ARUP

Sheffield City Council

Zero Carbon Commission

Work Package 3.1 - City-level Zero Carbon Mitigation pathway for Sheffield

Sheffield City Hall

Contents

Cornish Place & Brooklyn Works

Executive Summary

Sheffield City Council has declared a Climate Emergency and has set a target for the city to be zero carbon by 2030. This report sets out a recommended pathway to achieving that target.

Overview

Transitioning to a zero carbon economy will require massive change in many (if not all) aspects of life. It will need the buy-in of every citizen, company, institution, third-sector organisation and industry body across the city. It is the uncomfortable truth that there is no zero-compromise solution, but the wider benefits are significant – from improved air quality, better health outcomes to a stronger economy and greater resilience as a city.

When considering the fact that compromises must be made, we must always remember that failure to reduce our emissions down to zero will result in consequences that are unimaginable. The runaway effects of climate change are already starting to be seen in real manifestations from global biodiversity loss and devastating wildfires to local extreme weather events such as flooding and heatwaves. Further failure to act will bring in ever-more large-scale impacts from climate refugees to national protectionism over scarce resources.

We also need to reconcile ourselves with the obvious fact that Sheffield cannot solve climate change on its own. We are responsible for a relatively small proportion of the UK's emissions that themselves form a relatively small proportion of global emissions. We could in theory take no action, relying on others to solve the problem while we carry on with a high-impact wasteful lifestyle. This is a temptation everyone faces and is probably one of the reasons behind the lack of international action in the decades since climate change became scientifically irrefutable.

The time for this sort of thinking is over and, thankfully, there are signs that the tide is beginning to turn.

Sheffield is fundamentally linked to Earth systems and nature as the Outdoor City and is a place many people are fiercely proud to call home. We must combine these elements to galvanise action across the city – to not only play our part in a bigger transition but to lead, taking inspiration from our history of leading the steel industry.

Sheffield has already made some progress in reducing carbon emissions over the last 15 years, as detailed in Work Package 1, particularly in the industrial and commercial and domestic sectors. However, the business as usual emissions projections, detailed in Work Package 2, show that there remains a significant gap to net zero carbon unless further actions are carried out.

Many of the actions contained within this report are directed towards the Council but none of them can effectively be carried out by the Council in isolation. In many cases, the role of the Council is as a facilitator, making it easier for others to take action. In addition to this, there is one role the Council must adopt with vigour – that of a leader. A transition of this type relies on momentum – of everyone trusting that others are making strides and that change is imminent on a city-wide scale which then gives them confidence to drive their own actions forwards. Ultimately, large-scale emissions reductions will be achieved as a result of many thousands of small actions that, in isolation, may seem insignificant. Momentum is essential to these small actions.

The final aspect of this plan that must be highlighted here is that of speed. The level of difficulty associated with the degree of change is exacerbated by the rate at which the transition must be achieved. In some cases, this might mean taking action based on the best information available at the time instead of waiting for all final pieces of the jigsaw to fall into place. Short-term action that is 95% optimised will have more impact than action delayed whilst waiting for a perfect plan to be finalised. This impact will be not only in terms of emissions reductions but in the momentum created that encourages others to act.

The actions needed to achieve the target are undoubtedly challenging. Achieving them will require a change in mindset – we must approach even the most seemingly insurmountable barriers with positivity, energy and optimism. In striving for zero carbon, there is very little that is impossible – there are just actions that would previously have been considered unpalatable.

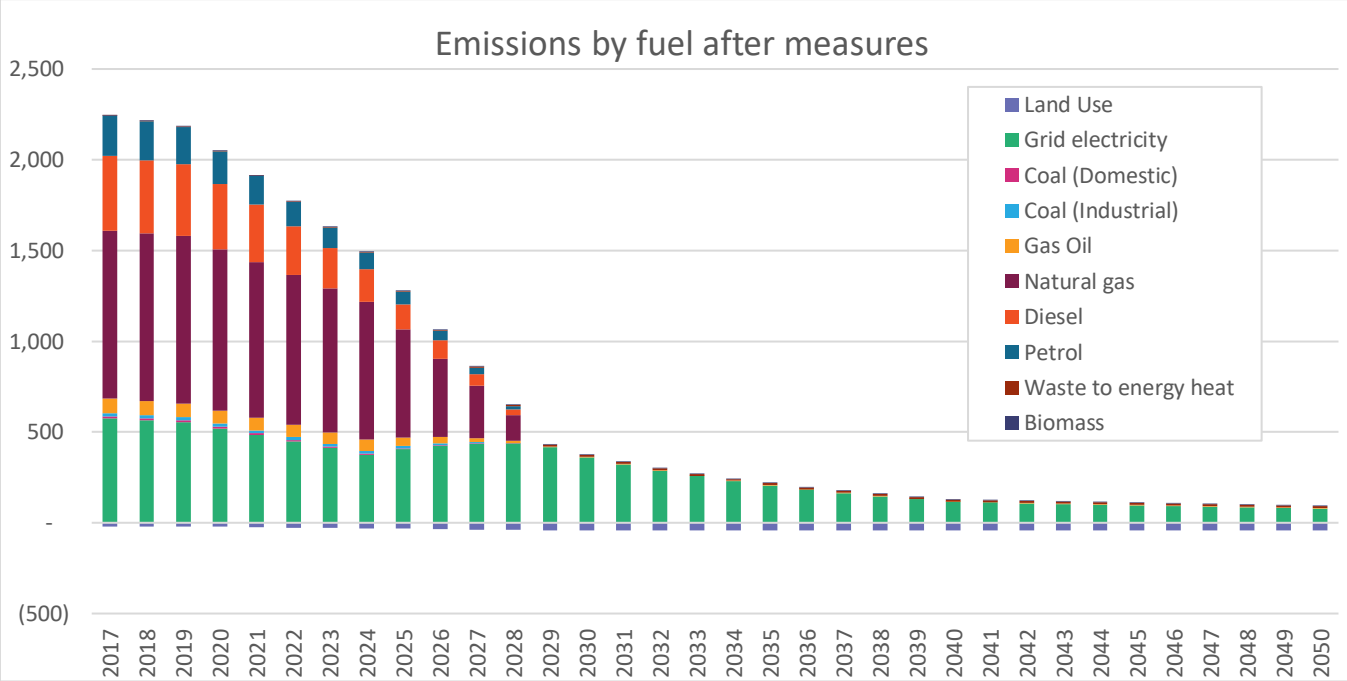
Overall trajectory

The report sets out the types of measures that will be needed for Sheffield to be zero carbon by 2030. The measures within this report are high-level to demonstrate the magnitude of change required and the estimated carbon savings that they can lead to. It is expected that these estimates will be refined when they are evaluated at the more detailed level and further engagement is undertaken.

Building on the structure determined by the datasets available to set out the baseline emissions and determine business as usual, the actions are set out in the following sectors:

- Domestic
- Commercial and industrial
- Transport
- Energy
- Land use, Land use change and forestry

The emissions trajectory is by fuel-use shown in the graph below.



Emissions by fuel after measures

This graph includes locally generated building-mounted renewables but does not include large-scale renewables as these are often connected directly into the national grid and so technically contribute to the reduction of the overall carbon intensity of the grid.

In 2030, emissions have been reduced to 334ktCO_2 – an 85% reduction from the baseline year. Almost all the residual emissions are from the use of grid-supplied electricity which is not projected to be entirely zero carbon in 2030.

The report produced by the Tyndall Centre for the Council last year recommended that Sheffield consider ‘zero carbon’ to be a 95% reduction. In order to achieve this target, an additional 223ktCO_2 would need to be removed. With energy savings maximised, fossil fuels eliminated and no way to single-handedly completely decarbonise the national grid, these savings would need to come from locally generated renewables. As these renewables would need to be larger-scale installations than those already accounted for in the trajectory, they must be considered separately. In strict emissions-modelling terms, they will not reduce directly Sheffield’s emissions, instead contributing to the decarbonisation of the national grid (into which they will supply energy).

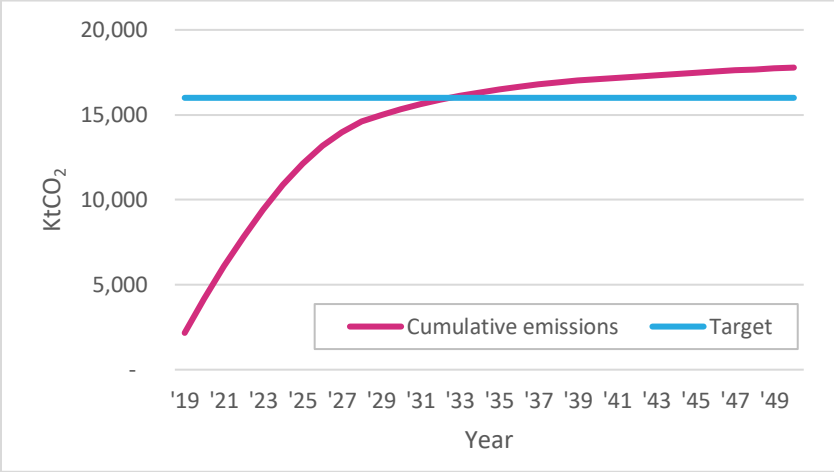
They can, instead, be considered alongside the trajectory as, should the city prioritise and incentivise large-scale renewable generation as a direct result of its 2030 target, these installations may well be additional to the business-as-usual grid decarbonisation.

Examining, at a high level, the opportunities for wind and solar within Sheffield's boundaries indicates that it would be possible to generate enough power to yield an indirect saving of 100ktCO_2 in 2030. This takes the balance of emissions to 224ktCO_2, a reduction of 90% over the 2017 baseline year.

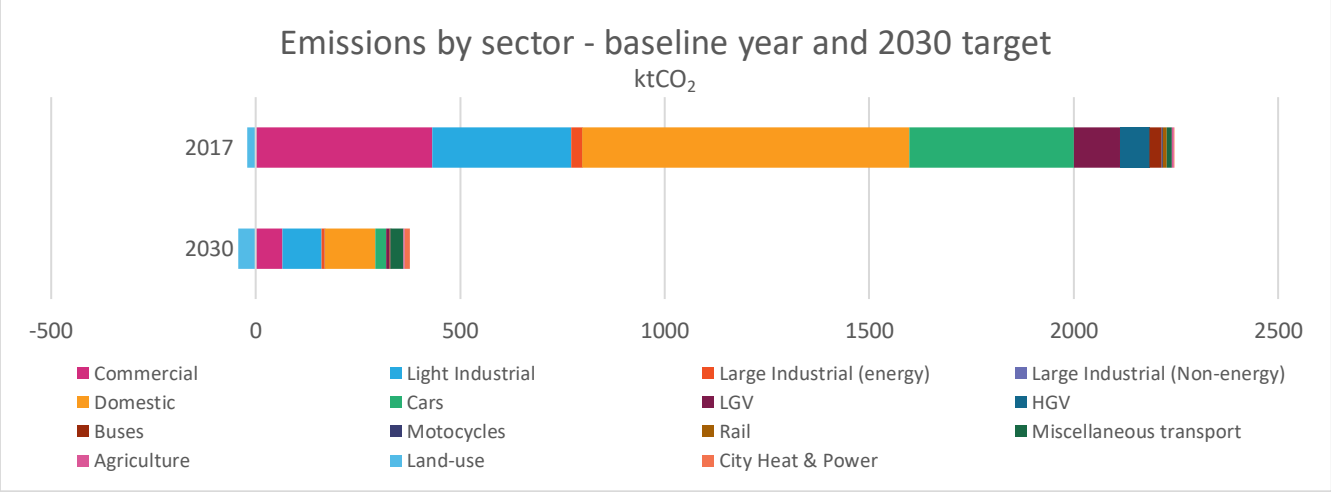
Assuming that local efficiencies have been maximised, going further than this 90% reduction would require Sheffield to take on a greater proportion of energy generation at which point we must ask ourselves whether this is the right approach. To quantify and address Sheffield's emissions, we are drawing a slightly arbitrary boundary around the city – the reality is that Sheffield is not an island and it fits within a national context. We must question whether further generation in Sheffield is the best solution in the national context. Could our land be better used to address other issues, with others generating power, for example? This wider context allows us to consider Sheffield's place within the City Region Energy Strategy

In addition to the zero carbon target, the Tyndall Centre report recommended a carbon budget of 16MtCO_2e between now and 2100. Taking 2019 as the starting point for this target (the year the Tyndall Centre report was written), cumulative carbon emissions to 2050 are 17.8MtCO_2e. Much of this is due to the fact that emissions start off at such a high annual rate that ~75% of the budget is used up in the early years to 2025.

This reinforces the message that it is essential to act fast with no delay.



The residual emissions in 2030 consist of the sectors indicated in the graph below. As previously stated, they are primarily as a result of non-zero carbon intensity of grid-supplied electricity. Whilst the 95% reduction target is not being met, it is clear that the reduction needed in the next 10 years is very large.



Emissions by sector – baseline year and 2030 target

LGV and HGV stand for Light- and Heavy-Goods Vehicles respectively

Interventions

The diagrams below shows the scale of emissions reductions as a result of each intervention type in each of the sectors.

Domestic sector

New home construction is set to be modest over the next 10 years in comparison with the existing stock. Focus on energy retrofits is therefore a priority. Improving the thermal performance of the fabric of the building has a massive part to play, as do more general energy reduction measures.

However, the largest improvement, not just within the domestic setting but in the context of all measures in all sectors, is the removal of fossil fuels from heating and cooking by moving to electricity, installing heat pumps and connecting to district heating networks. There are many significant barriers to this being successfully achieved which are cross-cutting enough to propose that this intervention be prioritised as a way of giving a focus to very initial efforts.

It is a clear example of an intervention that will require engagement and support from many stakeholders (i.e. citizens) over which the Council has few direct policy levers at their disposal. When this issue is on its way to being solved, we can have confidence that others will follow.

Improve fabric

113

$ktCO_2$ reduction

Reduce energy consumption

54

$ktCO_2$ reduction

Remove fossil fuels

386

$ktCO_2$ reduction

Commercial and industrial sector

Unsurprisingly, the structure of the interventions needed for the non-domestic buildings are similar to those needed in homes – albeit with a different focus. Improving fabric is, in this case, less impactful than general energy consumption reductions as process-related consumption is significant. The electrification of the sector is once again the most important area to address.

Improve fabric

33

$ktCO_2$ reduction

Reduce energy consumption

50

$ktCO_2$ reduction

Remove fossil fuels

151

$ktCO_2$ reduction

Transport sector

Buildings interventions are redolent of those that need discrete actions by many stakeholders but transport takes this one step further by needing these actions to be repeated over time. Once a house is insulated, the work is largely finished, but the decision to cycle instead of drive needs to be taken daily. Transport, therefore, is the area that relies most heavily on behaviour change. Whilst this has its challenges, the benefits – both in terms of carbon and more broadly – are significant.

Once again, the greatest opportunities lie in modal shift to sustainable modes and decarbonisation of residual vehicles, including the public transport network.

Increase active travel

104

$ktCO_2$ reduction

Increase public transport

9

$ktCO_2$ reduction

Consolidate freight

16

$ktCO_2$ reduction

Decarbonise all vehicles

290

$ktCO_2$ reduction

Energy sector

The energy sector can seem hard to separate from the others. After all, the energy generated goes into building and transport solutions – creating energy is not an end in itself. However, there are useful ways in which pulling this sector out can help us focus on cross-cutting issues. The first is the expansion of Sheffield's district heating schemes to replace gas boilers in many homes and businesses with low-carbon heat.

Both small- and large-scale renewable energy generation also have a part to play in contributing to a zero carbon Sheffield. Due to the way they interact with the national grid they need to be treat separately and only small-scale generation can be said to directly reduce Sheffield's emissions. Large scale generation contributes instead to national grid decarbonisation but if it is driven by Sheffield's low carbon agenda and, as such, is additional to expansion in that sector than might have otherwise happened, it is appropriate to recognise its benefits indirectly and quantify them alongside direct emissions reductions.

Decarbonise heat

91

$ktCO_2$ reduction

Small-scale renewable energy

58

$ktCO_2$ reduction

Large-scale renewable energy

100

$ktCO_2$ reduction

Land Use, Land-Use Change and Forestry (LULUCF)

The potential for practical accountable carbon emissions reductions from nature-based solutions (technically called Land Use, Land Use Change and Forestry) is relatively limited when compared to other solutions yet these actions can provide a multiple of additional benefits to wellbeing and nature. Extending tree cover and peatland restoration are the most relevant direct actions.

Double LULUCF savings

21

$ktCO_2$ reduction

Non-carbon benefits

Across each of the sectors, the non-carbon benefits are enormous. Done correctly, this programme of emissions-savings measures has the potential to benefit every aspect of life and work in Sheffield, from warmer homes and better health to more vibrant communities and a stronger economy.

Costs

The carbon savings necessary for Sheffield to meet its zero carbon 2030 target come from such a diverse range of interventions that it is not particularly practical to add up the costs to give a total final figure. The fact that this cost will need to be borne by a wide variety of stakeholders also adds another layer of complexity. Finally, to provide a total cost in terms of capital expenditure without quantifying operational cost changes and, most importantly, monetising the wider non-carbon benefits would give unfavourable focus on the challenges that we all know exist.

Costs are provided throughout the report in the format most relevant to each individual intervention – giving those considering the delivery of the interventions the information they need to understand each potential action in the context of others that are comparable.

A summary of the initial capital costs for each sector are provided below. These costs are anticipated to be split between the both the public and private sector. The balance will vary depending on the sector but the costs that are expected to be borne by the Council is expected to be a relatively small proportion of the total.

Sector	Estimated costs	Comments
Domestic	£2 billion - £5 billion	The costs include improvements to building fabric, LED lighting, smart heating controls, decarbonising cooking equipment and installing heat pumps. It excludes district heating connections, solar thermal collectors and building-mounted PV which have been accounted for in the energy section.
Commercial and industrial	£1 billion - £10 billion	The costs for the commercial and industrial sector are much more difficult to estimate as they are heavily dependent on the size and function of the buildings. An estimated cost range has been provided to cover improvements to building fabric, LED lighting, smart heating controls, building services upgrades and installing heat pumps. It excludes district heating connections, building-mounted PV which have been accounted for in the energy section. Costs associated with decarbonising processes have also been excluded as there will be significant variation depending on the process equipment.
Transport	-	The costs for the transport sector are highly dependent on the mix of measures chosen. Some high-level costs for measures include: • £1m - £1.5m per km for cycle superhighways • £0.45m - £0.9m per km for strategic cycle routes • £0.2m - £1.5m for junction modifications • £0.45m per km for bus lanes • £25,500 per space for a park and ride facility • £0.2m - £0.35m per electric bus • £075 - £1m per single track km for rail electrification However, these costs are not direct carbon savings as they rely on behaviour changes.
Energy	£1 billion	The costs include expanding the district heat networks, installing building-mounted PV and solar thermal collectors. Large scale energy generation from ground-mounted PV and wind turbines have been excluded and would need require additional investment above these figures.
Land Use, Land-Use Change and Forestry	-	Costs are impossible to predict but are likely to be small scale in comparison to others.

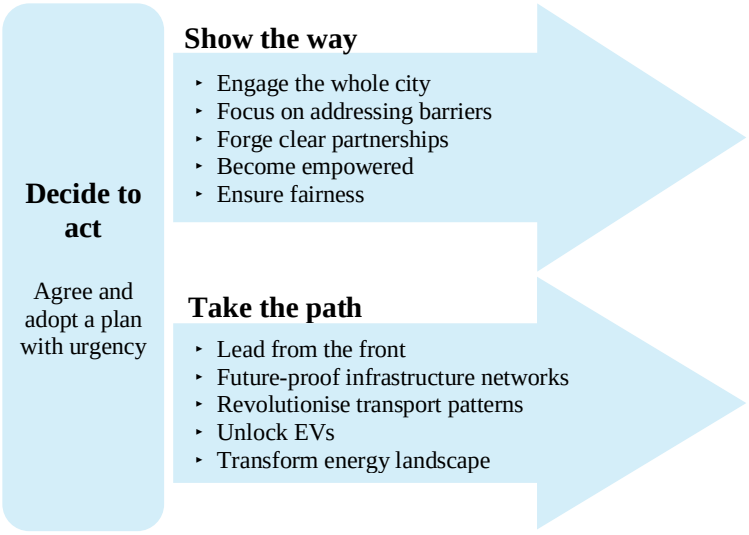
It should be remembered that a proportion of these costs will be offsetting sums that would have been spent on traditional solutions such as gas boilers or diesel cars. However, the degree to which these costs are additional is impossible to calculate with any meaning at the level of detail of this current study.

Prioritised actions

To achieve these emissions reductions, a number of actions will be needed. In the body of the report, these are detailed in each sector as Council actions, city-wide actions and actions needed from central government. Where city-wide actions are needed, direct actions the Council can take to facilitate progress are also detailed.

However, many actions have synergies across the sectors, leading to a set of consolidated prioritised actions as shown in the diagram (right).

The first action is that the Council must absorb the recommendations of this report and immediately develop and agree a programme of works. This may include some adjustments to



actions recommended but should be sure to encompass all of the areas. This programme should be prepared and agreed without delay. An imperfect plan agreed now will achieve much more than a perfect plan agreed in six months' time – not only in practical terms but in terms of momentum and a sense of urgency. A two-stage approach may be appropriate – an initial programme of works that can be implemented almost immediately in parallel to an Action Plan being developed and agreed.

Following this, enabling actions ('show the way') can begin in parallel with more direct interventions ('take the path'). It is obvious that, in an ideal world, many enabling actions would take place before more direct interventions. However, we do not have the luxury of time which means that some inefficiencies are inevitable and have to be accepted. The alternative is an ideal process that results in failure as it does not progress quickly enough.

These actions sit alongside a parallel set of recommendations identifying how the Council can best organise itself in order to successfully achieve the target it has set itself. Work Package 4 provides the Council with recommendations on actions to revise its current structure and governance in order to drive carbon-related action throughout all services.

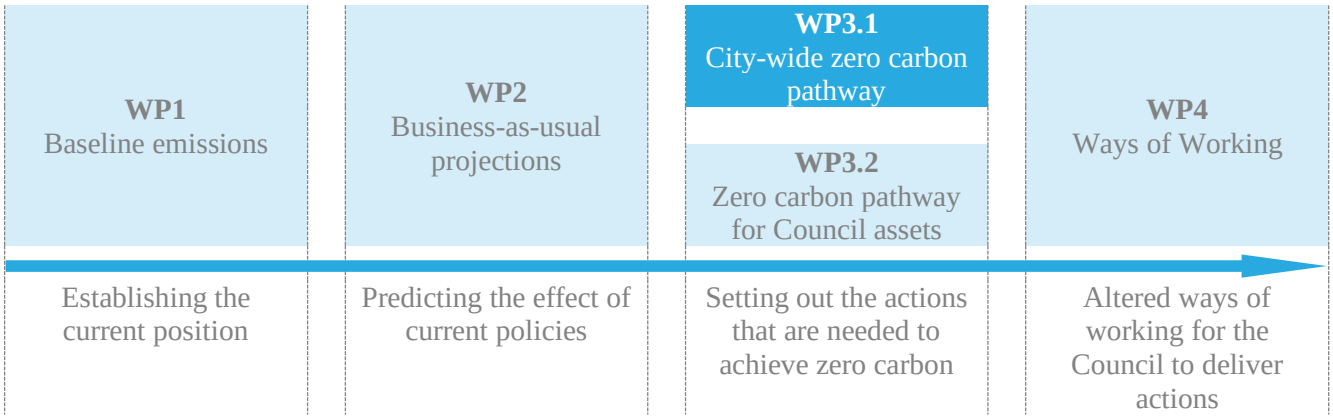
The Diamond, University of Sheffield

Introduction

Sheffield City Council has declared a Climate Emergency and has set a target for the city to be zero carbon by 2030.

The Council has been working with the Tyndall Centre for Climate Research to establish a carbon budget for the city. In their report of June 2019, the Tyndall Centre recommended that the city should stay within a cumulative CO_2 emissions budget of 16 $MtCO_2$ for the period of 2020 to 2100, which would mean achieving near zero carbon emissions by no later than 2038 (1).

This report sits within a wider suite of documents reflecting various stages of the overall project, being the output of work package 3.1:



Study overview

This report sets out the types of measures that will be needed for Sheffield to be zero carbon by 2030. The measures within this report are high-level to demonstrate the magnitude of change required and the estimated carbon savings that they can lead to. It is expected that these estimates will be refined when they are evaluated at the more detailed level and based on further engagement.

The report highlights that everyone has a role to play if the zero-carbon target is to be achieved. Reaching a zero carbon Sheffield will require the contribution of Council partners, businesses, community groups and individuals. Wider afield, the impacts of the City Region and national government will obviously be significant.

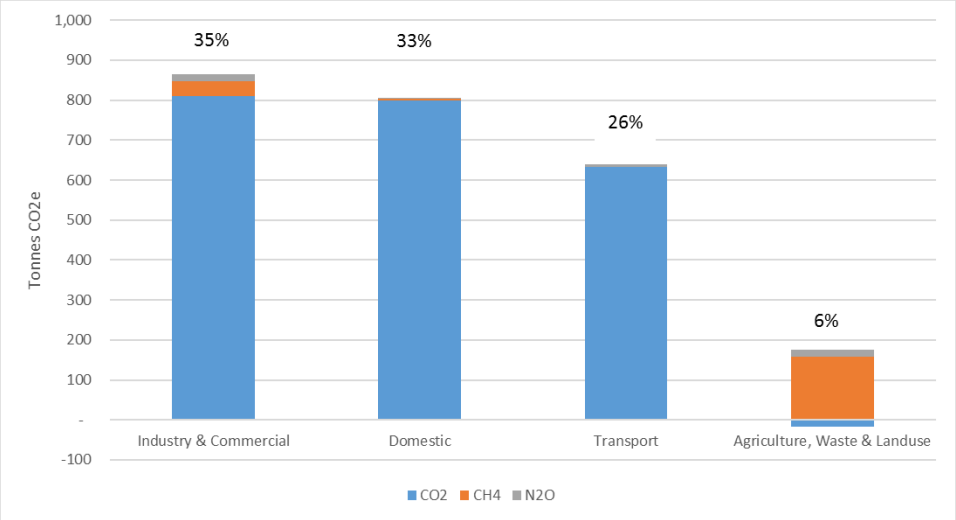
Within the context of all these stakeholders, this report is specifically aimed at identifying the actions the Council can take to facilitate, enable and encourage action where they do not have direct control over a decision. It is clear that the Council has a clear leadership role to take the city towards zero carbon in 2030.

Sheffield has already made some progress in reducing carbon emissions over the last 15 years, as detailed in Work Package 1, particularly in the industrial and commercial and domestic sectors. However, the business as usual emissions projections, detailed in Work Package 2, show that there remains a significant gap to net zero carbon unless further actions are carried out.

Building on the structure determined by the datasets available to set out the baseline emissions, the actions are set out in the following sectors:

- Domestic
- Commercial and industrial
- Transport
- Energy
- Land use, land use change and forestry

The emissions for the baseline year are as shown in the graph below



GHG emissions in Sheffield
Using 2017 baseline data

Note that, whilst the baseline included non-CO_2 emissions, it was identified that they were minimal in most sectors. For the sake of clarity, non-CO_2 emissions have therefore not been considered.

Approach to zero carbon

There are many ways to reach zero carbon and even the definition of zero carbon is not universally agreed. In summary, the approach used is:

Energy efficiency to be prioritised and maximised

Irrespective of the future availability of near-zero carbon electricity from the National Grid (as it moves away from fossil fuels and towards renewables), there is a need to reduce the amount of energy used. Reducing energy will aid the transition to low carbon electricity as higher-emission sources can be phased out earlier.

Fuels are switched to low- and zero-carbon alternatives

Fossil fuels are completely eliminated in the 2030 scenario. Energy is switched to low-carbon sources, particularly electricity from the National Grid. Low carbon energy sources are largely based on technologies which are available now. Technologies without a high degree of confidence in their immediate availability are excluded. This approach has been taken due to the relatively short timescales within which action must be taken to realise the 2030 target. The city does not have the luxury of waiting for technological solutions to appear.

Residual emissions from grid electricity use counteracted with local zero-carbon generation

As grid electricity is has a non-zero carbon factor in 2030, there will be some residual emissions resulting from its use. The extent of local zero-carbon electricity generation that is feasible to partially counteract these residual emissions is shown. However, due to the way locally generated energy is commonly fed into the National Grid instead of being used locally on independent systems. This calculation needs to be carried out in a specific way to avoid ‘double-counting’ – having the zero carbon electricity reducing the overall UK average carbon intensity whilst also assuming it is all used locally.

‘Zero’ in 2030 is taken as a 95% reduction

For the purposes of evaluating whether the target has been reached, a reduction of 95% from the baseline year is taken as meeting the definition of ‘zero’. Whilst, mathematically speaking, it is not zero, it is felt that the overwhelming majority of the emissions will have been dealt with if a 95% reduction is met by 2030. The remaining 5% is assumed to tail off before the country achieves its goal of 100% reduction in 2050. This ‘tail’ of emissions will provide a way of balancing the need for drastic cuts with a small degree of pragmatism and reflects language and recommendations made in the Tyndall Centre report. The performance of the plan against the 16MtCO_2 budget is also discussed.

No offsetting is considered

Offsetting is the reduction or avoidance of emissions outside of the geography being considered. Whilst in some circumstances it can be a valid way of reducing overall (global) emissions levels, it is not considered in this report due to the fact that local emissions reductions are seen as preferable.

Consumption-based emissions are not considered

This report focusses on direct emissions and those as a direct result of electricity consumption (Scopes 1 and 2 respectively under the Greenhouse Gas Protocol). Consumption-based emissions (Scope 3) from the use of goods and services is a wider definition of zero carbon and is not considered here. Avoided emissions (sometimes informally called Scope 4) are also not considered. Emissions types not considered could be the source of further work within the city.

Framework

The approach set out above has been translated into each of the sectors in the following ways:

Domestic		 Improve fabric	 Reduce energy consumption	 Remove fossil fuels
Commercial and industrial		 Improve fabric	 Reduce energy consumption	 Remove fossil fuels
Transport	 Increase active travel	 Increase public transport	 Consolidating freight	 Decarbonise vehicles
Energy generation		 Decarbonise heat	 Small-scale renewable electricity	 Large-scale renewable electricity
Land use, land-use change and forestry				 LULUCF savings

Wider strategies

There are a number of policies and strategies that are being developed and adopted within Sheffield City Council and Sheffield City Region that will support the zero-carbon plan. These include:

- Sheffield Development Framework Core Strategy, Adopted March 2009
- Sheffield City Region Transport Strategy
- Sheffield Transport Strategy, March 2019
- SCR Municipal Waste Strategy 2016-2021
- Green City Strategy
- Sheffield City Region Integrated Infrastructure Plan
- Our City Centre Plan 2018-28
- Housing Strategy 2013-2023
- New Homes Delivery Plan 2018-2023
- Lower Don Valley Masterplan Study
- SCR Active Travel Implementation Plan
- SCR Integrated Rail Plan
- Sheffield Parking Strategy
- SCR Strategic Economic Plan
- SCR Energy Strategy
- Housing Infrastructure Fund

These strategies have been considered in this work. Where appropriate, the proposed actions have had their importance reinforced and where greater action is needed, this has been highlighted.

