Lancashire
Independent Economic Review

Final Report:

Lancashire Net Zero Pathways Options

Main Document

Notice

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Client signoff

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Contents

All appendices are contained within a separate document.

1. Introduction and Background

1.1. Introduction

Lancashire County Council, Blackburn with Darwen Council, Blackpool Council and the Lancashire Economic Partnership have commissioned Atkins to provide an evidence-based assessment of Lancashire's current carbon footprint at territorial level and to generate robust and realistic carbon reduction pathways that would put the region on track to achieve three targets as follows (against the national target of Net Zero by 2050):

- Net Zero emissions by 2030 (100% reduction relative to 1990 levels);
- 68% reduction of emissions by 2030 (relative to 1990 levels); and
- 78% reduction of emissions by 2035 (relative to 1990 levels).

The first target is an extremely ambitious target for the region aiming for Net Zero 20 years before the national target. The second and third targets are intended to be consistent with interim targets the Government has set to align with their committed carbon budgets for future five year intervals[1] (i.e. legal commitments to limit the total amount of greenhouse gas emissions released in the interval), as defined on the basis of guidance from the Climate Change Committee (CCC). The second target is in line with interim commitments of at least 68% reduction in greenhouse gas emissions (GHG) by the end of the decade, compared to 1990 levels, announced in December 2020[2]. The third target is aligned with further government interim commitments to reduce GHG emissions by 78% by 2035 compared to 1990 levels, announced in April 2021[3].

The carbon budgets and associated targets represent interim milestones that the CCC identify need to be met by the UK on its decarbonisation pathway to Net Zero, in order to contribute fairly to reducing global cumulative greenhouse gas emissions and keeping emissions within the budget available to limit temperature growth to below 2°C and close to 1.5°C.

Other climate scientists take a different view on the rate at which the UK should decarbonise. The Tyndall Centre suggest that the rate of decarbonisation should be more rapid for the UK to make its fair contribution to meeting global objectives to reduce climate change. The Tyndall Centre pathway derived for the Lancashire region as part of this study has therefore been used to show an aspirational, more ambitious pathway to Net Zero, against which to gauge the level of ambition in terms of emissions reductions and carbon removals over time.

To understand the scale of change required to meet the target pathways, an analysis of potential emission reductions measures across key energy use sectors in Lancashire has been undertaken for the region and at local authority level.

In developing the three target carbon reduction pathways up until 2035, consideration of the decarbonisation technologies available at scale in the timeframe resulted in electrification being the main alternative (to fossil fuel use) across key energy use sectors, alongside behaviour change. However, when extending the analysis to target pathways beyond 2035 to 2050 and aiming for Net Zero at an earlier date than 2050, it is possible that hydrogen will also become a decarbonisation alternative, and this results in the consideration of two alternative technological scenarios for the later time period:

- High electrification: exploring the impact of using widespread electrification to support transport, heating, and industry decarbonisation coupled with deep decarbonisation of electricity supply.
- High hydrogen: exploring the impact of using low-carbon hydrogen more extensively, particularly for decarbonising buildings, industry and heavy vehicles.

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[1] The targets were adopted because they were two national commitments that received attention in 2020 and 2021. However, it is important to note that they are calculated on slightly different assumptions. The 68% target relates to emissions excluding international aviation and shipping and was used as the UK's Nationally Determined Contribution for the Paris Climate Agreement process. The 78% includes international aviation and shipping and is the target intended to represent the UK's 6th carbon budget. The equivalent figure excluding international aviation and shipping would be a target of 82% reduction by 2035 relative to 1990. To align with the CCC's Balanced Pathway to Net Zero both the 2030 and 2035 target of 68% and 82% would need to be met.

[2] https://www.gov.uk/government/news/uk-sets-ambitious-new-climate-target-ahead-of-un-summit

[3] https://www.gov.uk/government/news/uk-enshrines-new-target-in-law-to-slash-emissions-by-78-by-2035

Considering maximum carbon sequestration interventions in the region through forest preservation, peatland restoration and tree planting, combined with extending the carbon emissions reduction pathways beyond the target dates of 2030 and 2035 under the two technological scenarios, the likely dates when Net Zero could be achieved with each pathway have been established.

Indicative capital expenditure costs have been derived for key interventions identified in the Net Zero pathways for the region.

Lancashire is developing a new economic strategy to transform the region, promoting inclusive economic growth and sustainable development - the Greater Lancashire Plan. Sustainability, including action on Net Zero, is an integral part of the Greater Lancashire Plan. Recommendations to place the region on an effective Net Zero pathway and inform the development of the Greater Lancashire Plan are provided in this report.

1.2. The scale of the challenge

1.2.1. Keeping 1.5ºC alive

The emission of greenhouse gases (GHG) since the beginning of the Industrial Revolution has a known effect on the atmosphere, and in turn, is responsible for changes to the climate globally. Carbon dioxide (CO_2) and other GHGs trap heat in the atmosphere, with higher concentrations leading to higher average global temperatures. Global GHG emissions amounted to 33 billion tonnes of carbon dioxide equivalent (CO2e) in 2019[4]. As of 2016, atmospheric CO_2 concentrations exceeded 400 parts per million for the first time in around 3 million years[5], with global average surface temperature 1ºC higher than pre-industrial levels.

There is a global consensus, expressed through the 2015 Paris Agreement, that climate change is a real and present threat to the stable climate in which natural ecosystems and our livelihoods can be sustained without substantial disruption. It was agreed in the Paris Agreement to hold the increase in global average temperatures to 'well below' 2ºC above pre-industrial levels, and 'pursue efforts' to limit the temperature increase as close as possible to 1.5ºC.

The UK is one of the world's largest emitters of greenhouse gases, with emissions for 2018 being 451 million tonnes of CO2e[6]. To support these international efforts, the UK Climate Change Act 2008 (as amended) sets a national legal reduction target of 100% (Net Zero) against 1990 levels by 2050.

The Government has set a series of carbon 'budgets' for five-year periods, to act as stepping-stones to the overall reduction. In December 2020, and in April 2021, the Government increased its level of ambition with interim targets to reduce GHG emissions by 68% by 2030[7] and 78% by 2035[8], respectively, relative to the 1990 baseline.

Leading up to the 26th UN Climate Change Conference of the Parties (COP26) hosted by the UK in Glasgow on 31 October – 12 November 2021, the government published the UK Net Zero Strategy: Build Back Greener in October 2021[9]. This strategy sets out policies and proposals for decarbonising all sectors of the UK economy to meet net zero target by 2050. Tackling the twin challenges of biodiversity loss and climate change, another major milestone for the UK, the Environment Act[10] became law whilst the UK was hosting of the COP26 summit. Government says the Act will improve air and water quality, tackle waste, increase recycling, halt the decline of species, and improve the natural environment.

COP26 itself was meant to ensure the world remains committed to preventing global heating exceeding more than 1.5ºC above pre-industrial levels. Although nations agreed on the Glasgow Climate Pact[11], which states that carbon emissions will have to fall by 45 percent by 2030 to keep alive the 1.5°C goal, the ultimate success of COP26 relies on pledges for future action which pose a risk of failure. According to COP26 President Alok

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[4] https://www.iea.org/articles/global-co2-emissions-in-2019
[5] https://e360.yale.edu/features/how-the-world-passed-a-carbon-threshold-400ppm-and-why-it-matters
[6] https://www.gov.uk/government/collections/uk-greenhouse-gas-emissions-statistics
[7] https://www.gov.uk/government/news/uk-sets-ambitious-new-climate-target-ahead-of-un-summit - for emissions excluding international aviation and shipping i.e. the scope covered by the Nationally Determined Contribution to the Paris Climate Agreement process
[8] UK enshrines new target in law to slash emissions by 78% by 2035 - GOV.UK (www.gov.uk) - for emissions including international aviation and shipping, i.e. the scope covered by the UK's 6th Carbon Budget. The equivalent target reduction for 2035 for emissions excluding international aviation and shipping is 82%.
[9] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1033990/net-zero-strategy-beis.pdf
[10] https://www.legislation.gov.uk/ukpga/2021/30/contents/enacted
[11] https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf

Sharma[12] '*We can now say with credibility that we have kept 1.5 degrees alive. But, its pulse is weak and it will only survive if we keep our promises and translate commitments into rapid action.'*

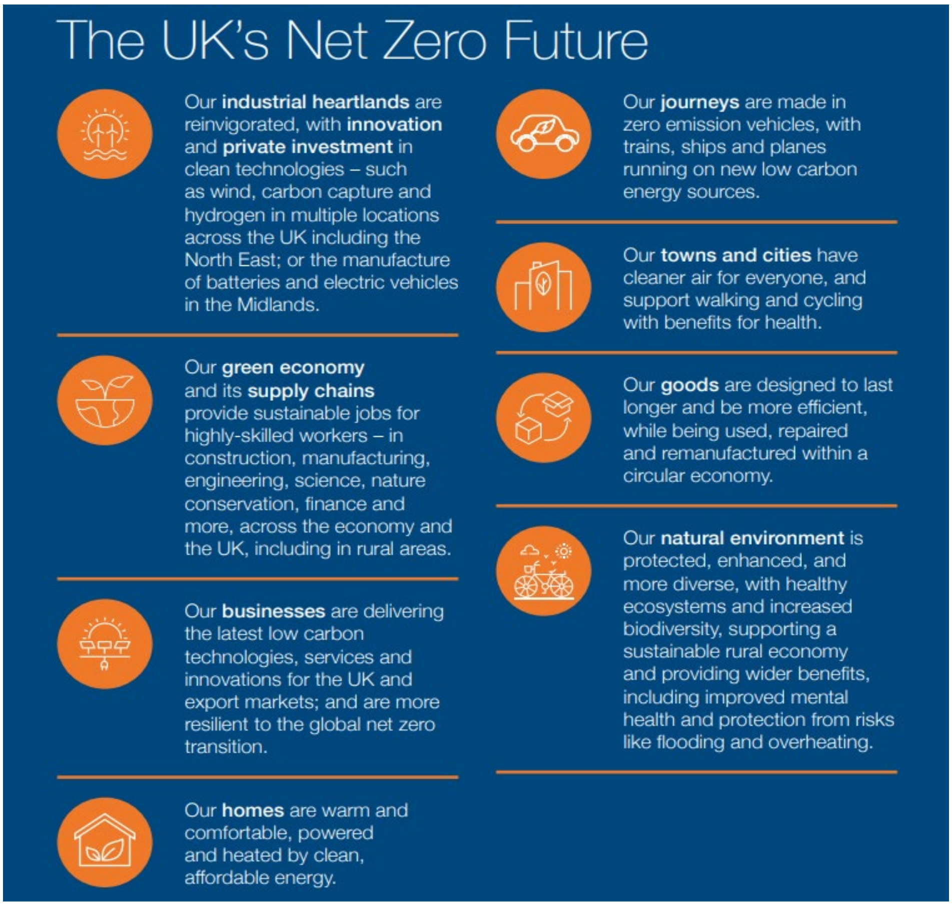
Following Government's earlier commitments during 2019, and wider awareness of the threat of climate change and the need for urgent action, many local authorities and local organisations acknowledged the climate emergency, setting Net Zero carbon emissions targets and started to prepare strategies to deliver those targets. The 2021 government commitments leading to and during COP26 have intensified efforts to tackle GHG emissions at all levels of society and all sectors across the UK.

In 2019 Lancashire's councils started to make declarations of a climate emergency, with all but one now setting a goal of achieving net zero carbon emissions by 2050 or earlier. The whole of Lancashire is covered by an ambition to achieve net zero emissions by 2030, with Lancashire County Council and the two Unitary councils of Blackburn with Darwen and Blackpool all having adopted this target for their respective territories. This report is the first step for the region to understand the far-reaching implications of such commitments.

1.2.2. UK Net Zero pathways

In the recently published Net Zero Strategy, the government provides a vision of the UK's Net Zero Future (Figure 1-1). This is highly relevant for the Lancashire Net Zero Pathways Options study as it is nested within this wider government vision.

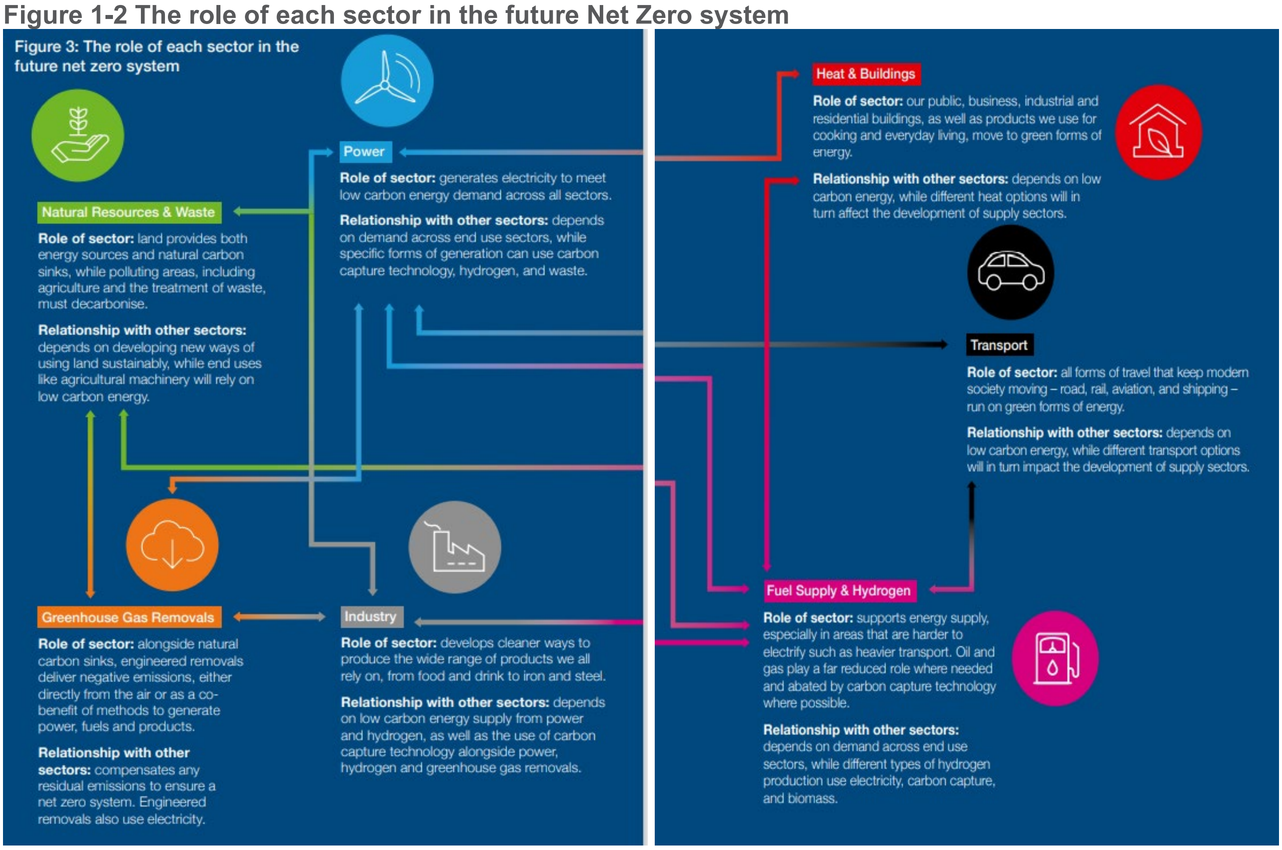
Figure 1-1 The UK's Net Zero Future



Source: extracted from Net Zero Strategy 2021[13]

Government is taking a systems approach to policy which will help to navigate the complex characteristics of the net zero challenge – requiring action by multiple parties across the public and private sectors, delivery at pace, and management of large uncertainties which underlines the need for strong coordination in policy development and clear signalling to markets. The environment, society, and economy are considered as parts of an interconnected system, where changes to one area can directly or indirectly impact others. A systems approach does not attempt to design a 'perfect' net zero end-state thirty years into the future. It aims to enable innovative and desirable solutions to be developed, and to ensure that decisions are made when needed, based on the best evidence available at that time and with the fullest possible range of considerations brought to bear. This includes taking a dynamic approach to policymaking and updating our assumptions on an ongoing basis; considering public reactions to a policy; accounting for where a particular investment or technology deployment may affect another sector's decarbonisation; and considering the net costs and benefits across different parts of the economy and environment. As summarised in Figure 1-2 below, each sector of the economy will play a vital role in the future net zero system, and these are highly connected – changes in one area can directly or indirectly impact others. The same is equally true in the Lancashire region.

Figure 1-2 The role of each sector in the future Net Zero system



Source: extracted from Net Zero Strategy 2021[14]

Government sets out that the exact technology and energy mix in 2050 cannot be known now, and the path to net zero will respond to the innovation and adoption of new technologies over time. However, it is expected to rely on the following key green technologies and energy carriers, which interact to meet demand across sectors and to remain low carbon:

- Electricity from low carbon generation and storage technologies meets higher demand for low carbon power in buildings, industry, transport, and agriculture;
- Hydrogen can complement the electricity system, especially in harder to electrify areas like parts of industry and heating, and in heavier transport such as aviation and shipping. A range of low carbon production methods could be used;
- Carbon capture usage and storage (CCUS) can capture CO_2 from power generation, hydrogen production, and industrial processes – storing it underground or using it. This technology also supports negative emissions from engineered greenhouse gas removals – bioenergy with carbon capture and storage (BECCS) and Direct Air Carbon Capture and Storage (DACCS); and
- Biomass combined with CCUS can remove carbon from the atmosphere and support low carbon electricity and hydrogen generation. Biomass and other wastes can also support low carbon fuels for industry, buildings, and transport.

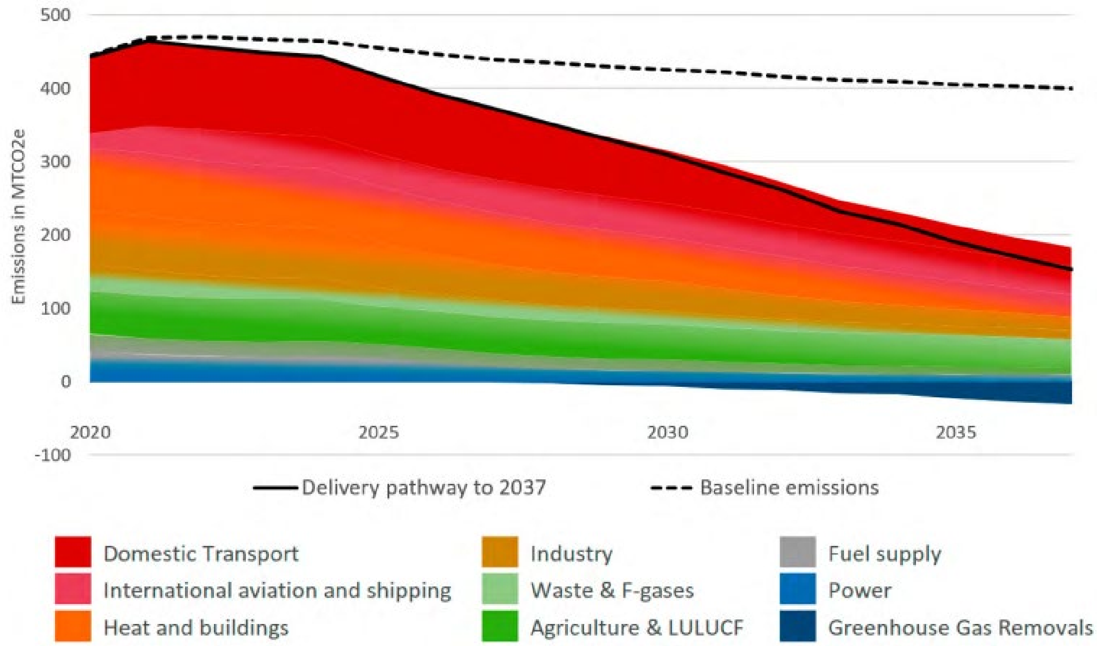
The Net Zero Strategy explores three 2050 scenarios which are summarised below:

- High electrification: explores the impact of using widespread electrification to support transport, heating, and industry decarbonisation coupled with deep decarbonisation of electricity supply.
- High resource: explores the impact of using low-carbon hydrogen more extensively, particularly for decarbonising buildings and heavy vehicles. It assumes higher levels of tree-planting are achievable, increasing the 'negative emissions' available from land-use sinks.
- High innovation: explores a world in which successful innovations, such as synthetic fuels and zero emission aircraft, enable lower residual emissions to be reached sooner in aviation. Higher capture rates – above baseline assumptions –increase the impact of carbon capture technologies, particularly higher deployment of direct air capture.

Drawing on the insights from the illustrative 2050 scenarios, Government have developed a delivery pathway: an indicative trajectory of emissions reductions which meets targets up to the sixth carbon budget ending in 2037 (Figure 1-3). The pathway is based on understanding now of the potential for each sector to reduce emissions up to 2037, considering the balance between sectors that is optimal for the entire economy in terms of delivery and cost. Emission reductions beyond our existing policies combine evidence on theoretical potential for abatement with judgements about barriers to delivery, the rate at which low carbon options could be adopted in practice and timescales for key decisions. An economy-wide view has been taken, including to balance end use sector demands with supply side considerations, such as infrastructure and the operation of the electricity and other fuel supply sectors. As a general principle, the indicative pathway to 2037 prioritises emissions reductions where known technologies and solutions exist and thereby minimises reliance on the use of greenhouse gas removals to meet our targets. It is designed to drive progress in the short-term, while creating options in a way that seeks to keep the range of options presented in the illustrative 2050 scenarios open.

The same general approach to pathway development is being applied in this report in the Lancashire region but the analysis extends to 2050, applies to key energy end user sectors in territory only and explores the high electrification and high resource (referred to as 'high hydrogen' in this study) 2050 scenarios. The third high innovation scenario of UK Net Zero Strategy has not been considered as aviation is not a sector included in this study (see Section 2).

Figure 1-3 UK indicative delivery pathway to 2037 by sector



Source: extracted from Net Zero Strategy 2021[15]

1.2.3. The role of local authorities and businesses in delivering Net Zero

Alongside the central government, local authorities and business will play a critical role in delivering Net Zero and they will need to work in partnership to deliver the ultimate Net Zero target.

The National Audit Office report 'Local government and net zero in England'[16] concluded that local authorities will have a critical part to play in delivering Net Zero as they provide a range of services to people in their areas which impact on net zero, such as transport planning, social housing and land use planning. They also have a key role to play in encouraging and enabling wider changes among local residents and businesses to reduce emissions, through local authorities' investment and procurement decisions, planning responsibilities, and direct engagement with local people. However, the report identifies several obstacles in this regard:

- Central government has not yet developed with local authorities any overall expectations about their roles in achieving the national net zero target and has yet to determine, in consultation with the sector, local authorities' overall responsibilities and priorities in achieving the national net zero target, and whether or not any of these might require a statutory basis.
- Government has not yet set out to local authorities how it will work with them to clarify responsibilities for net zero. Decisions about local authorities' role in achieving the national net zero target are tied up with government's overall strategy for net zero as well as with the underpinning sector decarbonisation strategies. The engagement has yet not been sufficiently strategic or co-ordinated to determine, in partnership with the sector, as clear as possible a role for local authorities on the national net zero target.
- Overall, local authorities find it hard to engage with central government on net zero.
- Departments have started to coordinate their engagement with local authorities on net zero but there is no single senior point of responsibility for making more fundamental improvements.

In a similar fashion, the CCC's report on the role of local authorities in delivering the UK's Net Zero ambition accompanying the 6th Carbon Budget[17] recognises that local authorities have a range of existing levers that can

[15] https://www.gov.uk/government/publications/net-zero-strategy
[16] Local-government-and-net-zero-in-England.pdf (nao.org.uk)
[17] Local Authorities and the Sixth Carbon Budget - Climate Change Committee (theccc.org.uk)

be used to deliver local action that reduces emissions and prepares local areas to a changing climate. However, these levers alone are unlikely to be sufficient to deliver local authorities' Net Zero ambitions, due to gaps in powers, policy and funding barriers, and a lack of capacity and skills at a local level. Additionally, without some level of coordination from Government, the UK risks pursuing a fragmented strategy towards Net Zero. The report provides a framework for aligning climate action at the local level with the CCC's pathways for the UK, as well as recommendations for local, regional and national Governments aiming to remove barriers to delivering local climate action in the UK.

The recent government Net Zero Strategy offers some new insights with regards to the role of local authorities by acknowledging that:

- devolved and local government play an essential role in meeting national net zero ambitions. Across the UK many places have already made great strides towards our net zero future, having set their own targets and for meeting local net zero goals.
- the combination of devolved, local, and regional authorities' legal powers, assets, access to targeted funding, local knowledge, and relationships with stakeholders enables them to drive local progress towards net zero. Not only does local government drive action directly, but it also plays a key role in communicating with, and inspiring action by, local businesses, communities, and civil society.
- there are currently no net zero statutory targets on local authorities or communities in the UK, but that government do not believe that a new general statutory requirement is needed. This is because of the existing level of local commitment with the sector, and because it is difficult to create a uniform requirement that reflects the diversity of barriers and opportunities local places experience. However, government do understand that there is a real need to ensure local leaders across the board are supported by enhancing the capacity and capability of local areas to deliver net zero, coordinating engagement with local authorities, and clarifying expectations at a national level to accelerate local progress towards net zero.
- central and local government will need to work closely together to deliver net zero and our interim carbon budgets. Government analysis suggests that over 30% of the emissions reductions needed across all sectors to deliver on Carbon Budget 6 target rely on local authority involvement to some degree.

The Strategy recognises that to support all local government in developing and delivering their net zero delivery plans, government action is needed in three key areas:

- Setting clearer expectations for local places, clarifying how the partnership with local government should work, and considering how action at national, regional, local, and community levels fits together to tackle the emission and climate risk challenges we face, and the wider benefits the transition brings.
- Providing resources for local places to deliver stronger contributions to national net zero targets, across dedicated funding streams for net zero and non-ringfenced funding, noting the number of broader priorities on which local government needs to deliver.
- Building capacity and capability at the local level to support ambition and share best practice, while also providing support in areas that may not have made as much progress to date.

To act effectively across these areas, and for local government to translate national goals into local action, government will build on existing engagement to improve the way local and national government collaborate on net zero as follows:

- The Department for Business, Energy and Industrial Strategy (BEIS) will take overall responsibility for improving coordination with local government and other local actors on the effective design and delivery of local net zero policies, as part of the Department's overall responsibility and wider leadership on delivering net zero.
- Other departments will continue to lead on their specific policy areas such as Department for Transport on the decarbonisation of transport.
- Intend to build on many of the existing ways of working together to provide more consistency and clarity over roles and responsibilities between national and local government. We will do this by establishing a Local Net Zero Forum to ensure that there is direct input from local leaders. Chaired by BEIS, the Forum will be cross departmental and bring together national and local government senior officials on a regular basis to discuss policy and delivery options on net zero. The forum will build on our current engagement mechanisms through the representative bodies such as the Local Government Association (LGA), Association for Public Service

Excellence (APSE), Core Cities and the Association of Directors of Environment, Economy, Planning & Transport (ADEPT). The creation of the Forum also draws on the recommendations for a policy framework put forward by member network UK100. The Forum will support the establishment of clearer delivery roles for local government and provide a single engagement route into HM Government in a coordinated and coherent way.

The Net Zero Strategy also points out that, alongside local authorities, businesses have significant power to drive change towards achieving our domestic net zero goal. The approach to supporting businesses to deliver this change will need to be differentiated by business size and sector, as these factors will influence the ease with which a net zero target and other relevant actions can be adopted. Significant numbers of companies are signing up to science based targets alongside sector specific ambition being put forward already.

With businesses accounting for 18% of UK territorial emissions encouraging them to take action to reduce their emissions is important. But just as vital is the role businesses are playing in designing the ground-breaking new technologies, world leading products and innovative approaches are needed to develop the low carbon economy and enable others to reach net zero. Collaboration across sectors and value chains will enable faster innovation faster, create stronger incentives for investment and drive down costs for low carbon alternatives through the global mechanisms laid out in the Paris Agreement.

Through the small business campaign, government has taken an important step towards making net zero relevant to SMEs by helping them access the support they need. Government will continue to support UK businesses to meet their net zero commitments, including exploring a government-led digital advice service that consolidates and simplifies advice, funding, and other support on net zero.

For larger businesses, government want to ensure businesses are aware of their energy and carbon use so they can take action towards reaching net zero. Climate risks must be assessed and disclosed through the Task Force on Climate-related Finance Disclosures (TCFD). This is complemented by Streamlined Energy and Carbon Reporting, which requires energy and emissions reporting in all UK large businesses to improve awareness of energy costs. Government also requires large businesses and their corporate groups to carry out a broader assessment of their energy use from buildings, transport and industrial processes every 4 years under the Energy Savings Opportunity Scheme (ESOS), which is designed to identify practicable and cost-effective energy saving opportunities. In the future, building users and decision makers will be able to compare the performance of their buildings to other similar buildings using a performance-based energy rating to support targeted investments.

Building on the central government approach, Lancashire authorities will need work closely with central government as well as with businesses within the region in order to achieve net zero.

1.2.4. The cost of Net Zero

Lancashire authorities must recognise that Net Zero comes at a cost but there are many benefits that can arise from the transformative investments that are necessary, considering the repercussions of the ongoing COVID pandemic in particular.

The Climate Change Committee's 6th Carbon Budget[18] notes that the economic and social context for climate action has changed in important ways since the UK set its Net Zero 2050 target:

- The COVID-19 pandemic and measures taken in response to it have sharply changed the economic backdrop in the UK and globally. In the UK, 750,000 payroll jobs have been lost (with millions more supported by the Jobs Retention Scheme), GDP has fallen (e.g. by 9% from August 2019 to August 2020) and business investment has dropped by around a quarter despite record low interest rates. These effects imply considerable spare capacity in the economy and therefore that increasing investment could support the UK's recovery.
- The new Net Zero commitments by countries and businesses clearly demonstrate momentum building towards more climate action. This should drive down low-carbon technology costs that themselves can enable further commitments to action. These commitments are a demonstration that future markets lie with low-carbon products. Business models that are not compatible with a Net Zero future are increasingly risky.

- Costs of key low-carbon technologies have continued to fall. For example, the contracted price for electricity generated by offshore wind fell again in the latest auction round by around a third compared to the previous auction two years earlier. These cost reductions are driven by scale manufacturing, investor confidence and 'learning-by-doing' during deployment within an effective low-risk policy framework. These effects can be replicated in other areas of the economy, as markets scale up globally and the costs of low-carbon technologies continue to fall.

This background favours a decisive transition for the UK, quickly switching resources away from high-carbon activity and into low-carbon investments with lower operating costs than high-carbon alternatives.

The report indicates that low carbon investment must scale up to £50 billion each year to deliver Net Zero, supporting the UK's economic recovery over the next decade. This investment generates substantial fuel savings, as cleaner, more-efficient technologies replace their fossil fuelled predecessors. In time, these savings cancel out the investment costs entirely with a central estimate for costs of below 1% of GDP throughout the next 30 years.

The Net Zero Strategy further recognises that while there are significant costs in reaching net zero, the cost of inaction is much higher. The Office for Budget Responsibility's[19] recent report showed unmitigated climate change resulting in "debt spiralling up to around 290% of GDP thanks to the cost of adapting to an ever hotter climate and of more frequent and more costly economic shocks". In addition to reducing the risks of catastrophic climate change, net zero will also bring significant benefits and opportunities, such as economic growth and jobs in new green sectors, reducing air pollution with benefits for health, and enhancing biodiversity. It is also expected costs to continue to fall as green technology advances, industries decarbonise, and private sector investment grows. Most costs are the additional capital costs (and associated financing) of low carbon technologies, although significant fuel savings help to offset these. Government estimates that the net cost, excluding air quality and emissions savings benefits, will be equivalent to 1-2% of GDP in 2050.

1.3. Purpose of this document

This document outlines the means that Lancashire region and authorities can use to meet climate emergency goals, through reducing carbon emissions over time and additionally considering removals from the atmosphere of residual emissions also over time to meet Net Zero. The document is structured as follows:

- Scope of the study, scenarios and cross-sectoral approach (Section 2)
- Summary information from the Baseline emissions assessment (Section 3)
- Presentation and discussion of Tyndall centre carbon budgets (Section 4)
- Summary information from the BAU assessment (Section 5)
- Presentation of measures and potential scale of emissions reduction for Transport (Section 6)
- Presentation of measures and potential scale of emissions reduction for Buildings (Section 7)
- Presentation of measures and potential scale of emissions reduction for Large Industrial Installations (Section 8)
- Presentation of measures and potential scale of residual emissions removals for LULUCF (Section 9)
- Presentation and discussion of Net Zero by 2030 pathway (Section 10)
- Presentation and discussion of 68% reduction by 2030 pathway (Section 11)
- Presentation and discussion of 78% reduction by 2035 pathway (Section 12)
- Presentation and discussion of extending pathways to 2050 under two scenarios (Section 13)
- Presentation and discussion of local authority pathways (Section 14)
- Discussion on the issues associated with achieving Net Zero in Lancashire (Section 15)
- Conclusions and Recommendations (Section 16)

The following appendices to this document are provided (in a separate volume):

[19] https://obr.uk/frr/fiscal-risks-report-july-2021/

- Evidence Base Review (Appendix A)
- ‘Bottom-up baseline: methodology and calculations (Appendix B)
- Deriving the Business as Usual scenario (Appendix C)
- ‘Bottom-up’ carbon baseline results per key sector (Appendix D)
- Deriving pathway options: methodology and calculations (Appendix E)
- Building heat grant schemes (Appendix F)

1.4. Other relevant studies

Three other studies have been commissioned in parallel to this study are as follows:

- Renewable Energy Deployment Opportunities Across Lancashire to 2030
- Lancashire Climate Resilience Study
- Lancashire State of the Environment Report 2021

Elements of these studies have informed the development of this Net Zero Pathways Options Study where relevant.

