits are discounted to present day values. In accordance with Green Book supplementary guidance,[42] the following long-term discount rates are used:

- 0 – 30 years: 3.5%;
- 31 – 75 years: 3.0%.

As well as the direct economic benefits associated with energy system change (see Chapter 5), there are also wider social benefits that may be realised.

A.1 Levelised unit cost of energy

For both the reference case and the target run, levelised unit costs of energy must be calculated to monetise any energy savings for a cost-benefit analysis. As the modelling outputs from EnergyPath Networks predict how the energy networks will change over time, the costs of delivering this energy can also be calculated. The total costs of delivering each of the fuels (including any local generation) are added and divided by the total energy delivered to give levelised costs for gas, electricity and heat. These costs are taken directly from EPN, socialised across the whole LA area, and include:

- UK market price of energy[43];

40 HMT Green Book guidance: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/220541/green_book_complete.pdf

41 IAG guidance: https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal

42 Lowe 2008. *Intergenerational wealth transfers and social discounting: Supplementary Green Book guidance. HM Treasury.*

43 UK market prices of energy are inputs to the EPN tool and taken from the Energy Technologies Institute's ESME model. ESME is a National Energy System Planning and Design Tool, which underpins and informs UK Government's future Energy Policies - see http://www.eti.co.uk/modelling-low-carbon-energy-system-designs-with-the-eti-esme-model/

- Annualised network (transmission & distribution) investment costs, including both new-build networks and network reinforcements (this includes a 3.5% cost of capital);
- Network operating and maintenance costs;
- Annualised investment costs for local generation (excluding solar PV);
- Local generation operating and maintenance costs.

Any other resource costs (e.g. biomass or oil) are valued at the assumed UK market price, taken from the Energy Technologies Institute's ESME model, consistent with EnergyPath Networks input data. The presented costs are exclusive of any tax or profit for the energy suppliers.

In the cases of energy centres, which are producing both electricity and heat, the costs of the energy centre and generation fuel need to be apportioned between the two products to be represented in the calculated costs. The apportioning is done based simply on the electricity to heat generated ratio. If an energy centre is producing waste heat to access electricity generation, this is counted towards electricity generation and not heat.

A.2 Energy savings

The methodology developed during the pilot projects considers any fuel imported into the area (gas, electricity, oil, biomass, coal) used for domestic heating, either directly in domestic buildings or into energy centres to generate electricity or heat. Generated energy itself is not included, as this should be accounted for by the generation fuel and a reduction of imports in terms of electricity, with the same logic applying to both energy centres and solar PV. In this calculation we do not include heat as a vector (although it may theoretically be imported/exported across the analysis area boundaries), since heat is not exported outside the study area. At a local authority level, heat generated vs. that consumed will balance out.

After calculating the energy savings for each area for both the target and reference run, a comfort taking percentage is applied to the total energy savings value to reflect the fact that some households will utilise part of the energy saved to increase the level of comfort in their homes. The target-run energy savings are then subtracted from the reference-case savings to give a total energy saved by fuel, analysis area and time period, so that negative values are an increase in energy consumption.

A.3 Carbon savings

The economic value of the carbon saved locally can be valued using a carbon price. Carbon prices were taken from the latest Inter-departmental Analysis Group guidance and either "traded" for electricity to reflect the presence of a carbon market in the form of the EU Emissions Trading Scheme, or valued using a "non-traded" price for all other fuels. The carbon price is discounted using a 3.5% discount rate, as discussed above, but this can be varied in sensitivity analyses, for example to reflect the 1.4% rate advocated in the Stern Report[44].

The value of carbon savings is heavily dependent on the assumed carbon price.

44 The Stern Review on the Economics of Climate Change was released by the UK Government in 2006. It discusses the effect of global warming on the world economy.

A.4 Employment impacts

The Catapult was unable to find detailed information on the impact on employment when broken down by sector. Therefore, the employment impacts were calculated based on the amount of money spent. Using data from a range of studies estimating the employment impact of expenditure on domestic energy renovations[45], a value of 18 FTE per £1m spent was utilised.

With an inclusion of the reference case (no local carbon target) as the "baseline" for this calculation, the effect of "deadweight" (jobs that would have occurred anyway) can be accounted for. An adjustment is made for "leakage", i.e. the proportion of generated jobs that would benefit those outside the local authority area. A leakage value of 17.3% was used, which is the sub-regional mean leakage value for capital projects as estimated by the Department of Business Innovation and Skills[46].