Report structure

The following sections of the report address each sector in turn. The sections use the following structure:

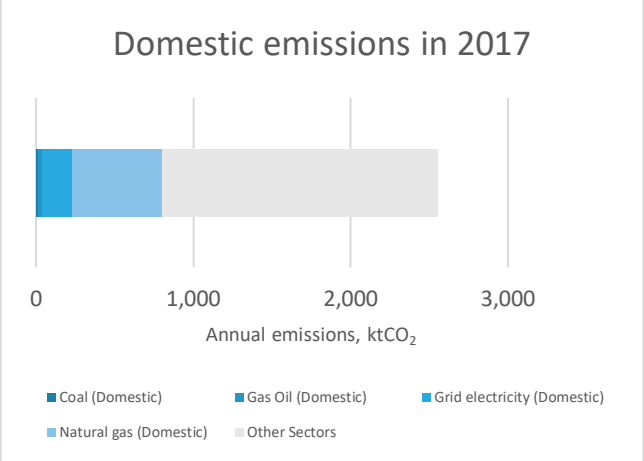
Overview	Setting the sector in context and clarifying the scale of the challenge.
Approach to zero carbon	Identifying the interventions needed to realise zero carbon, providing some detail on how they could be achieved, considering any Sheffield-specific relevance and estimating costs.
Benefits	Setting out some of the many the non-carbon benefits that could come from the interventions.
Barriers	Identifying the more significant technical, financial, political, societal and delivery challenges that exist. Barriers are considered in a positive way – by understanding them we can design more targeted actions to overcome them.
Actions	The actions needed to make the achieve success in the interventions. Direct actions required at by the Council are identified, as are the broader actions required at a city scale and those at by regional and national governments.
Funding routes	Any current funding routes are identified. However, this can only ever be a snapshot of current schemes as availability varies regularly.

Domestic sector

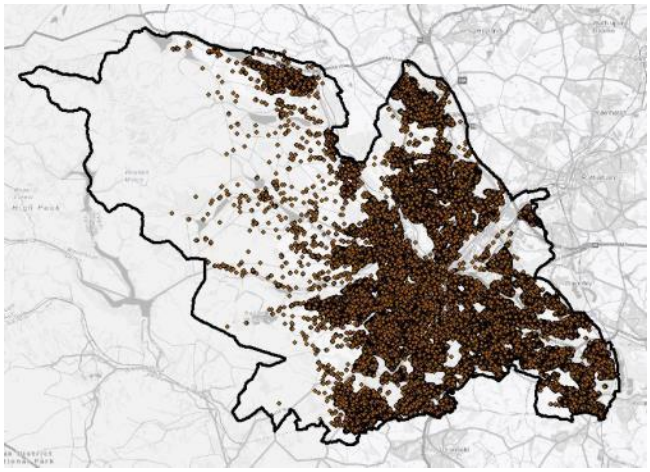
S1 Artspace Parkhill, Sheffield

1 Domestic sector overview

There are approximately 247,000 domestic properties in Sheffield. The emissions from the domestic sector contribute 799 $ktCO_2$ to the baseline. Within the domestic sector, gas consumption constitutes approximately 71% of emissions and electricity consumption 25%.



Carbon emissions from the domestic sector in Sheffield
Using 2017 baseline data

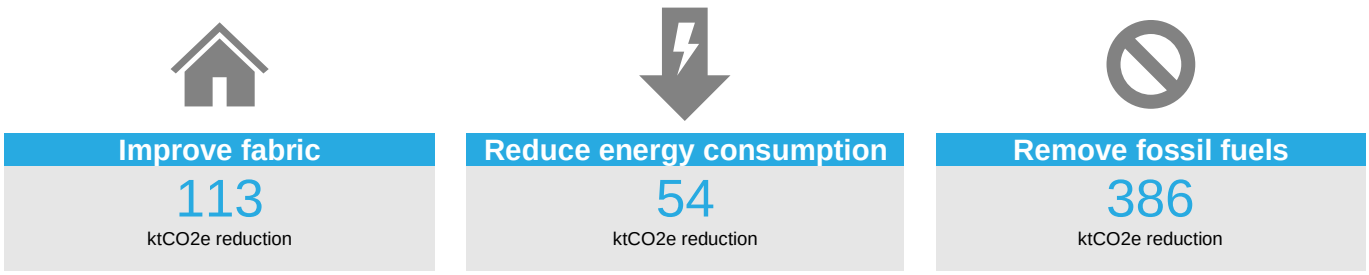


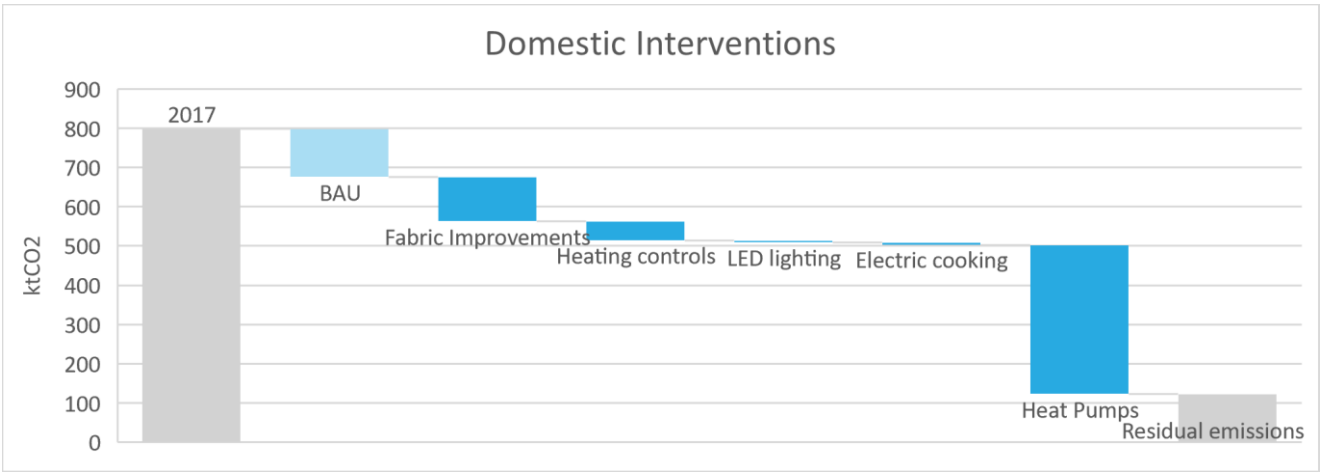
Locations of residential properties in Sheffield

2 Approach to zero carbon

The series of interventions proposed for domestic properties in Sheffield to reach the net zero carbon target include:

- Improve fabric of homes
- Reduce energy consumption in homes
- Remove fossil fuels





Carbon emissions reductions in the domestic sector from interventions

Zero carbon new homes

The Sheffield City Council New Homes Delivery Plan, published in 2018, sets out a plan to support the building of over 2,000 new homes, including 725 new affordable homes a year over the next 5 years. However, these numbers are small in comparison to the 247,000 existing properties. Therefore, the analysis focuses on existing properties as it is assumed that all new homes will be zero carbon in order to meet the zero carbon goal. As this is not a current policy, some of these developments may already be underway and not currently on track to be zero carbon and, as such, will need to be retrofitted by 2030 to meet the zero carbon target.

The aspirations for all new homes to be zero carbon aligns with the Sheffield City Council's Green City Strategy which highlights the need for very low or zero carbon homes that are constructed to high standards of energy efficiency, which will generate their own heat or power. These homes will use significantly less energy and as a result have lower running costs for residents, as well as reducing the city's overall carbon emissions. Local Authorities in England currently have the ability to ask for these standards through the Local Plan process. However, the UK Government has recently consulted upon the Future Homes Standards, under which national standards may be set for implementation at a local level.

The current development of the new Sheffield Local Plan (starting with the Issues and Options document) offers an opportunity to strengthen how climate is considered within the planning system. Policies could be designed to reflect the interventions required and the urgency of the 2030 target. The creation Supplementary Planning Documents could also be investigated as a way of adding further specific detail to adopted Local Plan policies.

Sheffield 2030 carbon target will mean than the need for zero carbon new developments will be ahead of vast majority of the UK. The Future Homes Standard will help to improve energy efficiency standards in homes and support low-carbon heating, however, it is only expected to come into force in 2025 which will limit the impact it has on Sheffield's 2030 target. The Standard will also not be expected to enforce net zero carbon new-build. The Council will need the support from developers, design teams and contractors and there may be some pushback on this but equally many of these companies are already setting their own carbon reduction targets and recognise that the market demands are changing.

Incentives, such as priority permitting, accelerated approval and fee reduction can help to encourage early adopters ahead of mandates.

Improve fabric of homes

66% of energy consumption within the domestic sector is attributed to space heating (2). Improving the fabric of homes helps to minimise the heat losses within the home by reducing the heating demand and associated emissions.

Improvements to the fabric are anticipated to help reduce emissions by a total of 113 $ktCO_2$. This reduction is as a combination of the following measures:

- Solid wall insulation
- Cavity wall insulation
- Floor insulation
- Loft insulation
- Draught-proofing
- Replacing glazing

The fabric improvement standards are stretching but are deemed to be what could feasibly be achieved in Sheffield within the 2030 time limit. The measures will not result in all homes achieving Passivhaus standards (a common benchmark for energy efficiency in homes) but will help to significantly reduce energy consumption and associated carbon emissions.

The scalability of the fabric improvement measures have been approximated based on Energy Performance Certificates (EPC) for domestic properties in Sheffield. Although EPC data is not available for every property and for some might be out of date, it is expected that it still provides a good representation of the current fabric standards of domestic properties in Sheffield at present.

Solid wall insulation

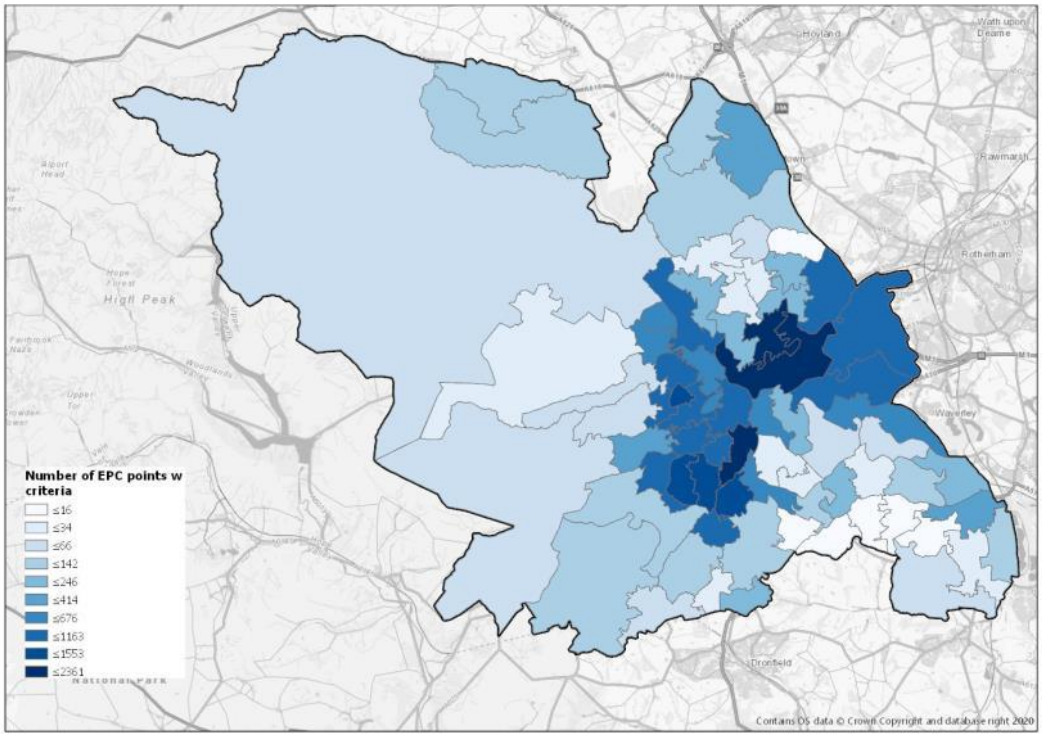
Installing or improving solid wall insulation can reduce the amount of heat lost through the walls, reducing the heating demand of the building. Insulating solid walls is predicted to reduce the heating demand of a property by 13% (3).

Approximately 18% of properties, roughly 44,000 properties, in Sheffield have solid walls that are currently uninsulated (4). The areas that have a high number of homes that require solid wall insulation are mainly towards the centre and east of the city in areas such as Burngreave & Grimesthorpe, Crabtree & Fir Vale and Highfield & Lowfield. This clustering could provide a useful way of targeting this type of intervention.

The cost of installing solid wall insulation is largely dependent on whether the walls are insulated externally or internally. The cost of installing solid wall insulation is expected to range between £6,800 to £15,000 per property (5). Therefore, the total cost across the properties in Sheffield where it is currently not installed would range between £302m to £667m, with an average cost of £485m. By installing solid wall insulation, household energy bill are expected to reduce by between £105 to £375 per year, leading to total savings of around £11m per annum if installed throughout the city (6).

Whilst practical challenges exist, on the assumption that the technology for this implementation exists and commercial products are available, this measure effectively needs to start to be implemented immediately. An average of around 6,000 properties per year would need to have solid wall insulation installed between now and 2027. In reality, the rate of installation in the initial years is expected to be lower whilst surveys are being carried out and supply chains ramp up.

There are a number of councils in the UK that are supporting solid wall insulation projects. Hull City Council are installing solid wall insulation in a selection of private homes in some priorities areas as part of a series of frontage improvement works (7). Durham County Council have partnered with Durham University and European Regional Development Fund to install new and advanced solid wall insulation systems on over 200 stone and brick built properties in towns and villages across County Durham (8). Nottingham City Council and the Department of Business, Energy & Industrial Strategy (BEIS) are funding a deep retrofit of 76 solid wall properties with Nottingham City Homes (9). These projects are on a smaller scale than what will be needed in Sheffield but provide great opportunities to learn from those trialling different approaches to solid wall insulation.



Locations of properties in Sheffield with no solid wall insulation
Numbers of properties in each area of the city based on EPC data, the scale ranging from 16 to over 2361 domestic EPCs

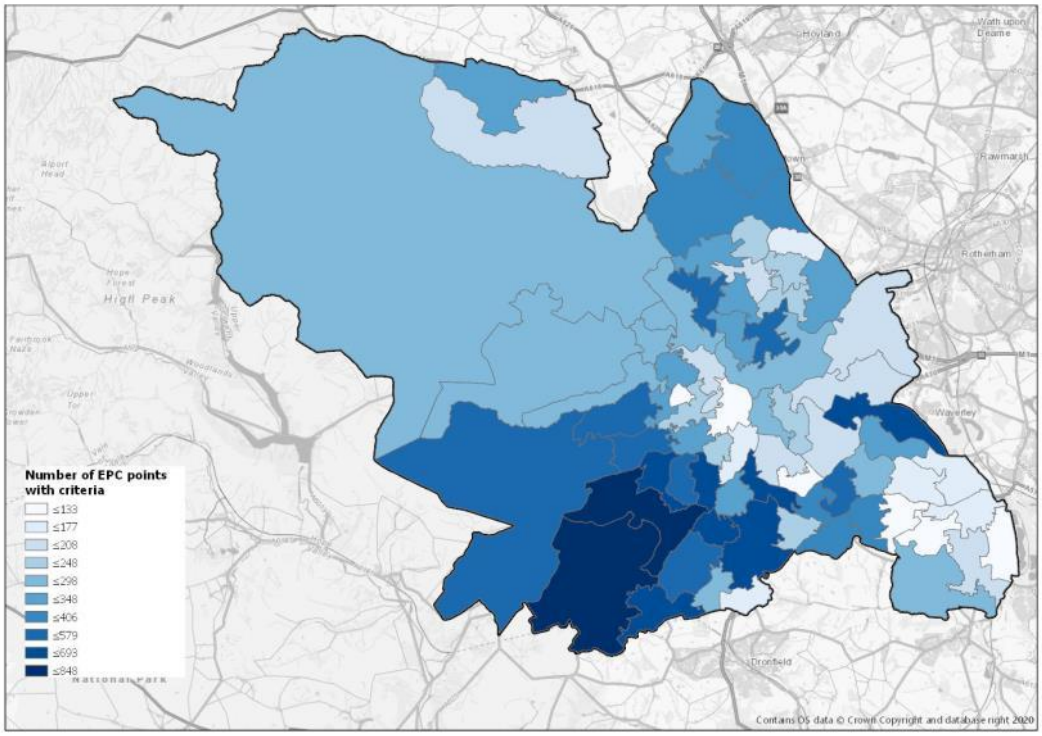
Cavity wall insulation

Cavity wall insulation is usually easier to install than solid wall insultation, but the energy savings are slightly lower in comparison. Insulating cavity walls is predicted to reduce the heating demand of a property by 7% (3).

Approximately 13% of properties, roughly 32,000 properties, in Sheffield have cavity walls that are currently uninsulated (4). The areas that have a high number of homes that require cavity wall insulation are mainly within the south west of the city in areas such as Dore & Whirlow and Bents Green & Millhouses. These are notably different to the areas with high proportions of uninsulated solid-walled properties.

Installing cavity wall insulation is much less intrusive than sold wall insulation so is much cheaper in comparison. The cost of installing cavity wall insulation is expected to range between £480 to £660 per property (5). Therefore, cost of installing cavity wall insulation across the properties in Sheffield where it is currently not installed would range between £15m to £21m, with an average cost of £18m. The resulting energy savings are typically between £85 to £280 per year, which would be in the region of £6m per annum across all properties (6).

This measure effectively needs to be instigated immediately and an average of almost 5,000 properties per year would need to have cavity wall insulation installed between now and 2027. Lower numbers are expected in the initial years but numbers should be increased as quickly as feasible once the supply chain is able to ramp up to meet the demand.



Locations of properties in Sheffield with no cavity wall insulation
Numbers of properties in each area of the city based on EPC data, the scale ranging from 133 to over 848 domestic EPCs

Loft insulation

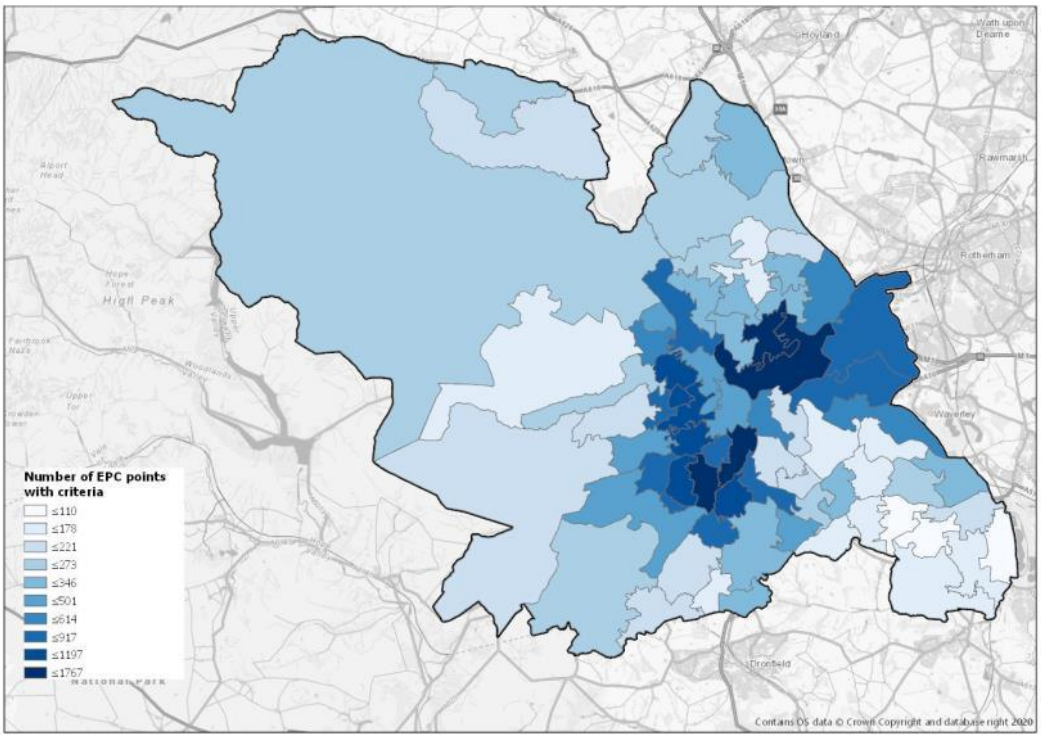
Installing or improving loft wall insulation can reduce the amount of heat lost through the roof, reducing the heating demand of the building. Insulating lofts is predicted to reduce the heating demand of a property by 4% (3).

Approximately 19% of properties, roughly 47,000 properties, in Sheffield have lofts or roof spaces that are currently uninsulated (4). The areas that have a high number of homes that require loft or roof insulation are mainly towards the centre and east of the city in areas such as Burngreave & Grimesthorpe, Crabtree & Fir Vale, Highfield & Lowfield and Nether Edge.

There are similarities between these areas and those with uninsulated solid walls, potentially opening up the opportunity for combined interventions. However, this effect may be indicative of the fact the common Sheffield archetype for solid walled houses includes a room in the roof. There will likely be a proportion of these properties for which standard loft insulation is not feasible, with the intervention instead being akin to internal wall insulation. However, these differences are not picked up in the data available.

The cost of installing loft insulation is expected to range between £230 to £395 per property (6). Therefore, cost of installing loft insulation across the properties in Sheffield where it is currently not installed would range between £11m to £19m, with an average cost of £15m. The resulting energy savings are typically between £135 to £250 per year, which would be in the region of £9m per annum across all properties (6).

It is anticipated that the measure could start to be implemented immediately and will be delivered by 2027. This would mean that almost 7,000 properties per year between 2020 and 2027 would need to have loft or roof insulation.



Locations of properties in Sheffield with no loft or roof insulation
Numbers of properties in each area of the city based on EPC data, the scale ranging from 110 to over 1767 domestic EPCs

Floor insulation

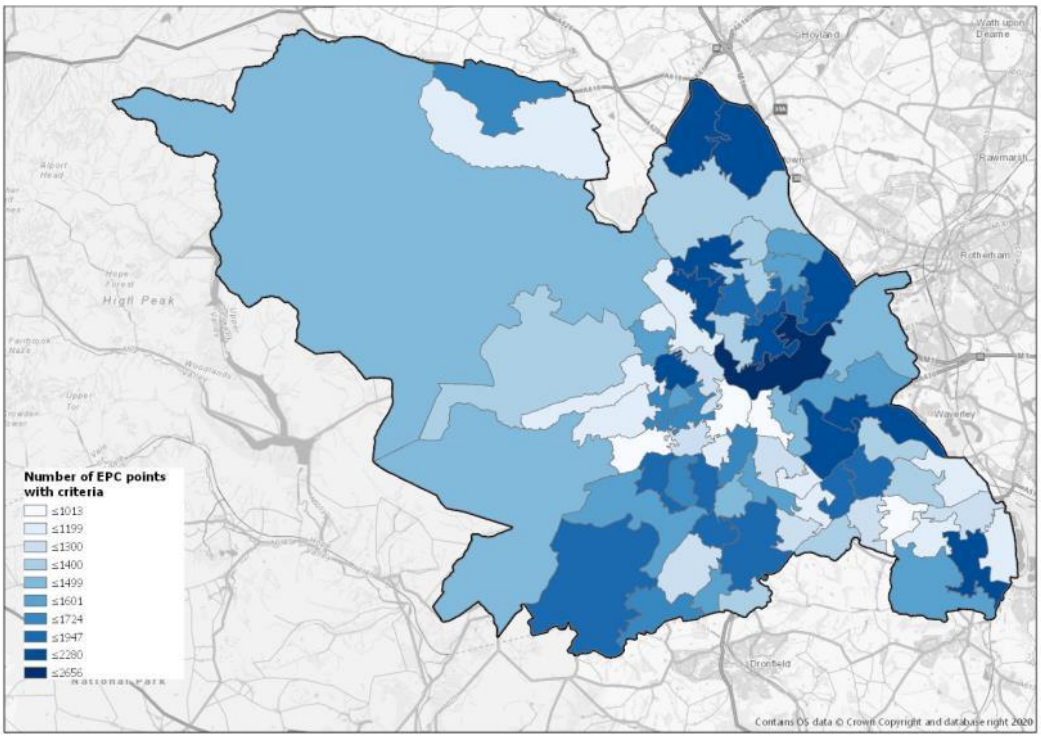
Installing or improving floor insulation can reduce the amount of heat lost to the ground, reducing the heating demand of the building. Insulating floor insulation is predicted to reduce heating demand of a property by 7% (6).

Approximately 61% of properties, roughly 150,000 properties, in Sheffield have floors that are currently uninsulated (4). The areas that have a high number of homes that require floor insulation are mainly towards the edges of the city in areas such as Burngreave & Grimesthorpe, Brightside & Wincobank, High Green & Burncross and Chapeltown.

The cost of installing floor insulation is expected to range between £520 to £1,300 per property (6). Therefore, cost of installing floor insulation across the properties in Sheffield where it is currently not installed would range between £78m to £196m, with an average cost of £137m. By installing floor insulation, household energy bills are expected to reduce by between £30 to £75 per year, leading to total savings of around £8m per annum if installed across all homes.

This measure effectively needs to be instigated immediately and an average of around 20,000 properties per year would need to have floor insulation installed between now and 2027. Lower number are expected in the initial years as it will take time to overcome the barriers around supply chains and disruption to occupants.

Installing floor insulation can be very disruptive to occupants and needs to be carried out by professionals to ensure that it does not lead to condensation or cold spots. However, the prevalence of cellars in many terraced houses in Sheffield may increase the viability of installation. Technologies such as the Q-Bot, a robot that sprays insulation under floorboards, can also help to minimise these disruptions (10).



Locations of properties in Sheffield with no floor insulation
Numbers of properties in each area of the city based on EPC data, the scale ranging from 1013 to over 2656 domestic EPCs

Draught-proofing

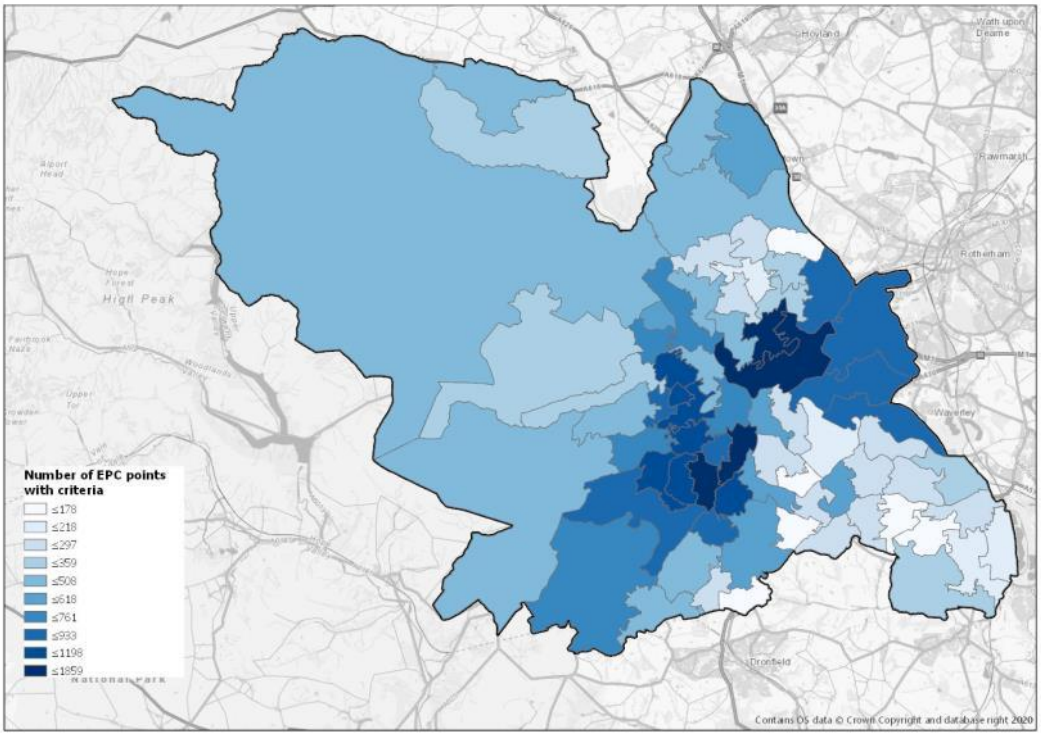
Draught-proofing measures can include sealing window frames, doors and adding draught excluders to letterboxes, doors and chimneys. Implementing draught-proofing measures increases air tightness and reduces unwanted air infiltration. This can lead to improve thermal comfort and help to reduce the heating demand. Installing draught-proofing is predicted to reduce the heating demand of a property by 5% (6).

Approximately 23% of properties, roughly 57,000 properties in Sheffield have an EPC rating of 'E' or lower (4). It is assumed that these properties will benefit from draught-proofing. The areas that have a high number of such homes are mainly towards the centre of the city in areas such as Burngreave & Grimesthorpe, Crabtree & Fir Vale, Highfield & Lowfield and Nether Edge.

Once again, there are similarities between the distribution of these properties and those with uninsulated solid-walls and lofts. A proportion of this similarity will be as a result of these characteristics contributing to a lower EPC rating, but it once again highlights the potential for combined interventions.

The cost of installing draught stripping is expected to range between £85 to £275 per property (5). Therefore, cost of installing draught stripping across the properties in Sheffield with and EPC rating of 'E' or lower would range between £5m to £16m, with an average cost of £11m. Draught-proofing could reduce energy bills by approximately £20 per year, leading to total savings of around £1m per annum if installed across all homes (6).

This measure effectively needs to be instigated immediately and an average of 8,000 properties per year would need to have draught-proofing installed between now and 2027. Lower number are expected in the initial years as it will take time to overcome certain barriers.



Locations of properties in Sheffield with EPC E or lower
Numbers of properties in each area of the city based on EPC data, the scale ranging from 178 to over 1859 domestic EPCs

Replacing glazing

Replacing existing glazing with better performing glazing can reduce the amount of heat lost through the windows, reducing the heating demand of the building. Replacing glazing with high performance or triple glazing is predicted to reduce the heating demand of a property by approximately 10% and much higher savings are expected when replacing single glazing with triple (6).

Approximately 90% of properties in Sheffield have double glazing and 1% have single glazing, roughly 225,000 properties in total (4). Although it is likely that almost all homes could benefit, it is assumed that 90% of properties will be applicable to take into account of localised constraints, such as conservation areas and listed properties.

It is difficult to find robust benchmarks on the cost of installing triple glazing in homes as the uptake is still low and costs largely depend on the number of windows needing replacing. The cost is expected to range between £2,000 to £7,000 per property (11). Therefore, cost of installing triple glazing across the properties in Sheffield where it is currently not installed would range between £445m to £1,556m, with an average cost of £1,000m. Improving glazing could reduce energy bills by between £30 to £120 per year, leading to total savings of around £17m per annum if installed across all homes (6).

This measure effectively needs to be instigated immediately and an average of 30,000 properties per year would need to have high performance or triple glazing installed between now and 2027. Lower number are expected in the initial years as it will take time to overcome come of the financial and supply chain barriers.

Reduce energy consumption in homes

Once the fabric of the building is efficient as possible, additional measures can be installed to help reduce emissions even further.

These additional measures to reduce energy consumption in homes are anticipated to reduce emissions by 52ktCO_2. These measures will be a combination of the following:

- Smart heating controls
- LED lighting

It has not been possible to accurately calculate the current uptake of both these energy reduction measures so assumptions have been made based on EPC data.

There are a number of simple measures that could also help to reduce energy consumption, such as:

- Reducing the heating thermostat setpoint
- Upgrading to more energy efficient home appliances
- Switching appliances off standby
- Turning off lights when they are not in use
- Spending less time in the shower

Whilst these measures are important and combined could have a large impact, they have not been included in the carbon analysis as the impact from home to homes is highly variable and it is impossible to estimate the proportion of homes they could be applied to. These interventions would need to take the form of a behaviour change communication campaign to residents.

Smart heating controls

Smart heating controls can help occupants have more advanced control over the heating system which can lead to a reduction in heating demand. Smart heating controls can also encourage occupants to reduce the heating set points through selecting eco-modes which can further reduce heating demand.

Installing smart heating controls is predicated to reduce the heating demand of a property by 7% (6). Smart heating controls are expected to reduce emissions by 49ktCO_2.

It is estimated that approximately 90% of properties, roughly 220,000 properties, in Sheffield could benefit from installing smart heating controls (4).

The cost of installing or upgrading to smart heating controls is expected to range between £200 to £400 per property (5) (12). Therefore, cost of installing smart heating controls across the properties in Sheffield would range between £44m to £89m, with an average cost of £67m, with additional costs to educate people about how to use them and to use them effectively. The potential savings from installing smart metering systems and reducing setpoints by one degree are expected to range from £60 to £135 per year, which when applied across all properties could be approximately £21m per annum (6).