2. Scope of the study and cross-sectoral approach

2.1. Target pathways

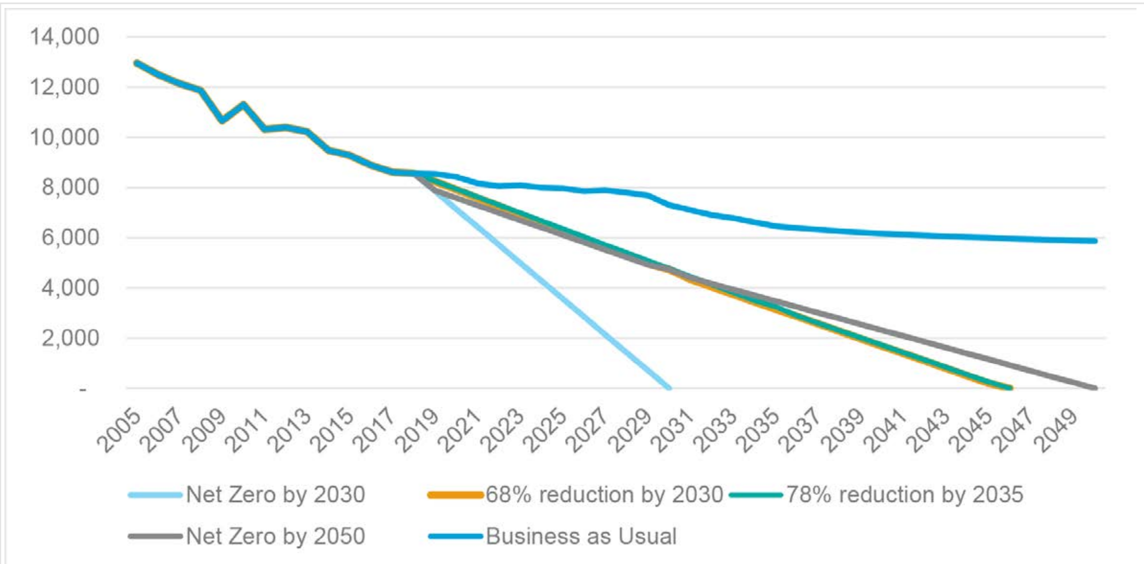
The three targets under consideration (against the national target of Net Zero by 2050) are:

- Net Zero emissions by 2030 (100% reduction relative to 1990 levels);
- 68% reduction of emissions by 2030 (relative to 1990 levels); and
- 78% reduction of emissions by 2035 (relative to 1990 levels).

Carbon reduction pathways to reach these targets for the Lancashire region are sketched out in Figure 2-1 below, with historical and baseline emissions and the 'Business as Usual' scenario included for reference (see Sections 3 and 5 below for further detail). These target pathways are shown here as the hypothetical straight-line reductions that would be required to meet the targets. The lines provide a useful reference when presented graphically against the aggregate savings over time achieved by a set of proposed carbon reduction measures and have been used to guide the development of Lancashire's pathways in this report.

The pathway followed to reach each carbon reduction target is important as it will determine the total cumulative amount of carbon emissions released between now and 2050. As carbon dioxide and other greenhouse gases remain in the atmosphere causing warming for decades, cumulative emissions are the key influence on climate change and limiting their total is more important than meeting individual annual emissions reduction targets. Pathways which slope downwards steeply and then level off as they approach the target year will be more effective in limiting climate change than curves which slope downwards at a gentler gradient.

Figure 2-1 Lancashire region's hypothetical target pathways, with BAU for reference



The working definition of Net Zero in this report is the one set out by the Climate Change Committee as follows: 'Net Zero' emissions means that following all efforts to reduce emissions, the total of active removals of Greenhouse Gas Emissions (GHG) from the atmosphere offsets any remaining emissions from the rest of the economy. The removals are expected to be important given the difficulty in entirely eliminating emissions from some sectors.

2.2. Scenarios

After 2035, this study considers two technological scenarios under which Net Zero could be achieved:

- High electrification: exploring the impact of using widespread electrification to support transport, heating, and industry decarbonisation coupled with deep decarbonisation of electricity supply.
- High hydrogen: exploring the impact of using low-carbon hydrogen more extensively, particularly for decarbonising buildings, industry and heavy vehicles.

Before 2035, only one technological scenario is considered - it is assumed that hydrogen will not be available at scale within Lancashire and therefore high electrification will provide the main decarbonisation route to moving away from fossil fuel use.

2.3. Territory

The Lancashire region under consideration in this study includes Lancashire County's 12 constituent local authorities and the two Unitary councils of Blackburn with Darwen and Blackpool, as follows:

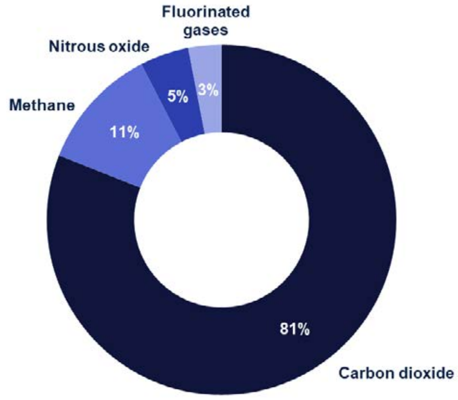
- Blackburn with Darwen
- Blackpool
- Burnley
- Chorley
- Fylde
- Hyndburn
- Lancaster
- Pendle
- Preston
- Ribble Valley
- Rossendale
- South Ribble
- West Lancashire
- Wyre

2.4. Emissions

While there are a range of GHGs which impact upon the atmosphere and have different global warming potential, such as methane (CH_4), nitrous oxide (N_2O), and sulphur hexafluoride (SF_6), CO_2 represents the bulk (80% in 2019) of the UK's contribution to climate change[20].

[20] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957887/2019_Final_greenhouse_gas_emissions_statistical_release.pdf

Figure 2-2 Breakdown of UK greenhouse gases by emissions type, 2018



Source: extracted from 2019 UK Greenhouse Gas Emissions, Final Figures[20]

This assessment relates to the mitigation of CO_2 emissions only. This is to align with the UK Government Department for Business, Energy and Industrial Strategy (BEIS) emissions regional data and the Tyndall Centre methodology for territorial carbon budgets which cover CO_2 emissions only. The following emissions are in scope:

- Scope 1 (direct) and scope 2 (electricity consumption) emissions from Buildings, Industry and Agriculture;
- 'Well to wheel' emissions from Transport[21] (i.e. end use emissions as reported in BEIS, accounting for Scope 1 tailpipe emissions, Scope 2 emissions from electricity consumption and upstream emissions associated with producing and transporting diesel and petrol); and
- Emissions and removals associated with Land Use, Land Use Change and Forestry (LULUCF) and Carbon Capture and Storage (CCS).

It is noted that the Power generation sector is considered to the extent of its contribution to scope 2 emissions only.

This assessment does not consider:

- Emissions from aviation or shipping, including any activities that take place within domestic borders (as these emissions are typically addressed by action at the national and international level);
- Emissions from waste management in territory (waste disposed of to landfill sites, waste incineration, and the treatment of wastewater). Waste management is not a key sector in terms of decarbonisation as it does not consume large amounts of energy such as the buildings, transport and industry sectors. It is estimated to have been responsible for around 4% of greenhouse gas emissions in the UK in 2019, with methane being by far the most prominent gas (accounting for 90% of emissions). The vast majority of these emissions is from landfill sites[22];
- Emissions associated with electricity generation in territory (as they relate to the Power generation sector);
- Scope 3 emissions, including embodied emissions in product/service imports (as these are generated outside the region's boundaries); and
- Emissions removals outside the region's boundaries.

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[21] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/957887/2019_Final_greenhouse_gas_emissions_statistical_release.pdf

[22] Well-to-wheel emissions consist of 'Well to tank' emissions i.e. emissions associated with producing the fuel/energy used and transporting it to the vehicle and 'Tank to wheel' emissions i.e. emissions produced in use by the vehicle

The study has modelled CO_2 emissions for the region as a whole and for each local authority.

Scope 1 emissions - CO_2 emissions from sources located within the region's boundary

Scope 2 emissions - CO_2 emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the region's boundary

Scope 3 emissions - All other CO_2 emissions that occur outside the region's boundary as a result of activities taking place within the region's boundary

2.5. Levels of influence

This assessment focuses on relevant emissions within the region's boundary for which the councils are not directly responsible and therefore doesn't attempt to cover council activities specifically. Considering Figure 2-3, this assessment focuses on opportunities associated with the following levels of influence:

- C Place Shaping
- D Showcasing
- E Partnerships
- F Involving, engaging and communicating

The only exception to this is social housing, in the rare instances that the council itself is a social landlord responsible for housing rather than a housing authority. However, the commission will identify interventions that also relate to activities under direct control of the authorities, for subsequent consideration elsewhere.

Figure 2-3 Opportunities by sphere of influence[23]

[23] A councillor's workbook on the local pathway to net zero | Local Government Association

2.6. Cross-sectoral approach to decarbonising Lancashire region emissions

The assessment takes a cross-sectoral approach in identifying pathways for decarbonising Lancashire, considering both national policy drivers and regional/local interventions as set out in Figure 2-4.

An evidence base review was undertaken to inform this approach (see Appendix A). Specialist reviews for the various sectors in scope (Transport, Domestic Buildings, Industry & Commercial and Carbon Removals - as set out in Appendices C, D, E and F) identified relevant interventions and informed the development and modelling of the baseline (Section 3), Business as Usual scenario (Section 5), Target Pathway Options (Sections 10, 11,12, 13 and 14) and Pathways to Achieving Net Zero (Section 15).

2.7. Consideration of national target of Net Zero emissions by 2050

The UK Government sets out the pathway towards net zero emissions by 2050 in its Net Zero Strategy[24]. Table 2-1 (adapted from the strategy) shows the level of deployment required in 2050 in key sectors. These measures and emissions reductions have been considered in the Lancashire pathway options analysis in order to achieve Net Zero by an earlier date than 2050, apart from Direct Air Capture due to it being an unproven technology within the timeframes under analysis.

Table 2-1 – Deployment levels in 2050 in the UK Net Zero Strategy

Sector	Deployment assumptions	Unit	2019	2050 illustrative range
Industry	Low carbon fuel switching*	TWh	110	190 - 210
	Resource and energy efficiency savings	$MtCO_2e$	0	13
	Industry demand for industrial CCUS (not including BECCS)	$MtCO_2e$	0	6-9
Fuel Supply	Low carbon hydrogen production	TWh	0	240 - 500
	Steam methane reformation with CCS as a percentage of total hydrogen generation	%	0	0-75%
	Electrolysis as a percentage of total hydrogen generation	%	0	15-75%
	Biomass gasification with CCS as a percentage of total hydrogen generation	%	0	0-20%
Heat & Buildings	Cumulative heat pumps installed domestically	Million installations	0.2	12-28
	Cumulative homes converted to 100% hydrogen	Million homes	0	0-14
	Demand reduction as a result of energy efficiency measures	%	0	15-20%
	Low carbon fuels* consumption as a percentage of total fuel consumption in commercial buildings	%	62%	90-100%
	Heat supplied via heat networks	TWh	14	70
	Biomethane injected into gird	TWh	3	0-20
Agriculture & LULUCF	Total area of peatland under restoration	kha	n/a	380
	Yearly area of afforestation (UK)	kha	13.6	30 - 50

[24] HM Government (2021), UK Net Zero Strategy, https://www.gov.uk/government/publications/net-zero-strategy

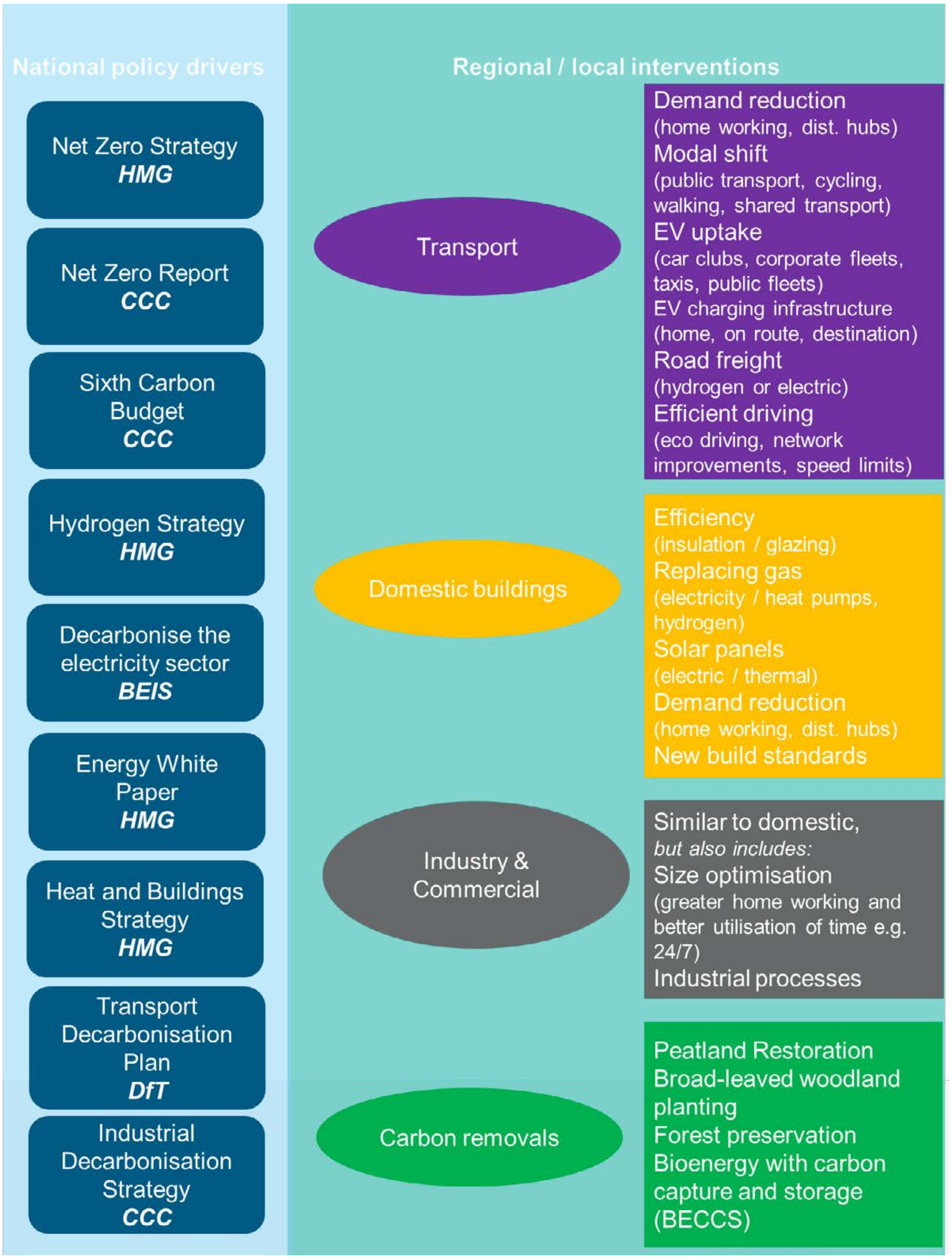
Sector	Deployment assumptions	Unit	2019	2050 illustrative range
	Yearly area of perennial energy crop and short rotation forestry planted	kha	0	53
Greenhouse Gas Removals	BECCS (all technologies)	$MtCO_2e$	0	52-58
	DACCS	$MtCO_2e$	0	18-29
Transport and IAS	ZEVs as a percentage of total car fleet	%	0.3%	96-97%
	ZEVs as a percentage of total van fleet	%	0.2%	88-90%
	ZEVs as a percentage of total HGV fleet	%	0.0%	95-97%
	ZEVs as a percentage of total bus and coach fleet	%	0.3%	91-95%
	Low carbon fuels* use in road transport as a percentage of total fuel use (in litres)	%	5%	30-60%
	SAF use in domestic and international aviation as a percentage of total fuel use (in tonnes)	%	0%	5-30%
	Low carbon fuels* use in domestic and international shipping as a percentage of total fuel use (in TWh)	%	0%	97%

** The table includes several deployment assumptions covering relevant low carbon fuels in different sectors. The low carbon fuels included are the following: electricity, biofuels, solid biomass, hydrogen, ammonia and methanol. All of these deployment assumptions include electricity and hydrogen both in the numerator and denominator, with the exception of low carbon fuels used in road transport (from which electricity and hydrogen are completely excluded).*

2.8. Intervention costs

Intervention costs calculated in this report for each of the sectors are indicative only and intended to help decision making by providing an understanding of the scale of the cost implications of carbon reduction pathways. For all sectors apart from carbon removals, estimates provide simple indications of total capital costs of the measures required to achieve decarbonisation. They do not account for the offsetting saving of costs that would have been incurred in the counterfactual (e.g. purchase of petrol cars instead of electric vehicles) or impacts on operating costs. For land use mitigation (peatland and woodland), the estimates also include private and wider social benefits. Detailed estimates of costs and savings and wider benefits of all measures will need to be developed as part of the action plan to deliver decarbonisation measures, once the region has decided on a target date to achieve Net Zero, as identified in the recommendations in the last chapter of the report (see Section 16).

Figure 2-4 Cross-sectoral approach to decarbonising Lancashire region's emissions



3. Baseline emissions

3.1. Introduction

To identify a pathway for the Lancashire region to achieve Net Zero emissions, it is critical to establish the current emissions across the constituent local authorities – the CO_2 emissions baseline. This baseline allows the authorities to understand the scale of the challenge they face in reducing emissions and identifies the key carbon emissions sources by sector and local authority, which will inform where efforts should be focussed to reduce emissions in the pathways analysis.

A CO_2 emissions baseline has been determined from historical data and broken down into county, district, unitary authority and sector. This is based on a 'top-down' level analysis drawing on data from BEIS for the Lancashire region[25]. The baseline year considered for pathways analysis is 2018 as 2019 data now available from BEIS were provisional at the time of preparing the baseline analysis for this study. Baseline emissions based on top-down level analysis are 8,568 $ktCO_2$ in the baseline year (2018).

In addition, a 'bottom-up' carbon baseline has been developed and modelled by Atkins through gathering specific emissions source data from local authorities and the region as a whole and combining such data with carbon factor multipliers to create detailed bottom-up analyses of current carbon emissions per source, closely matching the results of the 'top-down' BEIS data for each sector. The methodology that has been applied and details of the input data for these 'bottom up' baseline calculations per key sector and emission source are described in Appendix B.

The sectoral emissions obtained from 'bottom-up' calculations closely match BEIS 2018 data, hence the 'bottom-up' model is considered a meaningful basis to inform the development of interventions for each sector. The model has informed the BAU scenario (Section 5) and the different pathways analysis in Sections 10, 11, 12 and 13. The methodology applied in these simulations and details of the calculations are described in Appendices C and D.

This section presents the emissions for the region and local authority from 'top-down' analysis with BEIS data. It presents the breakdown of emissions from key sectors and breakdown of emissions by local authority. It then introduces the bottom-up emission calculations that have been used for modelling the business as usual and net zero pathway scenarios in this study.

3.2. Lancashire region 'top-down' emissions

Territorial emissions of CO_2 across the Lancashire region were 8,568 kt in the baseline year (2018), according to the 'top-down' baseline analysis (see Figure 3-1). The emissions have broken down by the following key sectors:

1. Industry and Commercial buildings and installations (Electricity, Gas, Other Fuels and Large Industrial Installations): 2868 $ktCO_2$
2. Agriculture: 98 $ktCO_2$
3. Domestic buildings (Electricity, Gas and Other Fuels): 2324 $ktCO_2$
4. Transport (A Roads, Motorways, Minor Roads, Railways and Other Transport): 2869 $ktCO_2$
5. Land Use, Land Use Change and Forestry – LULUCF: 409 $ktCO_2$

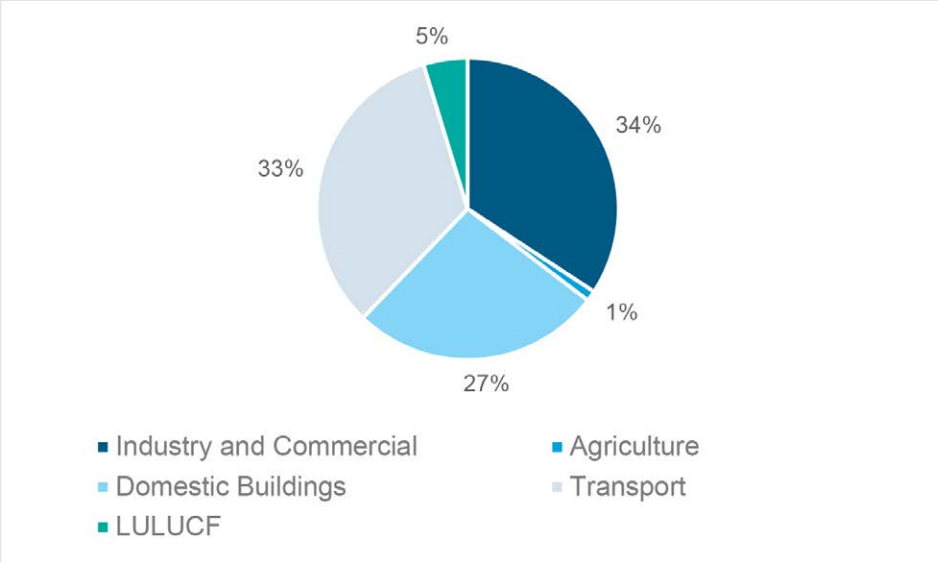
The following observations can be made:

- CO_2 emissions break down relatively evenly across three key sectors – Transport (33%), Domestic Buildings (27%) and Industry & Commercial (33%);

[25] The BEIS 'Emissions of CO_2 for Local Authority areas dataset' is the key data source used to establish the emissions baseline. The BEIS dataset covers Scope 1 (direct) and scope 2 (electricity consumption) emissions from transport, domestic buildings, the industrial/commercial sector, agriculture and Land Use, Land Use Change and Forestry (LULUCF).

- Agriculture CO_2 emissions represent an extremely small proportion of CO_2 emissions in territory (1%) and for this reason have been excluded from the pathway options analysis; and
- Nationally, LULUCF operates as a 'carbon sink' on a net basis, this is not true in Lancashire due to extensive use of land for crops and associated emissions[26]. As for agriculture, LULUCF emissions represent a small proportion of the emissions (5%) and as such have been excluded from the pathway options analysis. The LULUCF sector is considered only insofar as it offers potential carbon removals through nature-based solutions to achieve Net Zero.

Figure 3-1 - Breakdown of CO_2 emissions (2018) in the Lancashire region by emissions source from top-down analysis



3.3. Local authority area 'top-down' emissions

3.3.1. Historic emissions

The historic total carbon emissions for each local authority area from 2005 – 2018 are illustrated in Figure 3-2.

The figure shows that generally emissions have reduced across all local authorities over the last 14 years. Ribble Valley has seen a dramatic emissions reduction but is also quite variable over time. Similarly, Blackburn with Darwen has also seen a large overall reduction in emissions between 2005 and 2018.

3.3.2. Baseline year emissions

The 2018 emissions baseline, broken down per local authority and sector, is illustrated in Figure 3-3 and detailed in Table 3-1.

CO_2 emissions exhibit wide variations due to differences in population numbers, geography; the extent of the local road network and the structure of local industrial and commercial sector. Across the broader Lancashire region, total CO_2 emissions range from a low of 361.7 $ktCO_2$ in Rossendale to a maximum of 916.7 $ktCO_2$ in Ribble Valley. Lancaster and West Lancashire both have emissions of over 750 $ktCO_2$.

[26] Land use, land use change and forestry (LULUCF) is a net emitter: forests and grassland sequester CO_2, but cropland usage generates slightly more emissions.

The key takeaways from this analysis are as follows:

- Across the majority of the local authorities, Transport is the largest emissions source, followed by Industry & Commercial and Domestic, respectively.
- Agriculture and LULUCF are generally very small emissions sources accounting together for less than 6% of total emissions; in some cases, there are net negative emissions from LULUCF, due to the availability of carbon sinks to remove CO_2 from the atmosphere.
- Ribble Valley has the largest proportion of emissions (78%) coming from Industry & Commercial.
- West Lancashire has the largest proportion of emissions (25%) coming from LULUCF; Ribble Valley is the largest net emissions sink (-29.7 ktCO_2; -3%).
- Lancaster has the largest proportion of emissions (2%) coming from Agriculture.
- Blackpool has the largest proportion of emissions (208.4 ktCO_2; 43%) coming from Domestic buildings across all fuels; although Blackburn with Darwen has the highest level of gross emissions in Domestic buildings category (213.7 ktCO_2).
- Chorley has the largest proportion of emissions (52%) coming from Transport.

Figure 3-2 – Lancashire region historic emissions by Local Authority (2005-18)

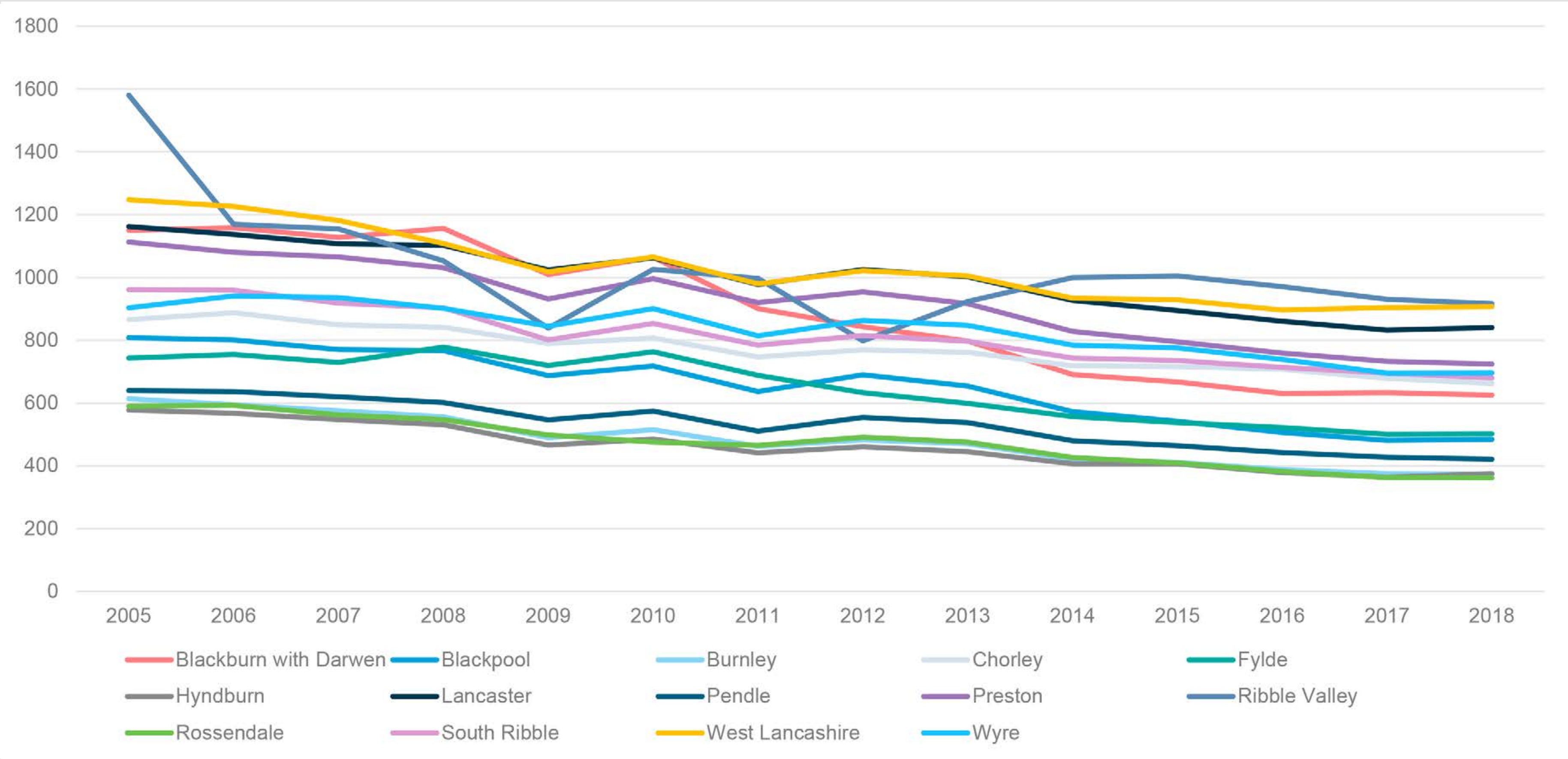


Figure 3-3 - Carbon Emissions Sources per Local Authority and sector (2018)

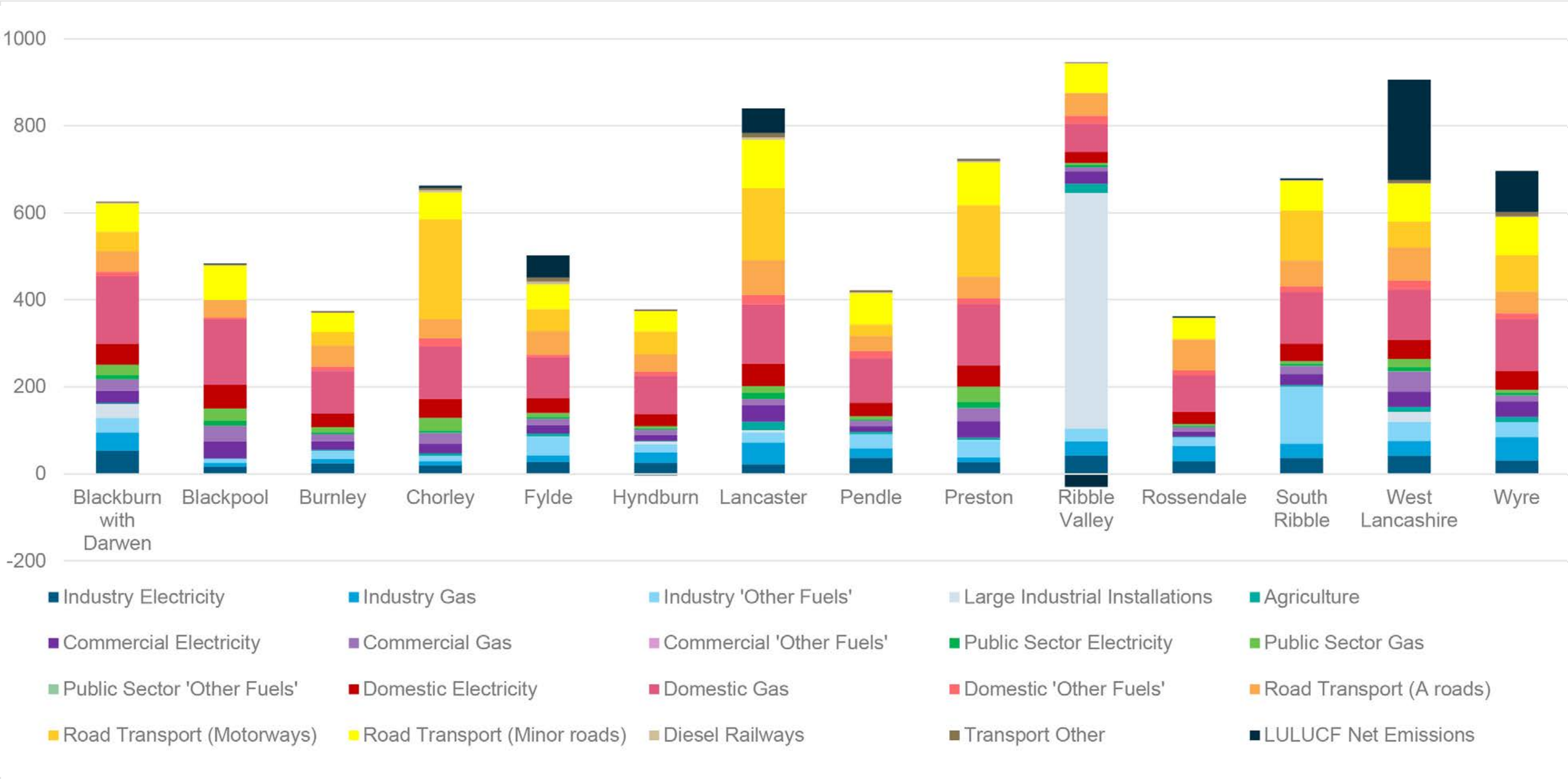


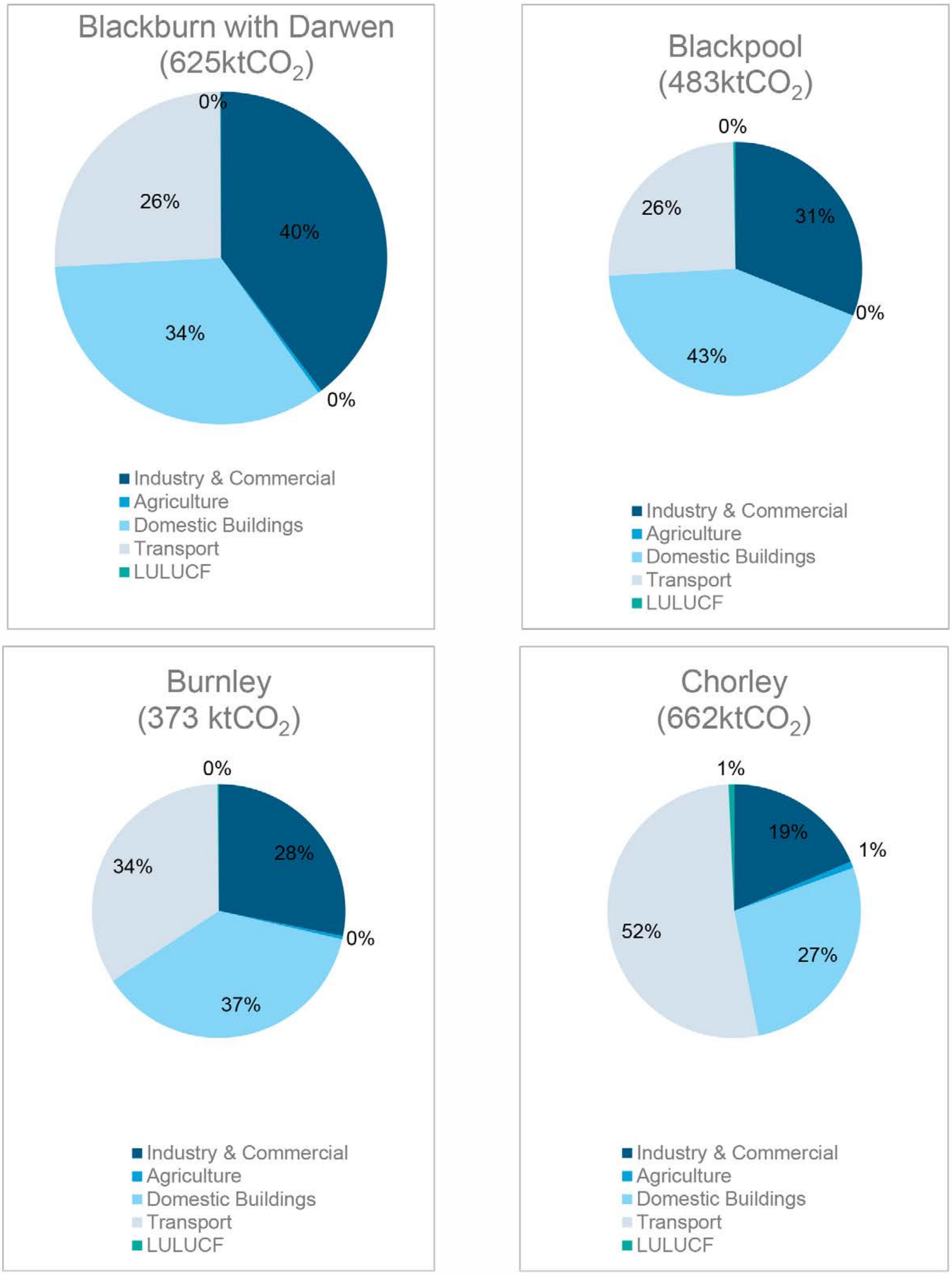
Table 3-1 - Detailed breakdown of baseline emissions results per local authority based on BEIS data (2018)