A.5 Air quality benefits

In addition to the direct benefits of energy savings and carbon savings, there are also air quality improvement benefits resulting from reductions in energy consumption.

The IAG guidance provides p/kWh values for the air quality damage associated with different fuels and for different location types[47]. These can be used to quantify the air quality improvements associated with energy savings. Electricity is not valued at the local level as the generation of any imported electricity would not directly affect the air quality in the local authority, with any local generation accounted for in the generation fuel.

These benefits can be highly variable depending on the local energy mix after decarbonisation. It should be noted that burning biomass produces more particulates than burning gas. The precise difference depends on the technologies used. However, if biomass is substituted for gas then air quality may be reduced rather than improved.

A.6 Health benefits

Energy savings are converted to *Quality Adjusted Life Years (QALYs)*, as recommended in the Her Majesty's Treasury Green Book. For the pilot projects, a value of £30,000 (the widely accepted monetary value commonly used in the healthcare sector) was used to value these years. As with previous calculations, the benefits for the target run are then subtracted from the reference case to give a monetised health benefit from domestic energy efficiency.

A.7 Fuel poverty

In England, according to the *Low Income High Costs (LIHC)* definition, a household is considered to be fuel poor if they have fuel costs that are above average and if they were to pay the fuel cost, would be left with residual income below the official poverty line. Although EPN can give an indicator of how fuel costs for a household may change over time, income levels are out of the scope of the tool. It is therefore not possible to accurately quantify the number of households who will leave or enter fuel poverty as a result of the decarbonisation pathway. Instead, the analysis focuses on how the cost of delivering energy to households may change.

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45 The following two studies provide summary statistics of the findings of a range of studies: http://www.ukace.org/wp-content/uploads/2012/11/ACE-Research-2000-09-Energy-Efficiency-and-Jobs-UK-Issuesand-Case-Studies-Case-Studies.pdf http://www.neujobs.eu/sites/default/files/publication/2013/01/Energy%20renovation-D14-2%2019th%20December%202012_.pdf

46 BIS Occasional Paper No. 1: Research to improve the assessment of additionality: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/191512/Research_to_improve_the_assessment_of_additionality.pdf

47 Domestic air quality damage cost are given for the following location types: inner conurbation, urban big, urban medium, urban small and rural.

The methodology considers how the energy demand for heating a household changes across the period of the transition and, using the levelised unit cost of fuels, how the cost of delivering this energy to the household may change. As with the rest of the analysis, this calculation excludes any tax or profit which may apply to the price of fuel, due to the uncertainty of these over time.

Calculated energy demand is generated on a per household basis, as a result of any retrofit and heating system transitions. Demand is then monetised, using the levelised costs for each fuel on an individual household basis, for both the reference case and target run. These are then subtracted from each other in order to quantify how the cost of delivering energy to that household may change.

In instances where the cost of energy delivery has increased, the value of this increase can be used to determine policies for any subsidies that may be required to ensure homes do not fall into fuel poverty as a result of the transition. Since the decarbonisation pathway generally results in switching from low cost gas to higher cost energy solutions, energy bills generally increase.

A.8 Comfort taking

Comfort taking is the proportion of energy saved that householders retain and utilise in order to increase the level of warmth in their homes. Increased levels of comfort and warmth in residents' homes is still a benefit and can be calculated as a separate metric.

A value of 15% is used as the percentage of energy savings utilised for increased comfort; this is consistent with the assumption used in government impact assessments of retrofit energy efficiency improvements, e.g. the impact assessment of changes to Part L 2013[48].

48 https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l

Appendix 2: Low-carbon heating systems

Different current and future heating system combinations have been considered within the pilot studies.

Table 3: 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

Table 3 provides details of how the main and secondary heating systems were 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 were 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 that 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 $45^{oC.}$ This temperature 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;
    - 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 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 Pumps, but provide hot water at a higher temperature (typically 55oC), 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 that 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) before releasing 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 that 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.

Disclaimer

This document has been prepared by the Energy Systems Catapult on behalf of the Energy Technologies Institute LLP.

Energy Systems Catapult supports innovators in unleashing opportunities from the transition to a clean, intelligent energy system.

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