This measure effectively needs to be instigated immediately and an average of around 45,000 properties per year would need to have smart heating controls installed between now and 2025. Lower number are expected in the initial years as it will take time to overcome certain barriers.

LED lighting

Light Emitting Diode (LED) bulbs are more energy efficient than traditional incandescent lighting and Compact Fluorescent Lamps (CFLs). Replacing existing light fittings with LED bulbs reduces the electricity consumption associated with lighting a home.

Replacing bulbs with LED lighting is predicted to reduce the electricity demand of a property by 20% (6). LED lighting is expected to reduce emissions by 5ktCO_2.

Approximately 81% of properties, roughly 200,000 properties, in Sheffield could benefit from low energy lighting in all fixed outlets (4).

The cost of installing LED lighting is expected to range between £200 to £500 per property (5) (12). Therefore, the cost of installing LED lighting across the properties in Sheffield would range between £40m to £100m, with an average cost of £70m. Costs will vary based on the number of light fittings that need replacing and the specification of the fittings themselves. Replacing bulbs with LED alternatives could save approximately £40 a year on electricity bill, so if adopted across all homes it could result in a saving of over £8m per annum (6).

Although the payback period for residents can be relatively short, the costs upgrading to LEDs throughout an entire home can be expensive. The Council should look to provide additional funding support to help cover the upfront costs and make it accessible for all residents to upgrade. For example, Sri Lanka is providing over one million LED lights to low-income customers with zero-interest financing (13). However, if upgrades to LEDs are carried out as part of a natural replacement cycle, costs will be less noticeable. The disadvantage of this approach could be that the extent of the upgrade is much harder to track, and it will be difficult to establish which actions are having an impact.

This measure effectively needs to be instigated immediately and an average of around 40,000 properties per year would need to have LED lighting installed between now and 2025. Although this is a high rate of installation, LED lighting is a readily available technology, and in many homes, the switch to LED lighting can be made without the need for a specialist installer.

Remove fossil fuels

Fossil-fuel consumption from gas, coal and gas oil account for 75% of the total carbon emissions in the domestic sector. To be zero-carbon, Sheffield will need to eliminate all remaining fossil-fuels by 2030.

Measure to remove fossil-fuels are anticipated to help reduce emissions by 386 ktCO_{2e}. These measures will be a combination of the following:

- Switching to electric cooking
- Connecting to district heating networks
- Replacing boilers with heat pumps

Electric cooking

Approximately 2% of gas use is associated with cooking in the domestic sector (2). All gas cooking appliances will be expected to be replace with electric equivalents. This is expected to reduce emissions by 6ktCO_2.

Switching from gas to electric cooking appliances will increase the electricity demand on the grid. Whilst no direct energy savings have been accounted for in the carbon modelling it is anticipated that some energy saving measures will be seen if older ovens, cookers and hobs are replaced with higher efficient electric alternatives.

Approximately 87% of properties, roughly 215,000 properties, in Sheffield have gas as the main heat source and it is assumed that these properties also utilise gas for cooking (4).

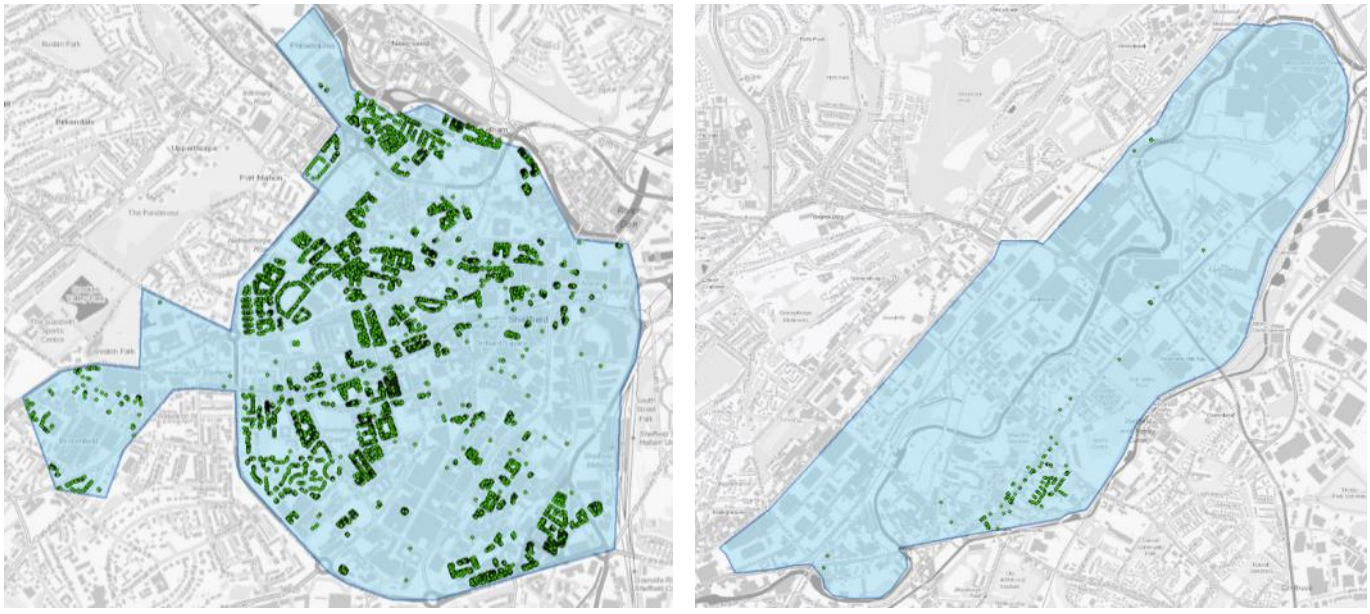
The cost of installing electric cooking appliances is expected to range between £250 to £1,000 per property (14). Therefore, cost of installing electric cooking appliances across the properties in Sheffield would range between £54m to £215m, with an average cost of £135m. Costs will vary depending on the type of appliance needing the be replaced (hob, oven, cooker) and the specification level.

Although this measure could start to be implemented immediately, it is anticipated that it would start to be implemented from 2025. This would mean that around 40,000 properties per year between 2025 and 2030 would need to replace gas cooking appliances. The delay will allow for homeowners and landlords to prepare for replacing existing gas appliances when they reach the end of their service life. Where possible, it is recommended that gas cooking appliances are phased out when they reach their normal replacement cycle, which is typically 10-20 years. However, there is likely to a number of gas cooking appliances that are still in operation that would need to be replaced ahead of their replacement cycle to meet the net zero carbon target.

District heating

Currently, there are two main district heating networks in Sheffield; the City Centre Zone supplied by the energy from waste heat network and the Don Valley Zone supplied by a biomass combined heat and power (CHP) heat network. Both currently have spare heat generation capacity and the district heating networks could be expanded to connect to additional homes to replace existing gas boilers.

Further details relating the district heating networks can be found in the energy section.



Domestic properties in the catchment areas for the City Centre Zone (left) and the Don Valley Zone (right)

Expanding the City Centre Zone heat network would mean that 19,000 domestic properties would fall within the catchment area. If 80% of properties within the catchment area connect to the City Centre Zone heat network, it would mean that there would be approximately 15,000 additional properties connected.
Expanding the Don Valley Zone heat network by he criteria set out in the Energy section would mean that an additional 166 domestic properties would then fall within the catchment area. If 80% of properties within the catchment area connect to the Don Valley Zone heat network, it would mean that there would be approximately 100 additional properties connected. This is obviously much lower than the city centre network due to the

industrialised nature of the area. However, there would be the potential with more detailed feasibility studies to target the expansion of the network in strategic directions to bring many more properties into range.

A connection to a high density heat network within these zones should offer the cheapest low carbon heating solution in terms of both connection cost and running costs. Connections within these zones could be mandated through the revised Local Plan but recognising the issues around timescales for Local Plan revisions, the potential use of Supplementary Planning Guidance and the unknown impact of the recent government White Paper on planning as noted earlier.

There are a number of smaller, mainly gas-fired, heat networks serving mainly housing association properties. These are considered to be similar enough in scale to be transferred to heat pump solutions. Further detail is available in the report for the work package looking at Local-Authority controlled assets.

The cost of expanding the district heating network and connecting these additional properties is estimated within the energy section. It is anticipated that it will start to be implemented from 2025 and an average of around 3,000 properties per year would need to connect into the district heating network between 2025 and 2030.

Heat pumps

In areas that are not served by the heat networks, locally installed heat pumps should be installed to replace exiting fossil fuel-based heating systems. All remaining domestic properties (i.e. those not on district heating) that have fossil fuel-based heating systems should be replaced with heat pumps. This is estimated to be in the region of 200,000 properties (4). Switching to heat pumps is expected to reduce emissions by 380kt$CO_{2e.}$

Switching from gas-boilers to heat pumps will increase the electricity demand on the grid. However, heat pumps have much higher efficiencies than gas-fired boiler. It is assumed that domestic heat pumps will have a coefficient of performance of 3.3 compared with a typical gas-boiler that has an efficiency of around 85%, depending on the age.

For heat pumps to work efficiently, homes will need to be well insulated and draught-proofed to minimised heat losses. Heat pumps produce heat at lower temperatures than traditional boilers and so emitters may need to be replaced to those better suited to operate at lower temperatures, such as underfloor heating or larger radiators.

As with many of the proposed measures, case studies for adoption are often limited to pilot schemes or low volume trials with early adopters, such as the Freedom hybrid heat pump project in Bridgend (15). Leeds City Council are developing six new district heating clusters to provide low-carbon heat for 26 council apartment blocks. The low-carbon heat options considered include the use of central air source heat pumps, central ground source heat pumps, and boreholes/ambient loops with individual heat pumps at each home. Acis Group are also currently looking into using heat pumps rather than gas in properties.

The cost of installing domestic heat pumps is expected to range between £5,000 to £7,000 per property, with an additional cost of approximately £2,000 to replace heat emitters (16). Therefore, the capital cost of installing heat pumps across the properties in Sheffield would range between £1,000m to £1,800m with an average cost of £1,400m.

The unit cost of electricity is higher than that of gas so despite the energy savings, the annual operation cost of heat pumps is expected to be similar or potentially higher to that of gas boilers (6). This situation will undoubtedly change as the energy markets react to the changes in role of gas and electricity but in the short term, the Council should lobby for the use of subsidies and grants to help address the operational cost difference between gas-boilers and heat pumps for those on low incomes where fuel poverty could be an issue.

As it will take time to ramp up the supply chain, it is anticipated that this intervention would start to be implemented from 2025 and an average of around 40,000 properties per year 2030 would need to have heat pumps installed between 2025 and 2030. As with switching to electric cooking, it is recommended that gas boilers are phased out when they reach their normal replacement cycle, typically 10-15 years, being replaced with heat pumps. However, there is likely to a significant number of boilers that are still in operation that would need to be replaced ahead of their replacement cycle to meet the net zero carbon target.

3 Benefits

In addition to the reductions in carbon emissions, there are several significant benefits associated with adopting the proposed measures to reach net zero carbon emissions.

Reduced energy costs

Improving the fabric of the buildings will reduce the energy needed to achieve a comfortable temperature, an effect that also has the potential to reduce the costs the costs of heating the home. This benefit may be offset to some degree by an increased energy cost on a switch from gas to electricity but the fabric measures will work to reduce any cost increases. Some of the simpler interventions such as draught-proofing, loft insulation and cavity wall insulation can have short payback periods, making them very attractive to a greater range of funders (including the occupiers). Some of the more significant interventions (such as glazing replacement) will still result in annual cost savings but the payback period is longer, perhaps requiring a different funding mechanism. Irrespective of these payback periods, reduced energy costs should assist in tackling fuel poverty, particularly for residents living in rented properties or where a high level of subsidy is provided for the works to be completed.

Improved comfort to occupants

In parallel to reducing energy costs, fabric interventions can also provide improved thermal comfort for occupants. This can be as a result of occupants being able to afford to heat their homes to a comfortable temperature or due to the fact that a well-insulated home will heat up more quickly to achieve a comfortable temperature. These more comfortable temperatures also bring health benefits from the avoidance of damp and mould.

Improve air quality

In some areas, domestic gas boilers are second only to transport in their contribution to harmful oxides of Nitrogen (NOx) in the atmosphere. As transport electrifies, this will place further emphasis on emissions from heating homes. Improvements to local air quality will be achieved by removing the local emissions associated with burning fossil fuels if heat sources are switched to cleaner technologies (such as heat pumps). Reductions in energy use from fabric efficiencies would also result in improved air quality but the effect will be much reduced when compared with fuel switching.

Employment and skills

The scale of the interventions needed within the domestic sector are so large that it is impossible to imagine that the current local industry in these areas will be able to cope with demand. As a result, there will be a need for a significant increase in the capacity for jobs such as general building and/or fabric energy efficiency specialists along with installers of technological solutions such as heat pumps, smart meters and PV.

Alongside these direct skills, there may also be an increased requirement for personnel and organisations indirectly facilitating the changes needed such as householder, community and business engagement and advisory skills.

Efforts are already being made (including those led Sheffield City Region and the Local Enterprise Partnership) to stimulate the local economy following the impacts of the Covid pandemic which would naturally align with moves for a stronger economy in the carbon-related sectors. The government's Green Growth Strategy indicated that the low carbon economy has a potential for a growth rate of 11% annually compared with 2.7% for the economy as a whole (these are pre-Covid figures, but the scale of the difference is likely to still be relevant).

A recent report by the Local Government association estimated that Yorkshire and the Humber could see 168,000 new jobs in low carbon economies by 2050. If national trends are followed, over 50% of these could be realised by 2030 in sectors such as low carbon heat and electricity and alternative fuels (17).

4 Barriers

It is inevitable that some barriers exist to the changes that are necessary. If there weren't then the low-carbon route would have been the default all along. However, barriers come and go in response to changes in policies, attitudes and aspirations in individuals, communities, cities and nations. It is important to see these barriers not as insurmountable obstacles but instead as clarifications of what the most impactful future actions are likely to be. Actions specified in the following section are often directly addressing these barriers.

Technical

Individual technical challenges will occur with a proportion of installations when the practicalities are considered in detail. In a way, these are the easiest to overcome within the timescales needed as we can rely on the flexibility and ingenuity of installers to develop appropriate solutions.

That said, there may be categories of individual installations that apply to enough homes to require consideration at scale. An example of this is the fact that the nature of the way heat pumps deliver heat means that they will only work with full effectiveness in homes that have what is currently considered to be reduced heat loss. As a result, heat pumps cannot be installed in many cases as a like-for-like replacement for the current gas boiler. This could cause particular difficulties for heritage homes or those in conservation areas which could have restrictions placed on certain types of work affecting the appearance of properties.

At a larger scale, there are potential technical barriers to consider with regard to the infrastructure needed to be able to supply electricity. It is not a given that the current electrical infrastructure will be able to cope with the increase in demand caused by electrically-powered heating (irrespective of the high efficiency of heat pumps).

In this report, hydrogen has not been considered as contributing significantly to Sheffield's energy needs – a position that is largely driven by the timescales within which zero carbon is being targeted. It is unclear how the infrastructure needed for hydrogen to meaningfully contribute to a broader solution could be designed and built in such a short space of time. However, this is not to say that it could not be a valid approach within the national government's 2050 timescales.

In response to these pressures, the Council can take a role of ensuring Sheffield's residents are aware of technical solutions whilst also facilitating discussions to ensure larger-scale issues are understood and addressed as quickly as possible.

Financial

Whilst reduced energy consumption should be seen as a potential benefit, there is no doubt that the capital costs of the interventions needed are a major barrier. Some of the simpler interventions will have short payback periods in which case the issue potentially becomes a societal one where homeowners lack the knowledge and motivation to act. However, it is a reality that even if paybacks are short, many households lack the access to the initial capital needed to realise future savings. This is exacerbated as payback periods become longer.

Additional funding mechanisms are necessary to address these barriers. These can either be local solutions or local facilitation of access to national schemes. For example, there is discussion around another version of the UK Green Investment Bank being launched.

The Council should call on Government to explore how it can support householders through more effective national retrofit programmes. It should seek for greater devolution of these funds and consider how it can work with adjoining local authorities in achieving this.

Sheffield City Council can move to address financial barriers by providing information to homeowners and landlords on low-cost interventions whilst enabling access to wider funding for more in-depth interventions. BEIS research on public attitudes to transforming heat indicates that the most trusted sources would be a non-government organisation (54% of people) whereas local council was only selected by 24% of people. These opinions will either need to be changed through engagement or should inform the type of body set up with the Council's assistance. (18)

These financial barriers are mainly in relation to the direct cost of installations and the role of the council is largely indirect. However, there will undoubtedly be a cost to the Council of performing this indirect role which will need funding and require continued local political support.

The costs associated with retrofitting and improving the fabric on homes could reduce over the next decade as the widescale uptake of retrofitting increase. In May 2019, BEIS launched a "Whole House Retrofit Innovation Competition", aimed at social landlords, exploring options to halve the cost of energy efficiency upgrades to homes. London Borough of Sutton, Nottingham City Council and Cornwall Council have been awarded funding as

part of this competition and are tasked with demonstrating how to reduce domestic retrofit costs whilst improving the energy performance of the homes.

Property Assessed Clean Energy (PACE) financing, such as those used in the United States and being piloted in the EU, allow homeowners to access loans for energy efficiency improvements and these loans are 'attached' to the home rather than the homeowner. These types of financing schemes help improve the affordability of retrofits which typically have high capital costs, longer payback periods, or where homeownership changes (19). Other innovative investment models are being investigated by the Green Finance Initiative including Green Equity Release, Domestic Energy Efficiency Salary Sacrifice Scheme and 'Add-to-my-Mortgage' platforms.

Political

Climate change is only one of many societal agendas that local and national government are under pressure to address. Whilst some may consider it the most important issue, it is unavoidable that any efforts to address the climate emergency will need to compete with other agendas. Bodies may have the best of intentions and the greatest ambition, but support is often unavoidably drawn to other issues.

There is also the issue that cities are effectively competing with each other for private investment funds. There is a danger that increased environmental standards applicable in Sheffield will redirect investment towards other cities with a lower requirement (due to a perceived lower cost burden). This imbalance will undoubtedly even out over time, but it creates challenges in the short term and the immediacy of the 2030 target means that the short term is critical.

Political barriers can, to a degree, be addressed by taking control of the agenda on the area in the city and reframing it, focusing on the longer term and wider benefits for the city and its people and prioritising sustainability and carbon reduction. More widely, the city can join with adjoining or similarly aspirational local authorities to clarify to national government what practical steps are needed to make progress outside of London.

Societal

The vast majority of decision-makers in the residential sector (i.e. homeowners and landlords) undoubtedly do not have all the required information in order to make a decision on emissions-reducing interventions. This knowledge gap combines with and exacerbates a lack of drive to reduce emissions and uncertainty around any negative impacts (such as the disruption caused during installations).

To make it clearer, people don't know what to do, what the implications might be and do not prioritise taking action. This is not meant to be judgemental – it is a simple fact that is completely understandable. A perception of bias, or lack of trust, has also been mentioned as potentially leading to a lack of confidence on the recommendations provided by installers (even if those recommendations are sought in the first place) which can add a further barrier.

One way to make it simpler for property owners to know what they can do to get to zero carbon is through Building Renovation Passports. Building Renovations Passports set out a renovation plan and form a digital logbook of renovations associated with each property, which can be passed on as ownership changes. Similar Building Passports are already commonplace in countries such as Denmark, France and Germany (19).

The Council has a role here as a trusted organisation in educating decision-makers and potentially providing some assurance of the reputable nature of selected installers. The Council will need to develop communications strategy to support, advise and mobilise homeowners on the actions needed. This will require additional funding and resourcing, however, costs will vary depending on the strategy adopted.

Delivery

An increase in jobs was cited as a potential benefit from action to reduce emissions. However, these jobs cannot be created and filled overnight. There is a need for a drastic increase in those skilled in installing emissions-reducing interventions. In the current post-Covid economic climate, private firms may be unwilling or unable to invest in upskilling existing or new employees and the timescale of the 2030 target is such that we cannot wait for simple market forces to drive an increase in enrolments onto relevant training courses. As an example, the 6,000 properties requiring solid wall insulation equates to around 120 properties every week. This scale of change will need action

across all elements of the supply chain, from the size of the market businesses' response to skills and materials availability.

The Council has a role to understand the state of the market and any potential market failures. In particular, the council has a role to influence local skills providers and Sheffield City Region to ensure that new and existing workers in the construction and retrofit sectors are informed on the agenda and that training is available and accessed. Perhaps the most direct way of encouraging an increase in delivery capability is to take action their own estate, thereby kickstarting the market. Directly commissioned works could also place increased requirements on competing firms to increase their skills pipeline. However, procurement regulations may prove an additional barrier to these direct commissions yielding Sheffield-specific increases in capacity.

5 Actions

The actions that are required in order to realise the interventions set out above are set out across three themes:

- what the Council can progress;
- what 'the City' can progress (partners / residents/ businesses / institutions); and
- where the Council and city partners will require the support of national government.

In each of the actions under these themes, the Council has a role to play, either as a direct actor or as a facilitator. The enabling actions the Council can take when trying to encourage city-wide action are shown. Where the support required of national government is set out, the role of the council is to lobby for change and communicate the issues to the best of its ability.

To avoid repetition some actions that span sectors are only included in the sector in which they are expected to have the greatest impact.

Sheffield City Council actions

Actions in italics apply across sectors to some extent and are similar to those mentioned in other sections of this report.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030
• *Put in place sufficient internal resource and governance procedures to be able to respond quickly to government financial supports and provide other support. Target funding to support.*	■	■	
• *Establish a governance model than enables swift action on the issues and reports on them. Maintain an aspirational stance.*	■	■	
• *Understand the capacity of the construction and retrofit sectors and look to address causes of market failure (either lead or engage actively with SCR work in this area)*	■	■	
• *Develop an intensive programme of works on Council-owned domestic properties to kick-start an increased local delivery pipeline. See WP3.2.*	■	■	
• *Develop mechanisms to enforce domestic Minimum Energy Efficiency Standards*		■	■
• *Identify leading cities and partner with them to learn from each other*	■	■	■
• Instigate planning policies that require all new homes to be zero carbon as soon as possible and by 2030 at the latest.		■	
• Immediately insist on high-efficiency zero carbon developments which rely on council-owned land to act as exemplars	■	■	■
• Comprehensive apprentice training programme kick-started by placing requirements on directly-commissioned works	■	■	
• Identify a programme of "shovel ready" projects and partnership frameworks to enable speedy response to funding opportunities.	■	■	

City-wide actions

Council enabling actions are shown in italics. It is worth noting that without these enabling actions, significant progress on these city-wide actions is highly unlikely to be realised.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030
• Homeowners and landlords to improve thermal efficiency of their homes and move to electricity-based heating. o *Council to create materials and a communication campaign to encourage people to take action* o *Council to provide ongoing advice to homeowners and landlords to understand concerns and ensure sufficient support is in place (potentially taking the form of resident/landlord support groups)* o *Council to promote access to Energy Company Obligation scheme among eligible groups.* o *Council to identify funding routes that reduce the initial burden of capital needed and promote their uptake (such as the current Green Homes Grant). Consider developing own scheme if eligibility gaps exist in current offerings.*	■	■	
• Local installation industry to stimulate the market by providing easier-to-access solutions o *Council to work with local industries and suppliers to develop a recommended list of local installers and maintenance companies* o *Council to work with local industries and suppliers to develop standard solutions for common local housing archetypes (e.g. solid-walled 3-bed terrace) including those 'hard-to-treat' including bringing in learning from other regions.*	■		
• Local training and education sector to develop retraining scheme towards low carbon economy o *Council to instigate discussions with sector and with SCR, understand immediate barriers and assist in developing ways of overcoming them* o *Council to encourage uptake in the scheme*	■		
• Local electricity infrastructure providers to plan to have sufficient capacity for the move to electrified heating o *Council to initiate discussions, understand any impacts on zero carbon target and take action as necessary.*	■	■	
• Local hydrogen sector to highlight any support from the Council which would improve long-term prospects of the technology locally o *Council to initiate discussions and take action as necessary.*	■	■	

Governing bodies actions

These actions set out the support needed from national government. In all instances, the role of the council is to lobby for change and communicate the issues to the best of its ability. Note that this is not intended to be a list of all governing body actions needed to reach zero carbon, more those that are directly linked to allowing the Council to more effectively progress Sheffield-specific actions but that are more appropriate to be driven at a national scale.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030
• *Increase direct funding available to councils to allow them to carry out the essential role of facilitator in low carbon interventions.*	■	■	
• *Provide a clear strategic direction and ongoing policy support around the future of hydrogen in the future low carbon economy*	■		
• *Coordinate learning between cities moving towards zero carbon*	■	■	■

- *Continue existing funding and introduce new options to reduce capital investment barriers to interventions and address potential negative social impacts of higher heating costs resulting from heat decarbonisation. Investment should be focussed on medium- to long-term as repeated short-term interventions often don't yield the structural changes needed.*
- Provide policy support on allowing Local Authorities to set planning requirements and ensure sustainability and emissions are at the heart of future changes to the planning system.

6 Funding routes

There are a number of funding routes available to support energy improvement measures in domestic properties. Those set out below are those that are currently nationally available. It is likely that further funding routes will become available as the country as a whole starts to move towards zero carbon – only relatively limited funds are available at the present time. Additional local funding routes could be developed to provide a Sheffield-specific solution but would rely on raising suitable funds.

Green Homes Grant

Under this scheme homeowners and landlords will be able to apply for a voucher to fund up to two thirds of the cost of hiring tradespeople to upgrade the energy performance of their home (up to a maximum contribution of around £5000). Low income households will be eligible for up to 100% government funding, up to around £10,000 (8).

Energy Company Obligation

ECO is the main scheme for supporting energy efficiency improvements including insulation and some heating improvements in low income and vulnerable households. Unlike other schemes ECO is not a government grant, it is an obligation placed on the largest energy suppliers to support households install energy improvements (8).

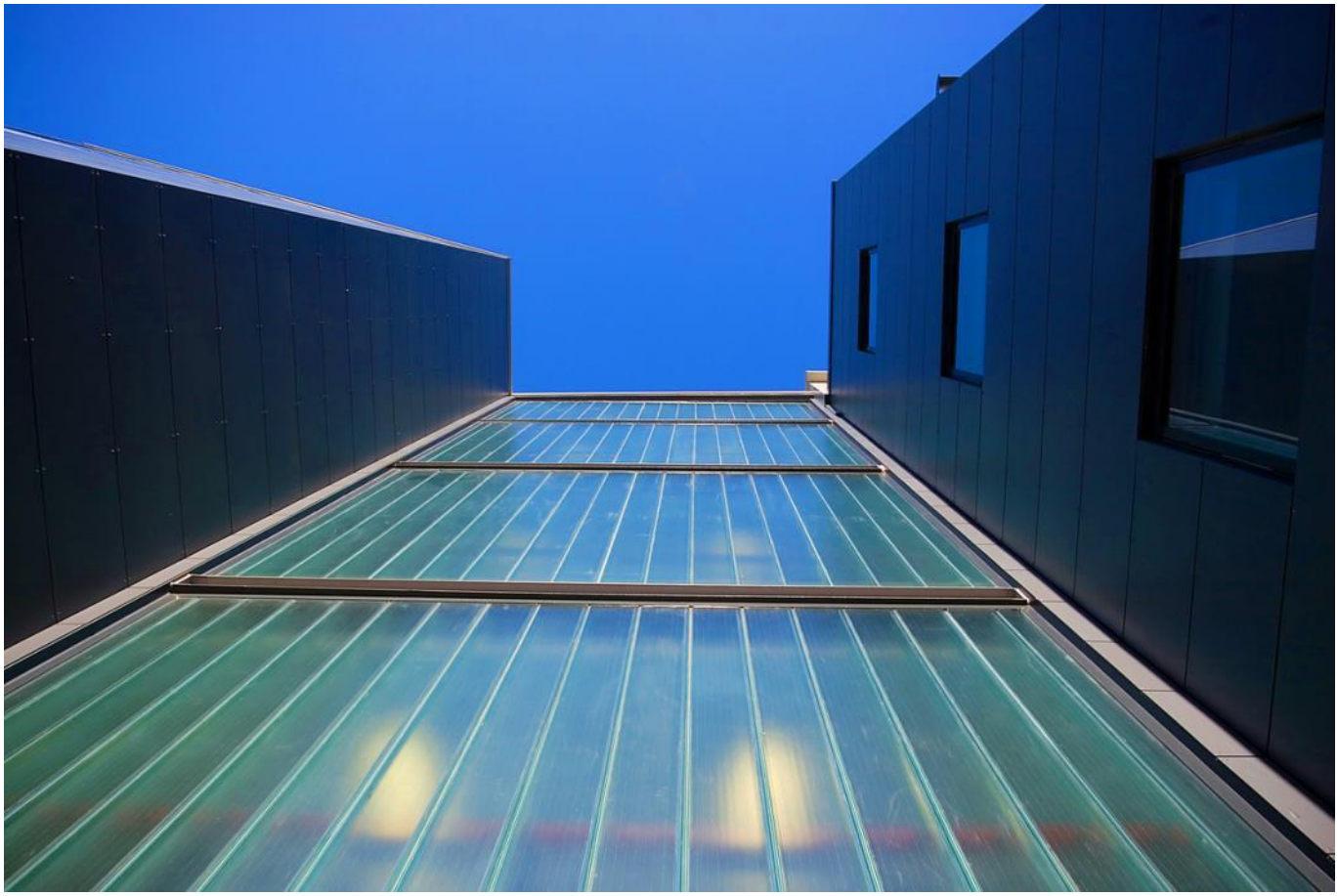
Renewable Heat Incentive

The RHI is a government scheme to support renewable heating systems like heat pumps and solar water heating. If you install a system that meets all the scheme requirements, you can be paid for every unit of renewable heat you produce for a number of years. There are two RHI schemes – the domestic RHI is for households with a renewable heating system just for the one home. The domestic RHI pays an amount (the tariff) for every unit of renewable heat you are considered to generate, for the first seven years from the date you apply (8).

Green Deal

Intended to help with funding using the option of a Green Deal Finance plan where repayments are less than the savings expected by energy efficiency. Charged as a supplement to the home's electricity bill that stays with the home if the owner moves. Provided by private financing companies in its current guise.

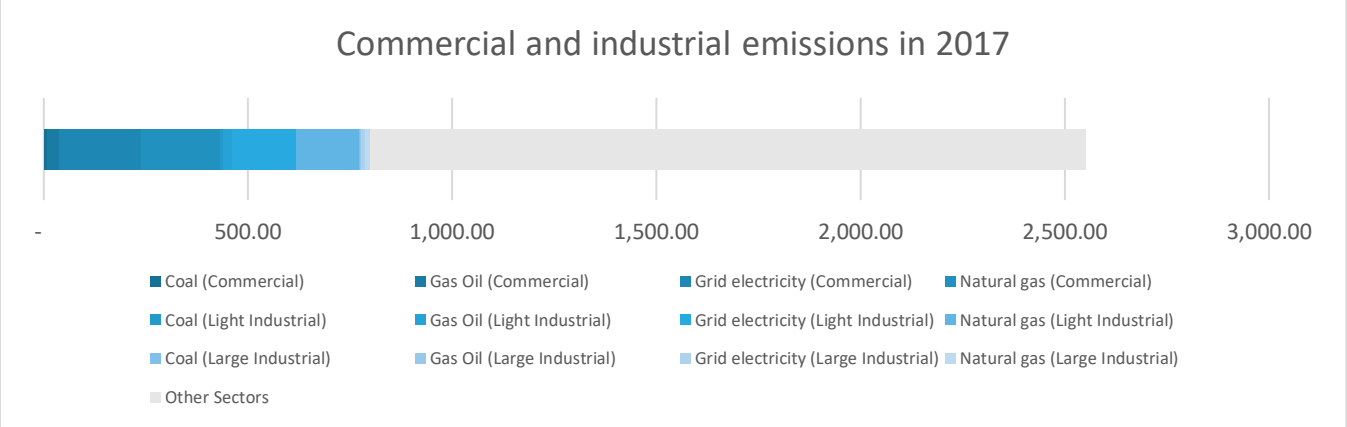
Commercial and industrial sector



University of Sheffield School of Clinical Dentistry

7 Commercial and industry overview

The emissions from the commercial and industry sector contribute to 801ktCO$_2$, equivalent to 35% of Sheffield's emissions. The commercial buildings accounts for 54% of these emissions, whilst industrial buildings account for 46%.