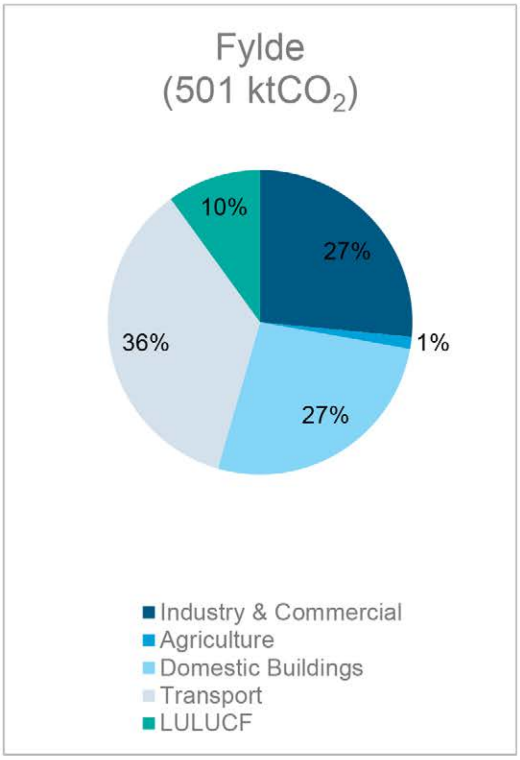
	Emissions Source ($ktCO_2$)														
Local Authority	Industry, Commercial Public Sector Electricity	Industry, Commercial ,Public Sector Gas	Large Industrial Installations	Industrial, Commercial, Public Sector Other Fuels	Agriculture	Domestic Electricity	Domestic Gas	Domestic 'Other Fuels'	Road Transport (A roads)	Road Transport (Motorways)	Road Transport (Minor Roads)	Diesel Railways	Transport Other	LULUCF (Net Emissions)	Local Authority Total
Blackburn with Darwen	91.0	92.2	31.3	34.0	2.2	47.7	156.2	9.8	47.2	45.0	65.1	1.0	3.2	-0.5	625.2
Blackpool	67.4	71.9	-	10.7	0.3	54.2	151.0	3.2	40.5	0.4	78.9	0.7	3.2	1.3	483.8
Burnley	48.5	38.0	0.1	19.1	1.6	30.8	98.8	9.6	48.2	31.1	44.4	0.7	3.5	-0.6	373.8
Chorley	46.2	64.1	0.1	12.9	5.6	42.0	121.8	17.9	44.8	230.1	61.5	4.8	5.7	4.7	662.2
Fylde	52.1	37.3	0.7	43.0	6.4	34.1	94.1	5.5	54.5	51.2	55.9	7.0	9.7	50.1	501.7
Hyndburn	41.7	42.3	5.9	18.5	1.7	26.9	88.7	9.1	39.9	52.5	46.6	0.4	4.0	-3.2	375.0
Lancaster	73.6	79.3	5.7	23.3	19.8	51.7	136.2	21.6	79.4	165.5	112.3	4.7	10.6	56.6	840.4
Pendle	53.2	41.0	-	32.6	5.5	30.9	102.4	15.6	35.6	26.2	72.7	1.5	5.1	-1.2	421.1
Preston	79.3	73.8	0.0	41.0	5.6	49.2	141.2	13.6	49.6	164.1	98.9	2.9	4.2	0.6	724.1
Ribble Valley	76.4	45.5	541.4	30.7	20.7	25.6	64.8	18.6	52.0	-	67.5	2.5	0.7	-29.7	916.7
Rossendale	43.1	50.0	0.0	20.1	1.7	26.7	85.0	11.3	69.2	3.3	47.7	-	1.0	2.7	361.7
South Ribble	67.2	56.9	0.0	131.2	3.5	40.1	118.1	13.5	59.7	114.6	68.7	1.0	1.1	3.9	679.6
West Lancashire	86.3	99.2	21.8	45.5	11.6	43.3	116.0	21.3	75.2	59.9	86.6	1.8	7.3	230.6	906.5
Wyre	71.5	74.0	0.0	35.5	11.7	43.2	119.4	13.6	50.2	83.9	87.7	1.4	10.6	93.3	695.9
Lancashire Total	897.6	865.6	607.0	497.9	97.9	546.4	1,593.7	184.2	746.0	1,027.7	994.4	30.5	70.0	408.6	8,567.7

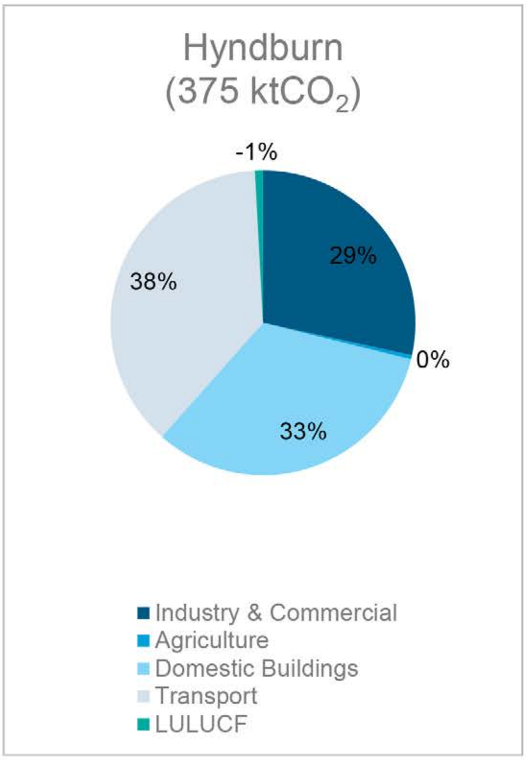
3.3.3. Breakdown of ‘top-down’ territorial emissions by Local Authority area

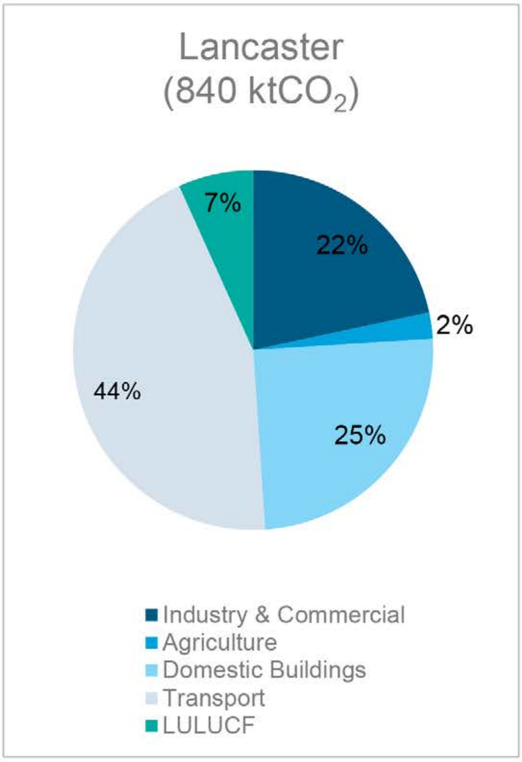
There is a diverse array of emissions sources across the county. The breakdown of the territorial emissions in 2018 for each of the local authorities based on top-down analysis (BEIS) data is presented below.

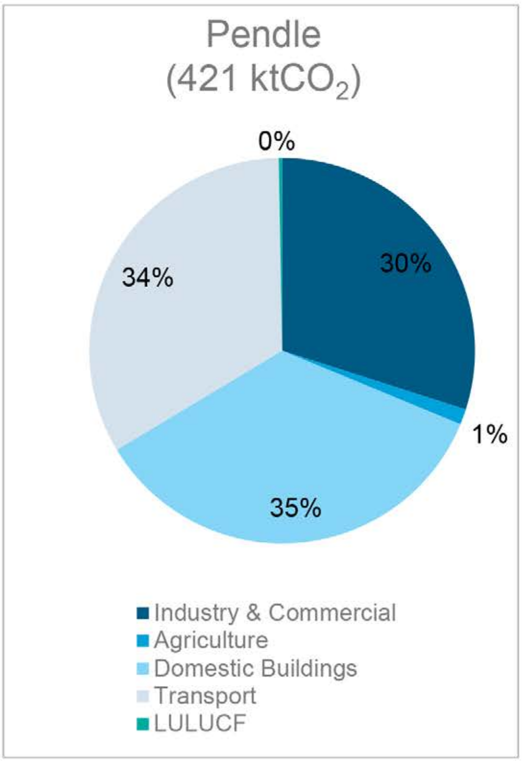
Figure 3-4 – Emissions Source Analysis by Local Authority and by sector

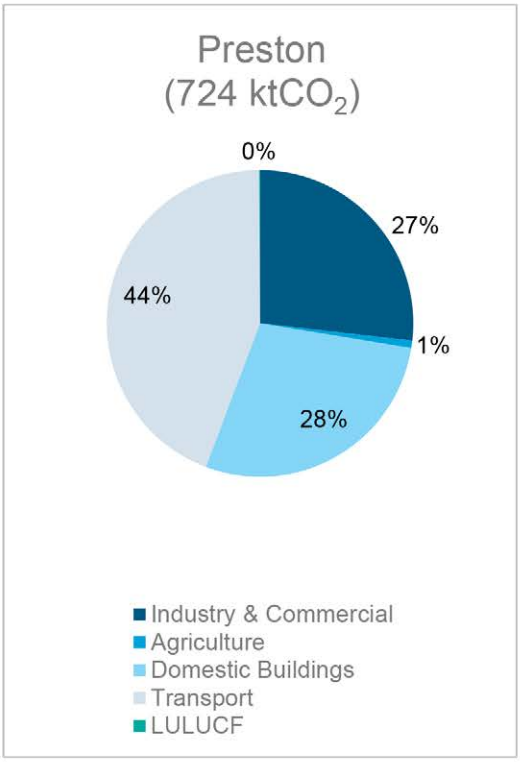


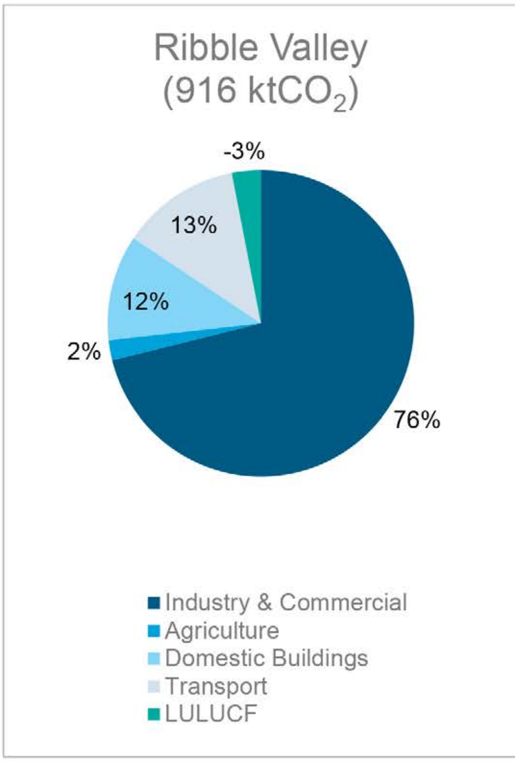

Fylde
(501 ktCO2)
10%
27%
1%
36%
27%
Industry & Commercial
Agriculture
Domestic Buildings
Transport
LULUCF

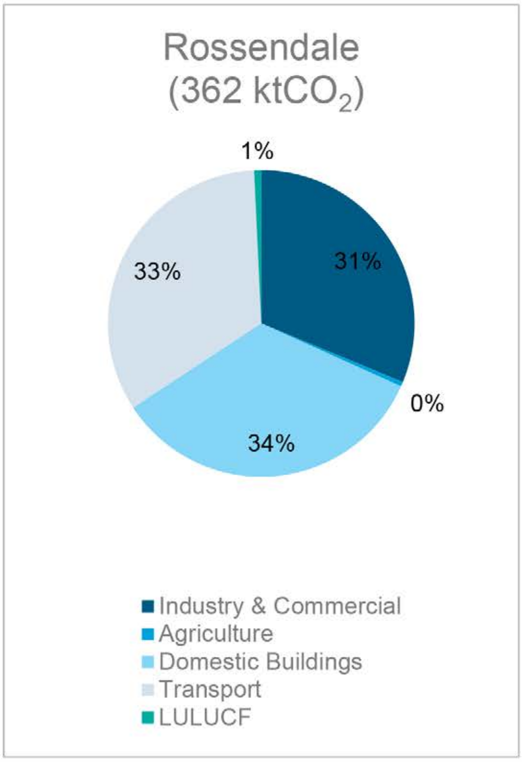

Hyndburn
(375 ktCO2)
-1%
29%
38%
0%
33%
Industry & Commercial
Agriculture
Domestic Buildings
Transport
LULUCF

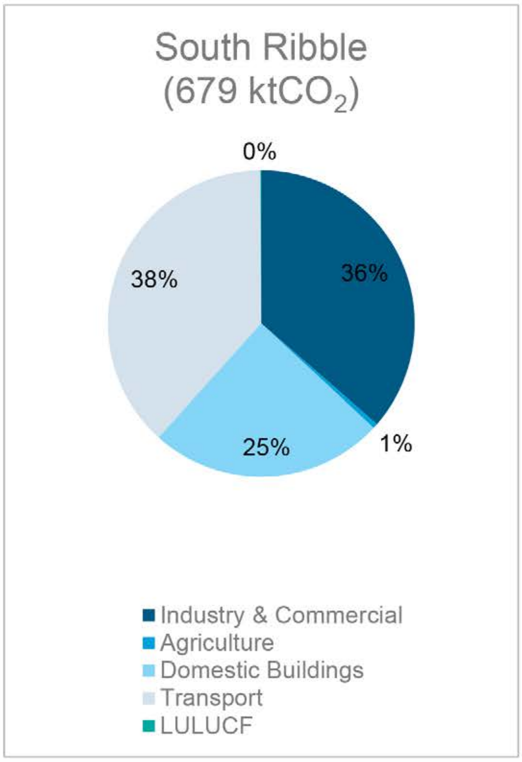

Lancaster
(840 ktCO2)
7%
22%
2%
44%
25%
Industry & Commercial
Agriculture
Domestic Buildings
Transport
LULUCF

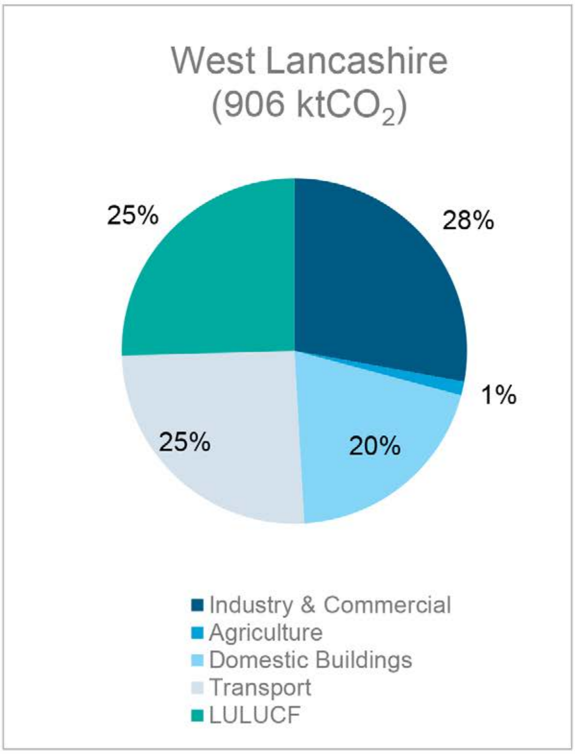

Pendle
(421 ktCO2)
0%
30%
34%
1%
35%
Industry & Commercial
Agriculture
Domestic Buildings
Transport
LULUCF

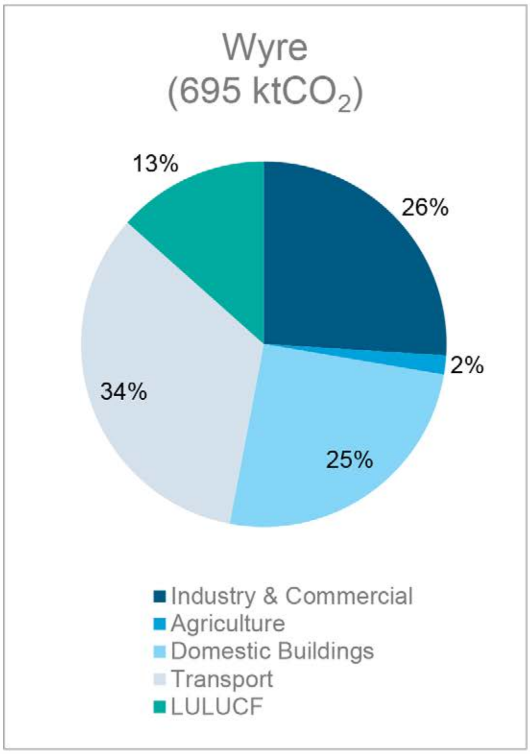

Preston
(724 ktCO2)
0%
27%
1%
28%
44%
Industry & Commercial
Agriculture
Domestic Buildings
Transport
LULUCF


Ribble Valley
(916 ktCO2)
-3%
13%
12%
2%
76%
Industry & Commercial
Agriculture
Domestic Buildings
Transport
LULUCF


Rossendale
(362 ktCO2)
1%
31%
0%
34%
33%
Industry & Commercial
Agriculture
Domestic Buildings
Transport
LULUCF


South Ribble
(679 ktCO2)
0%
36%
1%
25%
38%
Industry & Commercial
Agriculture
Domestic Buildings
Transport
LULUCF





3.4. ‘Bottom-up’ baseline emissions analysis

To establish the baseline emissions to be used for developing the business as usual scenario and net zero pathways for the region, both ‘top-down’ and ‘bottom-up’ analyses have been utilised. Further detail on the ‘bottom-up’ analysis carried out for each sector and its alignment with BEIS baseline data is presented below for each of the key sectors under consideration. As a result of comparison between the ‘bottom-up’ and ‘top-down’ analyses results, it was deemed suitable to use the BEIS ‘top-down’ baseline of 8,568 ktCO$_2$ emissions (2018) as the starting point to model emission reductions in this study.

3.4.1. Transport

The ‘bottom-up’ baseline transport emissions was estimated based on actual traffic levels in Lancashire and the figure obtained (3,120 ktCO$_2$) was within 12% of the BEIS ‘top-down’ data (2,869 ktCO$_2$). The difference is likely to be explained by minor differences in approach to speed and traffic by road type and the Well to Tank uplift applied. It was thus considered that the bottom-up baseline calculations formed a robust basis for the consideration of pathway options for emissions reductions in the Transport sector in Lancashire. To maintain consistency with the BEIS baseline data, the outputs from the transport model calculations were adjusted to match the BEIS ‘top-down’ figures and the equivalent adjustment was also made for subsequent years.

3.4.2. Buildings

For the buildings sector, the ‘bottom-up’ analysis was based on the most recent EPC certificate available for domestic buildings and DECC certificates and council tax information for non-domestic buildings. While the data within the EPCs provide a very granular understanding of existing residential buildings, it does not provide a blanket coverage of all residential buildings. This is mainly because EPCs are only regularly required for rental and newly developed properties. Like the domestic EPC data, the non-domestic EPC and DEC data does not provide a blanket coverage of all non-residential buildings either. Non-domestic EPC are only required when premises are rented or sold, or when there are changes to the number of parts used for separate occupation, whilst DEC are only necessary for public buildings above 500 m^2. Therefore, it was concluded that the data and analysis have limitations for setting a reliable baseline due to limited readily available building level data for the whole Lancashire building stock that could be gathered within the timescales for this study. For this reason, 'top-down' BEIS figures were used for setting the baseline emissions for the buildings sector. Notwithstanding, the EPC and DECC data created a useful detailed dataset of buildings at a property level for a very large proportion of Lancashire which allowed for carbon reductions associated with detailed interventions to be modelled to create pathways to Net Zero, as presented in the later sections of the report.

3.4.3. Industry

For the industrial sector, a pairing exercise was undertaken, comparing the 2018 BEIS 'Large Industrial Installations' CO_2 emissions for each local authority, with the list of sites with known locations as recorded within both the EA's Pollution Inventory and the UK National Atmospheric Emissions Inventory (NAEI). By looking at data at a site level, discrepancies were identified within some of the BEIS data, and a revised list was produced which is comparable to the BEIS 'large industrial installations', but with improved granularity at a sectoral and site by site level. Total emissions from these sites were 675,375 tonnes CO_2 in 2018, 11% higher than the 607,032 tonnes CO_2 reported by BEIS. For consistency with other sectors, the more detailed 'bottom-up' model, adjusted to match the BEIS 'top-down' baseline, was used to calculate emissions reductions measures to inform the development of pathway options.

3.4.4. LULUCF

The 'bottom-up' analysis of LULUCF CO_2 emissions was based on a single snapshot of all land use types in a year to estimate the carbon stocks for different land use categories. The emission or carbon removal rates of various land use categories depend on their age, quality and the management practices used. The central value calculated as a result of the' bottom-up' analysis of LULUCF emissions is +551,689 tCO_2e/year and this value is 35% higher than the BEIS 'top-down' baseline for LULUCF of +408,631 tCO_2 . As for the other sectors, the BEIS 'top-down' data were used for the baseline with the 'bottom-up' analysis used to inform estimates of the impacts of measures in the development of pathway options.

3.4.5. Agriculture

We note that this sector represents an extremely small proportion of CO_2 emissions in territory (1%) and for this reason has been excluded from the pathway options analysis (see Section 3.2). However, the contribution from this sector was accounted for and assumed to be constant to 2050 as part of the derivation of the Business as Usual scenario, using the 'top-down' BEIS baseline data.

3.4.6. Resulting baseline emissions trajectory (1990-2018)

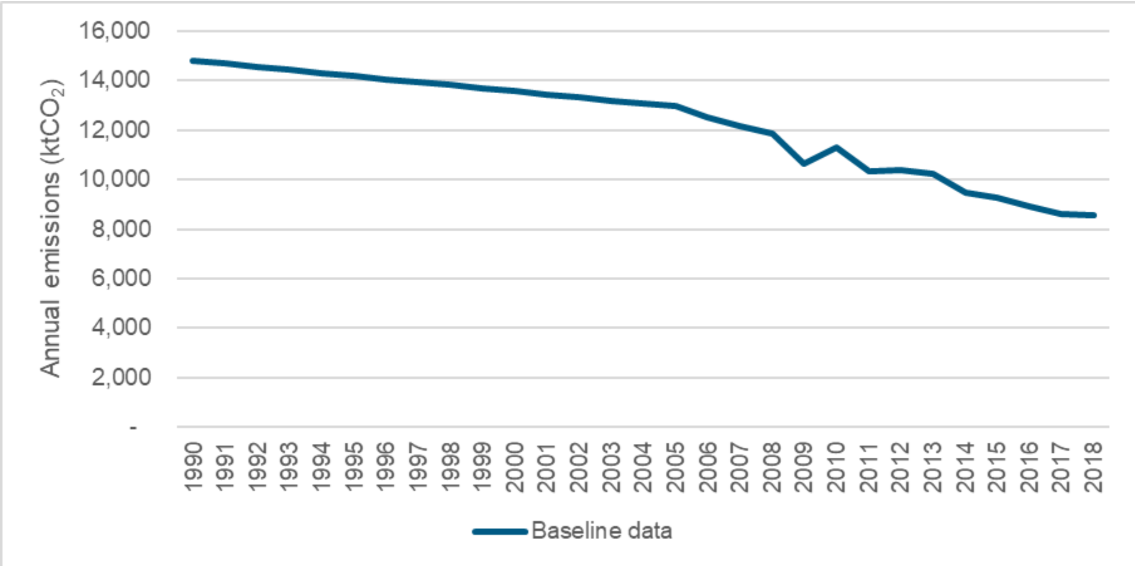
The resulting baseline emissions trajectory between 1990-2018 which has been used for developing the Business as Usual scenario and Net Zero pathways is presented in Figure 3-5. BEIS data has been used for the 2005-2018 emissions trajectory for Lancashire. Emissions have decreased by 34% between 2005 and 2018. This may be due to the reduction in the number of industrial sites giving rise to emissions, particularly so for Blackburn with Darwen which has reduced from six in 2005 to two in 2018. Other local factors include the impacts of industrial facilities improving the efficiency of their processes, and via the closure and reduction in outputs from larger industrial sites, e.g. closure of the Kruger paper mill near Belmont in 2007 and the DS Smith Paper Ltd mill in Blackburn with Darwen in 2012.[27]

Emissions in 1990 were estimated as 14,807 $ktCO_2$ through a back-projection based on the 12.5% reduction achieved nationally from 1990-2005, according to the CCC Net Zero report[28]. This illustrates a reduction in emissions at around 42% between 1990 and 2018. National factors driving these changes include changes to the energy mix as less carbon intensive fuels are used with less coal used and more gas used. In 1990 coal

[27] State of the Environment Report for Lancashire (2021)
[28] https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

accounted for 31% of UK energy consumption compared to just 3% in 2019, with the associated emissions from coal falling by 90% over the same period. There also have been reductions in emissions at large scale energy users as a result of both the EU Emissions Trading Scheme and the now withdrawn UK Carbon Reduction Commitment Energy Efficiency Scheme.[27]

Figure 3-5 – Baseline emissions trajectory for the Lancashire region (1990-2018)



4. Tyndall Centre carbon budget and pathway

4.1. Carbon budgets

A carbon budget is a key metric in considering the rate and pace of decarbonisation required to meet climate change commitments. A budget represents the cumulative amount of carbon dioxide (CO_2) emissions permitted over a period of time to keep within a certain temperature threshold. Signatory countries to the Paris Agreement committed to limiting cumulative emissions to global carbon budgets to pursue global temperature targets of well below 2°C warming.

The targets being considered for this report are based on the CCC's view of the carbon budget that represents the upper limit of emissions that the UK's can release before 2050 if it is to make a fair contribution to the Paris Agreement objectives. The overall budget is converted to interim 5 year budgets. The targets for annual emissions levels provide an important indication of the scale of change associated with meeting the budgets but the key requirement for meeting climate commitments is for carbon budgets to be met.

However, as noted in Section 1, it is important to recognise that other climate scientists take a different view on the carbon budget available to the UK. The Tyndall Centre for Climate Change Research (the Tyndall Centre) identifies a more limited budget is available to the UK once issues of equity are taken into account. This implies the need for more rapid decarbonisation than the levels identified by the targets considered in this study.

A pathway based on the Tyndall Centre carbon budget for Lancashire has therefore been included in the analysis to illustrate a high ambition decarbonisation pathway as the basis for comparison with the pathways considered. The following sections provide more detail on the Tyndall Centre carbon budgets.

4.2. Tyndall Centre maximum local authority cumulative budgets

The Tyndall Centre online carbon budgeting tool[29] provides estimated carbon budgets for local authorities in the UK. To provide the budgets, the Tyndall Centre has apportioned Intergovernmental Panel on Climate Change (IPCC)[30] global carbon budgets (cumulative quantity of CO_2 emissions from all anthropogenic sources to maintain warming well below 2°C) to local authorities until 2100. By combining emissions baselines with the allocated carbon budget for local authorities, an understanding can be gained of how long that budget will last, at current emission rates, in the context of the UK's commitments.

Carbon budget information for the year 2020 has been used as this is the most recent data available. As per the Tyndall Centre's methodology, the carbon budgets in this report are based on 'translating the well below 2°C and pursuing 1.5°C global temperature target and equity principles in the United Nations Paris Agreement to a national UK carbon budget. The UK budget is then split between sub-national areas using different allocation regimes.

The allocation regimes, used by the Tyndall Centre to apportion the UK carbon budget down to local authority level are as follows:

1. Grandparenting: Allocates carbon budgets on the basis of recent emissions data from local authorities
2. Population split: Shares the carbon budget equally across the UK on a per capita basis
3. Gross Value Add (GVA) split: Carbon budget is apportioned based on local authorities' proportion of UK GVA

The Tyndall Centre recommends that carbon budgets should be based on the grandparenting allocation regime, suggesting it is the most appropriate and widely applicable regime within the UK.

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29 Local and Regional Implications of the United Nations Paris Agreement on Climate Change (manchester.ac.uk)
30 https://www.ipcc.ch/

The apportioned carbon budgets for Lancashire's local authorities are detailed in Table 4-1. The carbon budgets are then combined with 2018 baseline emissions to establish a future emissions budget outlook in Table 4-2 below.

Table 4-1: Lancashire's Authorities Emissions Budgets (as of 2020)

Local Authority	Carbon Budget ($MtCO_2$)	Population Split Carbon Budget ($MtCO_2$)	GVA Split Carbon Budget ($MtCO_2$)
Blackburn with Darwen	**4.0**	5.1	3.7
Blackpool	**3.2**	4.9	3.1
Burnley	**2.4**	3.0	2.4
Chorley	**4.0**	3.9	2.4
Fylde	**2.9**	2.7	3.3
Hyndburn	**2.3**	2.8	1.9
Lancaster	**4.8**	4.9	3.8
Pendle	**2.6**	3.1	2.2
Preston	**4.6**	4.9	4.8
Ribble Valley	**3.4**	2.0	2.0
Rossendale	**2.4**	2.4	1.3
South Ribble	**4.3**	3.8	4.0
West Lancashire	**4.0**	3.9	3.0
Wyre	**3.8**	3.8	2.2
Lancashire Total	**48.7**	**51.2**	**40.1**

Table 4-2: Future emissions budget outlook for Lancashire

Local Authority	2018 Baseline emissions rate (tCO_2)	2020 Carbon Budget (tCO_2)	Number of years from 2020 whole budget will last at current (2018) emissions rate
Blackburn with Darwen	625,184	4,000,000	6.4
Blackpool	483,848	3,200,000	6.6
Burnley	373,773	2,400,000	6.4
Chorley	662,182	4,000,000	6.0
Fylde	501,706	2,900,000	5.8
Hyndburn	375,015	2,300,000	6.1
Lancaster	840,386	4,800,000	5.7
Pendle	421,058	2,600,000	6.2
Preston	724,103	4,600,000	6.4
Ribble Valley	916,702	3,400,000	3.7
Rossendale	361,677	2,400,000	6.6

South Ribble	679,640	4,300,000	6.3
West Lancashire	906,484	4,000,000	4.4
Wyre	695,946	3,800,000	5.5
Lancashire Total	**8,567,702**	**48,700,000**	**5.7**

The results show that the Lancashire region has an overall remaining emissions budget of 48.7 $MtCO_2$.Of the local authorities under consideration, Lancaster has the largest remaining emissions budget (4.8 $MtCO_2$) whilst Hyndburn has the smallest remaining budget (2.3 $MtCO_2$).

Combining the carbon budget information and the 2018 baseline emission rates, it is forecast that the Lancashire region's carbon budget will last a further 5.7 years (from 2020) without any emissions reductions measures. By comparison, Ribble Valley's budget will last only 3.7 years, which is the result of the large annual emissions from the local authority area, largely due to large industrial installations. On the other hand, Blackpool's carbon budget will last 6.7 years, due to relatively low annual emissions.

These results indicate the scale of the massive effort would be required to reduce emissions sufficiently to stay within the Tyndall Centre's identified carbon budgets for Lancashire.

4.3. Tyndall Centre and Climate Change Committee periodic carbon budgets

The Tyndall Centre has also derived energy CO_2 only budgets for each local authority, in the format of the 5-year carbon budget periods in the UK Climate Change Act. It is noted that to align the 2020 to 2100 carbon budget with the budget periods in the Climate Change Act, the Tyndall Centre have included estimated CO_2 emissions for each local authority for 2018 and 2019, based on BEIS provisional national emissions data for 2018 and assuming the same year on year reduction rate applied to 2019. These are presented in Table 4-3.