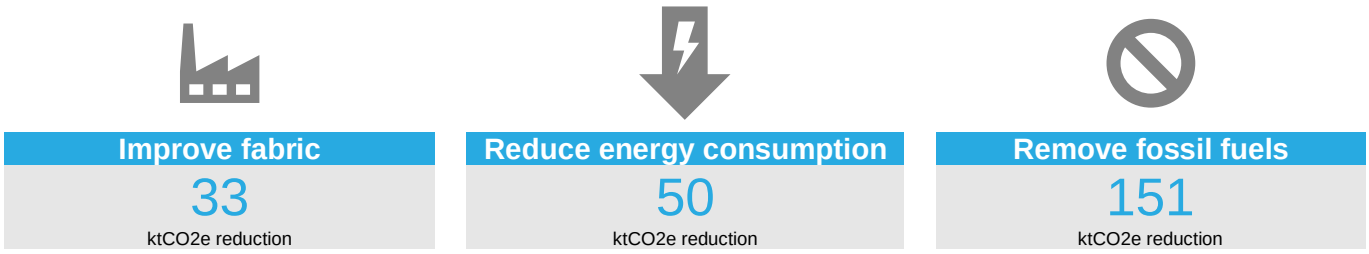
Carbon emissions from the commercial and industrial sector in Sheffield
Using 2017 baseline data

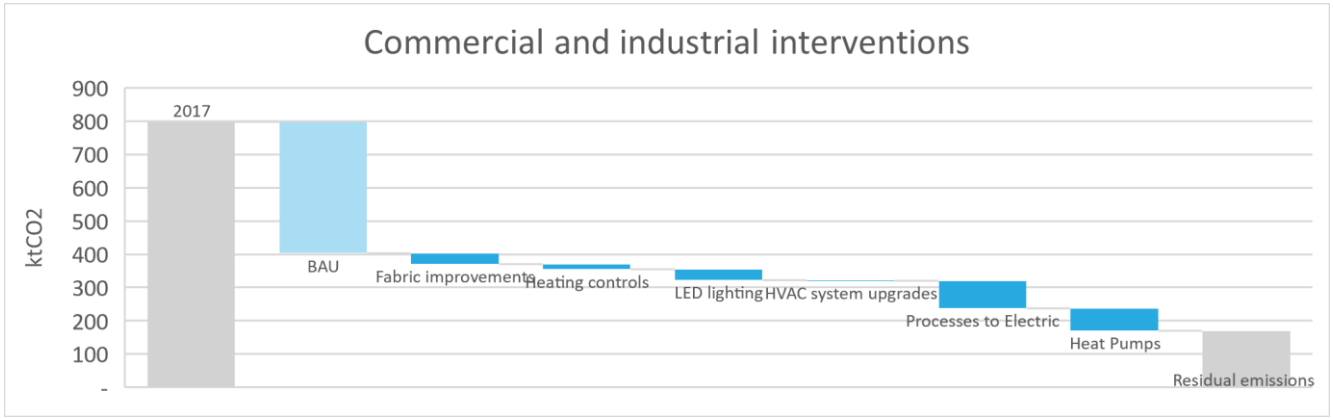
8 Approach to zero carbon

There are a series of interventions proposed for commercial and industrial properties in Sheffield to reach the net zero carbon target. These interventions include:

- Improve fabric
- Reduce energy consumption
- Remove fossil fuels

The analysis focuses on existing properties as it is assumed that all new buildings will be zero carbon.





Carbon emissions reduction from the commercial and industrial sector from interventions

Improve fabric

As with the domestic section, improving the fabric of commercial and industrial buildings helps to minimise heat losses and therefore emissions resulting from heating.

Improvements to the fabric are anticipated to help reduce emissions by 33ktCO_2.

Fabric upgrades

Improving the fabric of the building can help to reduce the amount of heat lost and therefore reduce the heating demand.

Improving the fabric of the building might involve retrofitting additional insulation to improve the u-value of the existing fabric, replacing elements of the existing fabric or improving the air tightness. Fabric improvements will likely be a combination of the following measures:

- Solid wall insulation
- Cavity wall insulation
- Floor insulation
- Roof insulation
- Draught-proofing
- Replacing glazing
- High-speed/rapid roll doors
- Air-locks/lobby areas

Fabric improvement measures are applicable to all buildings with poor performing fabric but there may also be limitations and restrictions on fabric improvements due to aspects such as the listed status, conservation area, age of the building, construction etc. It has not been possible to estimate the scale to which these measures could be applied across the commercial and industry properties as there is not sufficient data available. It is recommended that surveys are carried out throughout the commercial and industrial sector to identify the measures that would be most practical and provide the greatest carbon savings for the different businesses and building types. Actions set out in later sections prioritise facilitating individual building owners understanding the particular options available to them as opposed to rolling out blanket-coverage of a particular intervention.

The carbon savings will be dependent on the current fabric performance and the quantity and degree of improvements made. For example, if a property which is largely glazed and currently has poor performing glazing upgraded to high performance glazing then the carbon savings might be greater compared to with property that has a smaller proportion of glazing.

To estimate the potential impact, the assumption has been made that space heating is attributed to approximately 61% of the total energy consumption for commercial properties and 11% of energy consumption for industrial properties (2) (20). It is estimated that combined fabric improvement measures could reduce the heating demand of a property by 15%.

It is not possible to allocate meaningful estimates of costs for fabric upgrades as they will be bespoke for each business depending on the range of measures adopted. It is, however, recognised that the cost of fabric improvements is generally high and in some cases have not been commercially viable in the past. For example, in the workshop with commercial representatives, it was mentioned that it was not commercially viable to upgrade the windows in Fountain Precinct as part of the refurbishment works. However, if Sheffield is to get to zero carbon by 2030, there will not be the option of only selecting measures that have quick payback periods. Much of the low hanging-fruit has already been picked and we now have to acknowledge that measures that have previously been deemed too difficult or too costly may need to be implemented.

Other cities are also looking into ways to retrofit and upgrade commercial buildings at scale. Melbourne's 1200 Buildings Program aims to retrofit two-thirds of the city's commercial buildings since 2010 and over 540 commercial office buildings have been retrofitted so far (21).

This measure effectively needs to be instigated immediately. Fabric improvement measures should be treated as a priority and it is important that they are carried out either before or in conjunction with measures to remove fossil fuels in order to minimise the impact on the national grid. As with the domestic sector, buildings that have poor fabric performance will need upgrading before heat pumps are installed in order to achieved higher efficiencies.

Some fabric improvement measure can be very disruptive and should be coordinated with other refurbishment projects where practical.

Reduce energy consumption

Once the fabric of the building is efficient as possible, additional measures can be installed to help reduce emissions even further.

Measure to reduce energy consumption commercial and industrial are anticipated to help reduce emissions by 50ktCO_2. These measures will be a combination of the following:

- Smart heating controls
- LED lighting
- Building services and process upgrades

Similar to the domestic sector, there are a number of simple management or behavioural measures that can help to reduce energy consumption further. Whilst these measures are important and, when combined, could have a large impact, they have not been included in the carbon analysis due to the extreme difficulty in meaningfully quantifying impact.

Smart heating controls

Inappropriate or poorly functioning controls can increase energy consumption and reduce thermal comfort for staff by over or under using heating and ventilation systems. Upgrading the heating controls and installing a time control heating system allows spaces to only be heated as and when required, reducing the energy required for heating as well as improving occupant comfort.

Smart heating controls can make automatic adjustments in line with changes to the weather and can optimise heating start times. When controllers are linked to into building energy management systems they can be optimised with other controls (to ensure that heating and cooling systems are not operating simultaneously, for example).

Upgrading the controls generally requires minor refurbishment. It is applicable to all commercial properties that do not already have adequate heating controls. Whilst it is not known exactly how many commercial properties already have smart heating controls installed, it is estimated that approximately 90% of commercial properties in Sheffield could benefit from installing smart heating controls. Installing smart heating controls is predicated to reduce the heating demand of a property by 10% (22).

The carbon savings will be dependent on the amount of heating controls systems that need installing or upgrading but smart heating controls are expected to reduce emissions by 15ktCO_2.

The cost of upgrading the controls will be dependent on the size of the property and accessibility of the current systems installed along with the amount of ancillary equipment that will also be needed to support the upgrades. The cost of installing or upgrading to smart heating controls is expected to range between £1,000 to £15,000 per property. Therefore, the cost of this intervention across the businesses in Sheffield would be in the region of £100m.

Given that it will take time to mobilise businesses and supply chains, this measure effectively needs to be instigated immediately and would need to be delivered by 2025.

LED lighting

Light Emitting Diode (LED) bulbs are more energy efficient than traditional incandescent lighting and Fluorescent Lamps. Replacing existing light fittings with LED bulbs reduces the electricity consumption associated with lighting. LED lighting also provide other benefits, such as a longer lamp life, reduced heat gain and better controllability.

Lighting accounts for approximately 46% of commercial and 68% of industrial electrical consumption (20). Switching to LEDs can reduce lighting energy consumption by approximately 50%, depending on the existing fittings installed (22). It is estimated that approximately 75% of commercial and industrial properties could benefit from upgrading to LED lighting, however there is not robust data to back this up. LED lighting is expected to reduce emissions by 32ktCO_2.

Installing appropriate lighting controls can help to reduce the electrical energy consumption even further by ensuring that lighting is not on when it is not required. It is estimated that properly installed and managed lighting controls can reduce lighting energy use by 30-50% in a typical office environment (23). However, the carbon impact of lighting controls has not been incorporated within the carbon model due to insufficient data.

The cost of upgrading to LED lighting will vary significantly depending on the number of light fittings needing to be replaced. The Carbon Trust describes two case studies of industrial companies that updated to LED lighting and the costs were £14,100 for Pentagon Plastics and £24,000 for APS Metal Pressing. For smaller commercial properties the costs could be under £1,000. Each of these costs can be reduced by aligning with existing replacement schedules or by combining lighting upgrades with other works.

Although the cost could be high, it is expected that the majority of these costs will be covered by the businesses themselves as the energy savings will be imminent and the payback period is likely to be less than 3 years.

It is anticipated that the measure could start to be implemented immediately and will be delivered by 2025.

Buildings services and process upgrades

The energy consumption from building services and process equipment and varies significantly from business to business within the commercial and industrial sector. However, there are significant opportunities to reduce the energy consumption and associated carbon emissions through a variety of measures. These measures could include:

- Turning off unnecessary ventilation
- Incorporating automatic controls
- Localising ventilation
- Repairing and maintaining damaged pipework and ductwork
- Reducing energy related to compressed air
- Installing variable speed drives
- Recovering waste heat

The measures adopted will need to be review at an individual business level to determine what is most appropriate by taking consideration of the equipment currently installed and the processes being carried out.

It has been assumed that electricity consumption associated with fans, pumps, cooling and humidifying equipment account for approximately 21% of commercial electricity use and 12% of industrial electrical use (20). As part of the analysis, it is assumed that improvements and upgrades to HVAC and process equipment could reduce consumption by 10%. As such, building services and process upgrades are expected to reduce emissions by 3ktCO_2.

Again, it is not possible to allocate meaning estimates of costs for these building services and process upgrades as they will be bespoke for each business. Given that it will take time to undertake surveys to identify what upgrades can be carried out, this measure effectively needs to be instigated immediately and would need to be delivered by 2027.

Remove fossil fuels

Fossil-fuel consumption from gas, coal and gas oil account for 51% of the total carbon emissions in the commercial and industrial sector. To be zero-carbon, Sheffield will need to eliminate all remaining fossil-fuels by 2030.

Measures to remove fossil-fuels are anticipated to help reduce emissions by 151ktCO_2 (excluding emissions from district heating). These measures will be a combination of the following:

- Decarbonise processes
- Connecting to district heating networks
- Replacing fossil-fuel boilers with heat pumps

Decarbonise processes

One of the biggest challenges to the commercial and industrial sector will be replacing processes that currently use fossil fuels with zero-carbon alternatives. The most suitable zero-carbon alternatives would need to be determine based on the types of processes used and could be a combination electricity, local hydrogen, biomass etc.

Typical processes that use fossil-fuels are catering, high/low temperature processing and drying/separation (2). It is assumed that 10% of fossil-fuel use is associated with processes and that all these will be decarbonised. This is expected to reduce emissions by 82 kt$CO_{2e.}$

The costs of decarbonising processes will need to be calculated at an individual business level and the measures needed will vary significantly. For example, although the costs of replacing gas cooking appliances for a small café will be many orders of magnitude lower than the cost of installing an electric arc furnace, both could still be a financial strain to the individual businesses involved.

This measure effectively needs to be instigated immediately and would need to be delivered by 2030. Ideally, processes will be replaced once the existing equipment reaches the end of its serviceable life, however, some processes many need to be replaced before this in order to meet the 2030 goal. However, it is recognised that this is a significant change and this initial uptake might be slow as many businesses will need support in understanding the most appropriate alternatives and gather funding.

District heating

As described in the domestic section, there are two main district heating networks in Sheffield; the City Centre Zone supplied by the energy from waste heat network and the Don Valley Zone supplied by a biomass combined heat and power (CHP) heat network. These district heating networks could be expanded to connect to additional non-domestic buildings to replace existing gas boilers. The reduction in emissions from district heating is calculated in the energy section.

Commercial properties in the catchment areas for the expanded City Centre Zone (left) and the Don Valley Zone (right)

It is estimated that an additional 5,000 commercial properties and 800 industrial properties could connect to the City Centre Zone heat network and 1,000 commercial properties and 800 industrial properties could connect Don Valley Zone network. These have been based on areas that have high heat demand density and therefore are most suitable for district heating. A more detailed study would be required to understand the feasibility of expansion within these areas and if there are other opportunities for heat networks within the city. The cost of expanding the district heating network and connecting these additional properties is estimated within the energy section.

It is anticipated that it would need to start being implemented from 2025 and would be delivered by 2030. This means that approximately 150 properties per year would need to be connected.

Industrial properties in the catchment areas for the expanded City Centre Zone (left) and the Don Valley Zone (right)

Heat pumps

In areas that are not served by the heat networks, heat pumps should be installed to replace exiting fossil fuel-based heating systems. Heat pumps could be installed on individual buildings or there is potential (pending further investigation) for some areas to be suitable for heat pump-based district heating networks.

All remaining non-domestic properties that have fossil fuel-based heating systems which could be replaced with heat pumps. This is estimated to be in the region of 15,000 properties.

Replacing the existing heating system with heat pumps can help to significantly improve the overall efficiency of the heating system. Gas boilers typically have an efficiency of between 80-95% depending on the age of the boiler, whereas air-source heat pumps can have efficiencies in the region of 400%. Switching to heat pumps is expected to reduce emissions by 68ktCO_2.

Retrofitting heat pumps into a commercial property can be challenging for a variety of reason and for some buildings this will require a higher degree of refurbishment than others. Heat pumps operate at lower temperatures than traditional wet heating systems and therefore properties may require upgrades to the current heating distribution system (e.g. installing larger radiators or more heating coils) if the current system is unable to meet the required heating demand at the lower temperatures. Alternatively, hybrid heat pumps can be installed with a backup boiler to ensure the heat demand is met even in winter, when the heat demand is at its highest but the air temperature outside is low. However, this would compromise the zero fossil-fuel approach.

The cost of installing commercial heat pumps will vary dramatically depending on the heat demand for the property. Smaller sized systems may cost in the region of £5,000 whereas larger systems could be closer to £200,000. There may also be additional costs needed to replace existing heat emitters and distribution systems. It is anticipated that it would start to be implemented from 2025 and would be delivered by 2030. This means that approximately 3,000 properties per year would need to be replaced with heat pumps.

9 Benefits

As with domestic emissions, there are a number of meaningful benefits associated with adopting the proposed measures to reduce carbon emissions. Unsurprisingly, some of these are similar to the domestic sector but with altered scales and other variations as a result of the differences in building types.

Reduced energy costs

Whilst a number of energy efficiency measures will pay back financially in this sector, the reluctance to invest also exists. However, within the commercial sector it is often less of an issue around lack of capital as opposed to lack of awareness and motivation. Energy costs, despite rises, are still often only a small proportion of a business's costs when compared to rent and salaries. Energy-intensive industries are often already focussed on reducing these costs, though. Opportunities are for reduced energy savings are slightly increased in the non-domestic due to the prevalence of comfort cooling meaning temperature-related energy consumption often covers all seasons.

Improve air quality

Whilst improved air quality will be a benefit of reduced commercial emissions, the impacts will likely be lower than the domestic sector. Quantitatively, the sector has a lower gas usage (1880 vs. 3053 GWh in 2017) and, qualitatively, buildings are likely to be situated in less populated areas with emissions released at a higher level due to the scale of installations.

Employment and skills

Fewer discrete installations will be needed within this sector compared with domestic, but it is safe to assume that the industry supporting such installations has naturally sized itself on past demand which will need to rapidly increase to realise a 2030 target. Each intervention is likely to be more significant, drawing from linked consultancy and design services as well as installation. However, it could be assumed that firms of the scale that support these larger installations are more likely to operate across regional boundaries so there is the potential to tap into a wider resource pool if Sheffield's businesses are taking action out of step (i.e. in advance) of other areas. Conversely, any skills and businesses developing to support local action will likely have the opportunity to continue to serve the market in other areas as they follow Sheffield's lead.

Reputational

One benefit that applies in this sector that is doesn't exist in within domestic buildings is that of reputation. In a competitive marketplace for customers and the best staff, the ability to truthfully say you are taking action on climate change can reap rewards. The increasing popularity of the B-Corporation programme indicates there are real business advantages to taking action on sustainability (although this particular scheme addressed issues broader than just carbon). Supply chain engagements are increasingly requesting information on action and climate change that influences decisions around procurement.

There is the potential for this reputational benefit to be realised at a scale larger than individual businesses. Just as Sheffield is known as the Outdoor City, concerted efforts (and success) on the climate change agenda ahead of the national agenda could confer benefits to the city as a whole and all those within it.

Future-proofing

It is a virtual certainty that all elements of the commercial and industrial sector will need to transition to zero carbon in the future. The investment will need to made, the question is whether organisations react now or later. By addressing the issues early, organisations will have the benefit of being able to set their own agenda. The policy landscape in the carbon arena has shown volatility in the past, with initiatives being launched and rescinded with little notice and occasionally with seemingly little coordination. Organisations taking early action will be future-proofing themselves against inevitable changes in the marketplace (linking into reputational benefits as noted above.)

10 Barriers

The barriers for the commercial and industrial sector have been separated into the same five topic areas for consistency and again they directly lead into the actions. Whilst these five topic areas have been used for clarity, the barriers are highly interlinked across the areas, perhaps more so in this sector than the others due to the complexity and variability of the solutions needed.

In engaging with the sector, it became apparent that there is a large discrepancy between real and perceived barriers. Each can be just as problematic but can require very different strategies to effectively address them. So whilst the technical or financial barriers can seem the most tangible and important, societal and political barriers need addressing to release enabling factors to work on more quantitative issues. Even within technical and financial barriers there would be value in a role aimed at facilitating conversations that can dispel perceived barriers.

Technical

The technical barriers are significant in this sector – largely due to the complexity of installations and the variety across the sector. Solutions are very different for an office block compared to an energy-intensive manufacturing facility. However, these barriers are not insurmountable – technological solutions almost always exist. As a positive, the industry around low-carbon reductions in the non-domestic sector is well used to developing individual solutions so, in many cases, the skills already exist. The issue may well be that they require greater up-front investment to identify solutions, adding another layer to the financial barriers.

As with domestic properties, the greatest opportunity and most significant challenges come from the existing building stock. An almost insignificantly low proportion of buildings will have the benefit of being newly built between now and the 2030 target year (although any that are can have an impact beyond their quantitative emissions reductions by acting as catalysts and exemplars).

Financial

There are two types of barriers related to financial concerns. The first is simply the investment needed but it is exacerbated by the second caused by the complex structure of the sector where buildings can be owned, managed and occupied by three separate organisations.

Many short-payback interventions (the ‘low-hanging fruit’) will likely have already been carried out in the interest of bottom-line commercial cost minimisation. However, some of these may still exist, most likely within smaller organisations with less ability to have dedicated focus on energy costs. The relatively lower price of energy for large consumers will also tend to shift easy wins to smaller firms.

Longer-payback items will need access to capital investment which will likely need to come from outside firms’ own resources (which in many cases have been severely depleted by the Covid pandemic). The packaging together of interventions into investments of a scale that are more attractive to commercial investment vehicles may be a useful investment model to avoid the relatively higher costs of a large number of individual interventions. The Council, probably in partnership with SCR, can have a role in facilitating access to such funds. For example, SME’s in Durham have been given financial support through the Business Energy Efficiency Project (BEEP) towards energy efficiency improvements (24).

Ultimately, though, carbon emissions reductions will need interventions far beyond what is commercially beneficial when looking simply at paybacks from energy savings. At this point consideration of only tangible direct benefits will need to expand to include intangible benefits (e.g. reputational) and indirect benefits (e.g. air quality improvements). The Council can have a role in assisting organisations to understand these wider benefits.

Political

Many of the political barriers are similar to the domestic sector – a previously inconsistent prioritisation of climate issues which leads to a lack of support for industry, whether that is in the form of direct assistance with funding or indirect assistance with knowledge and policies; and the need to attract investment in competition with other cities. This is as true at a national level as it is at a local level. These concerns are manifested in the way the planning system is allowed to (or not) prioritise emissions reductions (discussed in more detail in relation to the domestic sector).

More broadly, though – and specific to the non-domestic sector to some degree – is the issue of being fixated on economic growth as measured by the metric of Gross Value Add. A relentlessly growing economy is not compatible with increasingly scarce resources (such as a carbon budget). This is largely a political aim, with much focus on prosperity which should potentially give way to broader definitions of value incorporating equality, health and quality of life indicators. The council could lead the way in this, and there are notable cities in the UK and further afield that are committing to alternative economic approaches.

In the workshop with the commercial representatives, it was reported that there have not been any city-wide Council led schemes that have encouraged businesses to reduce their energy demand. Without the drivers and support from the Council to encourage these types of measures to be adopted it then relies on businesses to prioritise them, whilst some business already do this, many will not.

The impacts of Covid-19 create significant political and financial barriers. The ask of businesses and landowners to invest in carbon reduction measures in the deepest recession in modern times, when the future of the office and high street is uncertain and, in many cases, the future of a business may be in doubt, is a difficult one. Sourcing grant funding to support businesses, and focusing on improvements which lead to savings (particularly processes) will be key in the short term.

Societal

Mirroring issues in the domestic sector, smaller organisations (SMEs) struggle with awareness and understanding around sustainability and climate issues. This is evident in the popularity of the recently launched Sheffield Sustainability Network for which people from over 100 organisations registered to attend. This awareness gap is not only limited to the technical issues but also around 'softer' elements such as how to embed climate issues into an organisation's ethos and strategic direction.

By tackling issues around awareness and understanding we can help organisations distinguish between real and perceived barriers and enable them to take action.

As previously mentioned, though, the barriers in this sector are very interlinked, with the fact that savings are needed beyond those that are commercially viable and the definition of value questioning the fundamental societal purpose of a sector that is focussed on providing profit, employment and income. These barriers are currently compounded by Covid-19 bringing into question even the short-term viability of many businesses and meaning capacity for activity or investment outside of the bottom line is further reduced.

Delivery

As mentioned within the discussion on benefits, the firms that would serve the larger installations within this sector are likely to operate beyond Sheffield so, assuming the city moves in advance of others, our organisations will be able to draw on a regional or national resource. Should all cities start to demand action at the same time then this resource will obviously quickly become constrained. That said, it is natural to want to prioritise the use of local firms which may encounter barriers in meeting demand such as the availability of skilled staff.

As with the domestic sector, the Council could use its direct actions on its own estate to catalyse growth, work with local education providers to foresee the potential impact of impending policies on the need for courses and with local SMEs to help them realise potential opportunities.

The gap between tenant, landlord and owners can also be an issue when it comes to deciding on who is taking responsibility for implementing the interventions that are required. There is the risk that if the building owners are not benefitting from the saving to utility bills then they may not want to shoulder the costs of upgrading the building fabric, for example. To tackle this, there needs to be a coordinated approach where all parties can see the wider benefits of the interventions.

11 Actions

Sheffield City Council actions

Actions in italics apply across sectors to some extent and are similar to those mentioned in other sections of this report.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030
• *Put in place sufficient internal resource and governance procedures to be able to respond quickly to government financial supports and provide other support. Target funding to support.*	■		
• *Establish a governance model than enables swift action on the issues and reports on them. Maintain an aspirational stance.*	■		
• *Obtain funding to develop an intensive programme of works on Council-owned non-domestic properties to kick-start an increased local delivery pipeline.*	■		
• *Lobby government for legislative support ad mechanisms to enforce non-domestic Minimum Energy Efficiency Standards.*		■	
• *Identify leading cities and partner with them to learn from each other*	■		
• Instigate planning policies that require all new non-domestic buildings to be zero carbon as soon as possible and by 2030 at the latest.		■	
• Work with local academic institutions to understand potential data sources or research themes that can increase understanding of energy consumption patterns in non-domestic buildings and to testbed innovative techniques. Use outputs to create more targeted action plans and a programme of "shovel ready" projects to facilitate access to funding.	■		

City-wide actions

Council enabling actions are shown in italics. It is worth noting that without these enabling actions, significant progress on these city-wide actions is highly unlikely to be realised.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030

• Organisations to access guidance and information to assist them identifying actions needed to reduce emissions.
  ○ *Council to work with bodies such as Sheffield Sustainability Network to increase awareness of sources of information and make connections.*
  ○ *Council to facilitate 'first steps' by developing standard routes through the journey to interventions.*
  ○ *Council to publicise Science-based Targets Initiative, encourage uptake and develop ways of publicising those taking part as a way of raising awareness.*
	■		

• Building owners to improve the thermal efficiency of their buildings and move to electricity-based heating.
  ○ *Council to identify 'major influencers' in the city such as multiple building owners and initiate conversations on action.*
  ○ *Council to partner with progressive building owners to develop a toolkit to guide the wider sector through actions and publicise. To include the benefits of enabling actions such as greater energy monitoring.*
  ○ *Council to create materials and a communication campaign to encourage organisations to take action (e.g. include exemplars and champions)*
  ○ *Council to extend work with domestic suppliers into non-domestic sector to cover small organisations with domestic-scale properties (e.g. recommended suppliers).*
	■	■	

○ *Council to work with bodies such as the Sheffield Sustainability Network, health bodies and others to develop messaging around the wider value of carbon reductions to encourage firms to go beyond the financially viable.* ○ *Council to identify funding routes that reduce the initial burden of capital needed and promote their uptake. Consider developing own scheme if none suitable exist.*			
• Energy intensive and/or fossil fuel-reliant industries to highlight support from the Council which would speed the transition to zero carbon operation. ○ *Council to initiate discussions and take action as necessary.*	■		
• Industry bodies such as the Sheffield Property Association to take a lead in engaging with the sector, identifying barriers and the support needed from the Council which would speed the transition to zero carbon. To include a drive for members to sign up to the World Green Building Council's Net Zero Carbon Buildings Commitment (support for which is provided by the UK Green Building Council) ○ *Council to initiate discussions and take action as necessary.*	■		

Governing bodies actions

These actions set out the support needed from national government. In all instances, the role of the council is to lobby for change and communicate the issues to the best of its ability. Note that this is not intended to be a list of all governing body actions needed to reach zero carbon, more those that are directly linked to allowing the Council to more effectively progress Sheffield-specific actions but that are more appropriate to be driven at a national scale.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030
• *Increase direct funding available to councils to allow them to carry out the essential role of facilitator in low carbon interventions.*	■		
• *Provide policy support around the future of hydrogen in the future low carbon economy*	■		
• *Coordinate learning between cities moving towards zero carbon*	■	■	■
• *Continue existing funding and introduce new options to reduce capital investment barriers to interventions*	■	■	
• Provide policy support on allowing Local Authorities to set planning requirements and ensure sustainability and emissions are at the heart of future changes to the planning system	■	■	

12 Funding routes

There are a number of funding routes available to support energy improvement measures in non-domestic properties. Those set out below are those that are currently nationally available. Additional local funding routes could be developed to provide a Sheffield-specific solution but would rely on raising suitable funds.

Energy Saving Opportunities Scheme (ESOS)

Whilst not a funding scheme, ESOS does effectively remove a barrier to identifying cost-effective energy efficiency measures by requiring large organisations to carry out a mandatory energy assessment every four years. Includes buildings, energy process and transport. There is no regulatory requirement for participants to implement the energy saving opportunities identified but the hope is that those that provide commercial returns will trigger internal investment by companies.

Enhanced Capital Allowances (ECAs)

The ECA scheme enables businesses to claim 100% first-year capital allowance on investments in energy-saving equipment. Therefore, ECAs provide accelerated tax relief resulting in cash flow benefits compared to standard capital allowances.

Salix

Provides interest-free loans to the public sector to improve energy efficiency and reduce emissions. Available for Local Authorities, Emergency Services, NHS Trusts and most education institutions so, whilst not open to private businesses, does apply to a significant number of organisations.

Industrial Heat Recovery Support Programme

Designed to encourage and support investment in heat recovery technologies and is open to businesses of any size. Grants are available to partially fund costs of projects. Applications need to be made within a series of rolling deadlines with the programme running to March 2022

Industrial Energy Transformation Fund

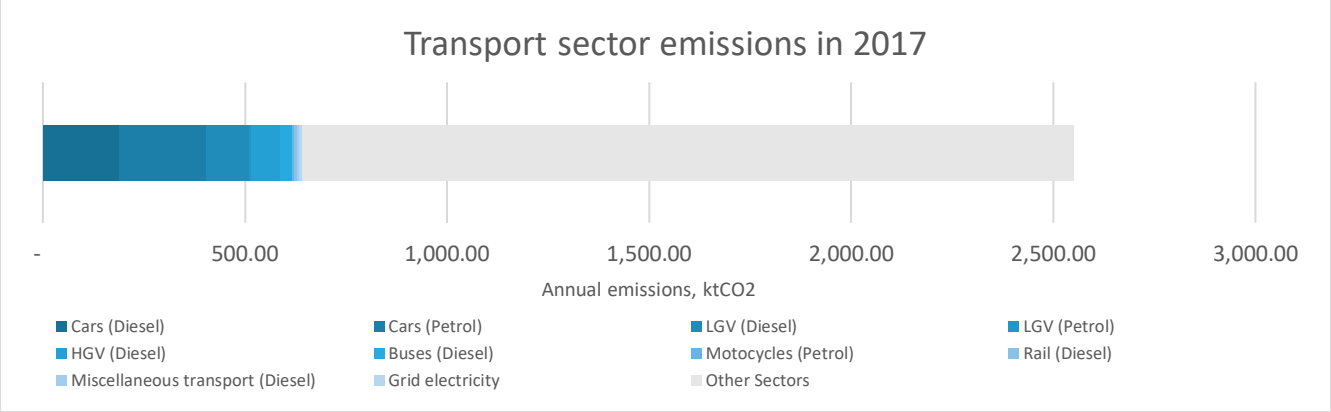
Only opened in July 2020, the IWTF will run to 2024 and is designed to help businesses with high energy use, such as energy intensive industries, to cut their energy bills and carbon emissions through investing in energy efficiency and low-carbon technologies. Grants can fund feasibility or engineering studies or energy efficiency deployment projects.

Transport sector

Sheffield Supertram

13 Transport overview

The emissions from the transport sector contribute 642 $ktCO_2$ to the baseline. Almost two-thirds of these emissions are from cars and over a quarter from light and heavy goods vehicles (LGVs and HGVs).



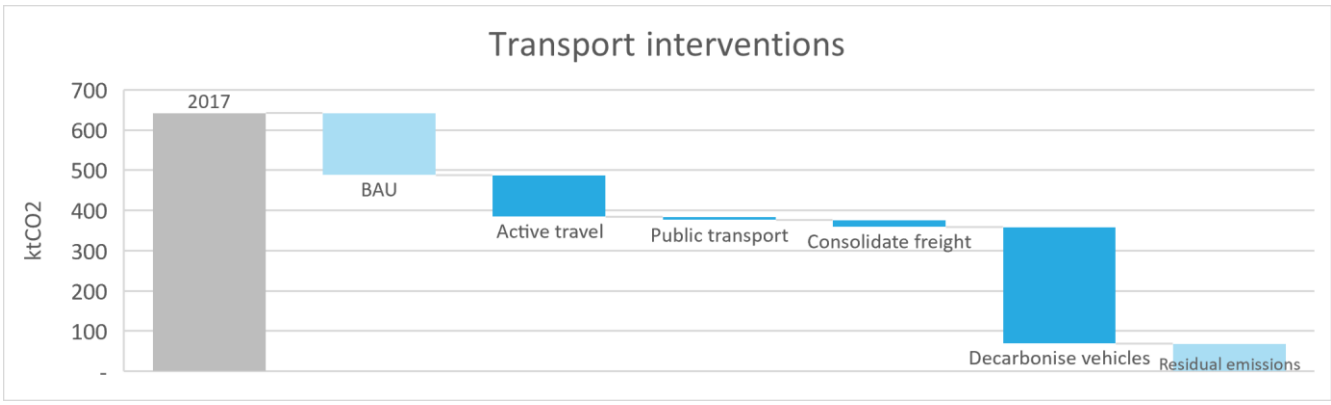
Carbon emissions from the transport sector in Sheffield
Using 2017 baseline data

14 Approach to zero carbon

There are a series of interventions proposed for transport sector in Sheffield to reach the net zero carbon target. The interventions include:

- Increase active travel
- Increase public transport
- Consolidate freight
- Decarbonise all vehicles

Increase active travel	Increase public transport	Consolidate freight	Decarbonise all vehicles
104	9	16	290
$ktCO_2$ reduction	$ktCO_2$ reduction	$ktCO_2$ reduction	$ktCO_2$ reduction

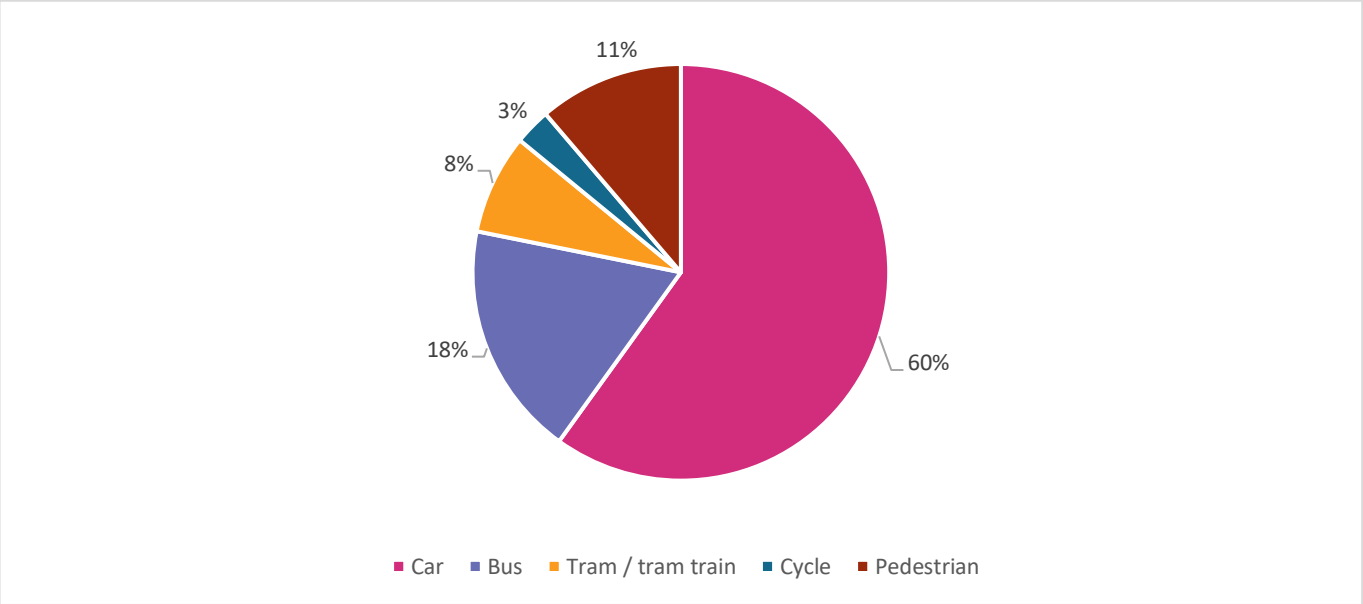


Carbon emissions reduction from the transport sector from interventions

Future travel demand and mode share

In order to understand what scale of intervention is necessary to achieve zero carbon by 2030, it is important to consider future travel demand in Sheffield. The starting point is taking the Business as Usual (BAU) transport and carbon emission projections provided in the WP2 report. The BAU assumes background growth in traffic to 2030 and the transition towards ultra-low emission vehicles due to the Government ban on petrol and diesel car and van sales as soon as 2032. Therefore, the interventions listed in this report are above and beyond this assumed trend.

Recent data indicates that 60% of people trips in Sheffield are taken by car, 26% by public transport and 14% by active travel:



Existing Passenger Mode Share (2016 Sheffield Cordon data)

Although theoretically zero carbon could be achieved by switching all private vehicles to ultra-low emission vehicles, this is not consistent with Sheffield's wider ambitions to address the adverse impact on the city's highway network predicted as a result of future growth (25). Reducing travel demand on the highway will be critical to the decarbonisation of Sheffield's transport network and is consistent with studies taken from elsewhere; for example, a study undertaken by the University of Bristol (26) that assessed the modal share required to make Bristol net zero by 2030 showed that a maximum of 20% of journeys need to be made by car, with a suggested 25% of journeys made by public transport and 55% by active travel.

As Sheffield's public transport mode share equates to the Bristol study target (25-26%), the Bristol mode share targets have been adjusted to provide target mode shares for Sheffield in the future, which are 20% trips by car, 30% by public transport and 50% by active travel. Assuming that the 20% target of trips by car is fixed in order to achieve zero-carbon, the resultant increase active travel trips seems consistent with Sheffield's emerging proposals to target development towards the city centre and developing a '15-minute city' – making active travel key modes for these shorter trips. Furthermore, the more modest increase in public transport trips of 4% is consistent with the current challenges the industry faces due to covid-19 recovery.

Although this approach is considered to be suitable for the purposes of identifying interventions required to decarbonise Sheffield's transport sector, it should be noted that it is an overly simplistic picture. External trends are already affecting UK travel patterns; in general people are travelling less than they used to, and we are seeing key trends such as young people driving less. The 'All Change?' report (27) on the future of travel demand and the implications for policy and planning highlights that travel demand reduction is a necessary part of meeting national climate change targets. The impact of Covid-19 on dramatically increasing remote-working during 2020 could have long-term impacts on travel demand that are not yet known. In addition, investment in digital connectivity and investment in neighbourhood service provision can support this trend and reduce the need to travel. It is recommended that these future trends are assessed in more depth as Sheffield develops its roadmap to decarbonisation of motorised transport.

Increase active travel

Petrol and diesel cars contribute to approximately 63% of carbon emissions from the transport sector. These emissions could be reduced through replacing a proportion of car journeys with active travel. Active travel could include increasing the uptake in walking or cycling – the targets set out in the previous section indicate a 257% increase in active travel by 2030. Walking and cycling are the most sustainable modes of transport and have many benefits not only to the environment but to the individual.

Measures to increase active travel are anticipated to help reduce emissions by 104ktCO_2. These measures will be a combination of the following:

- Improvements and extension to existing infrastructure (e.g. enhancing the cycling network, improving cycle routes, improving pedestrian crossings and public realm, low-traffic neighbourhoods, investment around schools)
- Providing cycle parking and facilities, including E-bike charging
- Enabling behaviour change (e.g. grants / subsidies / rewards to increase walking and cycling to work and schools)

It is difficult to put an exact figure on the cost of increasing active travel as costs are completely dependent on the degree to which the different measures are adopted to reach the target. Indicative costs have been provided below (28), and will be dependent on scheme-specific factors and exclude costs of land acquisition.

This measure effectively needs to be instigated immediately and would need to be delivered by 2030. In order to achieve the scale of increase, investment in active travel will need to be prioritised immediately and maintained throughout the next decade.

Cycle and pedestrian infrastructure

Improvements to cycle and pedestrian infrastructure includes expansion of cycle routes, modifying junctions, improving crossings and the walking environment, creation of low-traffic neighbourhoods and play-streets, and providing additional cycle network signage. SCR are currently developing minimum active travel standards, which should be adopted across Sheffield.

Cycle superhighways provide full physical segregation between cyclists and other road users. They are targeted at cyclists who travel between 5-20km, such as commuters, as a way to provide faster and more direct routes into and around the city. Developing key cycle routes that connect into the city centre from Broomhill, Highfield, Sharrow and Nether Edge are already being investigated. Cycle superhighways cost in the region of £1m-£1.5m per km, however, these costs are dependent on characteristics of the specific scheme, such as the number of bus stops needing relocation, road crossings, extent of traffic management, ground conditions, heritage and conservation requirements and road width.

However, cycle superhighways alone are not enough. As highlighted in the SCC Transport Strategy, the greatest opportunities to increase active travel is to encourage cycling for shorter journeys that would have otherwise been taken by car. This will mean providing a comprehensive and connected cycle network that includes strategic cycle routes that within neighbourhoods that connect to a wider range of key locations and services (such as schools, shops, workplaces etc.). Strategic cycle routes provide part segregation and cost in the region of £0.45m-£0.9m per km. As with cycle superhighways, the cost is dependent on extent of route segregated and space available, availability of parallel off-road alignments and heritage and conservation requirements.

Upgrading existing infrastructure will also be an important and cost-effective measure. Many existing cycle routes will likely need to be re-surfaced to make them suitable for the increased cycle traffic expected. Re-surfacing cycle track typically costs in the region of £0.15m-£0.20m per km and the cost is dependent on materials used, extent of signage, lighting and civil engineering works required.

Junctions and major road crossings will also need to be modified to increase the safety of cyclist and pedestrians. Junction modifications typically cost around £0.2m-£1.5m dependent on size of junction and number of roads, complexity of junction layout and number of cycle route trajectories across junction. A major road crossing can cost between £0.15m-£0.4m is dependent on extent of carriageway works required.

It is also important to have clear and identifiable cycle network signage. Cycle network signage typically £12,000 per km and are dependent on extent of bespoke design, entry point features and sculptural designs.

Cycle parking and facilities

An increase in cycling will mean that more cycle parking and cycling facilities will be needed in the city. Cycle parking hubs will be needed at major destinations, and a city centre cycle hub is currently a priority for the Council. Providing adequate and secure cycle parking at homes is also essential, particularly to ensure inclusive uptake of cycling and catering for residents that do not have a garage for example. The cost of cycle hubs is expected to be in the region of £0.10m-£1.25m dependent on land costs, economies of scale, nature of security and extent of facilities.

Cycle facilities such as cycle parking, lockers, drying rooms, CCTV, cycle pumps and accessories will also be needed in workplaces and schools. Grants for business and centres could help to cover the cost of these facilities.

Behaviour change

Enabling behaviour change is integral to the mode shift required for a zero-carbon Sheffield. This goes beyond provision of infrastructure, and requires a clearer understanding of the barriers, incentives and actions to address perceived barriers to active travel. Arup's report on inclusive cycling in cities and towns (29)found that women, disabled people and older people are subject to numerous barriers to cycling that need to be overcome through better governance, better place-based infrastructure and better support programmes.

Measures could include bike sharing schemes, educational programmes for schools, higher education and workplaces, targeted cycle training and family bike schemes.

Sheffield's topography is often a barrier for those considering cycling but new technologies such as electric bicycles can help to overcome this. Electric bicycles are not currently an affordable option for many residents so support will be needed to help improve access to these. SYPTE have a behaviour change team that provide initiatives and incentives to increase active travel in South Yorkshire, including electric bicycle trials. It is understood that the Council are planning to support hire bike providers in Sheffield, including to test and develop electric and cargo bikes and that they will continue to work with partners offer electric and/ or cargo bicycles for short term loan to residents, employees and businesses in Sheffield, under the Cycle Boost loan scheme.

Increase public transport

The emissions from cars could be further reduced through replacing a proportion of those journeys with public transport. Cheap and reliable public transport complements active travel measures by catering for journeys that cannot be made by walking or cycling, whether due to journey distance, journey purpose or personal preference. Effective services are particularly essential for our more elderly citizens and for other for whom cycling is not possible.

Measures to increase public travel are anticipated to help reduce emissions by 9ktCO_2. This assumes a 15% increase in public transport uptake from pre-Covid levels. These measures will be a combination of the following:

- Improvements and extensions to bus and tram infrastructure
- Increasing the number of buses and trams and frequency of services
- Increasing the quality of buses and trams
- Improving reliability through bus priority
- Expanding and improving park and ride facilities
- Better integration and facilities at interchanges
- Possible road pricing or parking levies to discourage travel by car

As with active travel, it is difficult to put an exact figure on the cost of increasing active travel as costs are completely dependent on the degree to which the different measures are adopted to reach the target. In addition, the impact of Covid-19 on public transport demand has presented significant uncertainty around future usage. However, public transport remains a vital component of Sheffield's transport network by providing affordable and inclusive accessibility and to reduce the impacts of widespread private vehicle travel such as congestion. In

challenging times, enabling a moderate increase in public transport uptake will require adequate funding and local democratic oversight of services. Integration between the active travel and public transport networks will be crucial in enabling a shift from private vehicles, particularly in a post-Covid world. Even with these incentives, it is likely that restraints on motoring, whether through financial penalties or policy-driven restrictions, will be necessary to make this transition happen.

Whilst public transport travel within the city uses busses and trams, further shifts away from private vehicle use can be facilitated by improved rail services between local and national urban centres. The decarbonisation of these services (such as the electrification of the Midland Main Line) is then an essential component of reaching zero carbon.

Bus and tram infrastructure

Prioritising buses through improvements and extensions to bus lanes can enable faster and more reliable connections and allow buses to by-pass congestion. This in turn encourages a mode shift towards public transport. Indicatively, a new bus lane costs around £450,000 per km. Other measures to prioritise buses could include traffic signal control improvements and extending the hours of operation of existing bus lanes.

Installing new bus stops can help to make public transport a more convenient alternative and upgrading existing bus stops can help to increase the safety and comfortable for those waiting to board. A review of the location of bus stops is needed to increase safety and help avoid congestion at bus stops in the city centre, it is understood that the Pond Street interchange in being reviewed

Whilst Sheffield already has a flagship tram network, extending the tramline can help connect more neighbourhoods and increase the number of users. Work is underway to identify priority routes for extension. In addition, a large major scheme business case has been submitted to the Department for Transport for the renewal of the existing Supertram infrastructure, which is vital to the future operation of the network, and for the zero-carbon ambitions of the city.

Increasing the number of buses and trams in operation can help to reduce waiting times as well as help to connect to a wider number of users.

Park and ride facilities

There are currently seven park and ride facilities in Sheffield that connect to the city's bus, tram and train network. Many of these are understood to be operating at capacity. Expanding park and ride facilities throughout the city can encourage more people to take public transport for part of their journey. A £14m new park and ride facility is being implemented in Leeds, which will provide 550 spaces (30). This equates to an indicative cost of around £25,500 per parking space

Road pricing and parking levies

Whilst improving the public transport systems can incentivise public transport use, measures such as congestion charging or parking levies can also be introduced to disincentivise trips to be made by cars. The Clean Air Zone proposed for Sheffield city centre will charge non-compliant vehicles and this could be extended both in geographical scope and compliance criteria in the future. These charging mechanisms would also provide the Council with an additional revenue stream that could be reinvested into supporting measures for zero-carbon.

Consolidate freight

Light and heavy goods vehicles contribute to approximately 184ktCO_2 (29%) of carbon emissions from the transport sector. Freight trips are forecast to increase as the nature of retail continues to move towards online shopping and door-to-door deliveries, which will further contribute towards congestion as well as vehicle emissions.

Measures to consolidate freight vehicles are anticipated to help reduce emissions by 16ktCO_2. These measures will be a combination of the following:

- Distribution hubs
- Effective route planning

- Alternative vehicles for last mile deliveries (e.g. cargo bikes)

This measure effectively needs to be instigated immediately and would need to be delivered by 2030. Urban freight consolidation centres have been successfully implemented for areas of London, as well as Bristol and Bath. It is reported that the number of onward trips was reduced by up to 70% to 80% by the freight consolidation scheme in Bristol between 2004 and 2018. This meant that for every 10 vehicles that made a delivery to the consolidation centre, just 2 or 3 onward journeys to the central area were made (31).

Cargo and eCargo bikes can be used as alternatives for last mile deliveries. Cargo and eCargo bikes have a significantly lower upfront costs compared to diesel vans. Smaller vehicles, such as cargo and eCargo bikes, can help reduce congestion and accessible cycle lanes enable them to bypass traffic and take more direct routes which can lead to faster and more sustainable deliveries (32). Sheffield recently secured funding to offer business eCargo bikes by the end of the year to kickstart take-up within the city.

Decarbonise all vehicles

Ultra-low emission vehicles (ULEVs) emit zero or very low amounts of tailpipe emissions. They include:
- Pure or battery electric vehicles (EVs or BEVs)
- Plug-in hybrid vehicles (PHEVs)
- Range-extended electric vehicles (E-REVs)
- Hydrogen fuel cell electric vehicles (FCEVs)

Switching to ultra-low emission vehicles can significantly help to reduce carbon emissions. Measures to decarbonise all vehicles are anticipated to help reduce emissions by 290 $ktCO_{2e}$; however, this excludes the additional CO_2 required to manufacture ULEVs. These measures will be a combination of the following:
- Working with public transport partners to decarbonise public services
- Installing electric vehicle charging infrastructure
- Disparate parking charges to encourage the use of low-emission vehicles
- Support transitioning to ultra-low emission vehicles (e.g. for private vehicles, but also buses, taxis / private hire vehicles and goods vehicles)

Ultra-low emission vehicles typically have higher upfront capital costs compared with petrol and diesel vehicles however, these are offset with lower running costs such as:
- Lower cost of fuel, especially when vehicles are charged at home with an off-peak overnight electricity tariff
- Lower servicing and maintenance costs

Other cities are already taking action to decarbonise vehicles. For example, Paris is banning on diesel cars by 2024 and phase out all internal combustion vehicles by the year 2030 (13). Montréal is in the process of converting 30% of its bus fleet to hybrids and 230 of its municipal fleet vehicles to electric by 2020 (13).

Decarbonise the public transport system

Ensuring all buses and rail are ultra-low-emission by 2030 is anticipated to help reduce emissions by 31$ktCO_2$. This will mean that all buses will need to be replaced with electric or hydrogen-fuelled alternatives and railways will need to be electrified.

Electric buses are expected to cost in the region of £225,000-£350,000 and they will also require additional infrastructure such as chargers and replacement batteries.

Hydrogen fuel cell buses are typically used for longer journeys. For hydrogen fuel cell buses to be adopted at scale would mean addressing the higher ownership costs and providing reliable refuelling infrastructure. The 'Joint Initiative for hydrogen Vehicles across Europe' aims to bring down the cost of hydrogen vehicles by buying in bulk with other authorities - helping put the price per bus on a par with the other cleanest fuels.

Rail electrification is anticipated to cost in the region of £0.75-£1m per single track km but this cost is highly dependent on the extent of track and civil engineering works to accommodate infrastructure.

Decarbonise private vehicles

Automatic Number Plate Recognition (ANPR) data from 2019 showed that among all the unique vehicles recorded in Sheffield City Centre almost 98% were petrol and diesel. Diesel is the predominant fuel type of most classes of vehicles in Sheffield City Centre. Currently electric vehicles make up a very small proportion, the 2019 Sheffield Transport Strategy stated that there are over 600 electric vehicles in the city.

Ensuring all private vehicles are ultra-low emission by 2030, is anticipated to help reduce emissions by 147ktCO_2. This assumes that the proportion of trips by car reduce by 66% from current levels to 20% of all trips, through mode shift as described previously. This reduction in car use (as opposed to just relying on decarbonisation) is key for reasons including:

- it would require significant CO2 to manufacture replacement vehicles and relies on a supply of lithium that is insufficient; and
- decarbonising private vehicles does not address other transport-related issues, such as the poor utilisation and occupancy of the total car fleet, significant particulate pollution from tyre and brake lining, the impacts of congestion and road safety.

Installing electric vehicle charging points can help promote the use of electric cars as an alternative to traditionally fuelled cars and therefore help to improve the local air quality. Residential electric charging points cost in the region of £500-£1,250 each. The cost of public charging points is higher and are typically around £1,500 to £20,000 depending on the charging speed.

Taxi companies will also need to transition to electric vehicles. City Taxis are already making plans to migrate to an all-electric fleet by 2025, which has been spurred by proposed Clean Air Zone in Sheffield city centre (33). The potential improvements in air quality in the area of the Rail Station are a good example of the overlap between wellbeing and carbon emissions in this sector and could be prioritised to serve as a very publicly-evident change bringing real benefits. City Taxis are also partnering with iCabbi and Nissan-Renault to provide additional charging hubs in the Sheffield available to both taxi drivers and the public.

Decarbonise freight vehicles

Following measures to consolidate freight, ensuring all light and heavy goods vehicles are ultra-low emission by 2030, is anticipated to help reduce emissions by 112ktCO_2. This move to reduced-emission goods vehicles could also include a move of long-distance road freight to electrified rail. Whilst potentially favourable for a number of reasons, this additional step may have limited consequences in pure carbon terms if road haulage is already decarbonised.

As with private vehicles, electric charging points will be required for light and heavy goods vehicles.

15 Benefits

Social benefits

Of all of the sectors that need to decarbonise, the transport sector has perhaps the most wide-ranging, strongest and most obvious secondary benefits. Even to call them secondary benefits is to negate their potential impact – many of these benefits would be worth the investment alone irrespective of the climate benefits that are ostensibly driving the future transformation.

Air quality is a significant concern in many UK urban areas and Sheffield is no different. The reductions in oxides of nitrogen and particulate emissions that are projected to occur as a result of the switch to electric vehicles will result in a significant improvement in respiratory conditions, reducing costs to society and improving lives. In addition to air pollution, noise reductions from quieter EVs is significant at the lower speeds seen on many busy roads which results in a marked reduction in annoyance levels for those living close by.

Alongside the benefits of a transition to EVs, the modal shift towards more active travel types will have significant health benefits. Physical inactivity is responsible for 1 in 6 UK deaths whilst 20 minutes exercise a day cuts the risk of developing depression by 31% (34). The reprioritisation of road space also results in a better street environment for leisure activities and allows local communities to thrive as more walkable areas are accessed more.

These health improvements will have many secondary impacts, including an increased population resilience to infection pandemics akin to the one currently being experienced.

As our transport network transforms away from the need to own a private car to access areas and services, so social inclusion will naturally increase. Removing this significant financial barrier will allow those on lower incomes to have more equal access.

Local economic benefits

Many of the social benefits have parallel economic benefits. For example, in England alone, the annual social cost of urban road noise is estimated to be £7–£10 billion (35) and physical inactivity is estimated to cost the UK £7.4bn (34). Reducing these costs is not only relevant to institutions such as the NHS, they are seen at every level including individual companies benefitting from reduced absenteeism and increased productivity.

In addition, in 2019 congestion cost the UK economy £6.9bn. Mode shift from private vehicles to active travel and public transport will help to reduce this cost to the local and national economy.

Active travel schemes can also directly increase business revenues in some areas, with an up to 40% increase in shopping footfall resulting from well-planned improvements in the walking environment[Error! Bookmark not defined.].

More direct economic benefits are possible for the Council, from reduced operating costs for road repairs to a potential new revenue stream, which could be used to fund carbon reduction interventions, in the form of Workplace Parking Levy or road pricing scheme.

Wider economic benefits

There are also wider economic benefits which Sheffield will reap a share of. These include new industrial and business opportunities such as services supporting bike sharing, bike hubs and maintenance offerings and low-emission cargo delivery services for example. Sheffield could expect to disproportionately benefit from these changes by taking action in advance of other cities and creating an environment where new businesses can flourish.

A faster, more efficient, more reliable and more resilient transport system will also generate agglomeration benefits, by effectively bringing labour markets and businesses closer to one another.

16 Barriers

Technical

There are very few technical barriers to a zero-carbon transport system. Electric cars, buses and light commercial vehicles all exist as, of course, do bicycles and walking requires no technology to access. Some heavier-duty vehicles (e.g. waste collection and more general heavy goods vehicles) are only just emerging but are expected to make significant progress in a short timescale.

The charging infrastructure to support EVs is not in place yet but this is not in the main a technical issue with the exception of unknown impacts on the national grid of a rapid large-scale roll-out. Perhaps the only place where a barrier has a significant technological component relates to the provision of at-home EV charging in areas where parking is on-street but solutions are being trialled.

Skills is also another potential barrier as the interventions will change the requirement for bike maintenance and EV maintenance. Bus depots, for example, will need to transition their skillset and technical equipment to support what will likely be a mix of technologies (electric and hydrogen).

Financial

EVs are currently more expensive than traditional vehicles which is a significant barrier, particularly to private car purchasers (irrespective of the potential savings from lower running costs). However, this is anticipated to reduce in coming years. The business model for installing charging points is also not clear, leading to a lack of infrastructure. There are also financial challenges related to the higher capital cost of electric (and hydrogen) buses, which is

unattractive to service operators; however, electric buses are cheaper to operate than diesel buses, and therefore the capital cost pays back over a short time period.

The ultimate financial challenge is securing sufficient funding to achieve the interventions. Enabling mode shift to active travel and public transport, as well as transitioning to ultra-low emission vehicles, will require significant capital investment, as well as potential increases to the council's maintenance budget to support ongoing initiatives and maintain any council-owned infrastructure. Although the council will not bear all the costs of decarbonising the transport network, it is clear that there will need to be a step-change in central funding to enable this transition, as current rates of funding struggle to create significant change. The council also has the opportunity to explore alternative funding mechanisms that support and enable the interventions, such as congestion charging.

Political

The transport system is complex, involving nearly every household in Sheffield along with numerous commercial organisations, the Council and many of their partners, with Sheffield City Region holding much of the budget. This complexity and the way many stakeholders rely on actions by others to enable their own action leads to a degree of paralysis with the first move being the hardest. The Council has a clear role to play in taking a lead and catalysing action by others, hopefully leading to a cascade of action as political leadership works to address societal and delivery barriers. There are tough decisions that need to be made to transition to a zero-carbon transport system, such as allocation of road space, funding priorities and possibly user charging mechanisms, which will require strong and clear leadership across the council.

The role of the city region in the transport agenda means that their support and allocation of sufficient budget to allow Sheffield to progress ahead of partners with later zero carbon targets will be crucial.

With an issue as ingrained in daily life as transport is, many of the societal barriers set out below will also manifest as political barriers with citizens understandably placing pressure on the Council to reduce short-term inconveniences. Confident leadership which increases awareness of the aims and benefits, alongside incentivising and enabling desired behaviour at the same time as potentially less popular interventions can assist in managing this.

Societal

In the short- to medium- terms, some direct disadvantages will be more apparent than indirect advantages, causing a barrier to behaviour change in the general population. For example, pilot schemes to reduce car usage or reallocate road space are often opposed by local businesses who (incorrectly) assume footfall will reduce. Similarly, the potential increased costs to motorists from a Workplace Parking Levy or increases to parking charges may result in resistance that needs to be addressed as outlined above.

That said, whilst it will be important for the Council to resist these short-term reluctances to realise real change, it must equally ensure that proposals do not unfairly affect disadvantaged groups and enable them to play a role in the transition to zero carbon and realise the benefits.

Delivery

Perhaps the most significant delivery barrier surrounds the provision of charging points for private electric vehicles. Zap-Map lists approximately 50 publicly accessible charging points in Sheffield (36). Whilst many more private installations exist, the numbers are still extremely small in comparison to what is needed. The technology exists but the infrastructure provision in Sheffield is currently only responding to demand rather than stimulating it. For comparison, Oslo has over 3,000 EV charging spaces which has led to substantial electric vehicle uptake in the city (13). The extent of the charging network (and equally the types of points installed) are proving a particular barrier to the transition of the taxi and private hire vehicle fleet which have particular needs for reliable access to quick charging facilities.

The issue with charging points extends into supply chain issues if demand increases. The supply chain for certain low emission vehicles is also still in its infancy. Whilst Ultra-low Emission Buses, and other larger vehicles exist, there are questions over whether the supply chain could cope with a what could be a drastic increase in demand over the next 5-10 years. Once again, the advantages of Sheffield acting out of step with others are clear.

There are a number of potential solutions to enable the installation of transformative numbers of charging points. Local authority owned charging points can potentially provide revenue in the longer term (and incentivise early uptake by subsidising electricity for users), whilst partnering with a private sector chargepoint provider can generate jobs and reduce risk.

As recognised in the South Yorkshire Bus Review, the current bus operating model gives authorities little control of the public transport network, and in particular, enacting a shift to ultra-low emission vehicles. Similarly, electrification of the railway is dependent on the agenda of national-level stakeholders. Even though there is a current lack of control, Sheffield City Council and the regional authorities do have strong influence, which can help to create change while moving towards a greater position of control if possible.

In line with the step-change in the scale of funding required to achieve a zero-carbon transport system by 2030, a similar step-change in the rate of action will be necessary. The Government's Transforming Cities Fund has highlighted the difficulty in delivering new transport infrastructure within a 3-year timescale, particularly for new public transport schemes. SCC will need additional resources to deliver the decarbonisation programme, it will need a clear roadmap of actions and appropriate governance procedures that minimise the barriers to delivery once funding does become available.

17 Actions

Sheffield City Council actions

The Council are responsible for the delivery of active travel infrastructure and supporting schemes, with funding for capital projects largely sourced via Sheffield City Region; however, there may be opportunity to harness private sector providers e.g. bike hire. The Council, along with the Sheffield City Region and South Yorkshire Passenger Transport Executive, are also key actors in enabling a modal shift to public transport. The Council can have a significant role to play in developing the infrastructure to catalyse the shift to electric vehicles, whether for private users, taxis, buses or goods vehicles, as well as influencing others to be part of the solution.