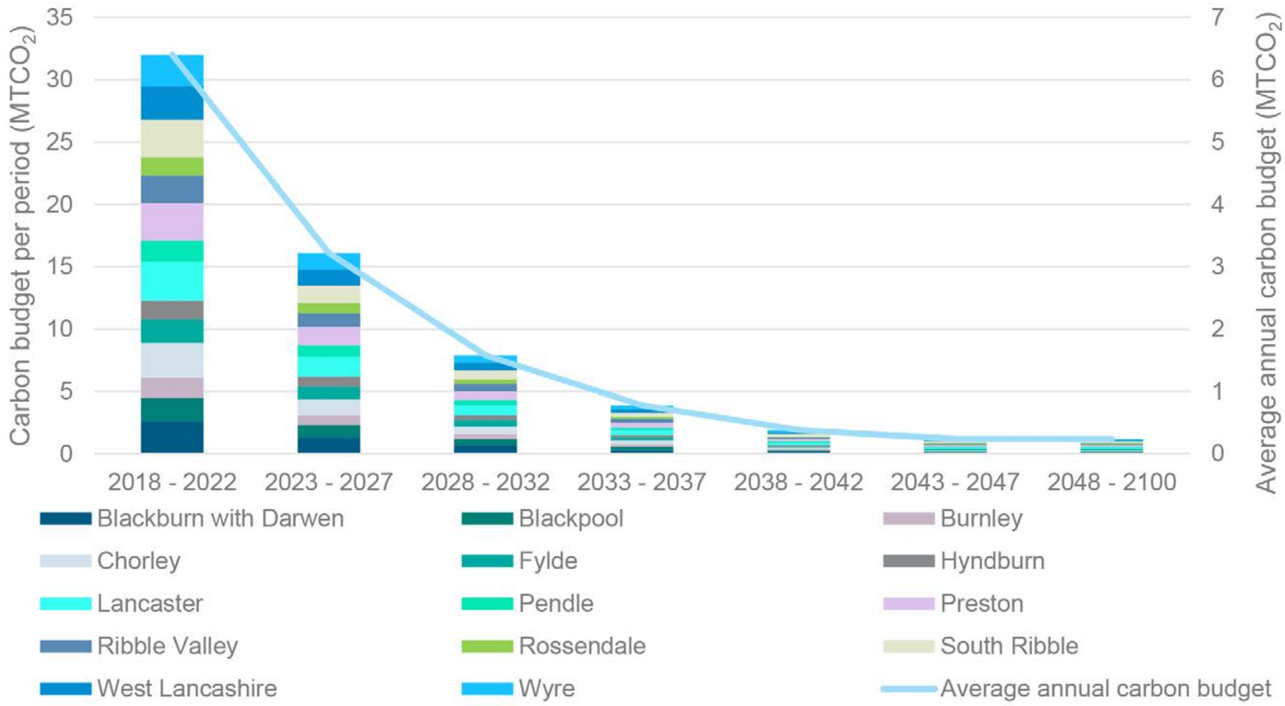
Figure 4-1 shows the Tyndall Centre pathway that has been derived for Lancashire based on the budgets set out in Table 4-3. This pathway is used in this study to illustrate an aspirational ambitious Net Zero pathway to 2050 for Lancashire.

Table 4-3: Periodic carbon budgets for Lancashire region

Local Authority	Carbon budget period/recommended carbon budget ($MtCO_2$)						
	2018 - 2022	2023 - 2027	2028 - 2032	2033 - 2037	2038 - 2042	2043 - 2047	2048 - 2100
Blackburn with Darwen	2.6	1.3	0.7	0.3	0.2	0.1	0.1
Blackpool	1.9	1.0	0.5	0.3	0.1	0.1	0.1
Burnley	1.6	0.8	0.4	0.2	0.1	0	0
Chorley	2.8	1.3	0.6	0.3	0.1	0.1	0.1
Fylde	1.9	1.0	0.5	0.2	0.1	0.1	0.1
Hyndburn	1.5	0.8	0.4	0.2	0.1	0	0
Lancaster	3.1	1.6	0.8	0.4	0.2	0.1	0.1
Pendle	1.7	0.9	0.4	0.2	0.1	0.1	0.1
Preston	3.0	1.5	0.7	0.4	0.2	0.1	0.1
Ribble Valley	2.2	1.1	0.6	0.3	0.1	0.1	0.1

Rossendale	1.5	0.8	0.4	0.2	0.1	0.1	0.1
South Ribble	3.0	1.4	0.7	0.3	0.2	0.1	0.1
West Lancashire	2.7	1.3	0.6	0.3	0.1	0.1	0.1
Wyre	2.5	1.3	0.6	0.3	0.2	0.1	0.1
Lancashire Total	**32**	**16.1**	**7.9**	**3.9**	**1.9**	**1.2**	**1.2**

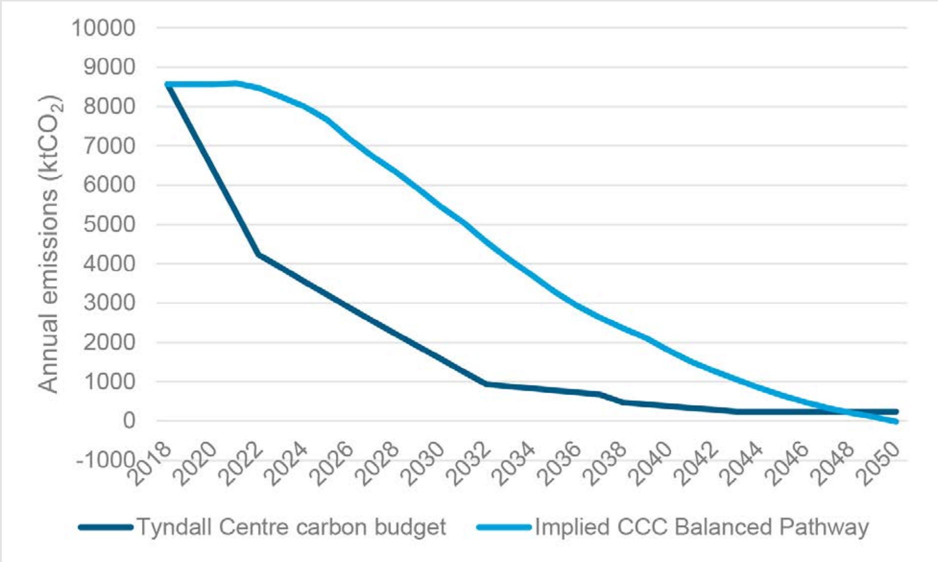
Figure 4-1 – Breakdown of Tyndall Centre budget for Lancashire



An indicative trajectory of emission reductions which meets the carbon budget targets set out by Tyndall Centre until 2050 is presented in Figure 4-2. As carbon budgets are set for periods of 5 years and there is flexibility as to how reductions occur within each period, it is noted that the pathway below provides one of a number of possible ways in which the carbon budget can be met in Lancashire. For comparison, Figure 4-2 also illustrates carbon pathway for emissions in Lancashire if they followed the CCC's Balanced Net Zero Pathway as set out in their report on the sixth carbon budget[31]. This highlights the scale of the additional challenge associated with meeting the Tyndall Centre's steeper and more ambitious pathway.

[31] Note that this representation is a slight simplification as it shows the path of the Balanced Pathway for all sectors included in the CCC analysis (including international aviation and shipping) and so does not match fully with the BEIS sectors. However, the impact on the pathway is minor and therefore the representation provides a good basis for comparison with the Tyndall Centre pathway.

Figure 4-2 – Tyndall Centre Carbon Budget Pathway and CCC Balanced Pathway applied to Lancashire



5. Business as Usual scenario

The Business as Usual (BAU) scenario to 2050 has been established with the three core sectors (Domestic Buildings, Transport and Industry & Commercial) as a focus (Figure 5-1). Given the current small contribution of the Agriculture and LULUCF sector to the total emissions, the contributions from these sectors were assumed constant to 2050.

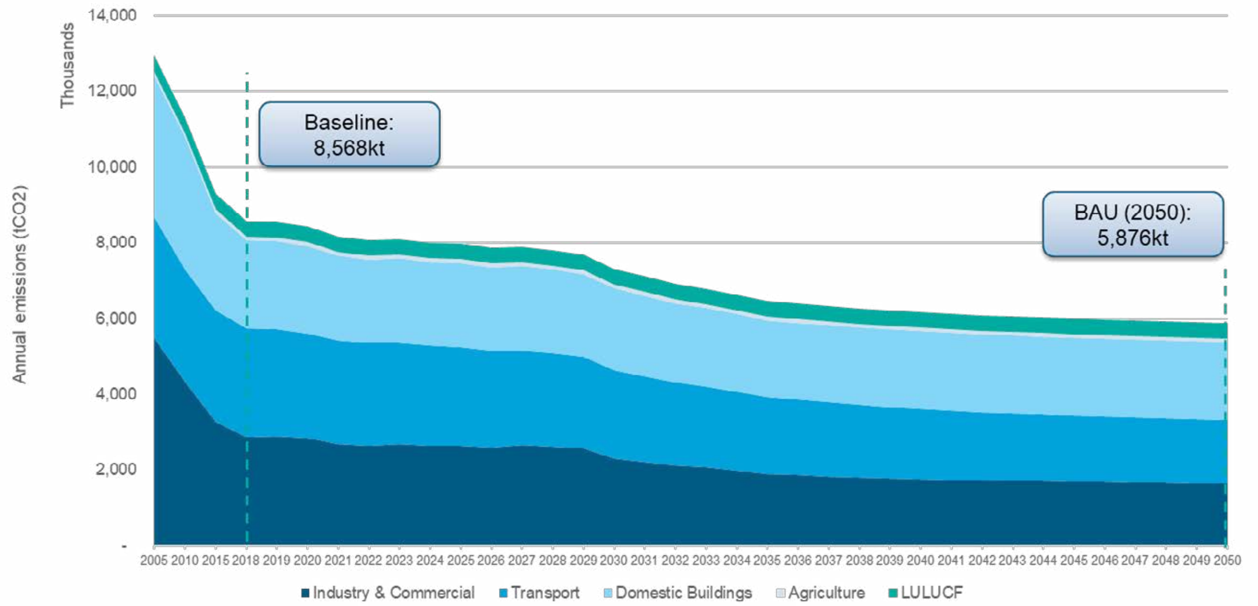
The BAU is intended to represent an emissions scenario in which no further action beyond current commitments is taken to reduce GHG emissions. The change in emissions through time from the baseline 2018 data for the three sectors in focus is forecast to result from the following factors:

- Expected growth in housing, population, traffic or economic activity (GVA);
- Policy at a national or regional level which are likely to stimulate a major change in sectors;
- Further committed major projects or schemes in the county, which will result in emissions in future years which have not been captured within the baseline; and
- Any other considerations relating to individual sectors.

An understanding of the current pipeline of committed activities has been built and any associated anticipated emissions fluctuations are included in the BAU scenario. A broad overview of any macro changes that will impact the baseline data in the future has also been considered (further detail is provided in Appendix D).

Figure 5-1 presents the forecast BAU emissions to 2050, disaggregated by sector.

Figure 5-1: Emissions to 2050 in the 'Business as Usual' scenario, broken down by emissions source



The BAU trend shows that, even if no further action was taken in Lancashire, some reduction in emissions would be expected over the period 2018-50 with emissions by 2050 reduced to 5,876 $ktCO_2$ from a 2018 baseline of 8,568 $ktCO_2$. External action, such as the decarbonising of the electricity grid (following a continuing trend since 1990) and improvements in vehicle efficiency[32], would mean that emissions would reduce by 15% by 2030, 25% by 2035 and 31% by 2050 (compared with the baseline year). However, such reductions would be clearly insufficient to meet the county's climate emergency goals.

[32] Note that the impact of the Government's ban on the sales of petrol and diesel vehicles (in 2030 for cars and vans and 2035 to 2040 for HGVs) has not been included in the BAU, it is included as national action in the decarbonisation scenarios presented later as the changes in the fleet will require considerable support at the national and local level.

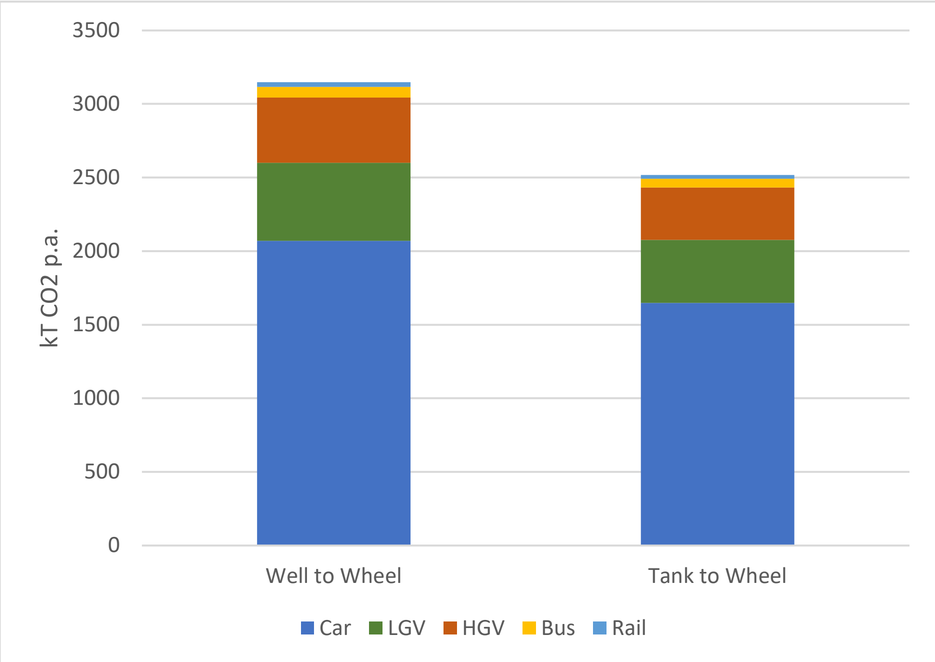
The following Sections 6, 7, and 8 set out the measures that could be deployed to meet the county's climate emergency goals and the potential scale of emissions reductions associated with such measures.

6. Measures to reduce emissions - Transport

6.1. Sources of transport emissions

Sources of transport emissions in the Lancashire region are set out in Figure 6-1. Further information about the sources can be found in section C1 of Appendix C. Bottom-up carbon baseline results per key sector.

Figure 6-1 Baseline (2018) surface transport emissions, Lancashire, $ktCO_2$ p.a.



6.2. Identification of measures

This section provides an overview of the measures needed to reduce transport carbon emissions. Views are generally consistent between different sources such as the Climate Change Committee (CCC)[33], the DfT's Transport Decarbonisation Plan[34] and the Local Government Association's (LGA) series of briefing notes on Decarbonising Transport[35]. They identify that diverse measures are needed to achieve the scale of carbon reduction required from transport. Emphasis is also placed on the need for collaboration and co-ordination between a range of stakeholders, including national government, different levels of local authority, other public bodies, local economic partnerships, businesses and residents.

The CCC groups the actions that Local Authorities need to take to reduce transport emissions into three categories:

- **Strategy/planning** – including working with partners to deliver improved provision of sustainable modes (walking, cycling and public and shared transport).

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[33] Climate Change Committee, Sixth Carbon Budget, 2020 and supporting papers on the Transport Sector and the Role of Local Authorities. Climate Change Committee (theccc.org.uk).
[34] Department for Transport, Transport Decarbonisation Plan, 2021
[35] Decarbonising transport | Local Government Association.

- **Infrastructure** – including measures such as charging for use of infrastructure, parking charges and clean air zones, as well as provision of digital infrastructure.
- **Communications and enabling actions** – highlighting the importance of raising awareness of options and the need for change in travel behaviour and of working with residents, businesses and other organisations to support change.

The LGA and several other bodies categorise the measures needed to reduce transport emissions in terms of the route through which they reduce carbon, broadly grouping them in terms of the **Avoid, Shift, Improve** hierarchy shown in Figure 6-2.

Figure 6-2 – Avoid, Shift, Improve hierarchy for measures to address transport emissions

Category	*Emissions reduction approach*
Avoid	Reduce overall travel through improved access (through reduced trips or length – logistics, land use planning, online activities)
Shift	Increase the proportion of travel by the most efficient and sustainable modes: active, shared and public transport
Improve	Increase energy efficiency of vehicles and driving conditions. Move to alternative, less carbon intensive fuel/energy sources, particularly electricity.

The main transport decarbonisation measures can be grouped into eight main policy areas against the Avoid, Shift, Improve categories as set out in Table 6-1.

Table 6-1 – Key policy areas for transport decarbonisation

Policy Area	Category
Land use planning	Avoid
Digital connectivity	Avoid
Active travel/personal mobility	Shift
Public/shared transport	Shift
Demand management	Shift
Supporting behaviour change	Shift/All
Efficient network management	Improve
Promoting ultra-low emission vehicles	Improve

The following sections provide more detail on each of the three categories of Avoid, Shift and Improve and the eight policy areas falling within them. The way in which each of the categories and policy areas could contribute to decarbonisation is set out, along with the types of measure involved, focussing particularly on those that could be applied at the local level, rather than relying on national action.

6.2.1. Avoid measures

Avoid measures reduce the number or length of trips made. The key mechanism for doing this is by replacing a physical journey with either online activity or a shorter journey to access more local activity. The potential for change of this type has been brought clearly into focus during the COVID-19 pandemic by the step change seen in remote working, online meetings and appointments and use of local shops and services.

Most travel is undertaken to provide people with accessibility to services, activities and opportunities and the key challenge for decarbonising the transport sector is to identify ways to provide equivalent access in an alternative and less emissions intensive manner.

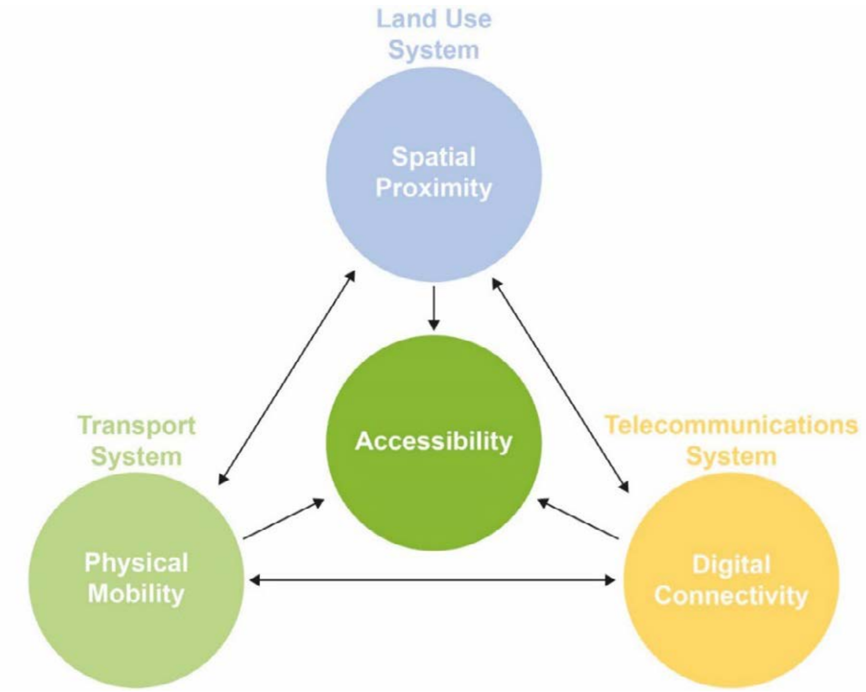
Travel planning to combine or shorten journeys is one potential route to reducing travel without reducing accessibility by increasing the efficiency of use of each journey made (for instance to serve two or more purposes) or optimising routes taken. Travel plans can be particularly effective when developed by major employers with the aim of reducing road travel for commuting and business trips and freight deliveries (see box)

Travel planning is likely to be particularly effective in relation to freight and deliveries. For instance, a common delivery hub (e.g. deliveries to central lockers rather than to individual homes) could be used to reduce the number of delivery trips to a given area associated with online shopping.

However, most Avoid measures are based on the fact that transport connections are not the only way to provide accessibility, it can also be delivered in two other ways, as illustrated in Figure 6-3, i.e.:

- **Land use planning for improved spatial proximity** – integrated land use planning to encourage localisation, bringing more services and activities closer to residents (e.g. the 20-minute neighbourhood concept); and
- **Digital connectivity** – providing the digital connections and the options to access services and opportunities online.

Figure 6-3 – Triple Access System[36], Glen Lyons & Cody Davidson



The following sections provide more detail on these two key policy areas which have the potential to reduce carbon emissions but fall beyond the usual scope of transport planning.

[36] Triple Access System, Glenn Lyons & Cody Davidson, 2016.

3.1.1.1. Land use planning (spatial proximity)

Local land use planning has the potential to reduce transport carbon emissions by increasing the opportunity for people to access services, activities, and opportunities without car use. This is achieved by improving access in two ways:

- **Increasing local access**, through planning for localisation of activity using the 20-minute neighbourhood principles (see box), typically reducing the number of trips made (as people combine purposes in individual trips) and increasing the likelihood of walking and cycling as trip lengths reduce; and
- **Increasing access by public transport**, through planning for transit oriented development around public transport hubs.

The changes in travel patterns in 2020 and 2021 in response to the COVID-19 pandemic have highlighted the potential scale of emissions reduction that could be achieved through localisation of activity.

Measures to use land use planning to reduce travel include changes in land use in existing developments to increase the range of activities and opportunities provided near to residential areas and developing mobility hubs to integrate transport modes with each other and wider facilities. For new developments, planning requirements can be introduced to ensure that the new sites limit car dependency and provide appropriate access to facilities by active and public transport. For instance, by identifying minimum levels of accessibility on foot and by public transport and introducing measures to limit parking availability and to promote car club use.

The planning measures required to support localisation fall outside the usual scope of transport planning. However, co-ordination between sectors is important and transport measures play an important supporting role through providing good quality walking and cycling facilities to support local movements and public transport services to the hub. Measures such as 20 mph zones and traffic calming on central streets are also important in contributing to the attractiveness of local centres.

20-minute neighbourhood are areas providing most of residents daily needs within a 20-minute walk or cycle ride. Key features include local shopping and health facilities, education, green spaces, affordable and diverse housing, safe streets, active travel and public transport, and employment (as shown in the widely used graphic below, originally produced by the Melbourne government).

3.1.1.2. Improving digital connectivity

High quality digital connections provide significant potential to reduce physical trips to activities by replacing them with digital connections, such as virtual work meetings or online doctor's appointments or training.

In 2020 and 2021, responses to COVID-19 caused a step change in levels of digital access, the range of opportunities offered online and people's familiarity with the options available, providing a clear understanding of the potential to reduce carbon emissions through this route.

Comprehensive access to strong and reliable 5G and broadband connections would reinforce these trends by further allowing access to services, work, and other opportunities remotely, where appropriate, reducing the need to travel. This would include the provision of local digital hubs to provide local access to good quality connectivity for those requiring an alternative to access at home.

To maximise the impacts of digital connections, it will also be important to develop clear plans to support development of online opportunities and services which take advantage of the connectivity, including services provided by the county council, districts and boroughs.

Home working during the COVID-19 pandemic

The Office for National Statistics showed that 20% of Lancashire's working population worked from home in April 2020, up from 8% in April 2019. The 2020 figures ranged widely between districts and boroughs, from 7% in Preston and 10% in Burnley to 33% in Fylde and 38% in Ribble Valley.

Source: ONS, May, 2021.

6.2.2. Shift measures

Shift measures encourage a shift in journeys up the sustainable travel hierarchy (shown in Figure 6-4), to use more efficient, less energy and emissions intensive modes. This typically involves moving away from car journeys to public transport, shared transport and active modes such as walking and cycling.

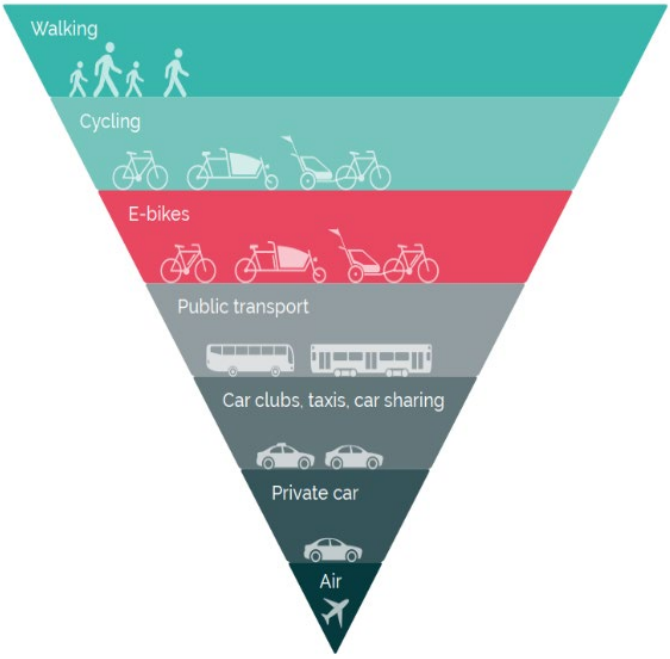
Shift measures can be closely related to Avoid measures that reduce journey lengths by increasing local activity which in turn means that more sustainable modes of transport (such as cycling) become feasible options for the newly shortened trips.

To be successful, measures to encourage **shift** need to ensure that the more sustainable mode is accessible, easy and attractive to use. Measures to reduce the priority currently given to car use are also typically required to encourage mode shift by creating a more even cost and convenience balance between car and more sustainable modes. Relevant measures include increasing charges for road use and parking and relocating parking to less central and convenient locations.

The following sections provide more detail on the types of measures required to:

- Attract shift to **active modes and micro-mobility options;**
- Attract shift to **public/shared transport;**
- Deliver **demand management** to encourage shift away from road travel; and
- Support the **behaviour change** required for mode shift**.**

Figure 6-4 – Sustainable Travel Hierarchy



Source: Decarbonising Transport: Growing cycle use, Local Government Association, 2020.

3.1.1.3. Active modes and micro-mobility

Measures to encourage active mode and micro mobility use

Encouraging a substantial mode-shift to walking/wheeling, cycling and other forms of micro mobility (such as e-bikes and e-scooters if they are legalised after the current trials) is a core requirement for decarbonising transport. A step change is needed, increasing levels of active travel several times over to reach the levels seen in some European cities, such as in the Netherlands. Measures to increase active travel also bring a wide range of additional benefits, such as health, air quality and public realm improvements.

Switch to active modes is likely to be greatest where there is a **high quality, integrated network** that directly serves key desire lines for travel providing a viable alternative to car travel, for instance linking residential areas to destinations including high streets and local centres, employment centres and healthcare. Public transport hubs are another important destination, helping to encourage mode shift on longer journeys where walking or cycling can be used for the first and last leg to and from the public transport network.

To be attractive the walking and cycling network should follow good practice design standards and be well maintained. It is typically considered that **cycle routes should be segregated where possible**. In some cases this could be achieved through removing on street parking (linking to demand management measures, described further below). Elsewhere, it may require wholly new high-quality cycle lanes to be built or

> **Micro mobility**: Technology is adding to the range of active and micro mobility options available. E-bikes are now well established. They bring similar benefits to conventional bikes and some additional advantages. They are suitable for a wider range of potential users, including the less fit and those travelling in more challenging terrain, and they extend travel ranges by up to 15 to 20 miles.
>
> E-scooters have also become increasingly visible in recent years. They have the potential to bring many of the same benefits as e-bikes, although they require less physical activity. They provide efficient personal mobility that is accessible to a wide range of physical ability levels and can cover ranges of up to 20 miles. However, they also bring some additional challenges, particularly around safety and are currently being trialled in a number of towns and cities around the country, to see how and if they can be rolled out safely and legally.

reallocation of existing road space to active modes. Reallocation requires careful design to ensure that it does not result in increased carbon emissions from traffic due to additional congestion.

Where segregation is not possible, **reduction in speed limits**, for instance 20 mph zones, and traffic calming measures help to provide a suitable and safe environment for cycling or scooting.

Provision of priority and **good quality facilities at junction and crossings** for pedestrians and cyclists are another important component of a high quality network, along with clear signage and wayfinding.

In addition to the provision of a high quality network, **supporting measures** that further encourage active mode use include:

- The provision of **supporting facilities** in residential areas and at cycle destinations, including cycle parking facilities, storage, changing and charging for e-bikes; and
- **Bike, e-bike and e-scooter hire schemes**. These provide the opportunity for single way connecting trips and the ability to cycle or scoot without the responsibility and cost of ownership, maintenance and storage.

There is also a role for active travel in decarbonising freight. Cargo-bikes and e-cargo-bikes used in conjunction with HGV restrictions and consolidation centres, will help to minimise emissions on the last leg of journeys to distribute goods

3.1.1.4. Public transport/shared transport

Shifting journeys away from using single occupancy cars to using more efficient public transport and other shared transport is another important component in reducing transport emissions.

Switch to public transport is likely to be greatest where there is provision of **reliable**, **high quality, affordable services providing connections between key locations**.

Good quality **connections between services**, both in terms of physical connections and timetable alignment for bus and rail services are also important in encouraging mode switch. The development of **Mobility Hubs or interchanges** can promote integration by providing clearly distinguished, attractive foci for public and shared transport access and connections, focussed around an existing rail or bus station or stop where possible and providing easily accessible information on travel options.

Measures to **improve the environment of stops and stations** and **on board vehicles** can also help to attract patronage.

> **Demand responsive transport** services typically serve an identified route and timetable but only run if passengers pre-book and only serve those parts of the routes required by the bookings. If well designed, they can provide an efficient and flexible service. However, some risks need to be avoided such as reduced visibility of the service (as it is no longer seen at set bus stops at identified times), potentially reducing its viability

Mode shift from car can also be increased by promoting use of efficient, well integrated **shared transport** to support public transport provision. Shared transport options are improving as a result of increased availability and accessibility of data on travel patterns to operators and flexibility of booking apps for users.

Shared options such as **e-bike and e-scooter hire** help to expand the coverage of public transport provision by providing integrated options for the first and last leg of the journey to and from the public transport stop/station.

Other shared transport modes such as **car share, car clubs** and **demand responsive transport** (see box) help to provide alternatives to private car use on routes that do not have sufficient demand to support public transport services.

Mode shift can also be encouraged through technology based measures such as provision of **Mobility as a Service (MaaS**) (see box), made possible by increasing data availability and mobile phones technology. Well-designed MaaS frameworks integrate public and shared transport modes and provide ease of payment, ease of access to reliable information and improved integration between services. The system makes planning and paying for trips as a single journey from start to finish easier, increasing the attractiveness of the option and mode shift.

Mobility as a Service applications bring together information on a wide range of transport modes and services for instance in a smartphone application. The applications provide features such as end-to-end journey planning, multi-modal ticket purchasing and the ability to earn and spend rewards. It provides a unified framework for accessing shared travel alongside timetabled public transport, reducing complexity and cost, and making the options more attractive and accessible to users.

3.1.1.5. Demand management

Demand management of road vehicles plays an important role in decarbonisation through rebalancing the costs and convenience of road based modes to provide a more even treatment with more sustainable modes. The result is to reduce the priority given to the convenience of road vehicle use over other priorities. This preference for road vehicles has been built into transport and urban design over several decades. This long term influence has led to the current position of high levels of road vehicle use and their dominance in urban areas, despite their widely recognised negative impacts. The wider impacts include those on air quality, noise, public realm and equality of access to facilities.

Measures to rebalance the situation and better reflect the wider negative impacts of road vehicle use on society in the costs of their use include:

- **Reducing parking spaces available and relocating** them to less central locations, freeing up areas in the centre for other uses.
- **Increasing parking charges,** with fees reflecting emissions impacts based on fuel type, vehicle size and ownership (private or car club). This has potential impacts on social equity due to likely increases in costs of using older vehicles. One way to offset this would be to combine parking charges with widespread access to car clubs including small electric vehicles (EVs) to ensure low cost access to low emissions vehicles for those on low incomes (who are more likely to have older less efficient cars).
- **Expanding the coverage of parking charges**, for instance:
    - Work place parking levies, reducing parking spaces available and relocating them to less central locations, freeing up areas in the centre for other uses; and
    - Charges for currently free parking such as local shopping centres, possibly with an allowance of a limited number of daily or weekly free visits to avoid deterring use of local facilities
- **Traffic calming, including 20 mph zones** which reduce the time advantage of car use and deter goods vehicles.
- **Road user charging/eco-levy** meaning that road users pay a charge for the environmental damage each kilometre of travel causes, rather than the costs being absorbed by wider society as they are now. Charging would be most effective if applied across all roads and would be most successful if applied as a regional or national system, avoiding rerouting effects. At the county level, the most feasible approach is likely to be to

Impact of demand management

Introducing parking or road use charges would put car travel on a more even footing with other modes, moving away from the current situation where costs (such as insurance) are largely paid up front annually and at each fill up of fuel, which means the cost of each new trip is perceived to be relatively low. The charges would help to reflect the wider impacts of road use on the environment and society. Increasing travel times through speed restrictions and relocation of parking spaces helps to reverse the speed advantage gained by the priority they are currently given on the road network and in urban space. The change in balance will encourage mode shift and more efficient travel planning.

charge entry to urban and sensitive areas, equivalent to Clean Air Zones being implemented in locations such as Birmingham for local air quality reasons.

For freight, additional potential demand management measures include **delivery bans and restrictions** for central urban areas that can be combined with **consolidation centres** and the use of electric vehicles or e-cargo bikes for the final leg of the delivery.

3.1.1.6. Supporting behaviour change

Behavioural change measures provide people and organisations with the **information, awareness and incentivisation** required to change travel choices going forward. Examples include supporting changes in habits to shop and undertake activities more locally, use online services more, cycle or walk more, use public transport, pay more to park or comply with lower speed limits.

A **variety of approaches** are required to influence different sectors of the community. For instance, targeted campaigns may focus on raising awareness amongst those travelling to key destinations such as workplaces to highlight the travel options available.

The more successful behaviour campaigns have been typically shown to be those that **focus on incentives** and encouragement rather than on telling people what ought to be done. Technology provides a range of opportunities to provide incentives, for instance smartphone apps to incentivise particular forms of travel behaviour with digital rewards or scores such as the Love to Ride, Betterpoints and Love Exploring Apps.