Actions in italics apply across sectors to some extent and are similar to those mentioned in other sections of this report.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030
• *Put in place sufficient internal resource and governance procedures to be able to respond quickly to government financial supports and provide other support. Target funding to support.*	■	■	
• *Establish a governance model than enables swift action on the issues and reports on them. Maintain an aspirational stance.*	■		
• Develop a roadmap for the decarbonisation of motorised transport as per the Sheffield Transport Strategy	■		
• Forecast changes in future demand related to the emerging Local Plan and other trends (including the impact of Covid-19), as well as measures to influence this such as better digital connectivity	■		
• Build on the SCR Active Travel Implementation Plan and other committed active travel schemes to develop a detailed active travel roadmap to 2030 for zero carbon Sheffield. Review planning policies to ensure they are robust enough to support the roadmap and work towards the development of '15 minute neighbourhoods'.	■		
• Work with collaborators such as Sheffield City Region, Cycle Sheffield, Living Streets, employers, education institutions and neighbourhood groups to engage with potential users, install walking and cycling infrastructure, and undertake initiatives to reduce barriers (real or perceived) to citizens including: o Improve and enhance existing routes to create fully-connected city-wide walking and cycling networks o Reallocation of road space for active modes	■	■	■

○ Improve walking and cycling routes to public transport stops and stations ○ Safe walking and cycling access to schools ○ Install bike hubs ○ Create low-traffic neighbourhoods ○ Implement play streets by every school (where possible) ○ Create standards for walking and cycling infrastructure to ensure safety ○ Rewards for journeys made on active modes			
• Implement the recommendations of the South Yorkshire Bus Review to encourage modal shift to public transport and set out future bus investment strategy for Sheffield.	■		
• Work with partners such as SYPTE, Sheffield City Region and service operators to invest in improvements and enhancements to the public transport system, including: ○ Enhanced bus priority measures ○ Introduction of bus rapid transport with segregation from traffic ○ Upgrades to bus and tram stops ○ Discounted public transport ticketing ○ Improved interchange between different public transport modes ○ Enhanced passenger facilities at stations ○ New park and ride facilities	■	■	■
• Initiate the installation of catalysing number of publicly-available EV charging points considering a range of charging needs including community-based solutions alongside those at workplaces and near commercial areas.	■	■	■
• Facilitate the shift to zero carbon transport through influence, investment and incentives for all motorised user groups (e.g. taxis and PHVs, private users, bus operators, rail), building upon Sheffield's Clean Air Zone.	■	■	■
• Enhance digital accessibility of Council services to remove need to travel and engage with major stakeholders to encourage similar action. Work with digital service providers to improve digital access.	■		

City-wide

Council enabling actions are shown in italics. It is worth noting that without these enabling actions, significant progress on these city-wide actions is highly unlikely to be realised.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030
• Work with partners to enable transition to electric / hydrogen bus network in Sheffield, including implementation of an electric bus trial.	■		
• All private vehicles to be electric ○ *Council to provide support to motorists to understand the options and potential benefits and work around any individual barriers (for example with city-centre advice centre)* ○ *Council to investigate opportunities in taxi licensing system to encourage take-up of electric solutions.* ○ *Council to investigate road pricing, workplace parking levies and differing parking charges for fossil-fuel and electric cars as incentives for electric alternatives* ○ *Council to play a role in communicating pace of impending change to build momentum and confidence in partners.*	■	■	■
• All Heavy and Light Goods Vehicles to be electric and/or be reduced in number through delivery consolidation ○ *Council to promote Electric LGV solutions to SMEs* ○ *Council to investigate road pricing for commercial vehicles*	■	■	■

- *Council to identify and work with organisations with larger fleets of LGVs operating in the city, identify barriers and solutions.*
- *Council to investigate advantages and disadvantages of consolidation centres compared with likely trajectory for transition towards electric HGVs coming into the city.*
- *Council to initiate discussions with potential operators of a city-wide distribution centre to understand policy positions needed to facilitate development.*

Governing bodies actions

These actions set out the support needed from national government. In all instances, the role of the council is to lead and facilitate change and communicate the issues to the best of its ability. Proposals should be coordinated with SCR, who are establishing new standards for active travel and first steps for investment across the region and SYPTE who manage Sheffield public transport service and are also promoting active travel schemes such as e-bike trials. Note that this is not intended to be a list of all governing body actions needed to reach zero carbon, more those that are directly linked to allowing the Council to more effectively progress Sheffield-specific actions but that are more appropriate to be driven at a national scale.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030
• *Increase direct funding available to councils to allow them to carry out the essential role of facilitator in low carbon interventions.*	■		
• *Coordinate learning between cities moving towards zero carbon*	■		
• Increase direct funding for the installation of active travel infrastructure.	■	■	■
• Continue existing funding and introduce new options to reduce barriers around increased initial cost of electric vehicles.	■	■	■
• Provide policy support around networks of out-of-city chargers to remove practical barriers to EV ownership.	■		
• Provide policy support for low-emission alternatives to battery-electric HGVs	■		
• Provide policy support on structural procurement and management of public transport provisions	■	■	

18 Funding routes

There are a number of known funding routes that can support the transition to a zero-carbon transport system; however, the scale of funding available is radically insufficient to deliver the step-change in transport infrastructure and usage that is needed.

SCR Devolution Deal

The SCR Devolution Deal consist of £30m additional funding per annum for the City Region over the next 30 years. This includes devolved powers and funding for transport; however, the amount is currently undetermined.

Economic Recovery Funding

Central Government have recently committed a £5bn capital investment to upgrade infrastructure and skills to fuel economic recovery in UK following the covid-19 pandemic. This includes "£900m for a range of 'shovel ready' local growth projects in England over the course of this year and next.

Transforming Cities Fund

Sheffield City Region is one of 12 shortlisted areas invited by Government to apply to the Transforming Cities Fund. The region was able to bid for up to £220m in funding focuses on public transport and active travel improvements, which should see significant change in Sheffield that will support the transition to zero-carbon.

Electric vehicle charging infrastructure

The government offers grants to support the wider use of electric and hybrid vehicles via the Office of Low Emission Vehicles (OLEV). The grant covers electric vehicle homecharge, workplace charging and on-street residential chargepoints.

Fix your bike voucher scheme

The Fix your Bike Voucher Scheme has been set up to encourage more people to embrace cycling, boost the number of commuting and leisure trips. It also aims to help reduce the number of short journeys made by private cars. The Fix your Bike Voucher Scheme allows members of the public to receive a voucher worth up to £50 towards the cost of repairing a bike.

Plug-in grant

Discounts on the price of brand new low-emission vehicles are through a grant the government gives to vehicle dealerships and manufacturers. Not all low-emission vehicles will get a grant. Only vehicles that have been approved by the government are eligible for a grant. The grant will pay for 35% of the purchase price of approved cars, and 20% of the purchase price of approved motorcycles, mopeds, vans, taxis, large vans and trucks up to a maximum value (37).

Revenue-generating funding options

There are a number of funding mechanisms that SCC can explore that ‘push’ behaviours towards sustainable modes / ultra-low emissions vehicles, while generating revenue that can be reinvested into the ‘pull’ measures, such as new infrastructure or behaviour change initiatives. These include workplace parking levies, low emission zones or congestion charges / road pricing and changes to parking provision and charges.

Energy sector

Solar farm, Sheffield

19 Energy generation

Approximately 151GWh of energy is currently generated from the city's biomass and energy from waste district heating schemes and 21GWh of renewable electricity is estimated to be generated from the domestic, commercial and industrial sectors.

Approach to zero carbon

There are a series of interventions proposed to increase the amount of low carbon and renewable energy generated within Sheffield. The interventions include:

- Increasing the district heating network to decarbonise heat
- Increasing renewable energy generation from small-scale systems, such as building mounted PVs and solar thermal panels
- Increasing renewable energy generation from large-scale systems, such as PVs farms and wind turbines

However, large-scale renewable energy generation have not been included in the emissions trajectory, to avoid the risks of double-counting as the reducing carbon intensity factors of the grid are already accounted for.

Decarbonise heat

91

ktCO2e reduction

Small-scale renewable energy

58

ktCO2e reduction

Large-scale renewable energy

100

ktCO2e reduction

Decarbonise heat

Approximately 6,300 GWh of energy for buildings in Sheffield is supplied by gas, coal or oil. There are approximately 200,000 commercial and industrial buildings where the heat is currently supplied by fossil fuels.

If Sheffield is to be zero carbon by 2030, it would mean replacing all fossil-fuelled heating systems either through connecting to low carbon heat networks or installing individual heat pumps. These measures to decarbonise heat would need to go hand in hand with measures to reduce heat demand that are described in the Domestic and Commercial and Industrial sections.

Hydrogen may have a significant role to play in the decarbonisation of heat for buildings in the future. However, it is unlikely to be a viable solution that could be adopted within the 2030 deadline.

Expanding heat networks

Currently, there are two main district heating networks in Sheffield; the city centre District Energy Network supplied by energy from waste heat and the Lower Don Valley Heat Network supplied by biomass combined heat and power (CHP).

The district heating map shows indicative zones where these heat networks could be expanded. These have been based on areas that have high heat demand density and therefore are most suitable for district heating. A more detailed study would be required to understand the feasibility of expansion within these areas and if there are other opportunities for heat networks within the city.

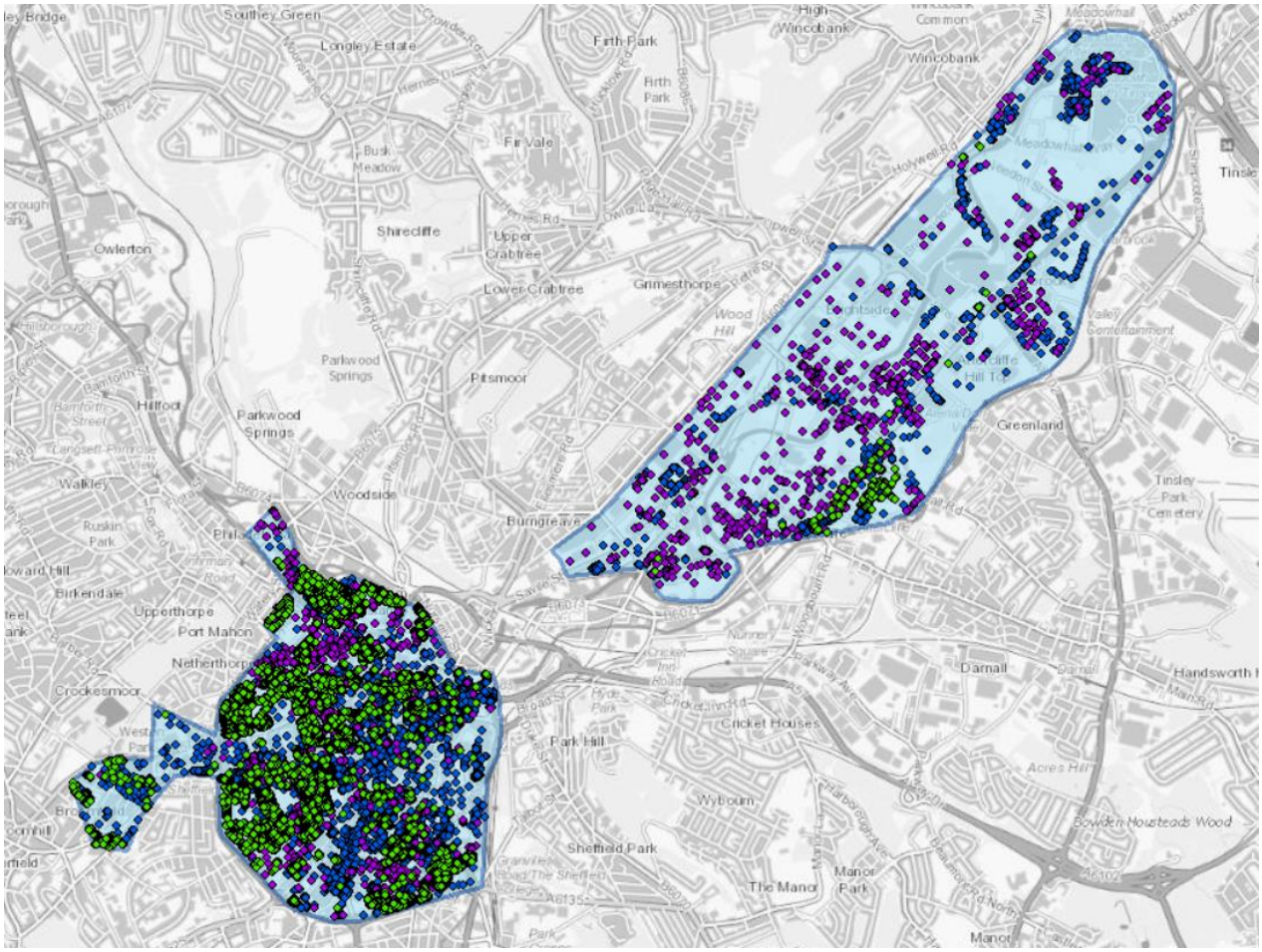
In areas of high heat demand density, heat networks are likely to offer the cheapest overall solution for decarbonisation of heating within the next 10 years. Increasing the density of connections is important to achieve economies of scale for heat network infrastructure expansion. Connecting to a district heating network would be

preferable for properties that are in areas where heat pumps would be difficult to install either due to space limitations, conversation/heritage stature or the function of the building.

It is anticipated that approximately 15,000 domestic properties, 6,000 commercial and 2,000 industrial properties could be connected to new heat networks, based on an uptake of 80% of properties within the zones connecting. Expanding the heat networks is estimated to reduce emissions by 91 $ktCO_2$.

The cost of expanding the district heating network and connecting these additional properties is estimated to be £1,500/dwelling or £3,000/non-domestic building for the hydraulic interface units and heat meters with an additional £200/MWh for the heat network infrastructure (38). The estimated capital cost of expanding the district heating network and connecting 80% of homes and businesses within the two zones is expected to cost in the region of £150m. If this scale of connection was achieved, additional heat generation and thermal storage would be required at additional cost which could be in the region of £100m-£200m.

Although the district heating schemes are low carbon, it should be highlighted that they are not zero carbon. It is understood from the Green City Strategy that SCC are looking to develop an approach to decarbonise the existing heat networks. Given the current contracts and agreements in place within the 2030 -time frame, switching to alternative zero carbon fuels have not been considered as part of this analysis, but it is an opportunity for the future. However, switching the heat networks to alternative fuels would need a thorough and detailed investigation to understand what the optimum solutions would be and these discussions should involve the current partners. If heat pumps are considered, there could be potential issues around the lower temperature that the system will run at, especially as the existing system and connections have not been designed to run at these lower temperatures so may need replacing. If the city moves away from the generating energy from waste, there will also need to be serious considerations about the carbon impact from the waste if it is not incinerated. However optimistic we are about reducing our waste consumption, by 2030 there is still likely to be a large amount of waste generated that cannot be recycled.



All properties in the catchment areas for the expanded City Centre Zone (left) and the Don Valley Zone (right)

Heat pumps

In areas that are not served by the heat networks, locally installed heat pumps should be installed to replace existing fossil fuel-based heating systems. All remaining domestic, commercial and industrial properties (i.e. those not on district heating) that have fossil fuel-based heating systems should be replaced with heat pumps. Further details can be found in the domestic and commercial and industrial sections of this report.

Hydrogen

Hydrogen is recognised as a potential solution that could be a key enabler in the decarbonisation of heat for buildings in the UK in the future. The existing gas infrastructure could be used to distribute hydrogen to homes and businesses in the city. It may therefore offer the most cost effective and least disruptive solution for decarbonisation of heating compared with district heating or heat pumps.

Hydrogen can be produced in low-carbon ways from electricity or with carbon capture and storage (CCS). Producing of hydrogen via electrolysis using renewable electricity is expected to have limited capacity and would be very expensive although costs are starting to come down. Hydrogen produced from gas with CCS is expected to have lower emissions when compared with gas boilers but is not a zero-carbon solution.

However, hydrogen is not currently a solution that has been tested at scale. If it is adopted in the UK, it will require clear direction from central government and the earliest timescale for widespread roll-out is likely to be from 2030 onwards (39). Sheffield could lobby government for a clear path on hydrogen for heating, in line with other cities.

Due to the timescales for roll out and the current uncertainties with production, hydrogen has been excluded as an option within this study as it is unlikely to be a viable solution that could be adopted within the 2030 deadline.

Small-scale renewable energy

In recent years, UK electricity demand has been falling due to energy efficiency improvements in lighting and appliances. The Domestic and Commercial and industrial sections describe how energy efficiency measures are expected to increase further through the mass roll out of LED lighting and the continued improvement in appliance efficiency. However, electrification of heating, industrial equipment and vehicles is required to reach the zero-carbon target which will increase the electricity demand for the Sheffield.

The zero carbon by 2030 target can only be met if the grid is also decarbonised by 2030. It is only right that every city and every area contributes to this transition by generating renewable electricity within the city.

Building mounted photovoltaics (PV)

PV panels convert sunlight directly into electricity. They are typically mounted on a roof and have higher efficiencies when oriented south.

There is the potential to generate up to 518 GWh of solar energy by installing solar PV on buildings within Sheffield. This would require solar PVs to be installed on 53,000 buildings. This will be a significant increase from the 5,451 PV installations there currently are in Sheffield. Building mounted PVs are estimated to reduce emissions by 54 $ktCO_2$.

It is worth noting that this is roughly aligned with Bristol's net zero carbon plan which estimates that building mounted PVs could generated 560 GWh of electricity.

It was beyond the times and resources available for his study to carry out a full citywide solar analysis for the potential generation from PVs. As such, the assumptions are based on 20% of properties being suitable for PV installations and the array being sized at 3kWp for domestic properties, 50kWp for commercial and 100kWp for industrial. This a modest estimate and could be increased to a higher proportion of properties but would require a more detailed analysis. Increasing the number of PV installations would likely mean accepting a slight reduced in the projected energy output per panel as the arrays would be installed on roofs that vary from the 'optimal' conditions (such as orientation, tilt, shading etc.).

The cost of installing domestic scale PV arrays is expected to range between £4,000 to £6,000 per 3kW array (40) (41), giving a total cost in be in the region of £245m. The cost of installing commercial and industrial scale PV arrays is expected to range between £50,000 to £100,000 per 50kW and 100kW array, giving total cost in be in the region of £450m.

Solar thermal

Solar thermal collectors are used to provide hot water by harnessing the sun's energy. The heat produced is most commonly used for domestic hot water production, with more heat produced during summer months. Like photovoltaics, they are typically mounted on a roof.

It is assumed that 10% (~25,000) of houses will be suitable to install a solar thermal array. A typical solar thermal array is expected to generate 1.5MWh/house/year, which is equivalent to approximately 2-3m² per home. This will have the potential to generate up to 39 GWh of solar energy and is estimated to reduce emissions by 4 $ktCO_2$.

The cost of installing a solar thermal hot water heating system is expected to range between £3,000 to £6,000 (6). Therefore, cost of installing solar thermal hot water heating systems across the domestic properties in Sheffield would range between £100m to £125m with an average cost of £113m.

This measure effectively needs to be instigated immediately and an average of around 6,000 solar thermal installations per year would be needed between now and 2030 . This would require a significant upscaling in supply chain capacity, given that only 4,000 new installations have been accredited through the domestic RHI scheme in the whole of the UK since 2014. As such, lower installations rates would be expected in the initial years.

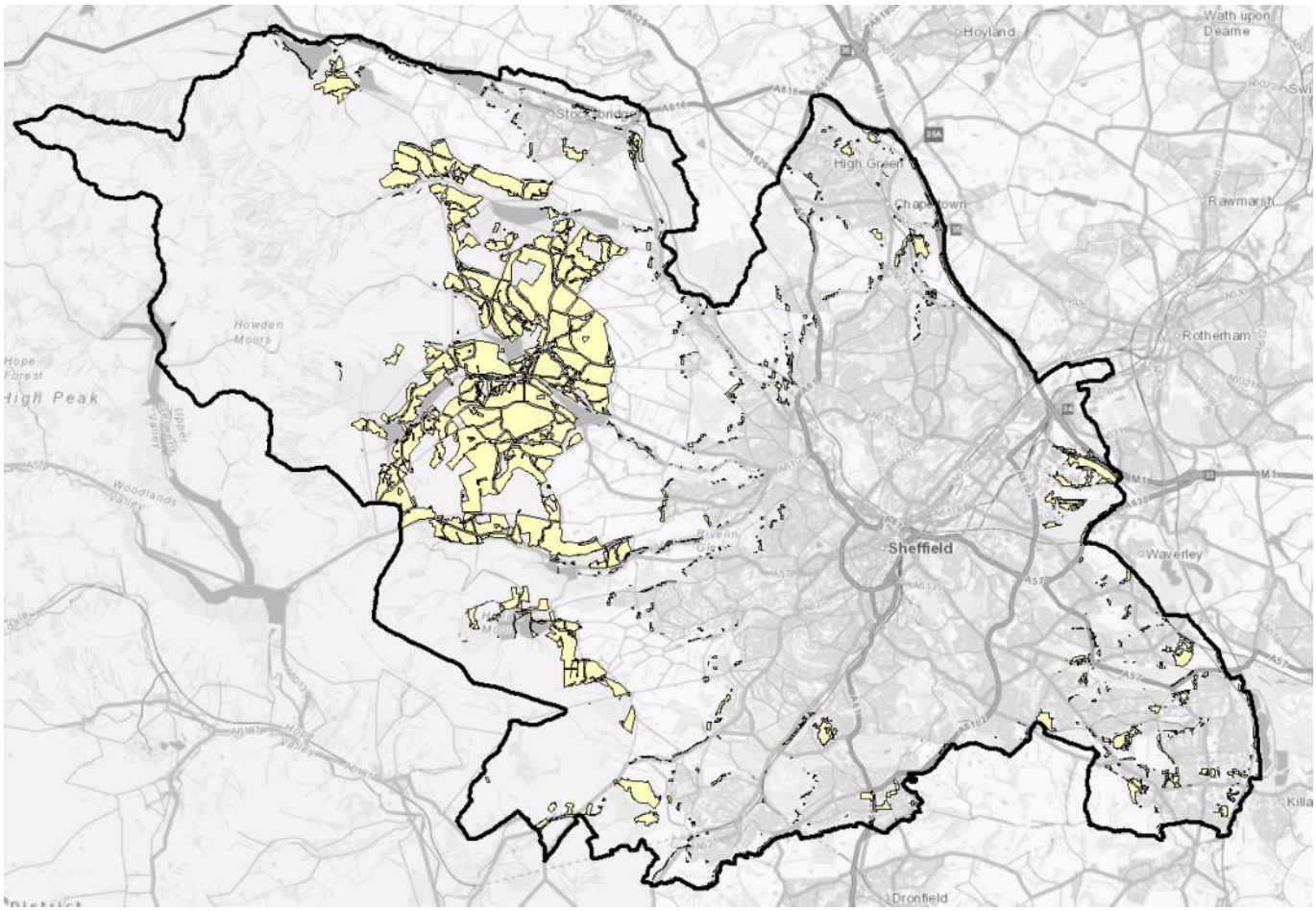
Large-scale renewable energy

Ground mounted PVs

In addition to building-mounted PVs, the potential exists for larger ground-mounted arrays. However, these larger systems need to treated slightly differently in how they are considered to contribute to emissions reductions. Building-mounted PVs often directly replace grid electricity, effectively by reducing the amount of electricity a building draws from the grid. Ground-mounted installations instead usually feed into the grid themselves, contributing to the overall decarbonisation of the grid. This risks double-counting as the reducing carbon intensity factors of the grid are already accounted for.

As a result, large-scale PV installations have not been included in the emissions trajectory. They can, instead, be considered alongside it as, should the city prioritise and incentivise large-scale renewable generation as a direct result of its 2030 target, these installations may well be additional to the business-as-usual grid decarbonisation.

A high-level constraints and opportunities exercise has been undertaken for PV arrays which indicates that around 31,000,000m^2 of land may be suitable as indicated below.



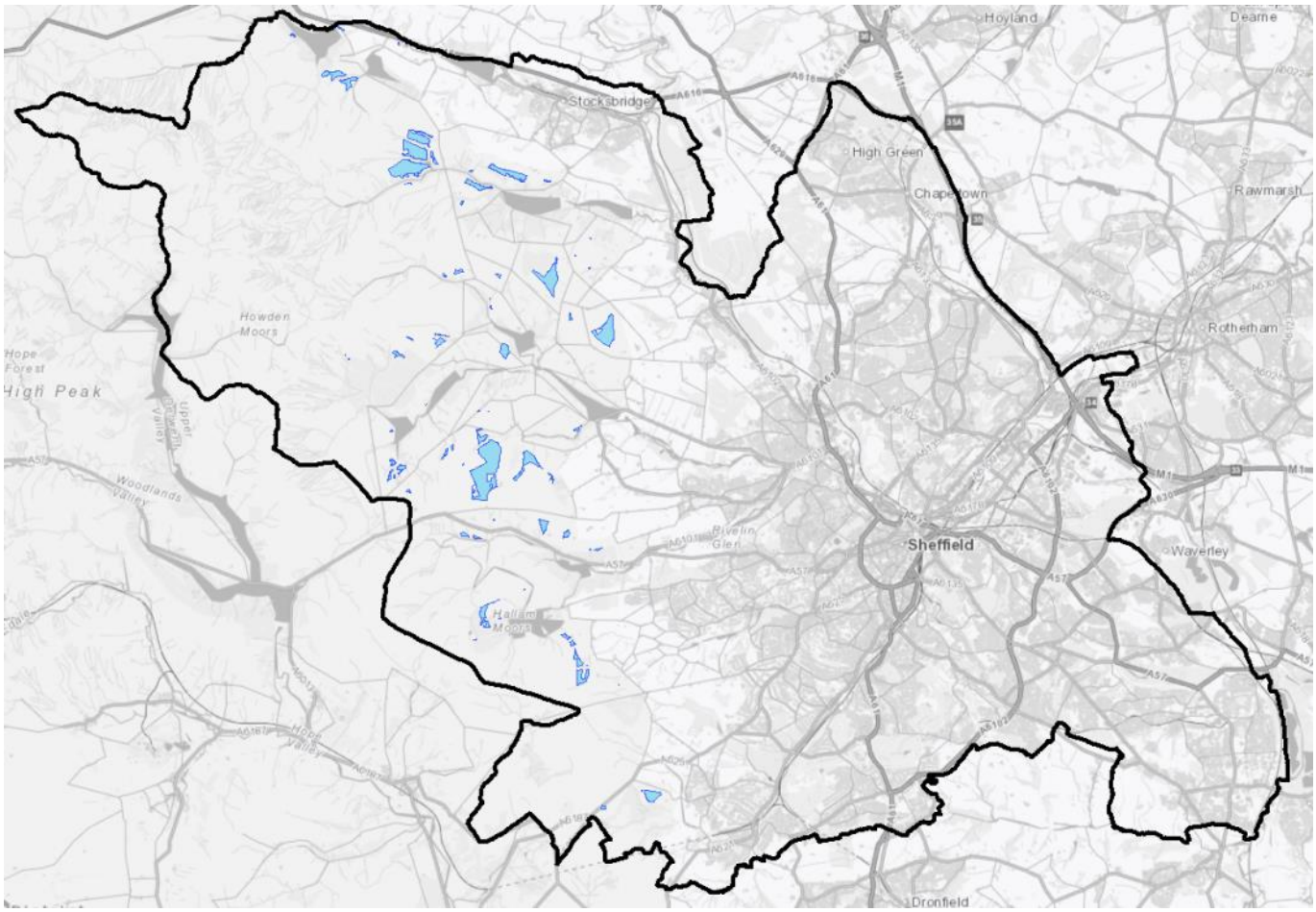
Output from high-level constraints and opportunities mapping exercise for ground-mounted PVs

This high-level study does not indicate areas that definitely are suitable – there may be many local factors that mean a parcel of land isn't suitable. More in-depth feasibility studies will be needed. However, standard industry figures indicates that this scale of land availability could yield in the order of 750GWh of electricity annually, equating to 98ktCO_2 (using 2030 grid decarbonisation factors).

Cost benchmarks for large PV installations are in the order of £500-750,000 per MWp of installed capacity. Taking an average figure yields a total cost of £550m. Strategic investors typically require a minimum rate of return of 5% for large-scale solar PV installations (42). However, there exists the opportunity for the Council to invest in these installations which would yield a return that can supplement revenue budgets with the potential for rates of return similar to third party investors. Rates of return in the order of 5% could lead to payback periods in the range of seven to ten years.

Wind

Similar to large-scale ground-mounted PV, wind turbines generally feed directly into the national grid so are not included in the base model assumptions but instead are considered alongside the trajectory. Understandably, there are significantly more constraints for wind power, especially when considering larger turbines. As a result, land availability is much lower as shown.



Output from high-level constraints and opportunities mapping exercise

Once again, this high-level study does not indicate areas that definitely are suitable – there may be many local factors that mean a parcel of land isn't suitable and designations may need to be aligned with current planning policies. Critically, the areas identified are all located within the Peak District National Park where historically wind energy planning applications have been refused. More in-depth feasibility studies will be needed. These land areas indicate the potential to generate of the order of 16GWh of electricity annually, equating to 2ktCO_2 (using 2030 grid decarbonisation factors) but there may be the opportunity to increase this by introducing a mix of turbine sizes (this initial study only considering the larger, most efficient 5MW turbines).

Using approximate figures of £750,000 - £1.4m per MWp, the cost of these turbines would be in the order of £2.4m. Strategic investors typically require a minimum rate of return of 5.2% for onshore wind installations (42). Similarly to solar installations, the opportunity exists for the Council to take a lead on these investments to yield a revenue stream.

Battery and thermal storage

Energy storage in the form of batteries and thermal stores are technologies that can play a role in individual installations of emission reduction measures. They can yield marginal emissions savings in themselves by shifting consumption to periods of time when the carbon intensity of fuels is lower or by capturing energy that would otherwise be wasted. For example, the carbon intensity of the national grid is lower at periods of lower demand (such as overnight). Charging batteries overnight in order to reduce grid energy consumption during the morning peak would therefore result in lower emissions.

However, these emissions reductions are too detailed to be able to be reliable accounted for at a city-scale and are likely to be marginal. That said, the potential for thermal stores to reduce peak demand levels of district heating schemes may allow those schemes to serve more buildings, potentially increasing their impact.

The location of the Centre for Research into Electrical Energy Storage Applications at the University of Sheffield introduces the potential for partnerships to be developed for pilot studies and to attract funding.

20 Benefits

The benefits relating to an altered energy infrastructure are slightly less direct than in the other sectors. In addition, there is a significant degree of overlap between energy and the other sectors, meaning care must be taken not to double-count benefits. In a way, an effective low-carbon energy infrastructure is an enabler of an interventions in the buildings and transport sectors.

To clarify, this section focusses on the non-carbon benefits directly realised by interventions on the energy infrastructure and energy generation such as an increased provision of renewables and more developed district heating networks and a more mature market for hydrogen.

Increased local business opportunity and jobs

As with any sector, the energy infrastructure in Sheffield will need to undergo significant change. This change brings with it the opportunity of additional job and economic development. Some of these jobs are within existing sectors such as PV installation and others derive from additional business benefits such as the development of the hydrogen industry.

The PV installation industry has undergone significant fluctuation since the initial boom in the early days of government grants such as the Feed-in Tariffs. As such there is a chance that a latent skills base exists (potentially aiding a quick ramp-up in capacity). In other areas, expansion will be needed at a scale not seen before. For example, the many thousands of new connections to district heating networks cannot be undertaken without significant upskilling.

In some emerging industries such as hydrogen, Sheffield has the potential to build on its already strong technical position to allow related businesses to develop and expand into serving other areas of the country. However, as has been mentioned, this strong growth (and the associate emissions reductions and job creation) is likely to occur outside of the 2030 target timeline.

Income generation

Many large-scale renewable energy technologies have reached the price point where they are able to provide financial returns with little or no subsidies. These technologies therefore have the potential benefit of providing revenue to those who are able to develop the schemes, whether that be the public or private sector.

Improved local air quality

Improvements from converting buildings away from fossil fuel combustion are covered elsewhere but local air quality improvements will also be seen from transitions to district heating. The central plants that serve these systems are often subjected to greater restrictions (such as stack heights) and are situated away from heavily populated areas.

Increased resilience

As the energy grid becomes more decentralised, it will inherently become more resilient. Multiple options will eventually exist for energy sources for a given consumption point. However, this is likely to rely to some extent on the grid becoming more flexible through the adoption of smart real-time management techniques.

Whilst it is not essential for emissions savings and is an industry less developed than renewable sources, energy storage will also eventually likely come hand-in-hand with a proportion of installations. At the moment it is only rarely included but significant price reductions and emerging battery technologies may start to change this by the end of the time period being considered within this target.

21 Barriers

Once again, barriers relating to heat provision in buildings is covered elsewhere, with this section focussing on energy generation and distribution.

Technical

The change the electricity grid is expected to undergo over the next decade is significant. A study will need to be carried out to understand what changes can be made without reinforcing local networks and which will need strengthening works to happen in parallel. This study may indicate that there are geographical regions which can be targeted first, avoiding delays as strengthening works are planned. This grid capacity has the potential to limit (at least in the short term) both additional loads and additional generation capacity.

The expansion of a heat network is also not a trivial matter. Heat loads need to be balanced with the available energy over the lifetime of an expansion, with new generation matching increased demand. Technologies to shift the peak heat demand for a development would also be valuable in increasing the annual energy able to be supplied by a system. These technologies are not currently often installed. A detailed heaty heat study would need to be developed for Sheffield to understand the feasibility of expanding the existing heat networks and if there are other opportunities for heat networks elsewhere in the city.

Financial

As with any intervention, the barrier of initial investment levels is present in all energy solutions. However, there is a significant appetite for renewable energy investments given the right commercial conditions.