6.2.3. Improve measures

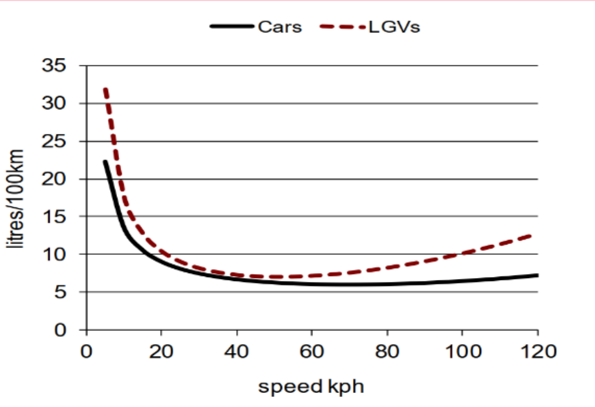
Improve measures increase the efficiency and reduce the emissions intensity of vehicles that are used. This category includes measures to improve the operational efficiency of the road network and driving styles so that vehicles operate at more efficient speeds (particularly avoiding inefficient congested conditions). However, increasing uptake of electric vehicles (EVs) and smaller more efficient vehicles is the key measure in this category, along with the use of hydrogen power for some vehicle types (currently primarily buses and local delivery vehicles).

3.1.1.7. Efficient network management and driving styles

Vehicles in slow congested conditions operate inefficiently producing high rates of emission per kilometre travelled. As speeds increase emissions per kilometre reduce until a point of about 80 kph, above which increasing speed causes emissions rates to rise again (as shown in box). Therefore, measures to manage the network more efficiently and smooth flow can help to reduce emissions from road traffic.

Emissions and speed

Emissions per kilometre are higher in congested conditions and at high speeds than in free-flowing conditions at moderate speeds (up to 80 kph).



Source: TAG Unit A1.3,

However, the measures need to be applied carefully to avoid encouraging additional traffic flow which would offset emissions savings.

Achieving efficient network management will involve **making best use of available data on network conditions** from the growing range of available sources. This will enable more efficient management of traffic conditions and provide appropriate information to drivers to inform route and timing choice.

Another key component involves ensuring that **traffic signal patterns are optimised** for changing conditions, particularly along key corridors and in central areas to minimise queueing.

Efficient network management may require some **minor road capacity increases to alleviate congestion hotspots** or to provide connections to new developments, that are well designed to reduce travel distances and encourage multi-modal travel. In some limited locations, there may be a case for new links to enable the removal of traffic from sensitive communities. In these cases, the change could be integrated with significant reallocation of road space within the affected community to support walking and cycling, meaning that there is no significant increase in total highway capacity.

Speed limit reductions on the fastest roads will provide a further option to significantly reduce emissions on the most heavily trafficked roads by reducing speeds from inefficient levels to more efficient levels of 80 kph to 95 kph.

Within urban areas, good quality, readily available **information for drivers on parking locations and availability** can help efficient use of the road network by avoiding circulation of drivers searching for parking spaces. The impact would be particularly effective if combined with measures to consolidate parking spaces to less central locations, as outlined under Demand Management above.

Network management measures can be supplemented with training, awareness raising and instruments to encourage drivers to adopt **eco-driving**. Changes in driving behaviour can reduce fuel use and emissions through adjustments such as smoother driving style, lower, steadier speeds and consideration of vehicle loads.

3.1.1.8. Shift to Ultra Low Emissions Vehicles (ULEV)

Shifting the vehicle fleet to ultra-low and ultimately **ultra-low emissions vehicles (ULEV)** and **ultimately zero emissions vehicles (ZEV)** is widely recognised to be a fundamental component of the decarbonisation of transport. However, organisations such as the Urban Transport Group, Local Government Association and Transport for Quality of Life stress that ZEVs are not the single solution to decarbonisation for a number of reasons:

- Fleet change cannot occur quickly enough to deliver the pace of change required, even with rapid take up electric cars and vans, petrol and diesel vehicles will remain in the fleet into the 2040s.
- Lifecycle emissions associated with the production of electric (and all) vehicles are significant.
- The replacement of petrol/diesel vehicles with ZEVs does not solve the wide range of other problems associated with high levels of road vehicle use, including congestion, severance, and the social inequality implications of lack of accessibility for those unable to afford or use cars.

Car clubs have the potential to provide a key role in the transformation of travel behaviour. They provide the opportunity to roll out access to EVs and ensure that each vehicle is well used. They also have the potential to reduce car use more generally by reducing individual car ownership. The clubs provide flexibility of access to cars for those journeys for which alternatives do not work well but help to deter car use by putting it on a pay per use basis like other types of travel. Car owners pay much of their car ownership costs up front, making each additional journey in the year relatively low cost. For those using cars relatively little each year, car clubs can save considerable costs as well as removing the responsibility of maintenance and updates.

Car club use also provides the scope to use the smallest vehicle appropriate for each journey. For instance, small or micro cars (or potentially even e-Scooters) could be used for most journeys as they involve only 1 or 2 people in the car. Instead, often an SUV or large estate car is used for these short local journeys as it is the household's only car, purchased to meet occasional needs (such as holidays). This increases the energy use and emissions associated with each journey made through the year.

For these reasons, private car is at the bottom of the sustainable travel hierarchy for personal travel (shown in Figure 6-4).

However, private cars (including in car clubs), taxis, buses, and freight vehicles will continue to be on the roads. Therefore, measures to rapidly switch the fleet to ZEVs are a key part of decarbonisation.

National government action will play a key role in achieving fleet change, in particular the ban on petrol and diesel car and van sales in 2030 (announced in November 2020). However, supporting action at the local level will be important to make sure this ban feeds through to electrify the fleet as anticipated.

Relevant measures to support the change include:

- Rapid development of charging/fuelling infrastructure.
- Accelerating uptake in vehicle fleets.

Planning and delivering well-positioned public charging infrastructure for electric vehicles (including e-bikes and e-scooters) will include providing on street charging in residential areas without off street parking and charging at destinations such as retail and leisure centres. This is important for ensuring all sectors of the community have access to charging and to increase confidence in the ability to charge vehicles widely, helping to overcome issues of range anxiety. Successful delivery of sufficient charging infrastructure in the timescales required will involve close partnership working between local authorities and the private sector, ensuring that public and private sector investment is carefully coordinated and complementary.

For a county such as Lancashire **accelerating uptake in vehicle fleets** could include promoting uptake of ZEV amongst the fleets over which they have influence i.e:

- **Council and supplier fleets** – procurement contracts provide the opportunity for councils to set minimum standards for emissions rates for the vehicles used by suppliers.
- **The taxi fleet** – this would involve districts and boroughs upgrading taxi licencing regulations to encourage/require taxis to be electric. This could be supplemented by a loan or grant to help taxi drivers with the hurdle of high upfront costs, combined with provision of charging at relevant locations and clear communication on the likely operating cost savings. Converting the taxi fleet brings a number of benefits. The vehicles are well used, maximising lifetime emissions savings and are visible on the roads, increasing public awareness and experience of EV use.
- **The bus and community transport fleet** – beneficial as the vehicles are large and well-used, maximising lifetime emissions savings and again are visible to the public, helping to normalise EV use.
- **Car club fleets**. Establishing and expanding EV car club fleets, encouraging small vehicle use through the pricing structure, could make an important contribution to carbon reductions (see box). The fleets could be part of the shared transport accessed through the MaaS system. They would provide lower cost access to EVs, accessible for those unable to afford a new electric car. This would be important in combination with any demand management measure differentiating parking or use charges by vehicle size and emissions.
- **Corporate fleets**. Although the Lancashire authorities do not have a direct influence over wider corporate fleets (beyond their suppliers) they could work with the private sector to support and promote measures to encourage take up of EVs within the fleets of companies. This is an efficient way to increase EV use rapidly as the annual mileage of company cars is typically more than double the mileage of privately owned cars[37]. Firms also often recognise the operating cost benefits brought by EV use, helping to encourage uptake.

It is also important to minimise the number and size of vehicles purchased wherever possible, rather than simply replacing the existing vehicle fleet with equivalent electric vehicles. Although the vehicle manufacturing emissions are outside the scope of emissions covered by transport sector emissions targets, they will contribute to national and international totals. Producing fewer vehicles and smaller vehicles will reduce emissions.

Car club expansion would also be beneficial in this area as distance travelled would be undertaken by fewer vehicles, rather than many individually owned vehicles (which are typically stationary for at least 95% of their life).

For the potential scale of emissions reductions by intervention, and the methodology that has been used to model these, see Appendix E.

6.3. Scoring of Transport measures

An analysis of the Transport measures under consideration in terms of their carbon reduction potential, deliverability (relating to costs, plus technology maturity and skills pipeline) and Council level of influence is presented in Table 6-2.

[37] National Travel Survey, 2019, NTS0901 showed company car mileage of 2.5 times private car mileage. In 2020, during the COVID pandemic, company car mileage was approximately double.

Table 6-2: Scoring of Transport measures

Key: highest high medium lowest

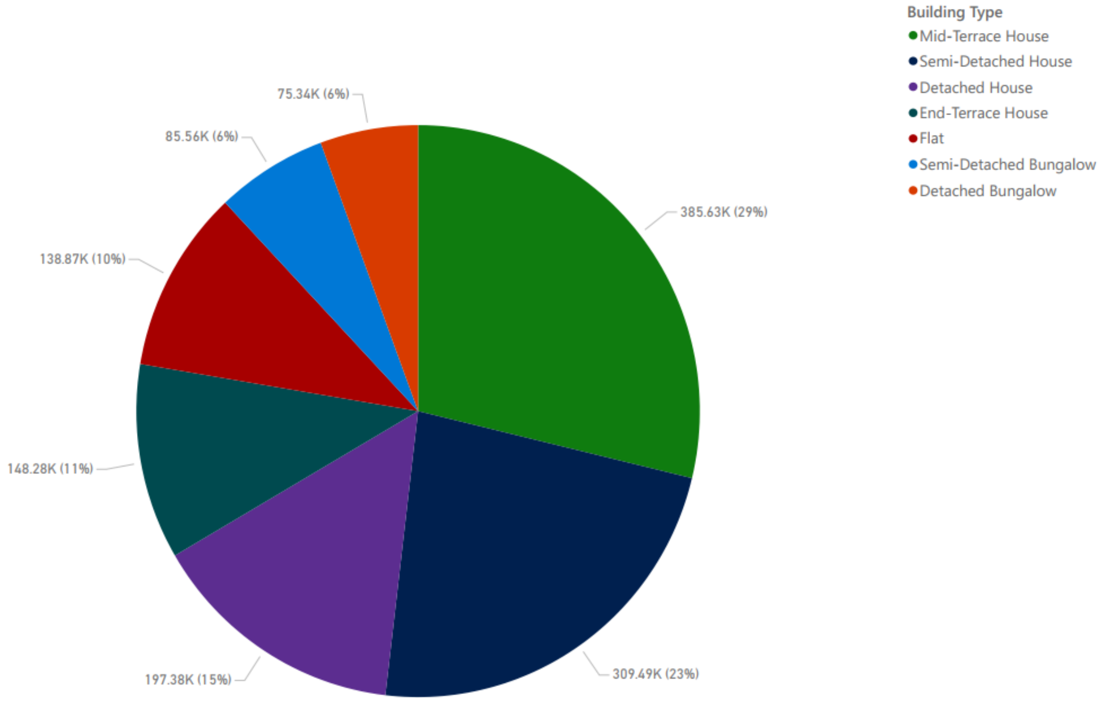
Measure	Reduction Potential	Deliverability (0-4)	Council influence (0-4)	Comments on deliverability and influence
National action: ban on petrol/diesel car/van sales	highest	n/a	lowest	Local influence is supporting charging points
National action: ban on diesel HGV sales	highest	n/a	lowest	Local influence is supporting fuelling/charging infrastructure
Accelerate ULEV uptake	high	high	medium	Stronger influence over e.g. taxi fleet than corporate fleets, car club uptake
Increase active travel/micro mobility use	medium	high	high	Requires community involvement and support
Increase public transport use	medium	high	high	Requires agreement with bus operators (BSIP)
Demand management	medium	medium	high	Deliverability restricted by public acceptability
Efficient network management	lowest	high	highest	Impact could be increased by introducing speed limits at 50mph or 60mph which would reduce deliverability
Land use planning (20 minute neighbourhoods)	medium	high	high	Requires coordination across several stakeholders
Digital connectivity	medium	high	medium	Roll out in areas that aren't commercially viable is challenging

7. Measures to reduce emissions – Buildings

7.1. Sources of building emissions

Sources of residential building emissions in the Lancashire region are set out in Figure 7-1. Further information about the sources can be found in section C2 of Appendix C. 'Bottom-up' carbon baseline results per key sector.

Figure 7-1 Proportion (%) of tonnes CO_2 emissions by residential building typology



Note: all figures are indicative estimates only.

7.2. Identification of measures

The key measures that have been considered as part of this study at a quantitative level for both residential and non-residential buildings are:

- Fabric improvements
- LED upgrades
- Decarbonising heating
- Building level renewables

Other measures have been considered qualitatively.

7.2.1. Fabric Improvements

Glazing and insulation improvements have been calculated using the floor area, building typology and building age. It has been assumed that any building built after 2007 does not need fabric improvements.

In all cases we would recommend taking a 'Fabric first' approach and focus initially on improving existing building stocks energy efficiency by improving glazing and insulation levels.

7.2.2. Lighting

Of the measures considered, lighting improvements are the cheapest but also have the smallest impact on overall carbon reduction. Low Energy Light bulbs use 70% less energy than traditional bulbs, LEDs use 90% less energy than traditional bulbs.

7.2.3. Decarbonisation of heating

The decarbonisation of the grid allows electrification of heat, and the most efficient way to use electricity for heating is to employ heat pumps. For electrification only Air Source Heat Pumps (ASHP) have been considered quantitively with a conservative COP used in calculations. Ground Source Heat Pumps (GSHPs) will also be discussed. For an alternative scenario where hydrogen becomes widely available, hydrogen boilers are also considered.

A summary of the current incentives and grants available for the decarbonisation of heating can be found in Appendix F.

7.2.3.1. ASHP

Air Source Heat Pumps (ASHPs) extract heat from the external air and condense this energy to heat a smaller space within a residential or non-residential building. A pump circulates a refrigerant through a coil to absorb energy from the air. This refrigerant is then compressed to raise its temperature which can then be used for space heating and domestic hot water.

They can feed either low-temperature radiators or underfloor heating and often have electric immersion heater back-up for the winter months.

ASHPs operate effectively in buildings with a low energy demand, as they emit low levels of energy suitable for maintaining rather than dramatically increasing internal temperatures. It is therefore vital that fabric improvements are considered as a first priority as ASHP's will not work effectively in a poorly insulated building.

Underfloor heating will give the best performance and so installing heat pumps in newer buildings with underfloor heating will give the biggest benefit. Oversized radiators can also be used in buildings without underfloor heating. Radiators will typically be 33-50% larger than a typical radiator used in a boiler fed heating system.

Other considerations:

- For larger loads where multiple ASHP's are required planning permission may be required.
- Multiple units could also exceed the noise abatement limit of 42dB.

7.2.3.2. GSHP

Ground Source Heat Pumps (GSHPs) are more efficient than ASHPs and are particularly suited to rural areas, to assess the impact of GSHPs in Lancashire further analysis would be required to assess the most appropriate areas and the ground make-up to predict accurate yields.

GSHPs extract heat from the ground and compress this energy to increase temperature for space heating and hot water. Pipework is installed into the ground, either through coils or in bore holes and piles, circulating a mix of water and antifreeze to extract energy from the ground, where the year-round temperature is relatively consistent (approx. 10℃ at 4 metres depth). This leads to a reliable source of heat for the building.

As with ASHPs, GSHPs perform best in well-insulated buildings with a low heating demand, they work most efficiently with an underfloor heating system but oversized radiators can also be used. But they require appropriate ground conditions to sink piles/bore holes or excavate for coils (which also require a large area of land.).

7.2.3.3. Hydrogen boilers

Hydrogen boilers are gas-fired boilers, similar to existing natural gas (methane) condensing boilers, the main difference being hydrogen boilers use either 100% pure hydrogen or a blend of natural gas (methane) and hydrogen. As natural gas boilers, hydrogen boilers use hydrogen as fuel to create a flame to heat-up water that will circulate through existing heaters.

Hydrogen being a more volatile gas and a smaller molecule than methane it requires specific safety measures, different to natural gas boilers, all these safety measures are included in the hydrogen boilers and have been tested for in different trials across the UK.

7.2.4. Building level renewables

PV panels have been considered for both residential and non-residential buildings. A number of assumptions have been made to estimate a total available roof area for each building. The calculations assume the maximum possible PV roll out and currently don't consider any shading from adjacent buildings or the orientation of the building. This will reduce the maximum yield that can be achieved from PV.

Other practical considerations:

- Panels will operate most efficiently on a south-facing sloping roof (between 30 and 45-degree pitch.)
- Shading must be minimal (one shaded panel can impact the output of the rest of the array.)
- Panels must not be laid horizontally on a flat roof as they will not self-clean. Panels will therefore need to be installed at an angle and with appropriate space between them, to avoid over-shading.
- Large arrays may require upgrades to substations if exporting electricity to the grid.
- Local planning requirements may restrict installation of panels on certain elevations.
- Installation must take into account pitch and fall of the roof, along with any additional plant on the roof to ensure there is sufficient room.

7.2.5. Other Net Zero measures

District heating is a key step to reaching net zero, it is a significant opportunity as it's directly 'investible' by an authority rather than reliance on national measures. However, this hasn't been considered in this instance as this analysis has been assessing only the existing building stock.

Energy from waste will also have a significant part to play in the path to net-zero and can be used in connection with district heating. There is already a number of these schemes within Lancashire that have the benefit of planning permission. The impact of these hasn't been investigated at a quantitative level in this report as it is difficult to attribute building-level savings.

7.3. Scoring of Buildings measures

An analysis of the Buildings measures under consideration in terms of their carbon reduction potential, deliverability (relating to costs, plus technology maturity and skills pipeline), Council level of influence, Growth and recovery (referring to Net Zero growth and COVID-19 recovery) and other influence (levels of influence of private sector or national Government in implementing the measure) is presented in Table 7-1.

Table 7-1: Scoring of Buildings measures

Key: highest, high, medium, lowest

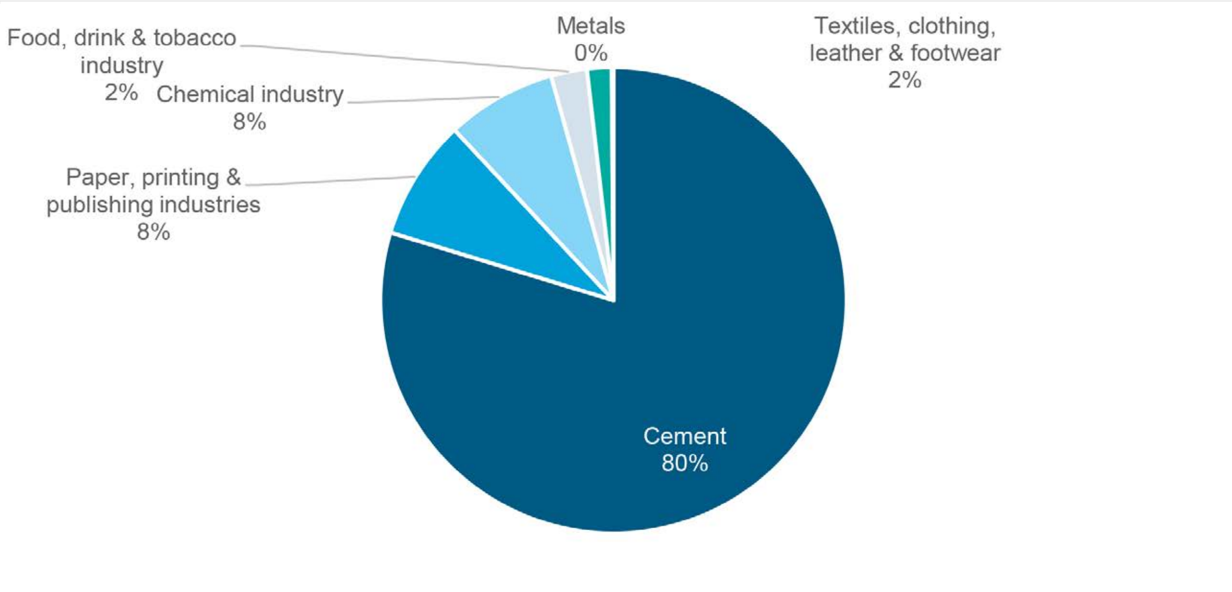
Measure	Reduction Potential (1-4)	Deliverability (1-4)	Council influence (1-4)	Growth & recovery (1-4)	Comments
Insulation (whole house) Strategic step in a 'fabric first' approach to reduce energy demand before implementing other measures.	medium	high	medium	highest	Mature technology costs, whole house requires complex roll-out and multiple contractors. Extensive installs offer an opportunity to re-skill in green jobs. Note that councils will have greatest influence in council-owned building stock.
Glazing Less attractive option in a 'fabric first' approach to reduce energy demand, but also useful in many cases.	lowest	high	medium	medium	Less attractive option. Note that councils will have greatest influence in council-owned building stock.
Decarbonisation of heat Air-source heat pumps to 'electrify' space heating and transfer it away from natural gas.	high	lowest	medium	lowest	Carbon savings will increase over time, as the electricity used will become even less carbon intensive compared with natural gas. Note that councils will have greatest influence in council-owned building stock.
Solar PV panels As a model for building-level renewables installations, modelled for install on every rooftop.	medium	lowest	lowest	lowest	Technology cost will continue to fall; advantage decreases over time as electricity displaced becomes less carbon intensive; asset life of 10-20 years with replacement parts needed during lifetime. Note that councils will have greatest influence in council-owned building stock.

8. Measures to reduce emissions - Large Industrial Installations

8.1. Sources of industrial emissions

The breakdown of large industrial sources of emissions in the Lancashire region is shown in Figure 8-1. Further information about the sources can be found in section C6 of Appendix C. Bottom-up carbon baseline results per key sector.

Figure 8-1 Proportion of CO_2 emissions from large industrial installations in Lancashire in 2018 by sector



Note: all figures are indicative estimates only.

8.2. Identification of measures

Under the Sixth Carbon Budget[38], the Balanced Net Zero Pathway sees emissions from the manufacturing and construction sector reducing by 70% by 2035 and 90% by 2040 from 2018 levels, based on improvements to resource and energy efficiency, fuel switching and carbon capture and storage (CCS). The pathway assumes that the Government establishes a policy framework to support emissions reductions in a way that does not drive manufacturers overseas and that benefits jobs and investment in UK manufacturing.

The pace of reduction accelerates gradually between 2020 to 2035. Improvements in resource and efficiency lead to the largest emission reductions in the early 2020s. Infrastructures for CCS and hydrogen are deployed from 2025, starting near industrial clusters. Electricity network connection capacity is also increased around newly electrifying sites. During the 2030s, there is a substantial scale up for electrification, CCS and hydrogen. Most decarbonisation is complete by 2040. The pathway assumes that:

38 Climate Change Committee (2020) The Sixth Carbon Budget. December 2020. Available online at: https://www.theccc.org.uk/publication/sixth-carbon-budget/. Accessed May 2021.

- policy develops rapidly to ensure that it pays for companies to implement societally cost effective measures and that non-financial barriers are addressed; and
- supply chains scale up at pace, with workers acquiring skills to implement low carbon measures, the supply of necessary technologies and equipment grows and the availability of finance increases.

Abatement measures to reduce CO_2 emissions from the industrial processes are identified within the CCC data. This data includes % reductions, unit costs per tonne CO_2 abated, equipment lifetimes and projected date of maturity of the technologies[39]. Information on these measures has been supplemented by a broader literature review, including national, regional and industry specific data sources.

The measures considered include:

- Resource efficiency and materials substitution
- Energy efficiency
- Fuel switching (incl. electrification and use of hydrogen)
- Carbon capture and storage
- Bioenergy with carbon capture and storage – a carbon removals technology

8.2.1. Resource efficiency and materials substitution

Material substitution can reduce manufacturing emissions by switching from high embodied-carbon materials to low-embodied-carbon materials. Measures include using replacements to clinker. Clinker substitution involves reducing the amount of clinker per unit of cement by substituting the clinker with other cementitious materials, such as pulverised fuel ash (a waste from coal fired power stations) or ground granulated blast furnace slag (a by-product from iron and steel manufacture), pozzolanic materials, and materials such as limestone[40] The UK Mineral Products Association[41] estimates that this could result in 12% emission reductions on a 2018 baseline.

Resource efficiency includes:

- reduction of end-user consumption of new resources; and
- improvements in resource efficiency in production, e.g. design optimisation, increased recycling and reuse and increase product utilisation and sharing.

Resource efficiency and material substitution measures have a substantial impact on the cement & lime sector, particularly as a result of measures in the construction, vehicles and fabricated metal sectors.

8.2.2. Energy efficiency

The paper sector has the highest fraction of abatement from energy efficiency (38% in 2050), with a substantial saving from clustering and using waste heat from other sites. The largest absolute abatement from energy efficiency is in the chemicals sector (1 $MtCO_2e$ in 2050), driven largely by equipment upgrades. Energy efficiency measures include:

- heat recovery;
- process upgrade;
- equipment upgrade; and
- integration / clustering.

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[39] Termed nth of a kind (NOAK) within the CCC literature

[40] Department for Business, Energy & Industrial Strategy, October 2017, Cement Sector Industrial Decarbonisation and Energy Efficiency Roadmap Action Plan. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/651222/cement-decarbonisation-action-plan.pdf. Accessed May 2021

[41] Mineral Products Association (2020) UK Concrete and Cement Industry Roadmap to Beyond Net Zero. Available online at: https://www.thisisukconcrete.co.uk/TIC/media/root/Perspectives/MPA-UKC-Roadmap-to-Beyond-Net-Zero_October-2020.pdf. Accessed May 2021.

8.2.3. Fuel switching

The location of sites may affect the choice of deep decarbonisation options when multiple options are possible – CCC evidence suggests that electrification has an advantage over hydrogen at dispersed sites, due to differences in electricity and hydrogen distribution options and availability, as well as existing infrastructure.

Electrification measures include electric boilers, switching from on-site generation to a grid connection, electric arc furnaces, electric mobile machinery, electric dryers and electric infra-red heaters.

Hydrogen fuel measures include hydrogen boilers, CHP, generators, mobile machinery and kilns. CCC latest evidence suggests that these measures can typically be retrofitted, limiting the need to wait for a replacement cycle or to scrap assets before fitting.

Hanson Cement is currently undertaking a government funded research project[42] into the feasibility of a 70% biomass, 20% hydrogen and 10% plasma energy mix for fuelling the kiln. Hanson Cement has applied for a hazardous substance consent to allow the demonstration of use of hydrogen.

The use of sustainable biofuels provides carbon abatement in itself. CCC also assumes that CCS is applied to all new bioenergy use in manufacturing and construction (apart from in mobile machinery). As such, the application of CCS to bioenergy (BECCS) results in further abatement, see below. this is applicable particularly in the cement sector, which already uses bioenergy (see above re Hanson Cement), and also has potential to fit CCS.

8.2.4. Carbon capture and storage

Carbon capture and storage (CCS) will be required where there are no identified alternative options to reduce emissions to near-zero. This includes processes that produce CO_2 from non-combustion processes, such as cement production as well as combust fuels (internal fuels or off-gases) that are produced as part of the industrial process.

CCS plants involve mainly four steps. One might contain some form of pre-cleaning of the gaseous stream from where CO_2 will be captured to ensure that the stream is free from other gases that may hamper the operation of the following stages of the process. The next step is the capture of CO_2, i.e., some technology that will separate the CO_2 from the gaseous stream and produce a nearly pure CO_2 stream. Next, there is the need to transport this CO_2 stream to the storage site and finally the CO_2 is injected at the storage site for permanent storage. Most storage involves some type of geological reservoir that might be located on land or in the ocean. Gas compression is usually needed in all of the steps of CCS. It is certainly important at the transport and injection stages and represents an important part of the energy demand of the whole process.

Pipeline, train, truck or shipping are considered as options to transport CO_2 from dispersed sites where CCS is their only deep decarbonisation option, such as cement, lime and other mineral sites.

The geographic location of Hanson Cement plant in Ribble Valley is likely to pose a challenge, increasing costs for deployment of CO_2 transportation pipelines. Although alternative means of transport of CO_2 by rail or road may be possible options.

8.2.5. Bioenergy with carbon capture and storage

This means installing a CCS plant to capture CO_2 that is produced from a bioenergy application. There are two components to this BECSS technology: CCS and the bioenergy. The CCS component of BECCS is not different from non-BECCS applications of CCS. It is a technology that captures CO_2 from a gaseous stream, for instance, from the combustion gases of a power plant or a cement kiln.

Such solutions have potential for removals, beyond emissions abated from the plant, due to combination with bioenergy.

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[42] Hanson Cement (2020) Fuel-switching research takes next step at Ribblesdale. Press release. 9 December 2020. Available online at: https://www.hanson-communities.co.uk/en/fuel-switching-research-at-ribblesdale. Accessed Jun 2021.

8.3. Scoring of Large Industrial Installations measures

An analysis of key Large Industrial Installations measures identified in Lancashire in terms of their carbon reduction potential, deliverability (relating to costs, plus technology maturity and skills pipeline), Council level of influence, Growth and recovery (referring to Net Zero growth and COVID-19 recovery) and other influence (levels of influence of private sector or national Government in implementing the measure) is presented in Table 8-1.

Table 8-1: Categories of abatement measures for application in the industrial sector

Key: highest high medium lowest

Measure	Reduction Potential	Deliverability (1-4)	Council influence (1-4)	Growth & Recovery (1-4)	Other influence (1-4)	Comments
Resource efficiency and material substitution	medium	lowest, medium	medium	lowest	highest	Potential for early wins (pre 2035) Majority of reduction potential in Cement Resource efficiency will require economy wide change. Engagement on material substitution (clinker) with Cement.
Energy efficiency	lowest	lowest	medium	medium	n/a	Potential for early wins (pre 2035) Limited reduction potential across sector
Fuel switching	high	lowest	medium	medium	n/a	Most reductions post 2035 Cross sectoral application (apart from process emissions)
Carbon capture and storage (CCS)	highest	lowest	medium	lowest	highest	Cross sectoral application, 2035-40 Requires central government support Required to address process emissions (particularly Cement)
Bioenergy with carbon capture and storage (BECCS)	highest	lowest	medium	lowest	highest	Potential for emission removals linked to biomass use, application in Cement and Paper industries Requires central government support

9. Measures to sequester residual emissions – LULUCF

This section outlines sequestration measures to remove residual emissions from the atmosphere (and also measures to prevent emissions from the LULUCF sector from being emitted) that could be considered, once all the available carbon reduction measures discussed in the previous sections have been applied in the pathway options analysis.

In deriving Net Zero pathways, this study has thus focussed on carbon removal measures through sequestration by biomass and soil in the Lancashire region – Land use/nature based measures.

9.1. Current land uses in Lancashire

Table 9-1 indicates that important land uses for carbon storage in the study area are Grassland (which holds around a 36% of total carbon, as a result of occupying 35% of total land area), Peatland (24% of stored carbon and 18% of the land area), Woodland (storing 11% of total carbon across all woodland types, covering 7% of land area) and Arable fields (storing 4% of total carbon, occupying 11% of land area). Values in Table 9-1 were calculated using data from the Natural England 2021 report[43]. Further information about the land uses can be found in section C.7. Land use, land use change and forestry (LULUCF) of Appendix C.

Table 9-1: Land uses for carbon storage in the Lancashire region

High level habitat	Habitat List	Area (ha)	Total Carbon stock (t)	%	Carbon stock tC/ha
Woodland	Broad-leaved, mixed and yew semi-natural woodland	14,845	4,646,485	8.0%	**313**
	Broad-leaved, mixed and yew plantation	1,777	556,201	1.0%	**313**
	Coniferous plantation	3,420	937,422	1.6%	**274**
	Dense scrub	4,665	512,684	0.9%	**110**
Semi-natural grassland	Improved grassland	130,662	20,766,547	35.9%	**159**
Enclosed farmland	Arable fields	40,993	2,371,445	4.1%	**58**
	Peatland / Bog - good condition	8,996	1,807,296	3.1%	**201**
	Peatland / Bog - NOT in good condition	60,204	12,094,984	20.9%	**201**
	Dwarf shrub heath	1,132	83,516	0.1%	**74**
Freshwater, open water, wetlands and floodplains	Freshwater (Rivers and Streams)	1,341	146,705	0.3%	**109**
Urban	Urban - Built Environment	39,271	0	0.0%	**0**
	Total	307,306	43,923,285	100%	

9.2. Land use / nature based measures

Land parcels carry the potential to remove emissions from the atmosphere (sequester carbon) and store this carbon in the biomass, dead organic matter and soils. Varied sequestration capabilities are attributed to different land use types, with certain land use types offering more beneficial carbon services (see Table 9-2).

[43] Natural England Research Report. NERR094. Carbon storage and sequestration by habitat: a review of the evidence (second edition)

In terms of strategy, there is both a need to preserve current land use stocks, reduce existing land use emissions and maintain existing sequestration rates, and actively drive improved sequestration states via land use change if carbon removals are to be increased in the Lancashire region.

9.2.1. Preservation actions

Conversion to other uses of any land use identified in Table 9-1 may occur through urban expansion or other strategic development or agricultural needs. With urban land uses typically storing little to no carbon, if land uses that originally stored large volumes of carbon are converted to these uses, this could result in a significant loss of carbon stocks, and the emission of this carbon to the atmosphere. With this in mind, it is evident that all carbon stocks should be preserved in Lancashire and new urban development should be prevented in greenfield land.

The land use type that stores the largest stocks of carbon in the Lancashire area is Grassland (20,767 ktC). However, Grassland (Biomass, dead organic matter and soils) only holds relatively low carbon stocks of 159 tC/ha and this large carbon stock value arises from the area occupied by grassland being more than double the size of the next largest land use category.

Therefore, when understanding which areas to preserve, a per hectare approach must be adopted. This identifies the parcels of land with the highest stocks per hectare, namely Peatland (201 tC/ha to a 30cm depth) and Woodland (313 tC/ha) as those with the greatest opportunity for preservation in Lancashire.

Woodland preservation

Existing woodland provides a simple carbon stock preservation opportunity. Existing woodlands in Lancashire include Sunnyhurst Wood, Billinge Wood, Roddlesworth Woods among many others[44] and they must be preserved. Fully mature woodland can continue to sequester carbon as well, albeit at a lower rate than less mature woodland. This continued sequestration has been accounted for as part of the baseline exercise, so woodland preservation will be needed both to retain existing carbon stocks as well as protect the existing sequestration being provided by this land cover.

Peatland restoration

Existing peatland represents a huge carbon stock that must be preserved as well as an opportunity to reduce emissions and can lead to enhanced sequestration rates. Peatlands are the UK's largest on-land store of carbon, holding three times as much as woodlands nationally. However, peatland can be a net source of emissions if damaged or managed incorrectly, and as a large carbon stock it needs to be preserved, protected from further damage, and restored.

Already, the Lancashire Peatland Initiative, run by the Lancashire Wildlife Trust, has delivered habitat restoration across over 200 hectares of degraded lowland raised bog over the past three decades, with active restoration activities on numerous sites, including Little Woolden Moss, Winmarleigh Moss SSSI and Astley Moss SSSI SAC. The Trust's efforts, in collaboration with Natural England and other partners, has ultimately halted the decline of these nationally significant sites and species, resulting in an expansion of active raised bog habitats.[45]

More recently, over a million pounds of funding from the Government's Nature for Climate Peatland Grant Scheme has been awarded for the Northern Lowland Peatland Coalition, made up of organisations including Lancashire and Cumbria Peat Partnerships and the Great Manchester Wetlands Partnership. This funding is to be used in peatlands across the North West that are in need of restoration. This includes 16 sites stretching from the Solway Mosses and Black Moss in Cumbria, through Winmarleigh and Cockerham Mosses in Lancashire, via areas of the once extensive Greater Manchester Mosses, to Holiday Moss on the Mersey floodplain[46].

[44] https://www.landscapebritain.co.uk/features/lancashire/woodlands/

[45] https://www.nhbs.com/blog/lancashire-peatland-initiative-qa-with-sarah-johnson

[46] https://aboutmanchester.co.uk/peatlands-the-size-of-250-football-pitches-will-be-restored-across-greater-manchester-lancashire-and-cumbria-thanks-to-over-a-million-pounds-of-funding-from-the-governments-nature-for-clima/

Other land use types

The degradation of other land use types can also lead to carbon emissions. An example of this is potential eutrophication in freshwater areas, often driven by fertiliser use, that has shown to significantly increase carbon emissions from freshwater sources[47]. Whilst not highlighted as key actions in this report, it should be noted that preservation of other types of land cover (shrub heath and freshwater habitats can also provide high stock carbon stocks per hectare) also present an opportunity for preservation of these carbon stocks.

9.2.2. Active sequestration actions – land use change

Land use change can enhance the carbon stocks in a particular land parcel by enhancing sequestration rates. By understanding the feasibility and time requirements in creating these land use types, certain options to actively sequester carbon can be identified to drive strategy for land use change to maximise carbon sequestration.

The Environment Agency have reviewed 12 land-based measures in their review of 17 offsetting measures. Of these measures peatland restoration and woodland creation have been explored in this analysis (see Table 9-2). This is because they already have established standards and means of verifying removals projects i.e. the Woodland Carbon Code and the Peatland Code. It is recommended that this analysis be built upon in follow-on stages of work to quantify and map opportunities for other intervention types, such as farm soil carbon capture and saltmarsh restoration, where new verification standards are emerging. This study identified existing landcover where peatland restoration and woodland creation could be appropriate based on ecological constraints and best practice e.g. not proposing woodland creation on peatland.

Table 9-2 Sequestration Potential by Land Use Type

Primary Land Use Type	Sub-category	Additional emissions removals (-) per ha year (tCO_2) through land use change				Source
		Woodland creation – first 30 years	Woodland creation – after 30 years	Peatland restoration – up to year 16	Peatland restoration – from year 16	
Woodland	Broadleaved Mixed & Yew (Semi-Natural)	N/A - preserve	N/A - preserve			
	Broadleaved Mixed & Yew Plantation	N/A - preserve	N/A - preserve			
	Coniferous	N/A - preserve	N/A - preserve			
Grassland	Improved grassland	-13.64	-6.64			Values taken for Grassland and Broad-leaved Woodland from Table B-6 in Appendix B
	Dense scrub	-12.1	-5.10			Values taken for Dense Scrub and Broad-leaved Woodland from Table B-6 in Appendix B

[47] https://www.phosphorusplatform.eu/scope-in-print/news/2075-eutrophication-significantly-increases-greenhouse-emissions.

Enclosed farmland	Arable fields	-14.29	-7.29			Values taken for Arable Fields and Broad-leaved Woodland from Table B-6 in Appendix B
Mountains, moors and heaths	Peatland / Bog - good condition	N/A - preserve	N/A - preserve			
	Peatland / Bog - NOT in good condition	N/A - restore	N/A - restore	-9.80	-15.33	Values for Peatland / Bog – not in a 'good' condition taken from Table B-6 in Appendix B, the flux values for the carbon which is restoring are from Hambley and others (2019) in the Natural England 2021 paper[48].
	Dwarf shrub heath	N/A - preserve	N/A - preserve			
Freshwater	Freshwater	N/A	N/A			
Urban	Urban – built environment	N/A	N/A			

Woodland

Woodland is a prime example of a habitat that can be planted to sequester carbon. According to the National Forest Inventory, less than six per cent of Lancashire has tree cover – less than half the national average and one of the lowest of any counties in the UK. Already, an ambitious £5m project has been launched to double the amount of woodland across Lancashire by the Ribble Rivers Trust[49]. The Trust has planted more than 150,000 trees across Lancashire over the last five years through the delivery of multiple woodland creation projects and is now creating 60 miles of new or restored woodland alongside the rivers Ribble, Lune and Wyre together with their network of tributaries.

Broadleaved woodland planting options outlined in Table 9-2 have the potential to achieve strong sequestration rates (-12.10 to -14.29 tCO_2e/ha/yr above existing land use depending on where they are sited) and are capable of storing large quantities of carbon per hectare (313 tC/ha). Woodland can, however, take up to 75-100 years to fully mature and requires extensive maintenance and management at the earlier years of its lifecycle. For projects to be verified by the Woodland Carbon Code there will be specific requirements on the length of project to enable it to be a certifiable scheme.

[48] Natural England Research Report. NERR094. Carbon storage and sequestration by habitat: a review of the evidence (second edition)
[49] https://www.lep.co.uk/news/huge-new-woodland-span-lancashire-1354903

9.3. Scoring of carbon sequestration measures

An analysis of the key carbon sequestration measures identified for Lancashire in terms of their carbon reducing potential, deliverability (relating to costs, plus technology maturity and skills pipeline), Council level of influence, growth and recovery (referring to Net Zero growth and COVID-19 recovery) and other influence (levels of influence of private sector or national Government in implementing the measure) is presented in Table 9-3.

Table 9-3 - Categories of carbon sequestration measures

Key: highest high medium lowest

Measure	Reduction Potential (1-4)	Deliverability (1-4)	Council influence (1-4)	Growth & Recovery (1-4)	Other influence (1-4)	Comments
Peatland Restoration	medium	medium	medium	lowest	highest	Potential for early wins (by 2030) Requires significant support to overcome lack of revenue Significant upfront expenditure to undertake restoration activities and private revenue streams do not exist for most peatlands Substantial public funding or support is needed to deploy
Forest preservation	lowest	high	medium	medium	highest	Potential for early wins (by 2030) Limited carbon reduction potential if woodland is already mature Limited public funding or support is needed to deploy
Broad-leaved woodland planting	high high	medium medium	medium medium	medium lowest	highest highest	Most reductions post 2035 Requires substantial capital expenditure to buy land and plant trees. Revenues earned from forestry occur many years after planting Large scale transformation requires significant changes in the way landowners are incentivised to manage land and provide valuable public goods Substantial public funding or support is needed to deploy

10. Net Zero emissions by 2030 pathway

10.1. Introduction

In the most ambitious target pathway identified, there is an ambition to reach Net Zero emissions by 2030 in the Lancashire region. It is noted that because CO_2 is the only GHG being considered, Net Zero emissions in the context of this study means that, following all efforts to reduce CO_2 emissions in the region, the total of active removals of CO_2 from the atmosphere in the region offset any remaining emissions from the economy.

This section identifies the extent to which ambitious roll out of carbon reduction measures available locally in each sector would be able meet the target of 100% emissions reductions over the next eight years. It then considers whether there would be sufficient carbon removals available in territory to offset any residual emissions by 2030.

10.2. Pathway overview

Figure 10-1 shows the estimated carbon reduction pathway achieved by a maximum local ambition scenario across all sectors. It is presented with the linear target pathway to Net Zero by 2030, the Tyndall Centre budget pathway and the baseline for comparison.

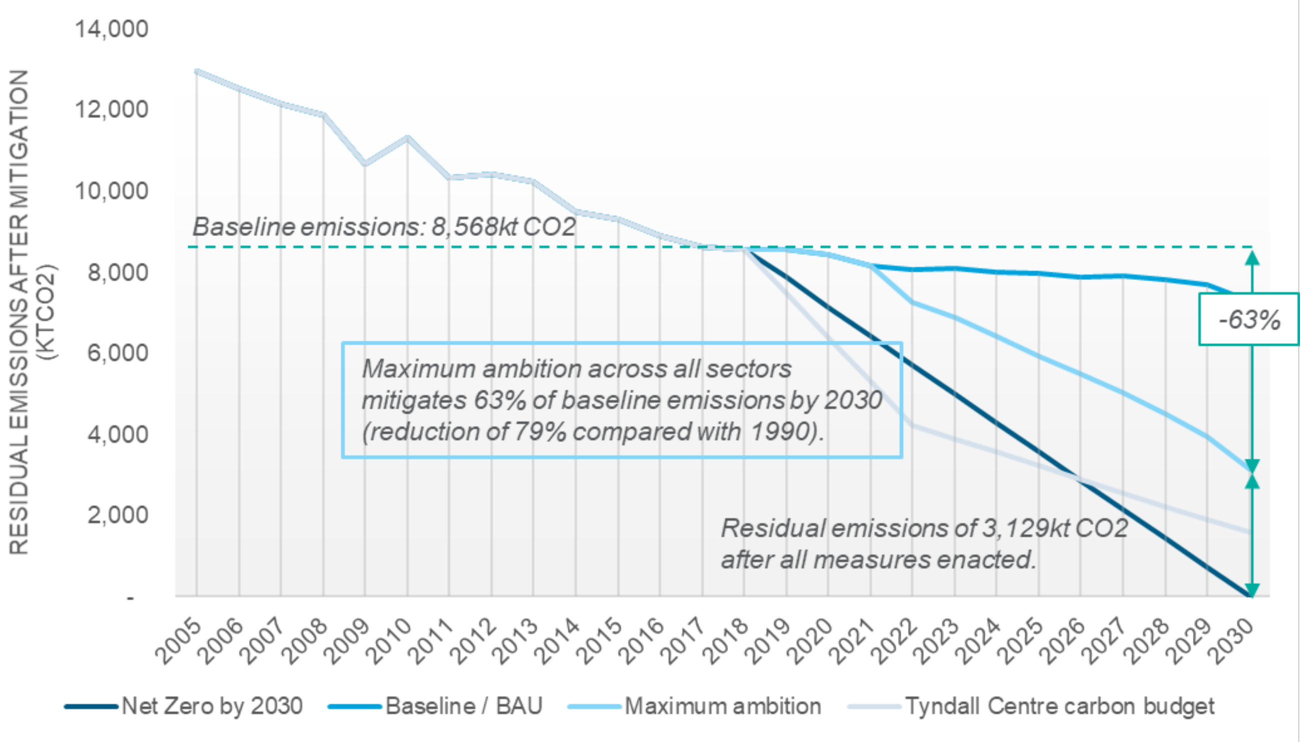
The baseline pathway shows that a meaningful reduction of baseline emissions is likely to be achieved without any intervention, due mainly from the decarbonisation of the electricity grid in the 'Business as Usual' scenario as outlined in Section 5. The carbon saving from the Business as Usual scenario is estimated to be 15% relative to 2018 by 2030, even taking into account some growth factors such as population and business activity.

The maximum ambition pathway shows that if the emissions reduction interventions available locally in all sectors were implemented to an ambitious level from 2022, in conjunction with currently identified national actions, a substantial further reduction in emissions would be achieved. The measures are estimated to mitigate CO_2 equivalent to 63% of 2018 baseline emissions, equivalent to a 79% reduction compared with 1990.

However, the mitigation achieved is not sufficient for Lancashire to achieve Net Zero emissions by 2030. Based on the measures and associated assumptions set out above (see Chapters 3, 5 and 6 to 9), it is not possible to identify removals to balance out the residual emissions across all sectors of around 3129 $ktCO_2$ p.a. in 2030.

Figure 10-1 also shows that the maximum ambition pathway is well above the Tyndall Centre budget pathway throughout the time period to 2030. This means that cumulative emissions (82$MtCO_2$) over the time period will exceed the budget (56 $MtCO_2$ for 2018-2032), increasing the contribution to climate change.

Figure 10-1: Net Zero emissions by 2030 target pathway with savings impact of mitigations (Maximum ambition)



10.3. Maximum ambition pathway analysis by sector

10.3.1. Overview

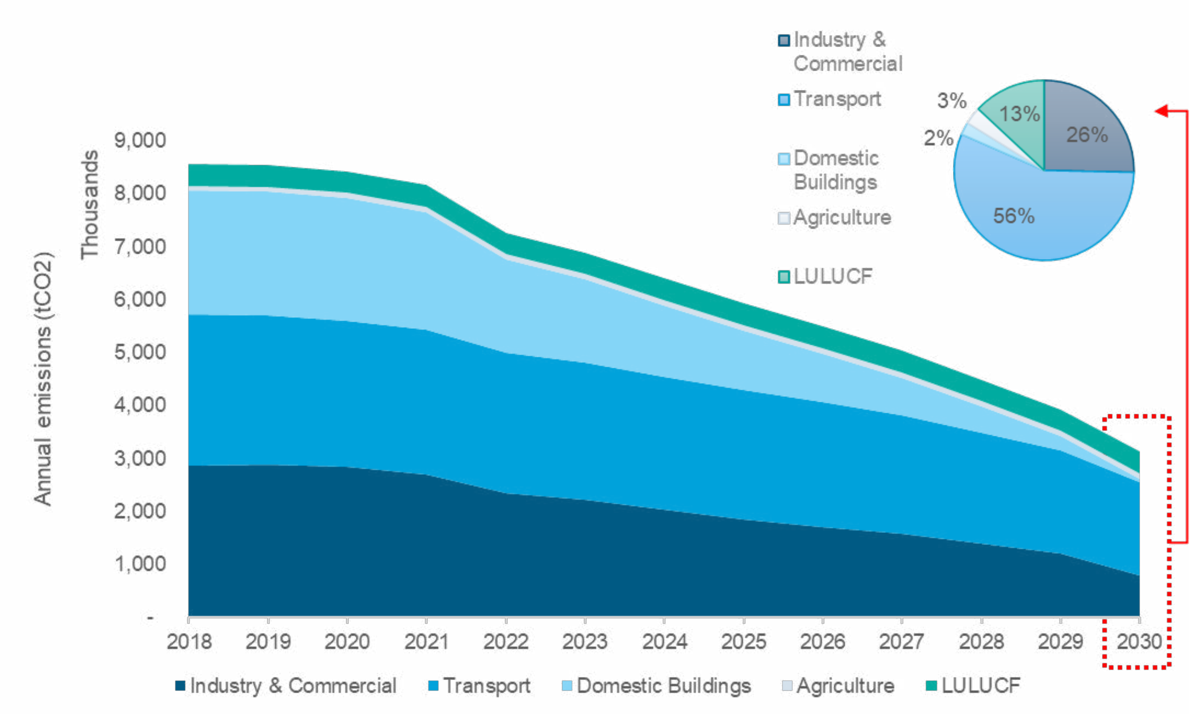
Figure 10-2 shows that the actions in the maximum ambition scenario are estimated to eliminate approximately 97% of emissions across the buildings sector.

It also shows that it is not possible to reach zero emissions by 2030 in this scenario because of the residual emissions in the transport and industrial sectors (56% and 26% respectively, compared with the baseline year). The scale of emissions remaining is largely due to constraints on the rates of uptake of measures and behaviour changes feasible in these sectors and availability of appropriate technology.

For the transport sector, whilst more significant reductions in emissions could potentially be achieved they would not be likely to be feasible through action at the regional/county level alone, without further national action (such as road pricing). The pathway shown represents a view of the impacts of currently planned national action and ambitious regional/county level action.

The following sections provide more detail on the estimated emissions savings in each sector.

Figure 10-2: Net Zero by 2030 pathway analysis, breakdown of CO_2 by emissions source



10.3.2. Transport emissions

Emissions reduction benefits of the national ban on petrol/diesel vehicles sales will be substantial in the 2030 timeframe under current forecasts of the impacts of national action but will ultimately be limited by the rate of turnover of the fleet. Local intervention to accelerate the uptake of ULEVs could be one of the most effective policies enacted at a local level, and might be anticipated to mitigate around 103 ktCO_2 annual emissions in 2030 if ambitious action was taken to encourage corporate fleet change, support EV car clubs and smaller vehicle use; and require taxi and bus fleet update[50].

Measures to reduce car travel through substantial mode shift to public, shared and active travel could have a similar scale of impact of nearly 101 ktCO_2 in annual emissions by 2030 (for public and active travel combined). This would require ambitious actions to be taken to improve the quality, reach, integration and accessibility of the public and active travel network to deliver a step change in travel behaviour.

Measures to avoid travel through providing digital or more local alternatives to trips could also have a similar scale of impact, potentially reducing annual emissions by approximately a further 101 ktCO_2 (for digital connectivity and land use planning combined), if rapid action was taken to build on the types of behaviour change seen during the COVID pandemic through high quality digital connectivity options and planning support for localisation of activity.

Introduction of strong demand management at the local level (through changes to parking charges and availability and allocation of road space) would also substantially increase the impacts of measures to achieve mode shift and reduce travel overall.

The emissions savings estimated for the scenario reflect the fact that there are limits to what can be achieved through regional/local action alone. The integrated, interconnected nature of the transport sector and fleet means that measures required to achieve even more rapid change, such as greater restraints on the vehicle fleet or the introduction of road pricing would be likely to require national action.

[50] Blackpool's transport is wholly owned by the Council, which means that it can directly influence its future plans for the adoption of electric fleets (such as EV buses). Works could commence with a rolling replacement programme from 2022 onwards.

10.3.3. Residential buildings emissions

These emissions could be largely eliminated through concerted action to roll out fabric improvements, decarbonise heat demand and install roof-mounted PV. But this would only be possible if most buildings in Lancashire were covered by all measures considered. It would be a massive undertaking, even with mature technologies.

10.3.4. Industrial emissions

Some savings could be achieved in this sector through similar measures to those deployed for residential buildings as industrial emissions include gas and electricity consumption from industrial and commercial (non-residential) buildings, including office buildings. Further savings (3%) would be achieved through measures such as resource efficiency, materials substitution, energy efficiency and electrification. Resource efficiency and materials substitution would yield the greatest savings in process emissions. However, the most significant savings in Industry would not be available until after 2030. Resource efficiency and materials substitution would yield the greatest savings in process emissions.

10.3.1. Net emissions

Although the tables show a range of interventions and carbon reductions, the residual emissions of 3,129 ktCO_2 following implementation of all available measures are substantial. This means that it is not possible to achieve the Net Zero target by 2030 under the assumptions used in this study. Any nature-based solution planted today will take at least 10-12 years to become established before it begins removing CO_2 from the atmosphere; this will take the impacts beyond the 2030 target date. In addition, no Negative Emissions Technologies such as BECCS (Bioenergy with Carbon Capture and Storage) are expected to reach maturity before 2035.

10.4. Summary of maximum ambition pathway impacts per sector

The assumed emissions reduction interventions and rate of ramp up for the three key sectors under consideration are detailed in the following Tables 10-2 to 10-4. The tables also show the potential impact of ambitious local roll out of the individual interventions in each sector on meeting the net zero 2030 target.

Table 10-1 shows the total contribution of each of the three key sectors to meeting the 2030 net zero target set out in Figure 10-2 and associated indicative costs. It is noted that the costs provide a high level indication of the total capital costs of implementing the decarbonisation measures. Net costs would be lower once the savings associated with reference case spending avoided (e.g. replacement conventional boilers) and operating cost savings have been accounted for.

The emission reductions shown are relative to the Business as Usual Scenario (in which emissions per year are approximately 1,268 ktCO_2 lower than in 2018).

Table 10-1 - Summary of emissions mitigated in 2030 in maximum ambition scenario and indicative costs across sectors

Sector	Annual emissions mitigated compared to baseline (in 2030, $ktCO_2$)*	Indicative costs (capital total expenditure, current prices, total to 2030)*	Comments
BAU contribution	1268	N/A	N/A
Transport	577	Approx. £15 bn	Net capital costs would be considerably (potentially 90%) lower as much of the zero emissions expenditure replaces conventional expenditure (such as EVs in place of petrol/diesel vehicles). Considerable opex savings would also be experienced due to the transfer to EVs.
Domestic Buildings	2,088	£16 bn	Net capital costs would be lower as net zero interventions replace conventional expenditure (such as LED lighting and heat pump installation vs gas boiler or light replacement) Considerable savings in energy bills would also be expected through reduced energy consumption as a result of efficiency measures in buildings.
Industry and Commercial	1,506	£7.5 bn	As above. For the industry, efficiency measures would be expected to lead to opex savings.
Total	**5,439 $ktCO_2$**	**Approx. £40 bn**	

Note: * All figures are indicative estimates only and show the total estimated cost of implementing the decarbonisation measures. The net additional cost associated with the measures would be considerably lower as in many cases the decarbonisation measure (such as a heat pump) would be instead of an alternative (e.g. conventional boiler). Several measures would also deliver operating cost savings.

Table 10-2: Summary of interventions with indicative carbon savings, roll-out rates and costs - Transport

Intervention	Extent of impact by 2025 (as % of 2030)[1]	Extent of impact by 2030[1]	Estimated annual emissions mitigated (in 2030; $ktCO_2$)[5]	Measures and estimated impacts by 2030[3]	Indicative costs (capex, current prices, total to 2030)[2, 4,5]	Comments on net costs	Allocation of costs public/ private sector
National action to ban petrol/diesel car/van sales	10%	100%	-154	Ban on sales of petrol/diesel cars and vans from 2030 (and plug in hybrids from 2035) and supporting public and private infrastructure. Assumed to cause 20% to 25% of car vehicle kms to be by EV by 2030	£13 bn	Potentially some income from electricity charges. Only 10% of total capital cost (i.e. £1bn) estimated to be net additional to the reference scenario (i.e. majority of capex would have been required to purchase non EVs). Reduced operating cost of EVs compared to petrol/diesel vehicles offsets approximately -40% of additional capex (based on CCC analysis)[51]	Mainly private sector. Some public sector support (particularly for charging infrastructure)
National action to upgrade HGV fleet/ban diesel vehicle sale	0%	100%	-103	*Ban of sales of diesel HGVs from 2035 (if < 26 tonnes) or 2040 (> 26 t). Limited impact by 2030, 5% to 10% of vehicles ZEVs.*	*£0.5bn*	Potentially some income from electricity charges. Only 20% of total capital cost (i.e. <£0.1bn) estimated to be net additional to the reference scenario (i.e. majority of capex would have been required to purchase alternative vehicles). Reduced opex of EVs compared to diesel vehicles offsets approximately -60% of	As above

[51] Commentary on costs based on analysis in CCC 6th Carbon Budget, 2020 and supporting dataset

Intervention	Extent of impact by 2025 (as % of 2030)[1]	Extent of impact by 2030[1]	Estimated annual emissions mitigated (in 2030; $ktCO_2$)[5]	Measures and estimated impacts by 2030[3]	Indicative costs (capex, current prices, total to 2030)[2, 4,5]	Comments on net costs	Allocation of costs public/ private sector
						additional capex (based on CCC analysis)	
Accelerate ULEV uptake (through publicly-owned fleets, support for car clubs and corporate fleet upgrades etc.).	5%	100%	-103	Promotion of uptake of amongst council (including taxi and bus), supplier and corporate fleets and through car clubs and additional charging infrastructure – leading EV uptake to accelerate locally ahead of national average by 9 months by 2030 and 12 months by 2032 then decreasing.	£0.5bn	Approx. 85% of total capital cost estimated to be net additional to the reference scenario (i.e. majority of capex would have been required to purchase alternative vehicles). Reduced opex of EV offsets approximately -30% of additional capex (based on CCC analysis). Additional opex associated with staff time to coordinate and raise awareness of EVS and carclubs and subsidise operation of car clubs	Private sector for vehicles. Public sector to support infrastructure, car club subsidy and staff time to support take up in taxi fleets
Increase active travel/micro mobility use	30%	100%	-52	Significant improvement in availability of routes suitable for cycling and in willingness to cycle, including use of e-bikes on longer journeys. Estimates based on expansion of DfT’s propensity to cycle toolkit (PCT) of 400% to 450% increase in cycling levels relative to the reference case (average across all purposes), increasing to 650% by the mid 2030s.	£0.5bn	Ongoing maintenance required and cycle hire schemes	Largely public sector

Intervention	Extent of impact by 2025 (as % of 2030)[1]	Extent of impact by 2030[1]	Estimated annual emissions mitigated (in 2030; $ktCO_2$)[5]	Measures and estimated impacts by 2030[3]	Indicative costs (capex, current prices, total to 2030)[2, 4,5]	Comments on net costs	Allocation of costs public/ private sector
Increase public transport use	15%	100%	-49	Better, more integrated, affordable, accessible, and reliable public and shared transport services and MaaS system. Leading to increased patronage of 25% by 2030 (relative to 2019), further increasing throughout the 2030s.	£0.5bn	Ongoing operating costs for running services likely roughly match capital costs every 5 years or so	Largely public sector
Demand management	30%	100%	-73	Increased charging for car parking and relocation of spaces out of central areas causing ~50% cost increase (including walk time) by 2030 for ~50% of commuting/ business journeys, ~ 35% of shopping journeys and 25% of journeys for all other types) – reducing car travel. Impacts forecast to continue to increase through the 2030s. Delivery restrictions, supported by consolidation hubs leading to a transfer of last mile trips reducing diesel freight vehicle kms by up to ~5% by 2030 with impacts further increasing through the 2030s	<£0.1 bn	Charging likely to be revenue generating	Largely public sector
Efficient network management	90%	100%	-28	Use of data and signals to improve management of network and reduce congestion - increasing average speed on 50% of the slowest links	£0.5bn	Limited ongoing maintenance required	Largely public sector

Intervention	Extent of impact by 2025 (as % of 2030)[1]	Extent of impact by 2030[1]	Estimated annual emissions mitigated (in 2030; $ktCO_2$)[5]	Measures and estimated impacts by 2030[3]	Indicative costs (capex, current prices, total to 2030)[2, 4,5]	Comments on net costs	Allocation of costs public/ private sector
				(<25mph) by 5 mph through congestion relief.			
Land use planning	40%	100%	-48	20-minute neighbourhood principles to diversify the range of land uses available in urban areas – by 2030 causing ~10% reduction in car travel for shopping and personal business trips and ~5% reduction for leisure trips (due to shorter and/or fewer, combined trips). Impacts forecast to continue to increase during the 2030s.	N/a	Staff time (potentially one role per authority) to coordinate planning and raise awareness	Largely public sector
Digital connectivity	95%	100%	-53	Improved digital connections and increased online opportunities and activities: Reduction in commuting and business trips of ~5%. Reductions of up to 5% for personal business, shopping, leisure trips	£1bn	Ongoing costs for maintenance of network and operation of hubs, including staff time.	Largely private sector for provision of digital network. Public sector to support delivery of digital network and hubs that are not commercially viable (e.g. rural areas)
Total			**-577 $ktCO_2$**		**~£15 bn**		

Notes:

1. 2025 percentages represent emissions savings as a proportion of 2030 emissions savings. The 100% in 2030 represents the fact that the ambitious local action scenario is fully implemented, that does not mean that all emissions can be mitigated through intervention within the timeframe.

2. Total costs provide an indication of the total capital expenditure involved in implementing the measures assumed in the scenario. It does not account for savings associated with being able to avoid reference case expenditure or impacts on operating costs. The next column to the right provides commentary on these issues
3. Further detail on the estimated impacts assessed is provided in the Appendices
4. Economies of scale not captured in this analysis; any costs represented are indicative and aggregated only to meet the target reduction (cumulative to 2030).
5. All figures are indicative estimates only.

Table 10-3: Summary of interventions with indicative carbon savings, roll-out rates and costs - Domestic Buildings

Intervention	Extent of roll-out by 2025[1]	Extent of roll-out by 2030[1]	Annual emissions mitigated (in 2030; tCO_2)[3]	Units (annual)	Indicative costs capital expenditure, current prices, total to 2030)[2, 3]	Comments on net costs
Insulation	50%	100%	-759	60,680	£3.6 bn	Operating cost savings from energy savings.
Glazing	50%	100%	-107	60,680	£4.3 bn	Operating cost savings from energy savings
Heat pumps	50%	100%	-833	60,680	£4.9 bn	Net costs would be much lower as there would be capital expenditure on alternative conventional heating in the reverence case.
LED lighting	50%	100%	-7	60,680	<£0.01 bn	Net costs would be much lower as there would be capital expenditure on alternative conventional heating in the reverence case.
Solar PV panels	50%	100%	-382	60,680	£3.1 bn	Operating cost savings from electricity purchase savings
Total			**-2,088 $ktCO_2$**		**~£15.9 bn**	

Notes:

- If all possible emissions savings are targeted through the mitigation measure, this will read 100%; that does not mean that all emissions can be mitigated through intervention within the timeframe.
- Economies of scale not captured in this analysis; any costs represented are indicative and aggregated only to meet the target reduction (cumulative to 2030).
- All figures are indicative estimates only.

Table 10-4: Summary of interventions with indicative carbon savings, roll-out rates and costs - Industry and Commercial (Non-Residential) Buildings

Intervention	Extent of roll-out by 2025[1]	Extent of roll-out by 2030[1]	Annual emissions mitigated (in 2030; $ktCO_2$)[4]	Units (annual)	Indicative costs (capital expenditure, current prices, total to 2030)[2, 4]	Comments
Insulation	50%	100%	-250	23,537	£0.7 bn	Operating cost savings from energy savings.
Glazing	50%	100%	-71	23,537	£2.0 bn	Operating cost savings from energy savings
Heat pumps	50%	100%	-596	23,841	£2.3 bn	Net costs would be much lower as there would be capital expenditure on alternative conventional heating in the reverence case.
LED lighting	50%	100%	-139	23,841	<£0.02 bn	Net costs would be much lower as there would be capital expenditure on alternative conventional heating in the reverence case.
Solar PV panels	50%	100%	-307	23,841	£2.4 bn	Operating cost savings from electricity purchase savings
Energy efficiency	50%	100%	-17	*Unable to quantify*	<£0.001 bn	Measures are applied to multiple processes at a small number of point sites to achieve incremental savings across all processes.
Resource efficiency and material substitution	50%	100%	-127	*Unable to quantify*	£0	
Electrification[3]	50%	100%	-0.175	*Unable to quantify*	£0	
Total			**-1,506 $ktCO_2$**		**~£7.5 bn**	

Notes:

1. If all possible emissions savings are targeted through the mitigation measure, this will read 100%; that does not mean that all emissions can be mitigated through intervention within the timeframe.
2. Economies of scale not captured in this analysis; any costs represented are indicative and aggregated only to meet the target reduction (cumulative to 2030).
3. Minimal savings available in this timeframe.
4. All figures are indicative estimates only.

11. 68% reduction of emissions by 2030 pathway

11.1. Introduction

The second carbon reduction pathway considered has the target of reaching a 68% reduction in emissions (relative to 1990) in the Lancashire region by 2030, rather than achieving net zero.

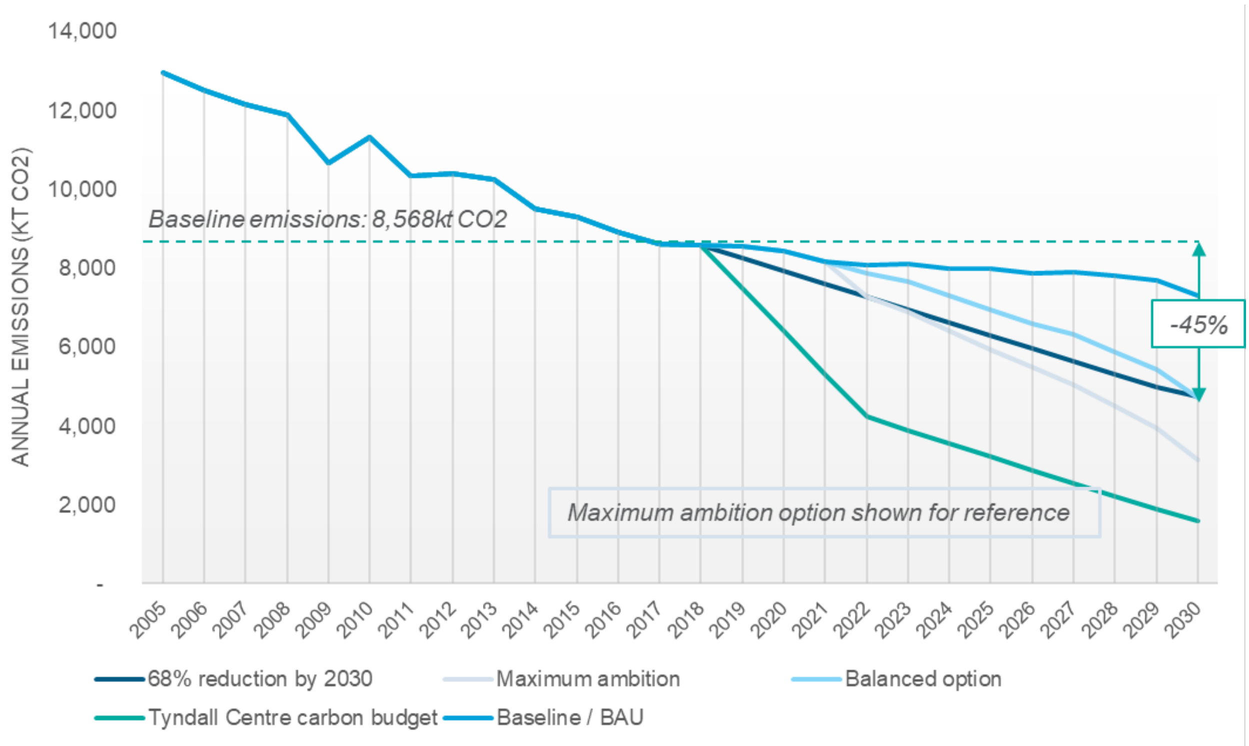
Given the less ambitious reductions required in 2030 compared to the net zero target analysed in Section 10, it is possible to introduce some of the measures identified at slower rates than in the maximum ambition scenario described in Section 10 and still meet this target.