In the case of the expansion of district heating networks, significant infrastructure investment is needed. Levels of risk are often too great for commercial organisations although heat networks can provide reliable long-term returns. For this reason, heat network development is often led by the public sector. There has been significant growth in the heat network sector particularly following the introduction of the HNDU and HNIP funds (see below). Other funding options including renewable energy bonds and Salix funding could contribute to the cost of connections.

Political

Many of the political issues relating to heat networks stem from the financial barriers to expansion set out above. There is risk in investing when only commercial returns are considered but investment is essential to meeting the 2030 target. This will likely need the Council to clarify their role in the networks, providing a clearer process for engagement and balance any investment needed with other priorities.

These commercial risks can be reduced, though, by a strong policy landscape that requires connection to a district heating scheme. If it is left to individual decisions, the critical mass of connections may never be reached. These individual decisions need to be strongly guided towards network connection.

With regard to more visible energy solutions (PV and wind, for example), there will likely be political challenges over the fact that much of the Council-owned land borders or forms part of the Peak District and there will be resistance to the visual intrusion. These issues must be considered in light of the bigger picture that there is no zero-compromise option to the achieving 2030 target but there are other natural services these land areas may be providing, such as having significance for nature conservation or flood alleviation (to name just two).

As with all areas covered in this report, planning policy which reflects the prioritisation of climate issues will help to ensure the right enabling environment for energy investments. Planning policy which supports greater roll out of renewable energy and district heating is necessary to accelerate investment. Possible routes to achieve this are discussed in more detail in relation to the domestic sector.

Societal

As with other sectors, the main societal barriers stem from the apparent contradiction in short-term tangible disadvantages and longer-term intangible advantages. The visual intrusion of wind power is immediate, for example, but the benefits of avoiding climate change are further away. There is always the belief that, if we just consider more options, then a solution will be found that avoids compromises. It will be the Council’s difficult task to dispel this myth.

With energy provision, possibly the biggest societal issue is the invisibility of it being delivered to the home. It is difficult for people to accept additional cost, curtailed choices or more inconvenience for something that they cannot see. Once again, the Council can play a role in helping citizens and business see the value in the services energy is providing for them. However, this role is not mentioned in the context of alleviating any additional fuel poverty that might occur with rising fuel costs. In this case, practical assistance with real funding will be needed, whether that is directly funded or as a result of central government lobbying.

Delivery

As with any sector that will need significant change, delivery will need to rely on effective upskilling. However, the energy sector has several advantages in this space. Small-scale building-mounted PV relies on local trades carrying out many installations which could be an issue but there is likely to be a community of skilled installers who were active in the peak of PV roll-out caused by Feed-in Tariffs. The retraction of these incentives caused a collapse in the market but there are likely many businesses out there capable of servicing an expansion in installations.

At a larger scale, ground-mounted PV, wind and district heating networks are likely to be able to draw on a wider resource pool of national organisations. As long as Sheffield is effective in taking action before congestion worsens in these industries, there should be some flexibility in delivery.

In addition to upskilling, the supply chain will need to significantly upscale capacity to cope with the additional demand that is to be expected at an unprecedented scale. For example, it is estimated that solar thermal collectors would need to be installed on 25,000 homes in Sheffield by 2030, however, only 4,000 new installations have been accredited through the domestic RHI scheme in the whole of the UK since 2014.

The planning system process will also need to be improved to cope with the increase in applications and to make it simpler for those wanting to install renewable and low-carbon energy technologies. This will help to send a positive message that the Council is supportive and encouraging of those wanting to make changes to reduce their carbon footprint.

22 Actions

Sheffield City Council actions

Actions in italics apply across sectors to some extent and are similar to those mentioned in other sections of this report.

	Short term Up to 2022	**Medium term** 2023-2026	**Long term** 2027-2030
• *Put in place sufficient internal resource and governance procedures to be able to respond quickly to government financial supports and provide other support. Target funding to support. WP4 of this Commission (Ways of Working) explores the potential SCC governance arrangements .*	■		
• *Establish a governance model that enables swift action on the issues and reports on them. Maintain an aspirational stance.*	■		
• Develop proposals for new powers needed to mandate new and existing buildings to connect to heat networks	■		
• Work with and drive commercial partners in district heating sector to develop ambitious expansion plans and identify current barriers, particularly around high connection fees. Long-term plans should include trajectory for total decarbonisation of heat sources. Develop financial solutions to barriers. Potentially commission expansion feasibility study to identify high priority clusters/areas.	■	■	
• Develop future programme for leveraging HNDU / HNIP funding to make private network investment more desirable.	■		

	Short term Up to 2022	Medium term 2023-2026	Long term 2027-2030
• Review all council-owned land and highlight for energy development everything not needed to satisfy other priorities (such as housing provision)	■		
• Review planning system for renewable energy projects in order to streamline process, give more confidence of approval and reduce perception of commercial risk.	■		
• Facilitate a forum where small energy providers (or those who wish to become one) can co-operate and organise themselves e.g. organising private wire connections, pooling resources to purchase technologies.	■		
• Form and drive a partnership aimed at maximising the impact of local hydrogen capabilities and capacity building within the Council. Include Cadent Gas Networks to consider the role of the gas network in a predominantly electricity-based energy future and how grid-delivered hydrogen might be suitable for some applications (e.g. hard-to-transfer industrial processes). This action will need to respond to a strategic direction set by central government (set out in Governing Bodies Actions below).	■		
• Work with businesses and education and skills providers to ensure that the city has appropriate skills provision for existing and future workers	■		

City-wide actions

Council enabling actions are shown in italics. It is worth noting that without these enabling actions, significant progress on these city-wide actions is highly unlikely to be realised.

	Short term Up to 2022	Medium term 2023-2026	Long term 2027-2030
• DNO to reinforce electricity networks ○ *Council to initiate discussions on additional loads from trajectory to zero carbon and work with DNO to develop a programme of strengthening works. [mirrors action in domestic section around decarbonisation of heating]*	■		
• All householders and businesses to install building-mounted PV where technically viable. ○ *Council to create materials and a communication campaign to encourage people to take action* ○ *Council to identify funding routes that reduce the initial burden of capital needed and promote their uptake (such as the current Green Homes Grant). Consider developing own scheme if eligibility gaps exist in current offerings.* ○ *Council to work with local industries and suppliers to develop a recommended list of local installers and maintenance companies* ○ *[Many of these actions mirror those relating to thermal efficiency interventions and can be aligned for efficiency]*	■	■	■

Governing bodies actions

These actions set out the support needed from national government. In all instances, the role of the council is to lobby for change and communicate the issues to the best of its ability. Note that this is not intended to be a list of all governing body actions needed to reach zero carbon, more those that are directly linked to allowing the Council to more effectively progress Sheffield-specific actions but that are more appropriate to be driven at a national scale.

	Short term Up to 2022	Medium term 2023-2026	Long term 2027-2030
• *Increase direct funding available to councils to allow them to carry out the essential role of facilitator in low carbon interventions.*	■		
• *Coordinate learning between cities moving towards zero carbon*	■		
• *Continue existing funding and introduce new options to reduce capital investment barriers to interventions*	■	■	

- Provide policy support and clarity on the expected role of hydrogen in a zero-carbon economy
- Provide support for the transition the electricity network is expected to undergo and ensure necessary regulation is in place.

23 Funding routes

Heat Network Development Unit (HNDU)

The HNDU provides grant funding for two-thirds of the cost of the early stages of heat network development (including expansion) covering heat mapping, energy masterplanning, techno-economic feasibility and detailed project development. Round 10 of the fund is currently open to applications until the end of the year. HNDU support does not provide funding for commercialisation costs and costs associated with the construction, operation and maintenance of a heat network.

Heat Network Investment Project (HNIP)

The HNIP is a £320m capital investment programme providing support for the capital costs of heat networks. It is open to public-, private- and third-sector organisations. HNIP support is designed to follow on from HNDU assistance. Building connection costs can, in some circumstances, also be eligible. The investment is offered as 'gap funding' through a combination of grants and loans, seeking to leverage around £1bn of private sector and other investment.

'Rent-a-roof' schemes

These schemes are where operators install PV panels free of charge (usually on domestic roofs), making their returns from the energy generated. Originally, operators claimed the Feed-in Tariffs associated with the energy, leaving the homeowner to benefit from reduced energy bills. However, FiTs are not open for new applications, having been effectively replaced by Smart Export Guarantee (SEG). In the SEG, large energy suppliers are obliged to pay households for the renewable energy they export to the grid. Given that around half of energy generated by domestic PV is used 'in-house' and the remaining exported, both the operator and the homeowners still benefit. Commercial returns are lower under the new scheme meaning the availability of schemes has reduced but options still exist.

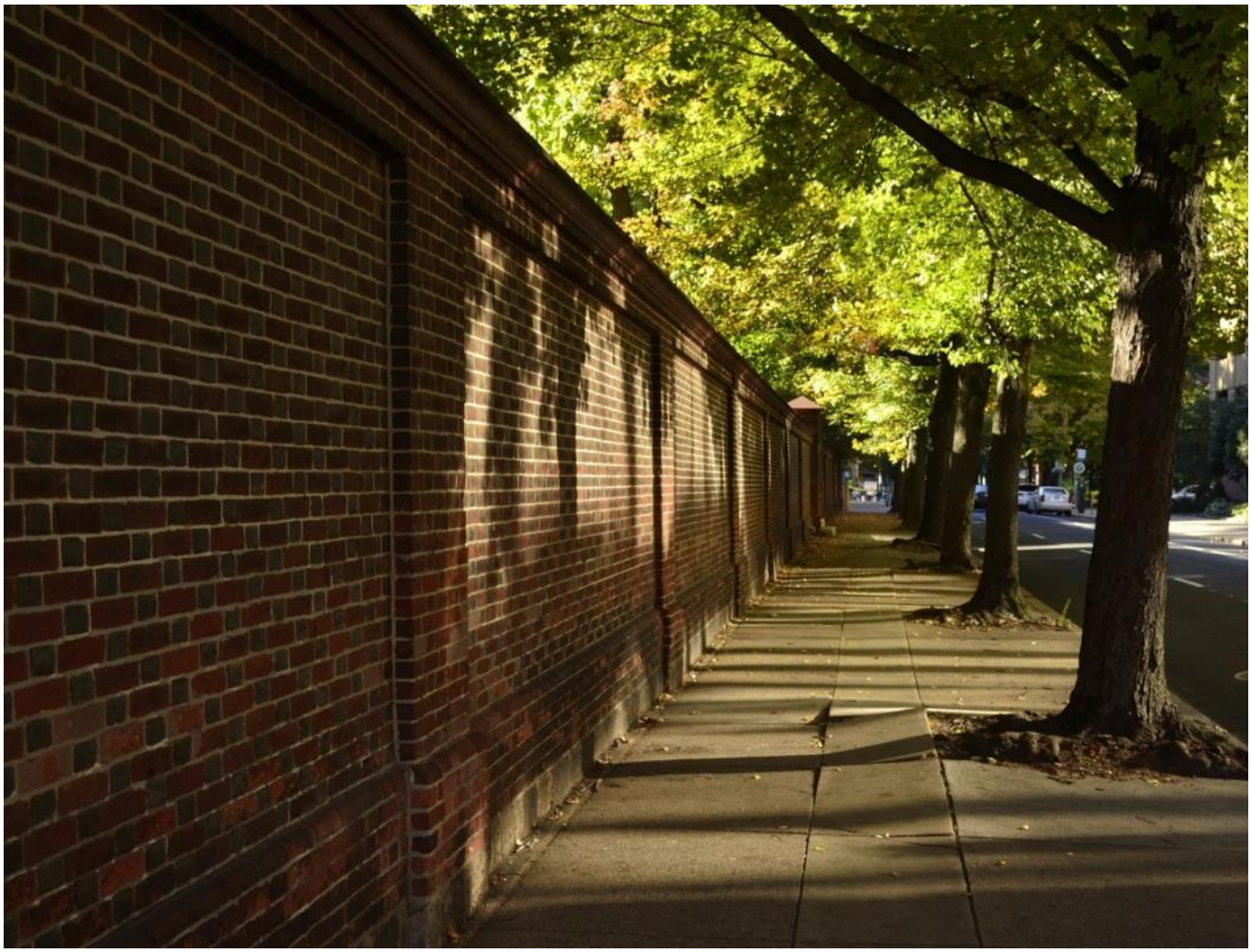
Community Bonds

Community bonds offer an opportunity for local citizens to invest in renewable energy or infrastructure projects. As a relatively new entrant to the market, schemes such as the Community Municipal Investments offered by Abundance Investment have a key role to play in allowing the Sheffield community to invest in large scale schemes making a direct impact on reducing carbon emissions and improving resilience in their community.

Salix Finance

Salix finance is available to public sector organisations across England, Scotland and Wales to invest in energy efficiency and decarbonisation schemes. Salix provides grant funding (eg. Public Sector Decarbonisation Scheme and Public Sector Low Carbon Skills Fund) or 100% interest-free capital (eg. Salix Energy Efficient Loans Scheme and Recycling Fund) for the public sector to reduce their energy costs by enabling the installation of modern, energy-efficient technologies and replacing dated inefficient technologies. This could include connections to a district heating network and the associated secondary side modifications to building heating systems. Cost savings from energy efficiency improvements are used to repay loans typically over a period of four or five years.

Land Use, Land-Use Change and Forestry (LULUCF)



Tree lined street

24 Land Use, Land-Use Change and Forestry (LULUCF) overview

The Land Use, Land-Use Change, and Forestry (LULUCF) sector refers to the carbon that is both emitted and absorbed by land-use cover and changes to this across the district. For example, as trees grow, they absorb carbon but conversely as peat bogs degrade they release carbon. When more is absorbed than emitted in any given year, this is described as sequestration and helps balance emissions emitted by other sectors. Related to this is the total amount of carbon stored within land-use and forestry at any one time – i.e. the amount of carbon locked up in trees, soils and so on.

Sheffield is one of the most densely wooded cities in the UK with 18.4% canopy cover (43), rising to 21.6% cover in the urban area, and it estimated that there are 3.86 million trees growing across the city (44). Sheffield City Council's 15-year vision for its trees and woodlands resource is: "Working in partnership to provide outstanding, resilient and sustainably managed trees and woodlands which are rich, diverse, healthy, attractive, and of maximum benefit to the public and wildlife." More than 36% of the area encompassed by the Sheffield City boundary is designated as being of European, national or local importance for nature conservation. Approximately 60% of this area comprises peatland habitats (heathland, moorland and bogs), which extend into the Peak District National Park.

Against this background LULUCF across all land in Sheffield (i.e. not just Council-owned land) sequestered 21 $ktCO_2$ in 2017, as compared to 20 $ktCO_2$ in 2005, according to the Department for Business, Energy & Industrial Strategy (BEIS) Local Authorities CO_2Emissions Inventory (45). This is an increase in sequestration, i.e. and increase in carbon absorption, of some 1 $ktCO_2$. To put this sequestration effect in context it the total amount sequestered in 2017 amounts to roughly 2.5% of Sheffield's overall CO_2 emissions. The figures provide a reality check not only of what is possible if Sheffield continues business as usual but also of the relatively limited scale of additional emissions reductions that might be achieved through use of LULUCF by 2030.

Although it is estimated that Sheffield's trees store a total of 545kt CO_2 (44) and its peatlands may store even more, it is only the annual change in this storage, i.e. the net difference in emissions and absorption, that is relevant to reducing carbon emissions by 2030. But given the amount of carbon started is it important that this storage is degraded, most notably as a result of peatland degradation, to ensure that the balance remains a net reduction in carbon. Thus, in general, the main ways in which LULUCF can contribute to achievement of Sheffield's target of zero carbon by 2030 are through extensive expansion of tree cover and restoration of peatlands. With Sheffield's strong background and significant effort, an aspiration of doubling sequestration from LULCF seems reasonable.

Double LULUCF savings

21

$ktCO_2$ reduction

25 Approach to zero carbon

Since land-use change take time, within the 2030 time frame, the approach to using to LULUCF to contribute to Sheffield's pledge to achieve zero carbon needs to be focused most immediately on sympathetic landowners, including those who took part in a consultation workshop as part of this work. These landowners are self-motivated to expand tree cover and restore peatland for biodiversity and the many other benefits that it provides to society, including carbon emissions, with carbon as a potential means to secure a step-change in funding for the integrated landscape-scale actions that they have been striving to achieve for some time.

While a doubling of carbon sequestered by all land in Sheffield (not just Council-owned land) is a reasonable aspiration, evidence suggests that it will be very hard to achieve. It is not possible to accurately estimate costs as it would require detailed knowledge of the actions to be undertaken and their location. However, if a quantum leap in expansion of tree cover and peatland restoration is to be achieved in the next 10 years then it will need to be

opportunistic. It seems unlikely to involve substantial land transfer or acquisition. Instead, it will rely on government funding, the public and third-sector organisations involved, and the support of the private sector and local communities.

The Council's own actions could make a significant contribution to this aspiration. It already has approximately 1,500ha of woodland of which 1,100ha is broadleaved and 400ha is conifer; the latter focused on upland areas. In 2018, the Council approved a Trees and Woodlands Strategy 2018-2033, which includes a headline action to *"plant at least 100,000 additional trees and replace trees on a 2 for 1 basis in our greenspaces and woodlands over the next 10 years".* These 100,000 trees would require planting 5-10 ha of tree cover per annum over the 10-year period, i.e. 50-100 ha of new woodland in addition to the 1,500 ha of woodland already owned. These trees will be planted in both upper catchments/rural areas and in urban areas, including deprived parts of the city. The strategy states that over the previous five years approximately 100,000 new trees were planted on land owned and managed by the Council across a number of directorates including parks, housing, schools and development sites so the same again over the next 10 years would seem achievable. In addition, the strategy notes that planting was undertaken on land owned by a range of partner organisations including parish councils, housing associations, sheltered housing, and the Peak District National Park Authority.

The Council is also a lead partner in the Sheffield Local Biodiversity Action Plan (46), a key partner in the Peak District Biodiversity Action Plan (47), and a core partner of the Sheffield Moors Partnership. Sheffield City Council has developed Habitat Action Plans (HAPs) for 130 target sites in Sheffield. The HAPs identify which of these sites are suitable for habitat creation, including the expansion of tree cover and habitat restoration, including peatland. All of which demonstrates the Councils ability to act in this area.

In terms of other significant landowners Yorkshire Water and the National Trust own ca. 3,000 ha in the Rother and Don catchments. They have been undertaking opportunity mapping in relation to a range of issues, including woodland expansion, and have identified priority areas for further ground truthing. They are also undertaking peatland restoration work, e.g. identifying and prioritising work with Moors for the Future, who have just had a grant for gulley blocking in relation to peatland restoration.

Similarly, the Sheffield Moors Partnership (48) is a landscape-scale initiative between the Peak District National Park Authority, RSPB, National Trust, Sheffield City Council, Sheffield Wildlife Trust and Natural England to improve connections for people and wildlife both across and in and out of the area. The Partnership's vision for 2028 includes *"Restoration of wildlife rich moorland and heathland, wildflower meadows and wetlands, with new deciduous woodland re-connect habitats across the landscape, and into the surrounding areas like west Sheffield and the Derwent Valley."* (49)

Also, the Eastern Moors Partnership on SCC land leased to RSPB and the National Trust has a long-term target for ca. 30% tree cover. The vision for the National Trust's High Peak estate is due for review as many tenancies are up for renewal or have Stewardship Agreements up for review in 2023, which may create major opportunities for expansion of tree cover and peatland restoration.

Despite the above plans and ambitions, the contribution of LULUCF to achieving zero carbon by 2030 will be relatively small. If carbon sequestered by LULUCF only increased by 1ktCO2 per annum between 2005 and 2017 during a period when SCC was planting approximately 20,000 trees per annum, then doubling the sequestration rate to 42 $ktCO_2$ per annum will require not only require a seismic expansion of tree cover, involving the planting of millions of trees, it will also require substantial actions to restore peatlands on a landscape-scale. It's difficult to estimate this directly but given the current level activity generated 1kt CO_2 benefit in 10 years roughly a 20-fold increase in activity is needed.

26 Benefits

Climate change adaptation and indirect emissions savings

The most important factor determining the intensity of the urban heat-island effect is the extent of green infrastructure (50). For example, Gill et al. (51) estimated that increasing green cover (e.g. through expanding urban tree cover) by 10% in dense urban areas of Greater Manchester could negate all projected increases in maximum surface temperatures due to climate change in the 2050s. Hence, in addition to carbon sequestration,

expanding urban tree cover could contribute to climate change mitigation through reducing overall energy consumption, e.g. on air conditioning (52).

Political

Sheffield takes prides in its tree cover, and its moniker of "the Outdoor City". Participants in the virtual workshop noted that from a political point of view increasing tree cover may be seen as a quick win. The reductions in industrial and commercial emissions required to achieve zero carbon by 2030 will take considerable effort. LULUCF cannot solve the problem but maximising expansion of tree cover and activities to restore peatlands on SCC's rural estate could be seen to make a worthwhile contribution that delivers a wide range of other benefits for people and biodiversity. As a source of inspiration, particular reference was made to the recent announcement by Leeds City Council that it intends planting 5 million trees over the next 25 years.

Health and wellbeing

While the United Nation's 2030 Agenda only explicitly addresses the use of biodiversity for sustainable development in Sustainable Development Goal (SDG) 14 "Life below water" and SDG 15 "Life on land" at the goal level, a recent study demonstrates that biodiversity may also directly support fulfilment of ten of the other SDGs, which may then indirectly contribute to achieving the remaining five. In doing so, biodiversity can thereby help to support all aspects of sustainable development (53). Hence, expanding Sheffield's tree cover and restoring its peatlands would provide economic benefits in contributing to people's health and well-being in a very wide range of ways. Workshop participants noted that this is increasingly recognized by other cities, including Doncaster, which is undertaking natural capital accounting, however, unlike Sheffield, the extent of its trees and woodland starts from a low base (ca. 8% cover).

The Council's Trees and Woodlands Strategy 2018-2033, specifically notes that Sheffield's trees and woodlands alleviate flooding, improve air quality, provide an accessible educational resource, maintain and improve people's mental health, and provide opportunities for physical recreation. Likewise, the Sheffield Moors are among the most popular areas to visit in the Peak District National Park, which is one of the most visited national parks in the UK.

Biodiversity

Climate change is already impacting upon biodiversity and is an important challenge for biodiversity conservation strategies. The UK's wildlife habitats are highly fragmented and surrounded by intensive land use making it difficult for species to keep in step with movement of their suitable climate space (54). Actions are needed at multiple scales to maintain and enhance habitat connectivity. The essence of what needs to be done to enhance the resilience and coherence of England's ecological network has been summarised in four words: *"more, bigger, better and joined"* (55). Expansion of native tree cover and restoration of peatlands within the Sheffield City boundary has a major role to play in enabling the widest biodiversity to survive and thrive.

Workshop participants noted that a focus on zero carbon could circumvent addressing the wider ecological crisis. They highlighted that in September 2019 Doncaster not only declared a climate emergency but also a biodiversity emergency and is aligning climate action with the recovery of nature. Workshop participants agreed that there is a need to focus land management on conserving biodiversity and the benefits it provides for people, one of which will be small carbon gains. However, they enthused that it would be great if carbon messaging helps gain the funding needed to drive forward expansion of tree cover and peatland restoration without misrepresenting how much LULUCF can contribute.

Flood alleviation

It is widely accepted that the stabilised soils encouraged by tree cover are able to store significantly greater volumes of water in rainfall events and release this water slowly over time, thereby acting as a natural flood defence by reducing peak flow volumes. Healthy peat bog habitats will also provide this service. This benefit manifests itself in financial benefits through lower insurance and flood recovery costs by increasing the resilience of the system as a whole. The social and emotional costs of flooding should also not be underestimated, aspects that would also be reduced with improved with greater resilience and protection from extreme events. These benefits may also not be limited to Sheffield but instead extend downstream to other catchment areas and other cities.

27 Barriers

Technical

Expansion of tree cover needs to be targeted within the city and on mineral soils, rather than on peatland soils where it may have a counterproductive impact on carbon storage and on biodiversity. A lot of the land owned by the National Trust is SSSI for peatland and moorland birds and, thus, expansion of tree cover would be contentious.

Timescale is a major challenge. Workshop participants noted that making projects "shovel ready" from the big ambitions takes a long time, particularly in working out where trees can go. Trees then take time to plant, grow and sequester carbon. Peatland restoration also takes time. Putting in dams to restore peatland may take many years to have a substantial carbon impact. Peatland restoration generally decreases emissions of CO_2 and nitrous oxide emissions but may temporarily increase methane emissions. However, over time restoration subsequently leads to greenhouse gas flux more akin to that of an undamaged peatland (56). Hence workshop participants noted that there is a desire to contribute to the 2030 target through LULUCF, but there is a need to be realistic.

Financial

The Forestry Commission provides woodland creation grants to private landowners. Countryside Stewardship provides one of the most financially attractive woodland creation grants for a couple of decades. A lot of the policy drivers behind the new Environmental Land Management Scheme (ELMS) are very positive towards LULUCF positive but it is a politicised debate and many private landowners and businesses are waiting to see what actions will bring the greatest rewards. Workshop participants noted that most farmers are businessmen, that ELMS will provide public money for public goods, and that attitudes will change as a result but that might take 5-6 years, i.e. more than halfway to the zero carbon 2030 deadline. In the meantime, they noted that public landowners will have quite a big opportunity to secure the existing grants. It was specifically noted that there is a need for investment in ground-truthing ambitions.

Political

The Council has had an initial meeting with elected members to establish their views on objectives for the rural strategy. It is then looking to bring forward a piece of work to consider how best to use its land. Dependent on the location of land there will be different opportunities. The Council owns substantial amounts of land in the northwest of the city, around Bradfield and on the upland moors around Burbage that provide greater opportunities for carbon sequestration, both expansion of tree cover and peatland restoration. Workshop participants noted the rural strategy still needs substantial development, which will create opportunities for LULUCF, however, it was suggested that it is questionable whether it can deliver substantial additional carbon sequestration by 2030.

Societal

Landowners inhibit landscape-scale action because of the investment of time and resources required to engage with them. They can also be overly concerned about how they are paid, and how expanding tree cover or restoring peatland may affect the subsidies that they already receive. Workshop participants reported particular concerns currently about how to bring landowners into schemes that will change when there is so much uncertainty. On a positive note, where the Environment Agency has started to deliver schemes then landowners have been enthusiastic, albeit gaining momentum over time. These barriers are generic to England and not specific to Sheffield. The Environment Agency hopes that it can bring big landowners on board who appreciate that subsidies will change.

Workshop participants agreed that while spatial targets can be set, activity inevitably has to be opportunity led. Hence, for example, it is easier for interested landowners like the Council, Yorkshire Water, National Trust and Sheffield Wildlife Trust to work in partnership and later bring on board large landowners. It was noted at the workshop that some moorland owners use their land for grouse shooting and that expansion of tree cover on their estates would be difficult to encourage.

Agricultural tenancies are a substantial barrier to rapid progress due to succession rights. The majority of Yorkshire Water and National Trust land holdings are tenanted. The Council does not own a substantial amount of land compared with other city councils and some of its farms are under agricultural tenancies. In the past, the Council has left agricultural tenancies very much alone. Regarding its development of a rural strategy, the Council is now

thinking about how to use its land more effectively to deliver the its wider objectives. They are working with existing farmers to encourage sustainable management that delivers its wider objectives and when tenancies come up the Council takes a different approach.

The Sheffield Lakeland Partnership involves many of the organisations represented at the workshop, as well as private landowners who own large estates, including grouse moors. Some of these landowners are talking about natural capital and natural capital mapping. However, expansion of tree cover or peatland restoration may be quite limited. Workshop participants noted that despite big ambitions and targets, getting agricultural tenants, private grouse moor owners and the National Trust to sign up to and deliver on targets that fundamentally change the landscape is not straightforward.

Delivery

The Environment Agency is working with the Council on a natural flood management programme. It is looking at the whole of the upper catchment, including the moorlands and peatlands, some of which is in the Council's ownership. It is considering nature-based solutions on the main tributaries of the River Don and the source of the River Don. In developing its 2021-2027 programme actions being considered include expansion of tree cover and peatland restoration. There is a desire to be ambitious but, as yet, there is no defined scale. The Environment Agency is keen that targets set for the programme should align with the Council's targets related to it carbon ambitions, however, it fears that may not prove to be the case. The Council does not have woodland creation targets and many people have been, or are on, furlough across key organisations leading to an impasse. The Environment Agency intends setting loose targets soon that will not be split by land ownership and is hoping to secure funding and deliver rapidly. Funding has just been secured from Defra for delivery next year. There is funding available through the woodland grant scheme and the Environment Agency is mindful that other grants can be sourced for natural flood management, involving the creation of riparian, catchment or floodplain woodland, which will all deliver carbon benefits.

Workshop participants noted that there is a danger of consultants looking at all the key players' documents and adding up all the figures to identify a very large figure that makes no sense because of double accounting and realities on the ground. At the workshop, the Yorkshire Water-National Trust partnership, Environment Agency, and the Council offered to try and provide broad-brush figures that capture the scale of their ambitions in relation to LULUCF over the next 10 years. However, they doubted whether it would be possible, especially with some organisations having so many people on furlough; the figures have not yet been forthcoming.

Sheffield & Rotherham Wildlife Trust does not have massive landholdings. It leases land from the Council and the Environment Agency. The Trust's main activities around natural flood management and carbon is to engage with farmers and land managers that are not addressed by other organisations who were represented at the workshop.

A Council representative noted at the workshop that the planning system will not have a massive impact on tree planting or peatland restoration. The amount of land that the Council planning authority influences each year is very small. It is planning to build ca. 2,000 homes per year and develop ca. 8-10ha of employment land per year. This will provide opportunities to plant trees as part of new development but they will be small scale, especially as most of the land will be built on. The Council's spatial strategy has gone out to consultation. It seeks to address whether or not growth of development should be concentrated in the urban areas. The Council representative stated that they would safeguard the woodland and trees within the urban area and that, if it extended development into the green belt, it would only grant permission to build on ca. 2-3% of grassland. Furthermore, it was suggested that perhaps a third of the land developed would be retained as open space on which trees could be planted but that the total area would still be small (ca. 30-50 hectares by 2030), so the carbon impact would be small.

It was noted at the workshop that most cities aspire to having Sheffield's existing tree cover. However, the Council has calculated that even increasing tree cover in the urban part of the city by 1% would require a great deal of woodland to be planted. A Council representative noted at the workshop that it would be brilliant if Leeds City Council can achieve its target of planting 5 million trees in 25 years and that it would be good to find out how they will achieve it. However, to put that target in context, if a desire to double the contribution of LULUCF to zero carbon by 2030 was to be achieved through tree planting alone, it would require a very similar number of trees to be planted in Sheffield in just 10 years. In contrast, Sheffield has been planting ca. 20,000 trees per annum and only has a target to plant at least 100,000 additional trees over the next 10 years. Hence, it was suggested by workshop participants that there is good reason to think at a whole catchment scale and work with the three adjacent

authorities rather than focus in on Sheffield, e.g. Doncaster, given its low woodland cover, which may facilitate more rapid progress.