This section provides more detail on the potential balance of carbon reduction measures across the sectors that could achieve the target and the shape of the carbon reduction pathway to the target year.

11.2. Pathway overview

Figure 11-1 summarises the estimated carbon reduction pathway achieved by a balanced option for meeting the 68% reduction target by 2030 across all sectors. For comparison, it is shown with the linear target pathway to the 68% reduction target, the maximum ambition scenario described in Section 10, the Tyndall Centre budget pathway and the baseline.

Figure 11-1: 68% reduction of emissions by 2030 target pathway with savings impact of mitigations (balanced option)



The balanced option pathway represents one view of a balanced combination of measures rolled out partially to meet the 68% reduction target by 2030, identified following testing of a range of 'intervention rates' for different measures.

For domestic and commercial buildings measures are assumed to roll out at between approximately 45% and just over 70% of the levels assumed in the maximum ambition scenario by 2030.

Insulation, glazing and commercial LED lighting measures are assumed to have the most ambitious rates of intervention. On the other hand, harder-to-reach measures are assumed to be rolled out at slower rates, in particular, heat pumps for decarbonisation of heat in buildings, for which roll out rates track only slightly above current Government commitments[52] in this option (approximately 45% of the level of implementation assumed in the maximum ambition scenario in 2030).

For the transport sector, local measures are assumed to roll out at approximately 70% of the levels assumed in the maximum ambition scenario by 2030 (with national action assumed to apply fully).

Measures to reduce emissions at large industrial installations (such as material substitution and energy efficiency) are assumed to apply at the levels assumed in the maximum ambition scenario.

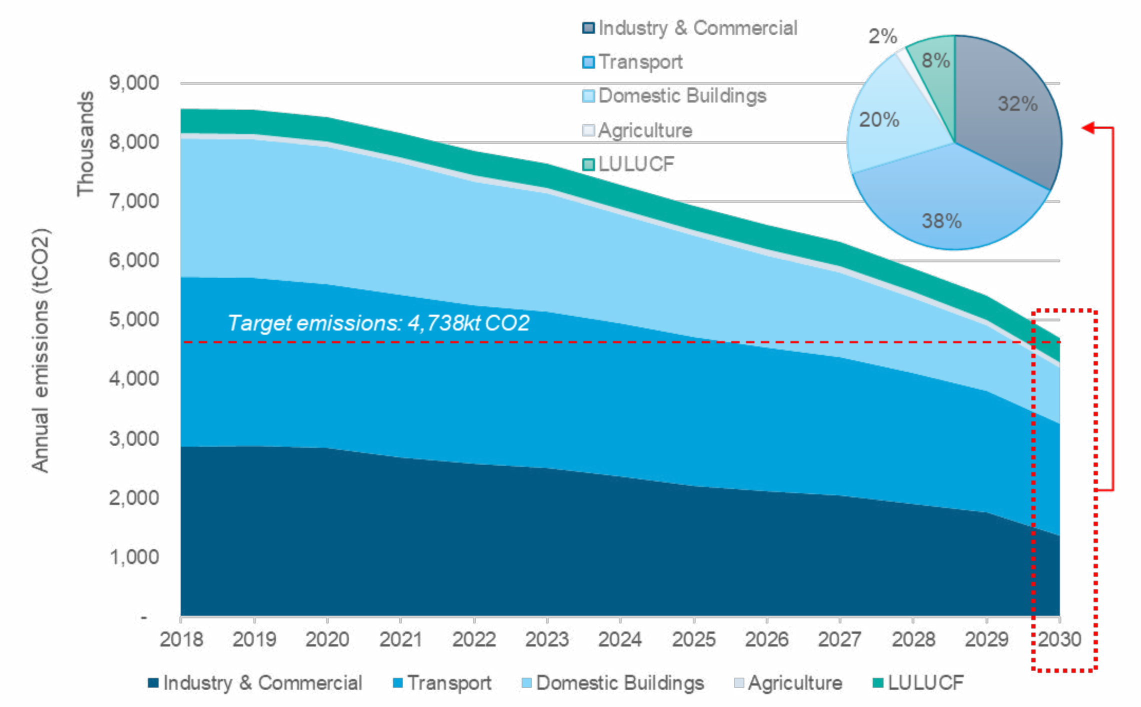
The tables at the end of this section set out the assumptions made for each sector.

Although the balanced option shown meets the target by the deadline year, the linear pathway to the target is only approximately matched, as emissions reductions are forecast to initially build up slowly and then to accelerate towards 2030. Consequently, the cumulative emissions associated with the pathway (92 $MtCO_2$) would exceed those associated with the linear target pathway and the Tyndall centre budget (56 $MtCO_2$ for 2018-2032 period), increasing the scale of contribution to climate change.

11.3. Balanced option pathway analysis by sector

Figure 11-2 shows the estimated emissions remaining by sector in the balanced option pathway.

Figure 11-2: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source



The residual emissions for the balanced option are forecast to be approximately 4,709 $ktCO_2$. in 2030 which just exceeds the target of 4,738 $ktCO_2$.

[52] We estimate that the commitment in the Energy White Paper to accelerate installs of heat pumps to 600,000 homes per annum by 2030 would aggregate to approx. 23% of households in Lancashire by 2030, if installed evenly across the UK. The target set here is to have 30% of homes in Lancashire equipped by 2030.

This option addresses all sectors together, but is weighted slightly towards buildings, where the technology is more mature and action can be taken more effectively in the nearer term. This results in Transport and Industry & Commercial contributing approximately 40% and 30% respectively to the residual emissions and Domestic Buildings only contributing approximately 20%.

The residual emissions for the Transport sector reflect how difficult early decarbonisation of the transport system would be. Prior to the effect of the petrol/diesel vehicle sales ban becoming significant, mitigation of this sector requires rapid roll out of measures to reduce road travel by encouraging mode shift and a switch to digital and more local activity.

11.4. Sensitivity testing

The balanced option represents one indicative view of how Lancashire could meet the 68% reduction target by 2030 (compared with 1990)[53]. However, there are multiple ways in which the target could be met. To illustrate the trade-offs and balances between measures and sectors involved, two options were tested to understand the balance between emissions reductions in the Transport and Building sectors if different 'at the limit' assumptions on levels of local transport intervention were taken. Option 1 assumed Ambitious local transport intervention (as in the maximum ambition scenario described in Section 10) and Option 2 assumed Limited transport interventions (no local transport measures and reduced national interventions).The pathways for both options are shown in Figure 11-3, alongside the balanced option.

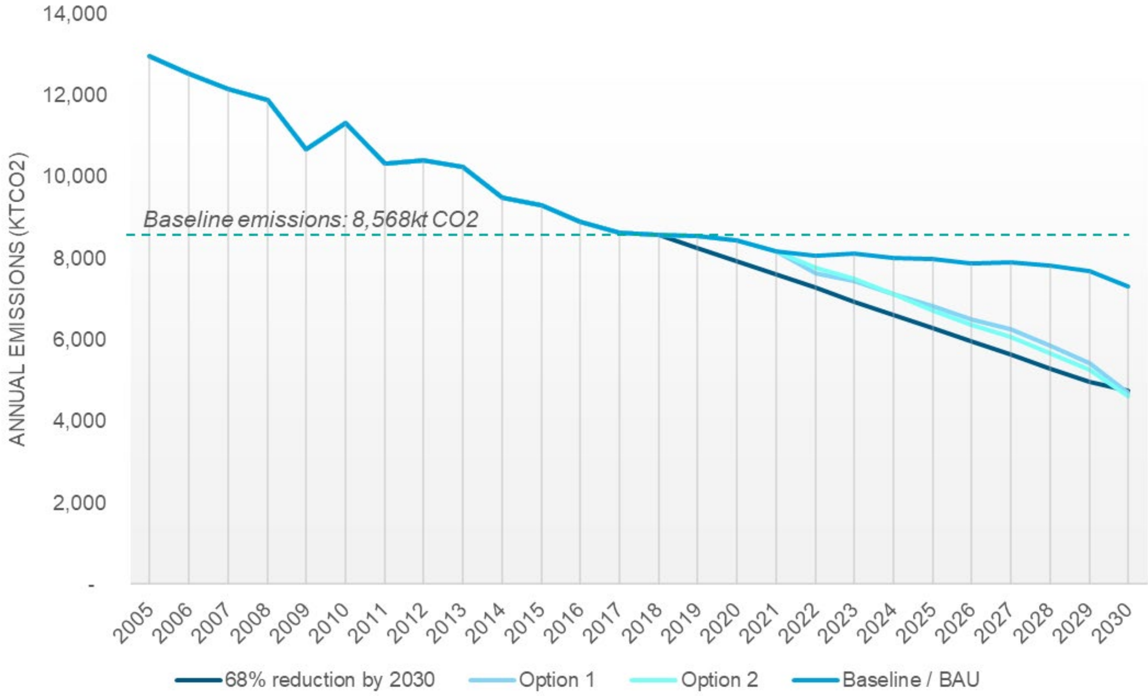
Option 1 shows that even if Lancashire were to focus on Transport measures and implement them at an ambitious level locally, substantial action to address emissions from buildings (Option 1) would still be needed to achieve the 68% reduction target. This highlights the reality that emissions from the Transport sector will continue to be significant by 2030, even with focused local action in the short term. This reflects the time taken for the vehicle fleet to change to new vehicle types (the average life of a car is 14 years) and the need for national action to support even more rapid change (for instance road pricing and action to change the HGV fleet).

In this option, it would be necessary to reach over 80% of Lancashire's buildings to install insulation and glazing; installation of heat pumps would also be required in over 40% of buildings [54], although no solar panels would need to be installed.

On the other hand, Option 2 shows that if action was taken in Lancashire to reach over 70% of the buildings in the county to apply a full set of measures (including heat pumps and solar PV panels) it could still achieve the target by 2030 even if no local measures relating to Transport were implemented and reduced levels of national action to support ULEVs (40% of the central case) was assumed.

[53] This represents a reduction 43% compared with baseline (2018) emissions, due to savings that have already been achieved between 1990-2018; the target will still be referred to as '68% reduction'.
[54] We estimate that the commitment in the Energy White Paper to accelerate installs of heat pumps to 600,000 homes per annum by 2030 would aggregate to approx. 23% of households in Lancashire by 2030, if installed evenly across the UK. The target set here is to have 30% of homes in Lancashire equipped by 2030.

Figure 11-3: 68% emissions reduction by 2030 target pathway with savings impact of mitigations (sensitivity tests)



11.5. Summary of balanced option interventions at regional level

Interventions and rate of ramp up for the three key sectors under consideration are detailed in the tables at the end of this section (Table 11.2 to Table 11.4). They show the extent to which the interventions in each sector are assumed to be rolled out to meet the target set out above with the balance of measures assumed. The tables provide an 'inventory view' of measures with an indicative rate of roll-out and a high level view of indicative associated costs.

Table 11-1 summarises shows the total contribution of each sector to meeting the 2030 target set out in Figure 11-3 and associated indicative costs. The costs provide a high level indication of the total capital costs of implementing the decarbonisation measures. Net costs would be lower once the savings associated with reference case spending avoided (e.g. replacement conventional boilers) and operating cost savings have not been accounted for.

The emission reductions shown are relative to the Business as Usual Scenario (in which emissions per year are approximately 1,268 ktCO_2 lower in 2030 than in 2018).

Table 11-1: Balanced option: summary of emissions mitigated and indicative capital costs of decarbonisation measures*

Sector	Annual emissions mitigated compared to 2018 baseline (in 2030, $ktCO_2$)	Indicative costs (capital expenditure, current prices, cumulative to 2030)*	Comments
BAU contribution	1,268	N/A	N/A
Transport	455	~£15 bn[55]	Net capital costs would be considerably (potentially 90%) lower as much of the zero emissions expenditure replaces conventional expenditure (such as EVs in place of petrol/diesel vehicles). Considerable opex savings would also be experienced due to the transfer to EVs.
Domestic Buildings	1,215	£9.5 bn	Net capital costs would be lower as net zero interventions replace conventional expenditure (such as LED lighting and heat pump installation vs gas boiler or light replacement) Considerable savings in energy bills would also be expected through reduced energy consumption as a result of efficiency measures in buildings.
Industry and Commercial Buildings	921	£4.5 bn	As above. For the industry, efficiency measures would be expected to lead to opex savings.
Total	**3,859 $ktCO_2$**	**~£30 bn**	

Note: * All figures are indicative estimates only and show the total estimated cost of implementing the decarbonisation measures. The net additional cost associated with the measures would be considerably lower as in many cases the decarbonisation measure (such as a heat pump) would be instead of an alternative (e.g. conventional boiler). Several measures would also deliver operating cost savings.

[55] Costs also shown as ~£15 bn as for max ambition. The costs for this pathway would be lower than the costs for the max ambition but the main expenditure on EVs is the same in both pathways. The variations are in more minor costs and given the level of uncertainty involved, both are most appropriately summarised to £15 bn.

Table 11-2: Balanced option: summary of interventions with indicative carbon savings, roll-out rates and costs – Transport

Intervention	**Extent of roll-out by 2025** (as % of 2030 max ambition)[1]	**Extent of roll-out by 2030** (as % of 2030 max ambition)[1]	**Measures and estimated impacts**[3]	**Indicative costs (capital expenditure, current prices, total to 2030)**[2, 4,5]		**Comments on net costs**	**Allocation of costs public/private sector**
National action to ban petrol/diesel car/van sales	10%	100%	Ban on sales of petrol/diesel cars and vans from 2030 (and plug in hybrids from 2035) and supporting public and private infrastructure. Assumed to cause 20% to 25% of car vehicle kms to be by EV by 2030	£13 bn		Potentially some income from electricity charges. Only 10% of total capital cost (i.e. £1bn) estimated to be net additional to the reference scenario (i.e. majority of capex would have been required to purchase non EVs). Reduced operating cost of EVs compared to petrol/diesel vehicles offsets approximately -40% of additional capex (based on CCC analysis)[56]	Mainly private sector. Some public sector support (particularly for charging infrastructure)
National action to upgrade HGV fleet/ban diesel vehicle sale	0%	100%	*Ban of sales of diesel HGVs from 2035 (if < 26 tonnes) or 2040 (> 26 t). Limited impact*	*£0.5 bn*		Potentially some income from electricity charges. Only 20% of total capital cost (i.e. <£0.1bn) estimated to be net additional to the reference scenario (i.e. majority of capex would have been required to purchase	As above

[56] Commentary on costs based on analysis in CCC 6th Carbon Budget, 2020 and supporting dataset

Intervention	Extent of roll-out by 2025 (as % of 2030 max ambition)[1]	Extent of roll-out by 2030 (as % of 2030 max ambition)[1]	Measures and estimated impacts[3]	Indicative costs (capital expenditure, current prices, total to 2030)[2, 4,5]		Comments on net costs	Allocation of costs public/private sector
			by 2030, 5% to 10% of vehicles ZEVs.			alternative vehicles). Reduced opex of EVs compared to diesel vehicles offsets approximately -60% of additional capex (based on CCC analysis)	
Accelerate ULEV uptake (through publicly-owned fleets, support for car clubs and corporate fleet upgrades etc.).	5%	70%	-72	Promotion of uptake of amongst council (including taxi and bus), supplier and corporate fleets and through car clubs and additional charging infrastructure – leading EV uptake to accelerate locally ahead of national average by 6 months by 2030 and 12 months by 2034 for a number years and then decreasing.	£0.5 bn	Approx. 85% of total capital cost estimated to be net additional to the reference scenario (i.e. majority of capex would have been required to purchase alternative vehicles). Reduced opex of EV offsets approximately -30% of additional capex (based on CCC analysis). Additional opex associated with staff time to coordinate and raise awareness of EVS and car clubs and subsidise operation of car clubs	Private sector for vehicles. Public sector to support infrastructure, car club subsidy and staff time to support take up in taxi fleets
Increase active travel/micro mobility use	20%	70%	-36	Significant improvement in availability of routes suitable for cycling and in willingness to cycle, including use of e-bikes on longer journeys. Estimates based on expansion of DfT's propensity to cycle toolkit (PCT) of 300% increase in cycling levels (average across all purposes), increasing through the 2030s.	£0.5 bn	Ongoing maintenance required and cycle hire schemes	Largely public sector

Intervention	**Extent of roll-out by 2025** (as % of 2030 max ambition)[1]	**Extent of roll-out by 2030** (as % of 2030 max ambition)[1]	**Measures and estimated impacts**[3]	**Indicative costs (capital expenditure, current prices, total to 2030)**[2, 4,5]		**Comments on net costs**	**Allocation of costs public/private sector**
Increase public transport use	10%	70%	-34	Better, more integrated, affordable, accessible, and reliable public and shared transport services and MaaS system. Leading to increased patronage of approaching 20% by 2030 (relative to 2019), further increasing throughout the 2030s.	£0.5 bn	Ongoing operating costs for running services likely roughly match capital costs every 5 years or so	Largely public sector
Demand management	20%	70%	-51	Increased charging for car parking and relocation of spaces out of central areas by 2030 causing ~35% cost increase (including walk time) for ~50% of commuting/ business journeys, ~ 35% of shopping journeys and 25% of journeys for all other types) – reducing car travel. Impacts expected to increase in the 2030s. Delivery restrictions, supported by consolidation hubs leading to a transfer of last mile trips reducing diesel freight vehicle kms by up to 5% by 2030.	<£0.1 bn	Charging likely to be revenue generating	Largely public sector
Efficient network management	50%	70%	-20	Use of data and signals to improve management of network and reduce congestion - increasing average speed on 35% of the	£0.5 bn	Limited ongoing maintenance required	Largely public sector

Intervention	**Extent of roll-out by 2025** (as % of 2030 max ambition)[1]	**Extent of roll-out by 2030** (as % of 2030 max ambition)[1]	**Measures and estimated impacts**[3]	**Indicative costs (capital expenditure, current prices, total to 2030)**[2, 4,5]		**Comments on net costs**	**Allocation of costs public/private sector**
				slowest links (<25mph) by 5 mph through congestion relief.			
Land use planning	25%	70%	-34	20-minute neighbourhood principles to diversify the range of land uses available in urban areas – causing ~5% to 10% reduction in car travel for shopping and personal business trips and up to ~5% reduction for leisure trips (due to shorter and/or fewer, combined trips).	N/a	Staff time (potentially one role per authority) to coordinate planning and raise awareness	Largely public sector
Digital connectivity	55%	70%	-37	Improved digital connections and increased online opportunities and activities: Reduction in commuting and business trips of up to ~5%. Reductions of up to 5% for personal business, shopping, leisure trips	£1.0 bn	Ongoing costs for maintenance of network and operation of hubs, including staff time.	Largely private sector for provision of digital network. Public sector to support delivery of digital network and hubs that are not commercially viable (e.g. remote rural areas)

Intervention	Extent of roll-out by 2025 (as % of 2030 max ambition)[1]	Extent of roll-out by 2030 (as % of 2030 max ambition)[1]	Measures and estimated impacts[3]	Indicative costs (capital expenditure, current prices, total to 2030)[2, 4,5]		Comments on net costs	Allocation of costs public/private sector
Total			**-455 $ktCO_2$**		**~£15 bn**		

Notes:

1. 2025 and 2030 percentages represent emissions savings as a proportion of 2030 max ambition emissions savings shown in Section 10. 100% in 2030 would represent the fact that the ambitious local action scenario is fully implemented, that does not mean that all emissions can be mitigated through intervention within the timeframe.
2. Total costs provide an indication of the total capital expenditure involved in implementing the measures assumed in the scenario. It does not account for savings associated with being able to avoid reference case expenditure or impacts on operating costs. The next column to the right provides commentary on these issues
3. Further detail on the estimated impacts assessed is provided in the Appendices
4. Economies of scale not captured in this analysis; any costs represented are indicative and aggregated only to meet the target reduction (cumulative to 2030).
5. All figures are indicative estimates only.

Table 11-3: Balanced option: summary of interventions with indicative carbon savings, roll-out rates and costs - Domestic Buildings

Intervention	Extent of roll-out by 2025[1]	Extent of roll-out by 2030[1]	Annual emissions mitigated (in 2030; $ktCO_2$)[3]	Units (annual)	Indicative costs (capital expenditure, current prices, total to 2030)[2, 3]	Comments
Insulation	32%	72%	-546	43,690	£2.6 bn	Operating cost savings from energy savings.
Glazing	32%	72%	-77	43,690	£3.1 bn	Operating cost savings from energy savings .
Heat pumps	16%	43%	-358	26,699	£2.1 bn	Net costs would be much lower as there would be capital expenditure on alternative conventional heating in the reference case.
LED lighting	23%	60%	-4	36,408	<£0.01 bn	Net costs would be much lower as there would be capital expenditure on alternative conventional heating in the reference case.
Solar PV panels	23%	60%	-229	36,408	£1.9 bn	Operating cost savings from electricity purchase savings.
Total			**-1,215 $ktCO_2$**		**~£9.6 bn**	

Notes:

- If all possible emissions savings are targeted through the mitigation measure, this will read 100%; that does not mean that all emissions can be mitigated through intervention within the timeframe.
- Economies of scale not captured in this analysis; any costs represented are indicative and aggregated only to meet the target reduction (cumulative to 2030).
- All figures are indicative estimates only.

Table 11-4: Balanced option: summary of interventions with indicative carbon savings, roll-out rates and costs - Industry and Commercial (Non-Residential) Buildings

Intervention	Extent of roll-out by 2025[1]	Extent of roll-out by 2030[1]	Annual emissions mitigated (in 2030; $ktCO_2$)[4]	Units (annual)	Indicative costs (capital expenditure, current prices, total to 2030)[2, 4]	Comments
Insulation	40%	72%	-180	2,118	£0.5 bn	*None.*
Glazing	40%	72%	-51	2,118	£1.4 bn	*None.*
Heat pumps	19%	44%	-262	1,311	£1.0 bn	*None.*
LED lighting	40%	72%	-100	2,146	<£0.01 bn	*None.*
Solar PV panels	30%	60%	-184	14,304	£1.5 bn	*None.*
Energy efficiency	100%	100%	-17	*Unable to quantify*	<£0.01 bn	Measures are applied to multiple processes at a small number of point sites to achieve incremental savings across all processes.
Resource efficiency and material substitution	100%	100%	-127	*Unable to quantify*	£0	
Electrification[3]	100%	100%	-0.175	*Unable to quantify*	£0	
Total			**-921 $ktCO_2$**		**~£4.5 bn**	

Notes:

- If all possible emissions savings are targeted through the mitigation measure, this will read 100%; that does not mean that all emissions can be mitigated through intervention within the timeframe.
- Economies of scale not captured in this analysis; any costs represented are indicative, and aggregated only to meet the target reduction (cumulative to 2030).
- Minimal savings available in this timeframe.
- All figures are indicative estimates only.

12. 78% reduction of emissions by 2035 pathway

12.1. Introduction

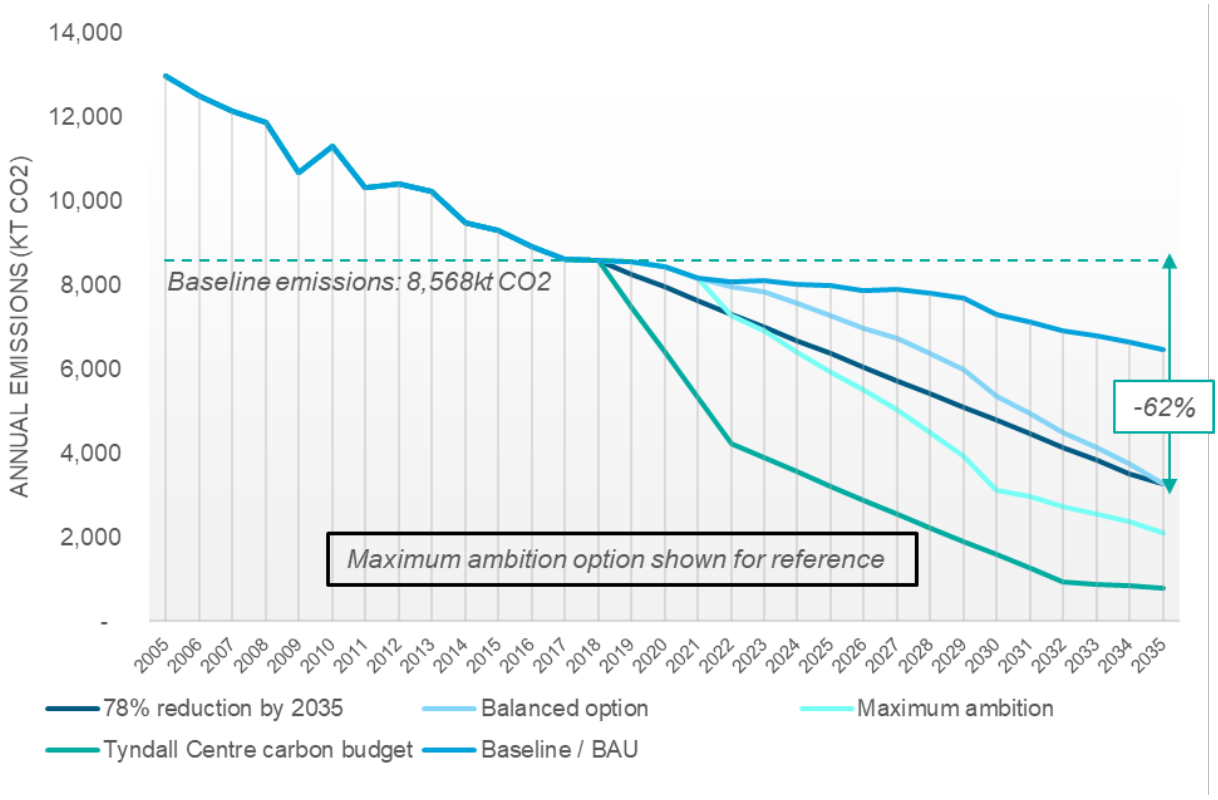
The third carbon reduction pathway considered has the target of reaching a 78% reduction in emissions (relative to 1990) in the Lancashire region by 2035.

Given the additional time scale for this target, and the less ambitious reductions required than for the net zero target analysed in Section 10, some of the measures identified can be introduced at slower rates and still meet this later target.

12.2. Pathway overview

Figure 12-1 summarises the estimated carbon reduction pathway achieved by a balanced option for meeting the 78% reduction target by 2035 across all sectors. For comparison, it is shown with the linear target pathway to the 78% reduction target, the maximum ambition scenario described in Section 10, the Tyndall Centre budget pathway and the baseline.

Figure 12-1: 78% reduction of emissions by 2035 target pathway with savings impact of mitigations (balanced option)



The saving achieved by the BAU scenario is estimated to be 25% by 2035 compared to 2018 baseline emissions and 56% by 2035 compared to 1990 emission levels, taking into account some growth factors such as population and business activity.

The balanced option pathway represents one view of a balanced combination of measures rolled out partially to meet the target reduction of 78% by 2035[57], identified following testing of a range of 'intervention rates' for different measures,

For domestic and commercial buildings, measures are assumed to roll out at between approximately 45% and 100% of the levels assumed in the maximum ambition scenario by 2035. For most measures roll out is assumed to be 70% of the levels in the maximum ambition scenario. Higher levels (100%) are assumed for commercial glazing and insulation. On the other hand, harder-to-reach measures are assumed to rolled out at still slower rates compared with the 68% reduction by 2030 target pathway. In particular, implementation of domestic heat pumps is relaxed to track current Government commitments[58].

For the transport sector, local measures are assumed to roll out at approximately 75% of the levels assumed in the maximum ambition scenario by 2035 (with national action assumed to apply fully). Measures to reduce emissions at large industrial installations (such as material substitution and energy efficiency) are assumed to apply at the levels assumed in the maximum ambition scenario.

Overall, the assumptions across the sectors result in a smaller scale reduction in emissions in 2030 than in the balanced option for the 68% by 2030 target pathway.

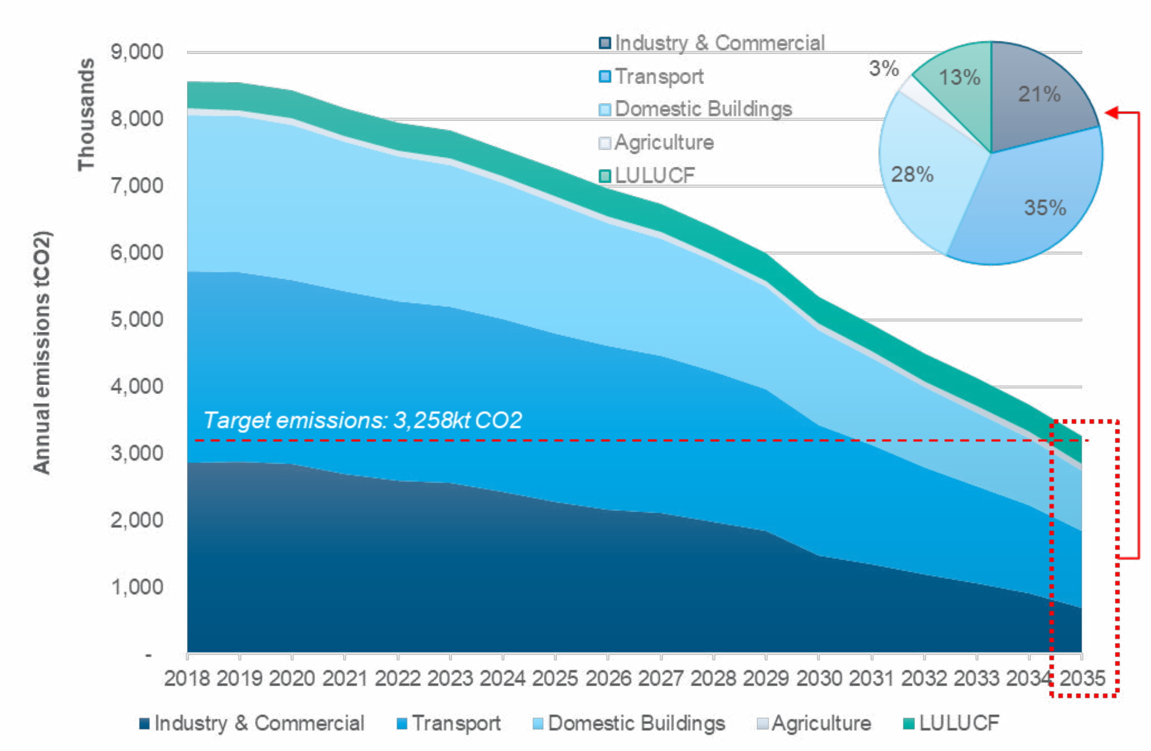
Although the balanced option meets the 78% target by the 2035 deadline year, the linear pathway identified is only matched from 2031 onwards, as emissions reductions are forecast to initially build up slowly and then to accelerate towards 2035. Consequently, the cumulative emissions associated with the pathway (116 $MtCO_2$) would exceed those associated with the linear target pathway and the Tyndall Centre budget (60 $MtCO_2$ for 2018-2037 period), increasing the scale of contribution to climate change.

12.3. Balanced option pathway analysis by sector

Figure 12-2 shows the estimated emissions remaining by sector in the balanced option pathway.

[57] This represents a reduction 61% compared with baseline (2018) emissions, due to savings that have already been achieved between 1990-2018; the target will still be referred to as '78% reduction'.
[58] We estimate that the commitment in the Energy White Paper to accelerate installs of heat pumps to 600,000 homes per annum by 2030 would aggregate to approx. 23% of households in Lancashire by 2030, if installed evenly across the UK. The target set here is to have 30% of homes in Lancashire equipped by 2030.

Figure 12-2: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source



The residual emissions for the balanced option are estimated to be 3,258 $ktCO_2$ in 2035 which meets the target of 3,258 $ktCO_2$.

Transport still represents the highest proportion of residual emissions by 2035 but the effect of the national petrol/diesel sales ban for cars and vans is forecast to have a more substantial effect in this timeframe, as people replace their vehicles and have no legacy option. Estimated savings from large industrial processes (mitigation only) in 2035 are almost double the levels estimated for 2030.

12.4. Sensitivity testing

The balanced option is one indicative view of how Lancashire could meet the 78% emissions reduction target by 2035 (compared with 1990)[59]. However, there are multiple ways in which the target could be met. To illustrate the trade-offs and balances between measures and sectors involved, two options were tested to understand the balance between emissions reductions in the transport and building sectors if different 'at the limit' assumptions on levels of local transport intervention were taken. Option 1 assumed Ambitious local transport interventions (as in the maximum ambition scenario described in Section 10) and Option 2 assumed Limited transport interventions (no local transport measures and reduced national interventions). The pathways for both options are shown in Figure 12-3, alongside the balanced option.