28 Actions

Sheffield City Council actions

	Short term Up to 2022	Medium term 2023-2026	Long term 2027-2030
• Plant more than 100,000 additional trees and replace trees on a 2 for 1 basis in Council-controlled greenspaces and woodlands over the next 10 years	■	■	■
• Resurrect the Urban Nature Programme, with partners, including Amey plc, relaxing mowing regimes on Council sites	■	■	■
• Implement the HAPs for 130 target sites in Sheffield where identified as suitable for expansion of tree cover or peatland restoration	■	■	
• Work with Environment Agency on natural flood management, across the whole upper catchment, including Council-owned peatlands	■	■	■
• Develop the rural strategy to create substantial opportunities for LULUCF	■		
• Explore the possibility of working across a whole catchment scale with neighbouring local authorities, notably Doncaster.	■		

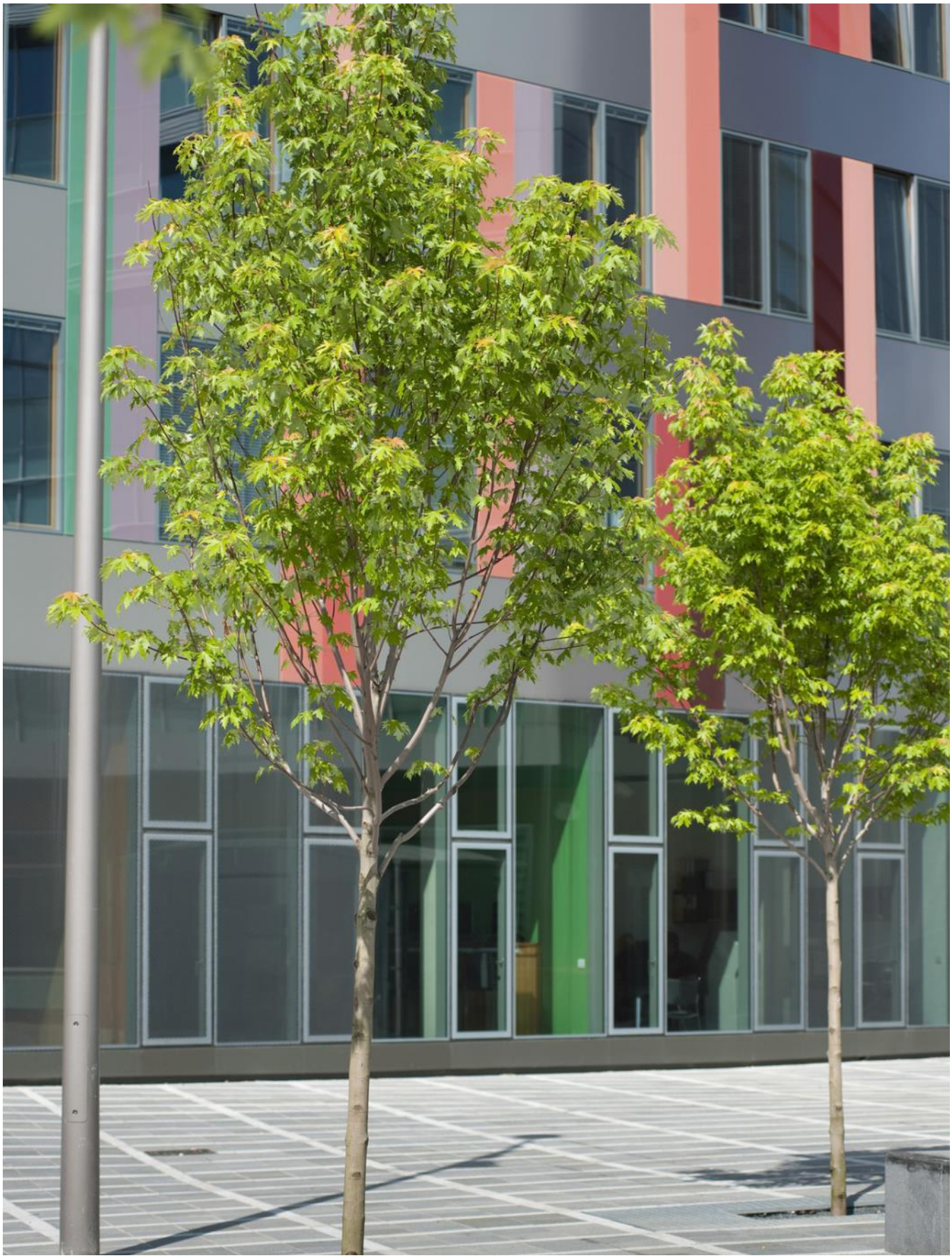
City-wide actions

	Short term Up to 2022	Medium term 2023-2026	Long term 2027-2030
• All major partners to align targets	■		
• National Trust to review tenancies and Stewardship Agreements in 2023 may create major opportunities for LULUCF		■	
• Sheffield Wildlife Trust to engage with farmers and land managers that are not addressed by other organisations	■	■	■

In all these city-wide actions, the role of the Council is to instigate, facilitate and drive discussions in order to create and maintain momentum.

Government bodies actions

	Short term Up to 2022	Medium term 2023-2026	Long term 2027-2030
Forestry Commission			
• Continuing provision of woodland creation grants	■	■	■
Environment Agency			
• Set targets for natural flood management	■		
• Work with SCC, other partners (e.g. Yorkshire Water, National Trust, Sheffield Wildlife Trust) and large landowners on natural flood management	■	■	■



University of Sheffield, Jessop West Building

Conclusion

The framework below shows the scale of emissions reductions as a result of each intervention type in each of the sectors.

Domestic sector



Improve fabric	Reduce energy consumption	Remove fossil fuels
113	54	386
$ktCO_2$ reduction	$ktCO_2$ reduction	$ktCO_2$ reduction

New home construction is set to be modest over the next 10 years in comparison with the existing stock. Focus on energy retrofits is therefore a priority. Improving the thermal performance of the fabric of the building has a massive part to play, as do more general energy reduction measures.

However, the largest improvement, not just within the domestic setting but in the context of all measures in all sectors, is the removal of fossil fuels from heating and cooking by moving to electricity and district heating. There are many significant barriers to this being successfully achieved which are cross-cutting enough to propose that this intervention be prioritised as a way of giving a focus to very initial efforts.

It is a clear example of an intervention that will require engagement and support from many stakeholders (i.e. citizens) over which the Council has few direct policy levers at their disposal. When this issue is on its way to being solved, we can have confidence that others will follow.

Commercial and industrial sector



Improve fabric	Reduce energy consumption	Remove fossil fuels
33	50	151
$ktCO_2$ reduction	$ktCO_2$ reduction	$ktCO_2$ reduction

Unsurprisingly, the structure of the interventions needed for the non-domestic buildings are similar to those needed in homes – albeit with a different focus. Improving fabric is, in this case, less impactful than general energy consumption reductions as process-related consumption is significant. The electrification of the sector is once again the most important area to address.

Transport sector




Increase active travel	Increase public transport	Consolidate freight	Decarbonise all vehicles
104	9	16	290
$ktCO_2$ reduction	$ktCO_2$ reduction	$ktCO_2$ reduction	$ktCO_2$ reduction

Buildings interventions are redolent of those that need discrete actions by many stakeholders but transport takes this one step further by needing these actions to be repeated over time. Once a house is insulated, the work is largely finished, but the decision to cycle instead of drive needs to be taken daily. Transport, therefore, is the area that relies most heavily on behaviour change. Efforts for emissions reductions also need to align seamlessly with city planning interventions to reduce the need for travel. Whilst these elements have their challenges, the benefits – both in terms of carbon and more broadly – are significant.

Once again, the greatest opportunities lie in decarbonisation which in this sector relies on infrastructure changes in the form of charging networks. However, the move to active travel will also yield significant carbon reductions.

Energy sector

Decarbonise heat

91

$ktCO_2$ reduction

Small-scale renewable energy

58

$ktCO_2$ reduction

Large-scale renewable energy

100

$ktCO_2$ reduction

The energy sector can seem hard to separate from the others. After all, the energy generated goes into building and transport solutions – creating energy is not an end in itself. However, there are useful ways in which pulling this sector out can help us focus on cross-cutting issues. The first is the expansion of Sheffield's district heating schemes to replace gas boilers in many homes and businesses with low-carbon heat.

Both small- and large-scale renewable energy generation also have a part to play in contributing to a zero carbon Sheffield. Due to the way they interact with the national grid they need to be treat separately and only small-scale generation can be said to directly reduce Sheffield's emissions. Large scale generation contributes instead to national grid decarbonisation but if it is driven by Sheffield's low carbon agenda and, as such, is additional to expansion in that sector than might have otherwise happened, it is appropriate to recognise its benefits indirectly and quantify them alongside direct emissions reductions.

Land Use, Land-Use Change and Forestry (LULUCF)

Double LULUCF savings

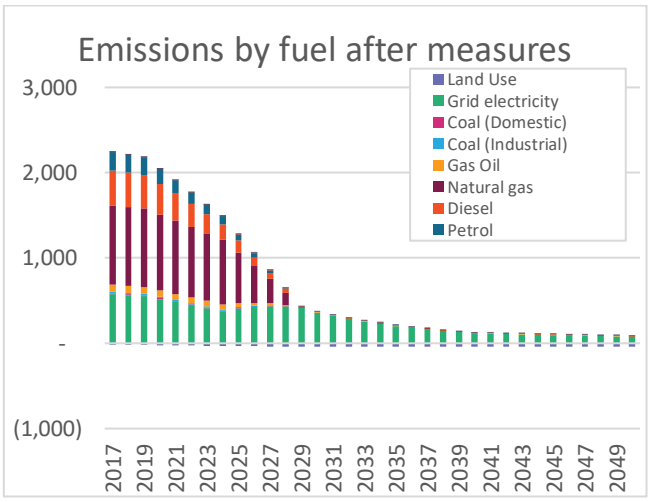
21

$ktCO_2$ reduction

The potential for practical accountable carbon emissions reductions from nature-based solutions (technically called Land Use, Land Use Change and Forestry) is relatively limited when compared to other solutions. Extending tree cover and peatland restoration are the most relevant direct actions.

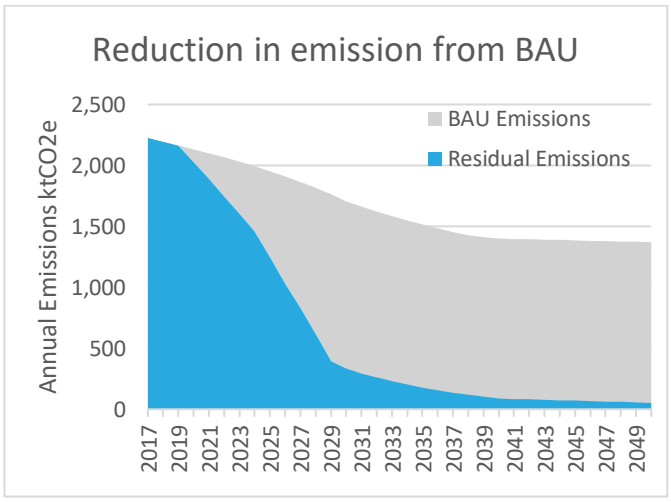
Overall

Combined impact of all interventions results in the trajectory as shown in the graphs below.



Emissions by fuel after measures

This graph includes locally generated building-mounted renewables but does not include large-scale renewables as these are often connected directly into the national grid and so technically contribute to the reduction of the overall carbon intensity of the grid



Projected annual emissions compared to the business as usual projection

In 2030, emissions have been reduced to 334ktCO$_2$ – an 85% reduction from the baseline year. Almost all the residual emissions are from the use of grid-supplied electricity which is not projected to be entirely zero carbon in 2030.

The report produced by the Tyndall Centre for the Council last year recommended that Sheffield consider 'zero carbon' to be a 95% reduction. In order to achieve this target, an additional 223ktCO$_2$ would need to be removed. With energy savings maximised, fossil fuels eliminated and no way to single-handedly completely decarbonise the national grid, these savings would need to come from locally generated renewables. As these renewables would need to be larger-scale installations than those already accounted for in the trajectory, they must be considered separately. In strict emissions-modelling terms, they will not directly reduce Sheffield's emissions, instead contributing to the decarbonisation of the national grid (into which they will supply energy).

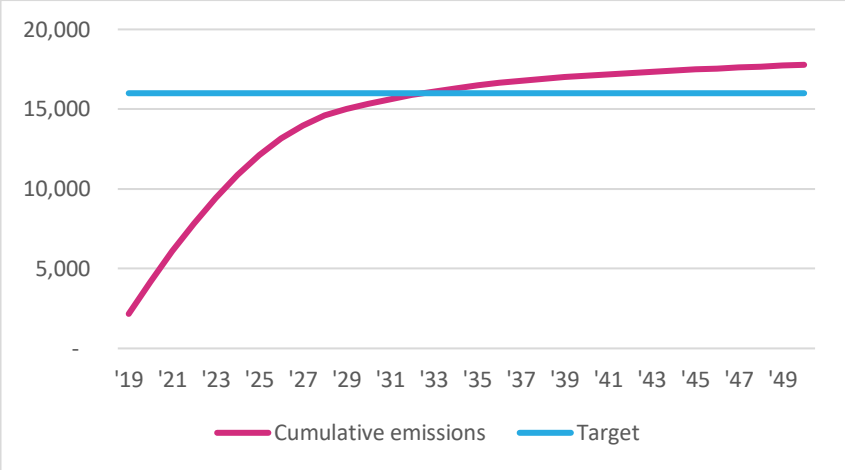
They can, instead, be considered alongside the trajectory as, should the city prioritise and incentivise large-scale renewable generation as a direct result of its 2030 target, these installations may well be additional to the business-as-usual grid decarbonisation.

Examining, at a high level, the opportunities for wind and solar within Sheffield's boundaries indicates that it would be possible to generate enough power to yield an indirect saving of 100ktCO$_2$ in 2030. This takes the balance of emissions to 224ktCO2, a reduction of 90% over the 2017 baseline year.

Assuming that local efficiencies have been maximised, going further than this 90% reduction would require Sheffield to take on a greater proportion of energy generation at which point we must ask ourselves whether this is the right approach. To quantify and address Sheffield's emissions, we are drawing a slightly arbitrary boundary around the city – the reality is that Sheffield is not an island and it fits within a national context. We must question whether further generation in Sheffield is the best solution in the national context. Could our land be better used to address other issues, with others generating power, for example? This wider context allows us to consider Sheffield's place within the City Region Energy Strategy

In addition to the zero carbon target, the Tyndall Centre report recommended a carbon budget of 16MtCO_2e between now and 2100. Taking 2019 as the starting point for this target (the year the Tyndall Centre report was written), cumulative carbon emissions to 2050 are 17.8MtCO_2e. Much of this is due to the fact that emissions start off at such a high annual rate that ~75% of the budget is used up in the early years to 2025.

This reinforces the message that it is important to act fast with no delay.



Prioritised actions

Overview

In each of the sectors there are clear actions that the Council can and must take to achieve the target of a Zero Carbon Sheffield in 2030. These actions relate not only to elements of the city's emissions that are within their direct control but also to emissions that are ultimately under the control of other actors. It is clear that the Council has a key role in encouraging and facilitating action by others. The Council also has an essential role in communicating with central government on the changes that are needed to effectively deliver zero carbon with practicality and realism.

It is worth highlighting that Sheffield City Council does not act in isolation within the sub-region. Much of the funding linked to transport, employment & skills and economic growth is currently apportioned via Sheffield City Region (SCR – includes Rotherham, Barnsley and Doncaster). Sheffield City's target of zero carbon in 2030 is ahead of the City Region and other partners. SCR will need to acknowledge this and allow it to be taken into account in funding decisions.

In addition, this report has been generated and is being released at a time of great uncertainty and rapid change within the situation around the Covid-19 pandemic. The situation undoubtedly presents challenges but also opportunities as the city rebuilds however, the current situation has not driven the evolution of these prioritised actions for fear that they would rapidly become out of date.

This section pulls together the wider set of actions previously set out into key measures that should be implemented and the steps that could form the initial movement. This section:

Includes actions the Council can take that cut across direct actions, city-wide actions and governing body actions, focussing on clear next steps.

Does not include actions relating to the internal resourcing, structure and governance of the Council needed to ensure continued focus and effective delivery. These elements are the focus of WP4.

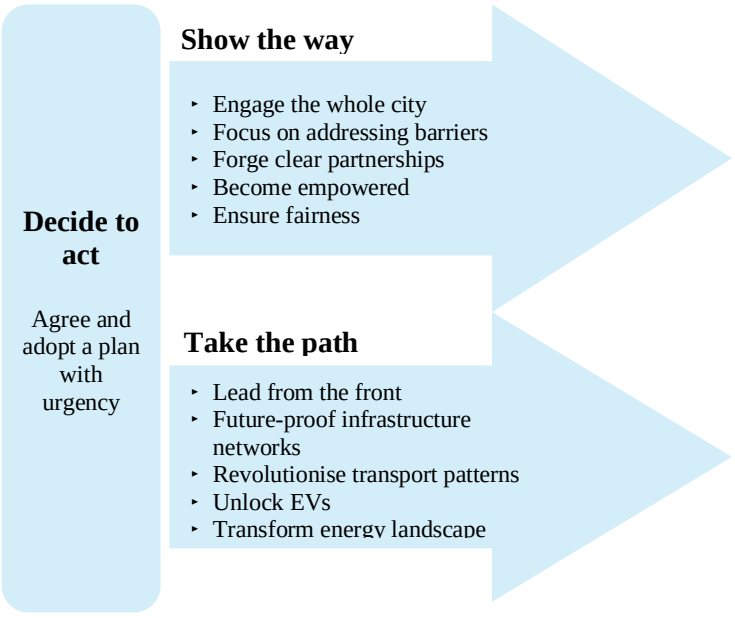
This section also specifically does not include any overarching recommendations on financing. Each of the priority actions will need funding in their own way but the issue of financing is included in detail within work package 4 (WP4 – Ways of Working) which has six of its 30 recommendations linked to finance, procurement, investment and resourcing.

The actions are broadly set into three categories (right). A prerequisite is an immediate clear mandate for action from all areas of the Council.

Following this, enabling actions ('show the way') can begin in parallel with more direct interventions ('take the path').

It is obvious that, in an ideal world, many enabling actions would take place before more direct interventions. However, we do not have the luxury of time which means that some inefficiencies are inevitable and have to be accepted. The alternative is an ideal process that results in failure as it does not progress quickly enough.

The actions within each of these categories is set out in the following sections.



Decide to act

The first action that sits above all those below is that the Council needs to absorb the recommendations of this report and immediately develop and work with partners to agree a city wide action plan and programme of works. This may include some adjustments to actions recommended below but should be sure to encompass all of the areas. A two-stage approach may be appropriate – an initial programme of works that can be implemented almost immediately in parallel to an Action Plan being developed and agreed.

This action plan should be prepared and agreed as quickly as possible, noting the need for engagement and the commitment to holding a citizen's assembly, there is not the luxury of delay. An imperfect plan agreed now will achieve much more than a perfect plan agreed in six months' time – not only in practical terms but in terms of momentum and a sense of urgency.

Show the way

These first enabling actions are relevant to all sectors. They are essential to move the ethos of the city, to change behaviours and to engrain climate action into everything everyone does. It may be tempting to consider them to be less relevant as they cannot be directly linked to particular emissions savings. This would be a mistake. These actions unlock the potential of the city – without them, all seemingly more direct action will be manifestly harder to implement and will ultimately be less successful, making achieving the target all but impossible.

Engage the whole city

Why?	It is abundantly clear that the Council cannot do this alone. Achieving Zero Carbon 2030 will take effort, investment and potentially compromise from everyone. However, the benefits will also be felt by all.
What?	**An intense and continuous programme of communication and engagement to drive awareness and change in all areas of life in Sheffield** Sheffield is a city that often invokes passion and loyalty amongst those that live here. Every citizen and business needs to personally engage, understanding the urgency of the climate agenda, the steps they can take to address it and the ultimate rewards for success. They need to feel that the Council is leading them and guiding them to make a difference with practical advice. Residents need to understand what their options are to reduce their footprint, tailored specifically to their circumstances, whether that's the tenure of their home, it's physical characteristics or their travel needs. Businesses need to understand the commercial future-proofing opportunity in embracing the climate agenda whilst also being aware of the risks of a changing market and future carbon pricing.

First steps:

- Widely disseminate the outcomes of this report and the resultant action plan using as many communication channels as possible so that it reaches partners, citizens and businesses. Use existing communication channels where possible. Zero Carbon 2030 shouldn't be seen as something additional, it should be seen as a change in focus on existing elements.
- Develop a communications plan that establishes branding and a consistent set of messages. The plan should have streams targeting particular stakeholders and be as specific and targeted as data availability allows. It will likely be more effective if coordinated with the partnerships that need to be developed (see below). This may need external assistance.
- Build and instigate a more detailed plan around the decarbonisation of heat in existing homes (as it is arguably one of the most challenging interventions and so needs addressing with urgency)

Focus on addressing barriers

Why?	The science on climate change has been clear for many years. There are reasons why little effective action has been taken to date. Understanding, addressing and removing these barriers is key to unlocking enthusiasm at all levels. No one is actively against making the world a better place – they just have to be feel like practical opportunities are available to them.

What?	**A brave and purposeful attack on the most often quoted barriers, embracing them as identifiers of real potential change as opposed to being too difficult to address.** There are many barriers to action that have been identified by stakeholders in the course of preparing this report. Some of these are real and some are perceived. Ongoing support is needed to work around these barriers with those that are experiencing them. This will build on the engagement programme by offering more targeted assistance to those that need it. The support may need various strands that vary in priority over time as the significance of barriers changes (for example in response to national policies or market movement). Support could include assistance in identifying and applying for funding, bringing together suppliers and purchasers, developing standard routes to emissions reductions to simplify options and acting as a facilitator/intermediary when detailed discussions are needed between stakeholders.

First steps:

- Develop a programme of support for each of the topic areas of domestic, industrial / commercial and transport (energy being able to be incorporated to the other topics to a certain extent). Understand funding required and clarify targets and specific actions.
- Roll out the programmes starting with the decarbonisation of heat in homes.

Forge clear partnerships

Why?	Partners that represent subsets of the population of Sheffield or who hold key roles in addressing barriers or unlocking areas of action will be able to magnify the impact the Council can have in isolation.

What?	**A series of key partnerships where the overall purpose and everyone's role is clearly understood and the Council takes a lead in providing direction and maintaining momentum.** Existing bodies within Sheffield have key roles to play in tackling barriers and promoting engagement. Maximising existing memberships, relationships and reputation can help to short-cut some of the difficult early stages in the work that needs to be carried out. However, the formation of these partnerships will take concerted effort on both sides. The Council needs to be clear on what it needs from partners, taking a proactive role in driving the agenda and maintaining momentum. Efforts that rely on others for both direction and drive with the Council being a passive occasional participant are likely to fail or not be aligned with the wider efforts. These partnerships can include the local universities, NHS Trusts, Sheffield Sustainability Network, Sheffield Property Association and education providers that will be instrumental in closing the skills gap for delivery. Partners external to the city should also be engaged with. An active collaboration amongst the core cities group would provide useful learning.

First steps:

- Identify someone to with sufficient resource to establish and manage the relationships set out above. Develop an informal Terms of Reference for each partnership to agree aims and roles. Vigorously drive the actions of the relationship to maintain momentum and develop real positive outcomes.
- Continue to reach out to the Core Cities Group (or selected key cities) in order to reinforce partnerships where the details of each city's efforts and successes can be shared. Cities within this partnership can agree to take leads on certain elements so the workload of pioneering solutions for others to learn from can be shared. Use this partnership to more effectively lobby for change from central government.
- Use the decarbonisation of heat in homes as a first priority to drive the establishment of partnerships and focus on actions to remove barriers and improve outcomes (such as addressing a future skills gap).

Become empowered

Why?	With its current powers, the Council is able to perform a very effective enabling role in the journey to zero carbon. However, greater powers would increase its ability to effectively guide the city and would allow a greater pace of change (something that is essential).
What?	**A clear 'ask' on what new powers are required to maximise the impact of work towards zero carbon and their benefits – coordinated with other cities if possible.** Maximise the impact of powers to raise and control funding streams would allow the Council to direct them as necessary towards areas where they are likely to have the greatest impact in terms of emissions reductions, whether that by direct expenditure or by catalysing wider action. There are also areas of legislation that could be used to galvanise action such as planning policies and requirements for the improvement of existing buildings by requiring the private sector access its own funding sources. More locally, there are potentially existing private-sector relationships that were develop before the climate crisis and can be renegotiated in order to allow the Council to more directly control the agenda (even if that means compromises in other areas such as the apportionment of risk or financial returns).

First steps:

- Clearly set out the ideal preferred set of policies that are needed to immediately drive a proliferation of zero carbon developments in the city. Partner with other Core Cities to identify changes needed to central policy or the balance of powers that would be needed to allow these preferred policies to be adopted.
- Re-examine existing key relationships around transport, heat supply and maintenance operations to investigate whether meaningful benefits could come from agreeing altered terms or with the Council taking a different role.
- Work with the City Region and other regional partners to start from a clean sheet to identify new powers and an ideal local structure. Ensure the reasoning behind the proposed new power structure is clear and engage with local stakeholders to achieve buy-in.

Ensure fairness

Why?	In order to achieve Zero Carbon 2030, Sheffield will need to undergo massive change. This level of change provides the opportunity to simultaneously address some of the inequalities that have been built into existing systems over time (often as a result of historic decisions that wouldn't get repeated now).
What?	**A clear plan to highlight the synergies between climate action and the ability to address inequalities and a mechanism to ensure these are investigated and acted upon.** Climate action touches on all elements of a city's operation and life within it. No city is perfect – they all contain structural inequalities. The change needed provides an opportunity to 'build back better' – not just in terms of physical infrastructure but in the provision of services that can equalise the opportunities afforded to all those who make up our city. Old assumptions should be challenged, areas for impact identified and fresh, more equitable, solutions should be sought.

First steps:

- Establish key relationships between those Council teams driving climate action and those working on aspects of inequality.
- Develop a set of key linkages for each intervention to identify areas where improvements to inequality are possible. Identify where the responsibility lies to drive improvements in order to be able to rely on a clear governance structure.

Take the path

These direct interventions are specific to particular sectors. They are prioritised actions to either realise real changes and build momentum or to ensure particular long-lead-time items are addressed. They should be informed by the enabling actions as they yield results and outputs. As such, the programmes should be flexible and able to maximise the benefits from, for example, increased engagement, effective partnerships and more local autonomy.

Lead from the front

Why?	Many of the interventions that need to be implemented across the city need to also occur in Council-controlled areas. By progressing with its own assets, the Council can show leadership, address barriers and provide exemplars.
What?	**An immediate and wide-ranging programme to convert all Council-controlled assets to a condition that is ready for Zero Carbon 2030.** The Council's own non-domestic buildings and its transport fleet along with all social housing in the city will need to be transitioned to exist in a zero carbon Sheffield. Equally, its operational practices (such as commuting modes) will need to change. By taking action early, the Council can indicate to the rest of Sheffield that change is possible, stimulate local supply chains and the market for low carbon services and installations whilst also gaining invaluable insight into methods of solving barriers. This can also include circumstances where the Council is playing a role more often seen in the private sector. For example, where the Council is acting as a developer (e.g. Heart of the City II) or a landowner, it can insist on zero-carbon ready solutions being taken forwards, addressing head-on any difficulties that this creates and accepting compromises it results in.

First steps:

- Develop WP3.2 of this Zero Carbon Commission into a funded action plan with an immediate start.
- Examine all current projects where the Council has a role and transition to a zero carbon ready solution unless construction has started and change is impossible. Includes changing emphases on long-running and/or ongoing projects.

Future-proof infrastructure networks

Why?	A city is reliant on many hidden infrastructure networks which can be placed under strain by small individual actions repeated many thousands of times. We must ensure a zero Carbon Sheffield has networks that can cope with the impending changes and even enable additional solutions where possible.
What?	**An identified set of critical networks, their vulnerabilities to the changes expected of them and a coordinated plan enabling a successful Zero Carbon 2030.** As the city transitions away from fossil fuels, it will unavoidably rely more heavily on the electricity network. It is not a given that this network could currently meet the increased demand. As a trajectory of city-wide emissions reductions interventions is developed, a parallel trajectory of any required infrastructure upgrades must be carried out. This could include neighbourhood upgrades in response to clusters of buildings ready to make the switch to electric-based heating. To reduce pressure on the electricity network, district heating schemes should be maximised, particularly if they overlap with areas with reduced electricity capacity or clusters of homes difficult to insulate to standards needed for effective heat pump operation. Simply encouraging new developments to use district heating where it is available will not drive expansion sufficiently quickly – a vision for the city's district heating assets in 2030 is needed along with an attendant investment and expansion plan including conversion of existing buildings. Sheffield also has unique assets in the hydrogen industry that should be maximised.

First steps:

- Instigate discussions with local Distribution Network Operator to examine the potential impact of Zero Carbon 2030 on the electricity infrastructure and develop a plan of works to accommodate changes.

- Work with stakeholders to develop a clear vision for a suite of zero carbon district heat networks and identify the actions needed to realise the vision.
- Evaluate and maximise the potential benefits of local hydrogen economy, addressing any barriers to progress.

Revolutionise transport patterns

Why?	Transport movements are responsible for a significant proportion of Sheffield's emissions. Whilst electric vehicles reduce emissions, they do not bring many of the parallel benefits of active travel (e.g. health improvements) or public transport (e.g. reduced congestion) so should not be considered a single solution. Reductions in travel distance are also considered economically beneficial as the city strives to become a '15 minute city'

Local centres connected by a network of cycling and walking infrastructure that complements excellent public transport provision.

What? If Sheffield reduces its transport emissions simply by switching all conventional vehicles for electric alternatives, a huge opportunity will be lost. Modal shifts to active travel and public transport bring many significant additional benefits over simple emissions reduction. Therefore, there is a need for a connected network of segregated cycle paths along with an increased focus on the walkability of neighbourhoods. With the rapidly increasing popularity and availability of e-bikes, Sheffield's natural oft-cited barriers to cycling (i.e. the hills) are effectively reducing in size. Public transport services need to be improved to provide a greater variety of service types over and above those that simply go into and out of the city centre from various directions. This may need a restructuring of the stakeholders currently involved in providing services, refocussing on service routes in need as opposed to (understandably) concentrating on those that can provide a commercial return.

First steps:

- Highlight highest priority improvements to the cycle network based on existing information and begin detailed design and construction immediately.
- Develop detailed and highly ambitious Active Travel Plan and implement without delay, considering wider economic plans to increase the importance of local centres for commerce to reduce the need to travel to the city centre or other main destinations.
- Develop detailed city-level response to the SCR Bus Review Report with a focus on taking action in as short a timescale as possible.

Unlock EVs

Why?	Cars, vans and trucks will continue to play a part in any integrated transport system for many decades to come. Therefore there is a need to eliminate the emissions associated with them.

Charging infrastructure and solutions that remove a significant barrier to the uptake of EVs and a series of communication and policy initiatives to drive the transition away from fossil fuel vehicles.

What? EV uptake is hampered by a chicken-and-egg situation between the number of EVs and the availability of charging points. There is therefore a need for a catalysing charging network that can reduce this barrier and unlock the clear benefits of EVs for consumers. This needs to focus on the significant proportion of households who do not have off-street parking. In addition, consideration of the particular needs of LGV users must be included.

First steps:

- With citizens and other stakeholders, identify/design and install a network of charging points that gives realistic charging options to the majority of vehicle users with a variety of charging solutions.
- Develop a communication strategy to inform citizens of how they can use these networks and the benefits of EVs. Give assurances of the longevity of the Council's commitment to these measures.

Invite immediate submissions for the creation of a delivery consolidation centre on the outskirts of the city that allow local deliveries by electric vehicles.

Transform energy landscape

Why?	Energy consumption cannot be reduced to zero. There is therefore a need to generate low carbon energy. It will not be possible for every city to rely on others to provide this low carbon energy and therefore each must maximise all opportunities locally.
What?	**A network of renewables installations (likely focussing on building-and ground-mounted PV) and a series of expanded district heating networks future-proofed for zero-carbon heat sources.** Commercial-scale PV and wind installations should be installed on suitable land parcels around the city, with the Council enabling these with favourable planning assumptions. All new buildings and planning applications for existing buildings (particularly those with extensive roofs) should require building-mounted PV. Supplementing this, existing district heating schemes should be expanded to maximise their effectiveness which may need funding interventions to remove barriers of high CapEx. Existing schemes should have a clear plan to being zero carbon. Additional new district heating schemes should be identified. Finally, Sheffield's hydrogen assets should be maximised to contribute as much as possible to emissions reductions

First steps:

- Identify sites for commercial renewables installations and progress with developers.
- With partners, develop detailed plans to expand DH networks including removing barriers and take action without delay.
- Encourage electricity distribution network operator, NPG, to work with the Council to develop the business case for timely investment in accelerated upgrade and smarter network management across the city so that it has a 'net zero ready' network by 2030.
- Instigate discussions with stakeholders involved in the hydrogen industry to develop an ambitious plan for the fuel. Encourage gas distribution network operator, Cadent Gas, to work with the Council to develop the business case for timely investment in hydrogen distribution networks.

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