Option 2 shows that if action was taken in Lancashire to reach 80% of the buildings in the county to apply a full set of measures (including heat pumps and solar PV panels), it could achieve the 78% reduction target in 2035 even if no action was taken to implement any local measures relating to transport and reduced levels of national action to support ULEVs was assumed (40% of the central case in 2030, rising to 90% by 2035).

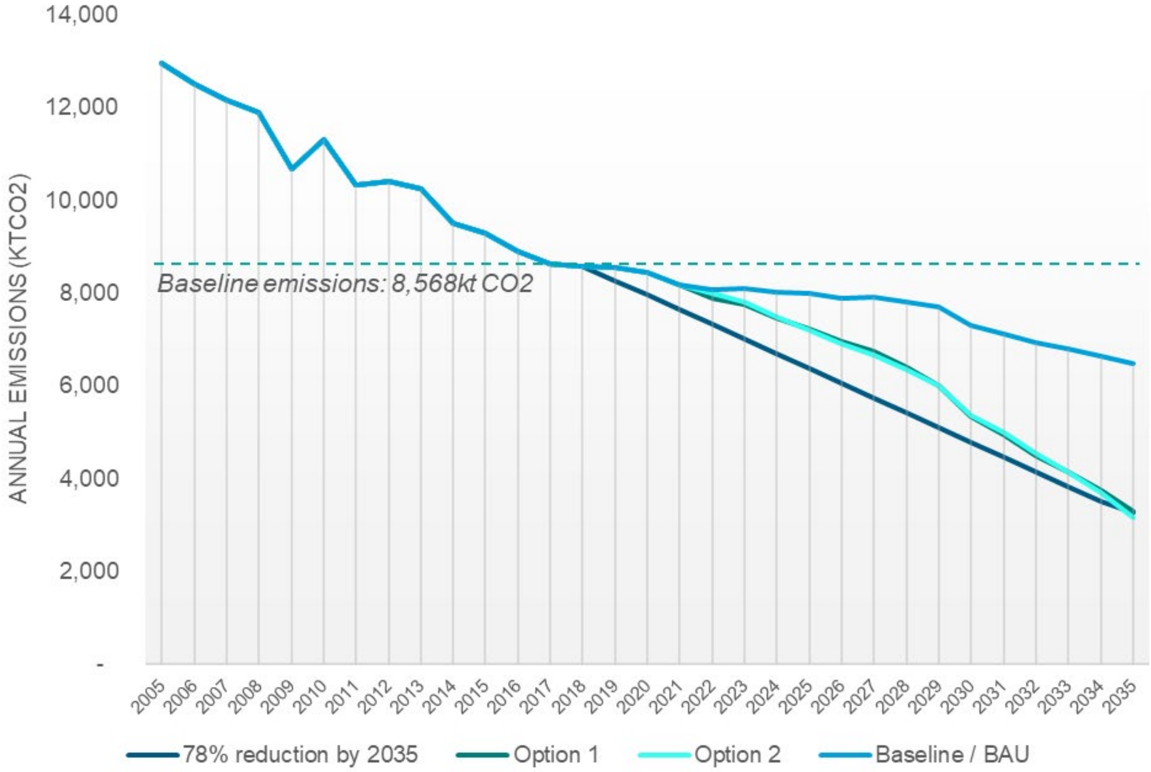
On the other hand, Option 1 shows that even if action in Lancashire was to focus on ambitious implementation transport measures, it would not be able to achieve the target in 2035 without meaningful action to address emissions from buildings.

[59] Note also that we have assumed 70% of commercial and industrial buildings will also need to be reached for installation of heat pumps. This has been proposed on the basis that commercial building owners are easier to influence than private home-owners.

In this option, it would be necessary to reach 70% of buildings in Lancashire to implement insulation and glazing measures; it would also be necessary to reach 40% of buildings for installation of heat pumps; although no solar panels would need to be installed.

Even though the estimated savings available from the Transport sector increase between 2030 and 2035, the ability to reduce its scale of Buildings measures required in Lancashire from the levels assumed for the sensitivity test for the 68% reduction by 2030 target would be limited.

Figure 12-3: 78% emissions reduction by 2035 target pathway with savings impact of mitigations (Sensitivity tests)



12.5. Summary of balanced option interventions at regional level

Interventions and rate of ramp up for the three key sectors under consideration are detailed in the tables at the end of this section (Table 12-2 to Table 12-4). They show the extent to which interventions in each sector are assumed to be rolled out, to meet the target set out above with the balance of measures assumed. The tables provide an 'inventory view' of measures with an indicative rate of roll-out and high level indications of associated costs.

Table 12-1 summarises the total contribution of each sector to meeting the 2035 target set out in Figure 12-2 and associated indicative costs. The costs provide a high level indication of the total capital costs of implementing the decarbonisation measures. Net costs would be lower once the savings associated with reference case spending avoided (e.g. replacement conventional boilers) and operating cost savings have been accounted for.

Table 12-1: Balanced option - summary of emissions mitigated and indicative costs

Sector	Annual emissions mitigated compared to 2018 baseline (in 2035, $ktCO_2$)	Indicative costs (Capital expenditure, current prices, total to 2035)*	Comments
BAU contribution	2,109	N/A	N/A
Transport	874	~£25 bn	Net capital costs would be considerably (potentially 90%) lower as much of the zero emissions expenditure replaces conventional expenditure (such as EVs in place of petrol/diesel vehicles). Considerable opex savings would also be experienced due to the transfer to EVs.
Domestic Buildings	1,117	£10 bn	Net capital costs would be lower as net zero interventions replace conventional expenditure (such as LED lighting and heat pump installation vs gas boiler or light replacement) Considerable savings in energy bills would also be expected through reduced energy consumption as a result of efficiency measures in buildings.
Industry and Commercial Buildings	1,210	£8 bn	As above. For the industry, efficiency measures would be expected to lead to opex savings.
Total	**5,310 $ktCO_2$**	**Approx. £40 bn**	

Note: * All figures are indicative estimates only and show the total estimated cost of implementing the decarbonisation measures. The net additional cost associated with the measures would be considerably lower as in many cases the decarbonisation measure (such as a heat pump) would be instead of an alternative (e.g. conventional boiler). Several measures would also deliver operating cost savings.

Table 12-2: Summary of interventions with indicative carbon savings, roll-out rates and costs – Transport

Intervention	Extent of impact by 2025 (as % of 2030 max ambition)[1]	Extent of impact by 2030(as % of 2030 max ambition)[1]	Extent of impact by 2035 (as % of 2030 max ambition)[1]	Annual emissions mitigated (in 2035 $ktCO_2$)[5]	Measures and estimated impacts[3]	Indicative costs (capex, current prices, total to 2030)[2, 4,5]	Comments on net costs	Allocation of costs public/ private sector
National action to ban petrol/diesel car/van sales	10%	100%	335%	-515	Ban on sales of petrol/diesel cars and vans from 2030 (and plug in hybrids from 2035) and supporting public and private infrastructure. Assumed to cause approximately 50% of car vehicle kms to be by EV by 2035.	£13 bn	Potentially some income from electricity charges. Only 10% of total capital cost (i.e. £1bn) estimated to be net additional to the reference scenario (i.e. majority of capex would have been required to purchase non EVs). Reduced operating cost of EVs compared to petrol/diesel vehicles offsets approximately -40% of additional capex (based on CCC analysis)[60]	Mainly private sector. Some public sector support (particularly for charging infrastructure)
National action to upgrade HGV fleet/ban diesel vehicle sale	0%	100%	525%	-89	*Ban of sales of diesel HGVs from 2035 (if < 26 tonnes) or 2040 (> 26 t). Approx. 35% vehicles ZEVs.*	*£0.5 bn*	Potentially some income from electricity charges. Only 20% of total capital cost (i.e. <£0.1bn) estimated to be net additional to the reference scenario (i.e. majority of capex would have been required to purchase alternative vehicles). Reduced opex of EVs compared to diesel vehicles offsets	As above

[60] Commentary on costs based on analysis in CCC 6th Carbon Budget, 2020 and supporting dataset

Intervention	**Extent of impact by 2025** (as % of 2030 max ambition)[1]	**Extent of impact by 2030**(as % of 2030 max ambition)[1]	**Extent of impact by 2035** (as % of 2030 max ambition)[1]	**Annual emissions mitigated (in 2035 $ktCO_2$)**[5]	**Measures and estimated impacts**[3]	**Indicative costs (capex, current prices, total to 2030)**[2, 4,5]	**Comments on net costs**	**Allocation of costs public/ private sector**
							approximately -60% of additional capex (based on CCC analysis)	
Accelerate ULEV uptake (through publicly-owned fleets, support for car clubs and corporate fleet upgrades etc.).	5%	55%	70%	-73	Promotion of uptake of amongst council (including taxi and bus), supplier and corporate fleets and through car clubs and additional charging infrastructure – leading EV uptake to accelerate locally ahead of national average by 6 months by 2035 and 12 months by 2038 then decreasing.	£0.5 bn	Approx. 85% of total capital cost estimated to be net additional to the reference scenario (i.e. majority of capex would have been required to purchase alternative vehicles). Reduced opex of EV offsets approximately -30% of additional capex (based on CCC analysis). Additional opex associated with staff time to coordinate and raise awareness of EVs and carclubs and subsidise operation of car clubs.	Private sector for vehicles. Public sector to support infrastructure, car club subsidy and staff time to support take up in taxi fleets
Increase active travel/micro mobility use	15%	55%	70%	-36	Significant improvement in availability of routes suitable for cycling and in willingness to cycle, including use of e-bikes on longer journeys. Estimates based on expansion of DfT's propensity to cycle toolkit (PCT) of 450% to 500% increase in cycling levels (average across all purposes) increasing through the 2030s.	£0.5 bn	Ongoing maintenance required and cycle hire schemes	Largely public sector

Intervention	**Extent of impact by 2025** (as % of 2030 max ambition)[1]	**Extent of impact by 2030**(as % of 2030 max ambition)[1]	**Extent of impact by 2035** (as % of 2030 max ambition)[1]	**Annual emissions mitigated (in 2035 ktCO₂)**[5]	**Measures and estimated impacts**[3]	**Indicative costs (capex, current prices, total to 2030)**[2, 4,5]	**Comments on net costs**	**Allocation of costs public/ private sector**
Increase public transport use	5%	55%	75%	-36	Better, more integrated, affordable, accessible, and reliable public and shared transport services and MaaS system. Leading to increased patronage of approaching 35% by 2035 (relative to 2019) increasing through the 2030s	£0.5 bn	Ongoing operating costs for running services likely roughly match capital costs every 5 years or so	Largely public sector
Demand management	15%	55%	75%	-56	Increased charging for car parking and relocation of spaces out of central areas causing >50% cost increase (including walk time) for ~50% of commuting/ business journeys, ~ 35% of shopping journeys and 25% of journeys for all other types) – reducing car travel. Delivery restrictions, supported by consolidation hubs leading to a transfer of last mile trips reducing diesel freight vehicle kms by over 5% by 2030.	<£0.1bn	Charging likely to be revenue generating	Largely public sector
Efficient network management	40%	55%	45%	-13	Use of data and signals to improve management of network and reduce congestion - increasing average speed on	£0.5 bn	Limited ongoing maintenance required	Largely public sector

Intervention	Extent of impact by 2025 (as % of 2030 max ambition)[1]	Extent of impact by 2030(as % of 2030 max ambition)[1]	Extent of impact by 2035 (as % of 2030 max ambition)[1]	Annual emissions mitigated (in 2035 $ktCO_2$)[5]	Measures and estimated impacts[3]	Indicative costs (capex, current prices, total to 2030)[2, 4,5]	Comments on net costs	Allocation of costs public/ private sector
					40% of the slowest links (<25mph) by 5 mph through congestion relief.			
Land use planning	15%	55%	65%	-32	20-minute neighbourhood principles to diversify the range of land uses available in urban areas – causing ~10% reduction in car travel for shopping and personal business trips and ~5% reduction for leisure trips (due to shorter and/or fewer, combined trips).	N/a	Staff time (potentially one role per authority) to coordinate planning and raise awareness	Largely public sector
Digital connectivity	40%	55%	45%	-24	Improved digital connections and increased online opportunities and activities: Reduction in commuting and business trips of ~5%. Reductions of up to 5% for personal business, shopping, leisure trips	£1.0 bn	Ongoing costs for maintenance of network and operation of hubs, including staff time.	Largely private sector for provision of digital network. Public sector to support delivery of digital network and hubs that are not commercially viable (e.g.

Intervention	**Extent of impact by 2025** (as % of 2030 max ambition)[1]	**Extent of impact by 2030**(as % of 2030 max ambition)[1]	**Extent of impact by 2035** (as % of 2030 max ambition)[1]	**Annual emissions mitigated (in 2035 $ktCO_2$)[5]**	**Measures and estimated impacts[3]**	**Indicative costs (capex, current prices, total to 2030)[2, 4,5]**	**Comments on net costs**	**Allocation of costs public/ private sector**
								remote rural areas)
Total				**-874 $ktCO_2$**		**~£25 bn**		

Notes:

1. 2025, 2030 and 2035 percentages represent emissions savings as a proportion of 2030 max ambition emissions savings shown in Section 10. 100% would represent the fact that the ambitious local action scenario is fully implemented, that does not mean that all emissions can be mitigated through intervention within the timeframe.
2. Total costs provide an indication of the total capital expenditure involved in implementing the measures assumed in the scenario. It does not account for savings associated with being able to avoid reference case expenditure or impacts on operating costs. The next column to the right provides commentary on these issues
3. Further detail on the estimated impacts assessed is provided in Appendices
4. Economies of scale not captured in this analysis; any costs represented are indicative and aggregated only to meet the target reduction (cumulative to 20356).
5. All figures are indicative estimates only.

Table 12-3: Summary of interventions with indicative carbon savings, roll-out rates and costs - Domestic Buildings

Intervention	Extent of roll-out by 2025[1]	Extent of roll-out by 2030[1]	Extent of roll-out by 2035[1]	Annual emissions mitigated (in 2035; $ktCO_2$)[3]	Units (annual)	Indicative costs (capital expenditure, current prices, total to 2035)[2, 3]	Comments
Insulation	20%	45%	70%	-531	19,216	£2.5 bn	Operating cost savings from energy savings.
Glazing	20%	45%	70%	-75	19,216	£3.0 bn	Operating cost savings from energy savings.
Heat pumps	5%	23%	43%	-376	15,730	£2.1 bn	Net costs would be much lower as there would be capital expenditure on alternative conventional heating in the reference case.
LED lighting	20%	45%	70%	-3	19,216	<£0.01 bn	Net costs would be much lower as there would be capital expenditure on alternative conventional heating in the reference case.
Solar PV panels	10%	40%	70%	-132	26,317	£2.2 bn	Operating cost savings from electricity purchase savings.
Total				**-1,117 $ktCO_2$**		**~£9.8 bn**	

Notes:

- If all possible emissions savings are targeted through the mitigation measure, this will read 100%; that does not mean that all emissions can be mitigated through intervention within the timeframe.
- Economies of scale not captured in this analysis; any costs represented are indicative and aggregated only to meet the target reduction (cumulative to 2035).
- All figures are indicative estimates only.

Table 12-4: Summary of interventions with indicative carbon savings, roll-out rates and costs - Industry and Commercial (Non-Residential) Buildings

Intervention	Extent of roll-out by 2025[1]	Extent of roll-out by 2030[1]	Extent of roll-out by 2035[1]	Annual emissions mitigated (in 2035; $ktCO_2$)[4]	Units (annual)	Indicative costs (Capital expenditure, current prices, total up to 2035)[2, 4]	Comments
Insulation	32%	72%	100%	-250	33,624	£1.0 bn	*None.*
Glazing	32%	72%	100%	-70	33,624	£2.8 bn	*None.*
Heat pumps	15%	40%	70%	-438	16,689	£1.6 bn	*None.*
LED lighting	20%	45%	70%	-54	16,689	£0.01 bn	*None.*
Solar PV panels	16%	46%	80%	-121	19,073	£1.9 bn	*None.*
Energy efficiency	100%	100%	100%	-25	*Unable to quantify*	£0.03 bn	Measures are applied to multiple processes at a small number of point sites to achieve incremental savings across all processes.
Resource efficiency and material substitution	100%	100%	100%	-188	*Unable to quantify*	£0	
Electrification	100%	100%	100%	-62	*Unable to quantify*	£0.01 bn	
Carbon capture and storage[3]	100%	100%	100%	-2	*Unable to quantify*	£0.09 bn	
Total				**-1,210 $ktCO_2$**		**~£7.5 bn**	

Notes:

1. If all possible emissions savings are targeted through the mitigation measure, this will read 100%; that does not mean that all emissions can be mitigated through intervention within the timeframe.
2. Economies of scale not captured in this analysis; any costs represented are indicative and aggregated only to meet the target reduction (cumulative to 2035).
3. Limited savings available in this timeframe (technology due to become more mature in latter 2030s).
4. All figures are indicative estimates only.

13. Extending pathways to 2050

13.1. Introduction

The previous sections 11 and 12 have presented pathways that include realistic interventions that would put the region on track to achieve the following targets (against the national target of Net Zero by 2050):

- 68% reduction of emissions by 2030 (relative to 1990); and
- 78% reduction of emissions by 2035 (relative to 1990).

In section 10, interventions were set out in a maximum local ambition pathway developed to make significant progress towards the target of Net Zero (100% reduction) emissions by 2030 but the target of 100% reduction is not achieved.

In deriving the pathways to the 2030s to meet the interim targets, a key assumption has been that electrification will be the main route available to replace the use of fossil fuels and therefore to reduce carbon emissions associated with energy use, alongside measures to reduce energy demand. This is because hydrogen is only expected to play a prominent role in energy decarbonisation after 2035 although industrial hydrogen energy applications are expected to become a reality sooner and associated emissions reductions have been accounted for in the BAU scenario.

These two scenarios have been modelled for pathways associated with the targets of 68% reduction of emissions by 2030 and 78% reduction of emissions by 2035 to present their trajectory towards Net Zero. Maximum ambition pathway (Net zero by 2030) assumes that all the interventions are already deployed at 100% by 2030 so no future scenario modelling has been carried out for this pathway.

13.2. High electrification scenario

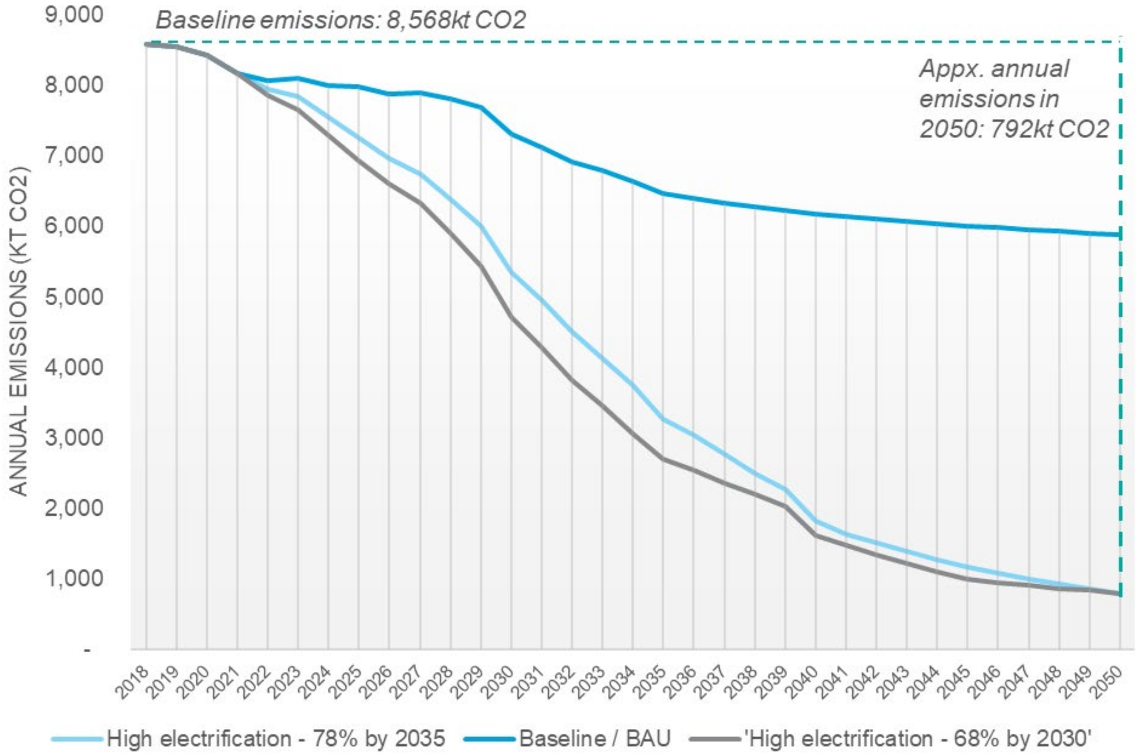
13.2.1. Scenario assumptions

This scenario assumed that the decarbonisation interventions applied within the initial timeframes in the two pathways (to 2030 and 2035) would continue roll out at the same rate until maximum implementation was achieved, with electrification being the main approach to changing energy sources. By 2050, it was assumed that all interventions modelled in the pathways to the 68% target by 2030 and the 78% target by 2035 would be rolled out at 100% of the identified likely maximum potential level, with most reaching 100% in the 2030s. Details of these interventions have been presented in Sections 6,7 and 8.

13.2.2. Pathways under high electrification scenario towards 2050

Extended pathways to 2050 under high electrification scenario are illustrated in Figure 13-1. As can be seen, both pathways continue to show rapid reductions in annual emissions, with emissions levels broadly halving between 2035 and 2040. Annual emissions are higher in the 78% reduction by 2035 pathway than the 68% reduction by 2030 pathway, however the difference between scenarios reduces through time and pathways merge as they approach 2050.

Figure 13-1: Extended pathways to 2050 under high electrification scenario



13.2.3. Summary of impacts of interventions at regional level in 2050

The following table shows the total contribution of each sector towards annual emissions reductions in 2050 in both target pathways. Once these reductions are added to the BAU emission reductions for 2050, residual emissions in the year 2050 are estimated to be 792 ktCO_2. Cumulative emissions between 2018-2050 are estimated to be 140MtCO_2 for the 78% target pathway and 131MtCO_2 for the 68% target pathway under the high electrification scenario.

Table 13-1: Summary of emissions mitigated across sectors by 2050 under the high electrification scenario

Mitigation	Emissions (total p.a. 2050, ktCO_2)
2018 Baseline	***8568***
BAU contribution	-2692
Transport	-1411
Domestic Buildings	-1992
Industry and Commercial Buildings	-1681
Total mitigated	**-7776**
Residual emissions	**792**

Note: * All figures are indicative estimates only.

13.3. High hydrogen scenario

This scenario assumes that hydrogen plays a prominent role after 2035 and hydrogen fuel and technologies replace some of the interventions such as heat pump deployment in buildings and electric heavy goods vehicles in transportation.

13.3.1. Scenario Assumptions

Based on research undertaken and conversations with industry representatives, the assumptions presented in this section have been used for developing the high hydrogen scenario.

13.3.1.1. Buildings

Hydrogen blend in Lancashire grid is expected to be largely driven by the HyNet Project as well as other green hydrogen production initiatives in the area. Phase 3 of HyNet is expected to come near to south Lancashire, however this is not expected to be before 2030, and the hydrogen injection planned as part of Phase 3 will be directed towards Manchester and not Lancashire. Based on this information, hydrogen at scale is only expected to be available in the Lancashire region after 2035. For comparison, the ENW System Transformation Scenario assumes the gas grid is used for hydrogen distribution in Lancashire post 2040.

The adoption of hydrogen ready appliances in buildings could start as early as 2026.[61] The adoption of hydrogen ready appliances is expected to start slowly in the early years and increase in pace as hydrogen starts to become widely available in the gas grid. As heat pump adoption will mainly take place until 2035, most of the remaining customers who have not adopted heat pumps by 2035 are assumed to adopt hydrogen boilers, while heat pump deployment is assumed to slow down after 2035. Around 57% of domestic and 30% non-domestic gas-heated buildings are assumed to switch to hydrogen boilers by 2050.

In a high hydrogen scenario, hybrid heating will also play an important role. Hybrids can be attractive cost-efficient options for customers. The deployment levels of hybrid systems are not separated from hydrogen or heat pump only systems within the study calculations due to the lack of granular building stock and customer preference information at this stage. Therefore the deployment levels around buildings with hydrogen or heat pumps also include take up of hybrid heat pump and hydrogen systems. This will not have an impact on carbon emissions modelled for 2050 due to the insignificant difference between the carbon factors of green hydrogen and grid supplied electricity. It is assumed that buildings that have deployed heat pumps can also switch to a hydrogen boiler option or a hybrid system with hydrogen boilers in the longer term.

It is assumed that 20% hydrogen will be available in the gas grid from around 2035, increasing to 100% by around 2049. The gas grid will first switch to 20% hydrogen in 2035 and then progress to 100% hydrogen supply. This is expected to be in stages across Lancashire, with the south part of Lancashire switching to hydrogen before North Lancashire due to HyNet. With this gradual approach, a gradual progression of hydrogen blend in the Lancashire gas grid is assumed in this study.

The table below presents year-by-year assumptions behind the hydrogen scenario for Lancashire.

Table 13-2: Hydrogen in the gas grid and hydrogen appliance uptake in buildings

Year	2026	2030	2035	2040	2045	2050
Uptake of hydrogen/ hydrogen-ready boilers in gas heated domestic buildings	1%	6%	18%	34%	48%	57%
Uptake of hydrogen/ hydrogen-ready boilers in gas heated non-domestic buildings	1%	5%	17%	30%	30%	30%
Average hydrogen blend in the gas network	0%	0%	20%	54%	83%	100%

13.3.1.2. Transport

As outlined above, hydrogen availability in Lancashire is expected to be largely driven by the HyNet Project as well as other green hydrogen initiatives in the area. Phase 3 of HyNet is expected to come near to south Lancashire, however this is not expected to be before 2030, and the focus of the project is to provide hydrogen

[61] Cadent – 2050 Decarbonization study expects Hydrogen ready appliances to begin being installed by 2026 or earlier.

to industries. Based on this, hydrogen is not expected to be available at scale for transportation in the Lancashire region before 2035.

In the Transport sector, the widespread roll out of a hydrogen distribution network would mainly influence the composition of the heavy vehicle fleet (heavy goods vehicles and buses). Most sources (including CCC[62] and DfT[63]) agree that, for lighter vehicles, Battery Electric Vehicles (BEVs) will continue to dominate, regardless of the status of hydrogen provision. As a result of rapid recent and ongoing development in the field, BEVs are an energy efficient and relatively cost effective option that can serve most needs for light vehicles. Whilst widespread availability of hydrogen may lead to some uptake of hydrogen cars and vans to serve specific, long distance purposes, this is likely to be a small proportion. Some forecasts such as those for the CCC's sixth carbon budget report[64] suggest that use of hydrogen for cars and vans will be negligible. .

In contrast, the impact of a hydrogen fuelling network on the road freight fleet could be significant, depending on timescales and other developments in the goods vehicle sector. Freight is known to be a particularly challenging sector to decarbonise given the intensity of usage of many heavy goods vehicles and the scale of their loads and trip lengths. At the moment there is no clear view on the most likely or viable route to decarbonising the freight fleet. The three main options identified are electric road systems, battery power (using advanced batteries and rapid charging) or hydrogen fuel cell vehicles. Authorities such as the CCC and DfT highlight the need for trials and research over the next few years to improve understanding and identify the best route forward.

The uptake of hydrogen for transport in Lancashire will particularly depend on the extent of the hydrogen distribution network across the whole of the UK (and internationally) to provide confidence in the ability to refuel on all trips. The presence of a hydrogen network within the county alone would only be beneficial to the subset of vehicles that operate within the local area and are able to return to base to refuel when required.

In addition to the need to rapidly develop fuelling/charging infrastructure to support the zero emissions HGVs, it will also be necessary to develop suitable vehicles, requiring considerable progress in several technologies (e.g. in relation to batteries and/or hydrogen storage). The balance between vehicle types in the future fleet will depend on how rapidly the various vehicle types develop in terms of both performance and cost.

Given the significant uncertainty over future infrastructure and vehicle availability, it is not yet possible to identify a clear differentiation between high hydrogen and high electrification in terms of rate or timing of uptake of ZEVs. For instance, the government's Net Zero Strategy[65] does not assume any difference in terms of the timing of zero emission HGV uptake for its high hydrogen and high electrification scenarios, just a different composition of vehicles.

Based on the above, the following assumptions have been made to represent the high hydrogen scenario:

- Impact on HGV fleet composition only (light vehicle fleet unaffected)
- Uptake of fuel cell vehicles starts after 2035, reaching the point where 75% of new zero emissions HGVs are fuel cell vehicles (compared to 25% in the high electrification scenario), based on the highest proportions in the National Grid's Future Energy Scenarios[66]
- Hydrogen fuel cell HGVs use green hydrogen
- Rate of uptake of zero emission HGVs remains as in the high electrification scenario (based on the CCC balanced pathway vehicle sales)

Table 13-3 shows the assumed take up of Hydrogen HGVs for the vehicles on Lancashire's roads through time.

Table 13-3: Hydrogen Heavy Goods Vehicle (as % of full fleet)

Year	2026	2030	2035	2040	2045	2050
Small HGVs (<26 t)	0%	0%	<1%	25%	60%	75%
Large HGVs (>26 t)	0%	0%	<1%	20%	60%	75%

[62] CCC, 6th Carbon Budget, 2020
[63] DfT, Transport Decarbonisation Plan, 2021
[64] CCC, 6th Carbon Budget, 2020
[65] Net Zero Strategy: Build Back Greener - GOV.UK (www.gov.uk)
[66] Net Zero and the Future Energy Scenarios | National Grid ESO

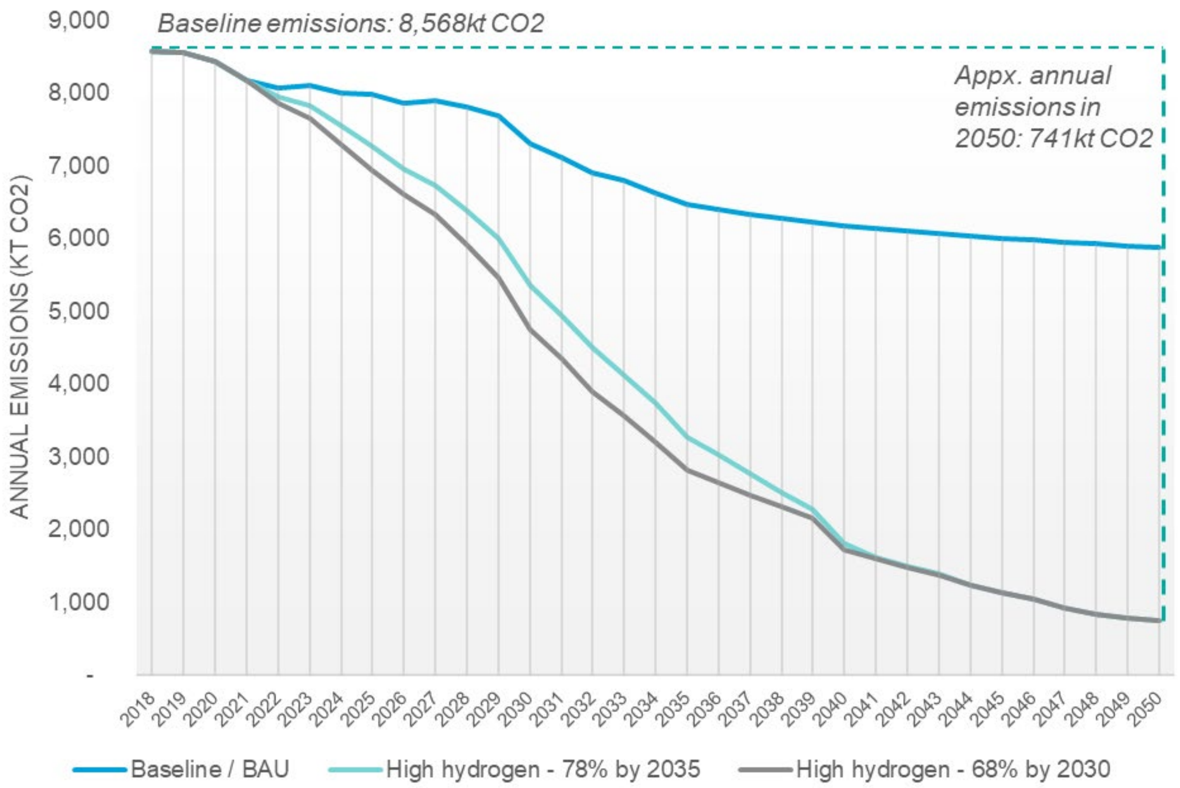
13.3.1.3. Industry

It is assumed that industrial clients will receive hydrogen earlier than the buildings and transport sectors depending on the demand and available hydrogen supply from HyNet. Hydrogen supply for industry from 2030 is already modelled in all pathways and scenarios and therefore assumptions do not differ between the high hydrogen and high electrification scenarios.

13.3.2. Pathways under high hydrogen scenario towards 2050

Extended pathways to 2050 under the high hydrogen scenario are illustrated in Figure 13-2. Similar to the high electrification scenario, emissions continue to reduce rapidly for both pathways. Emissions are greater in the 78% reduction by 2035 pathway than the 68% reduction by 2030 pathway. However, the difference between scenarios reduces as they approach 2040 due to hydrogen starting to take prominent role after 2035 for both pathways.

Figure 13-2: Extended pathways to 2050 under high hydrogen scenario



13.3.3. Summary of impacts of interventions at regional level in 2050

Table 13-4 shows the total contribution of each sector towards annual emissions mitigation in 2050 in both pathways. Once these reductions are added to the BAU emission reductions for 2050, residual emissions in the year 2050 are estimated to be 741 ktCO_2 per annum. Cumulative emissions in Lancashire over the timescale of 2018-2050 are estimated to be 140MtCO_2 for the 78% target pathway and 133MtCO_2 for the 68% target pathway.

Table 13-4: Summary of emissions mitigated across sectors by 2050 under high hydrogen scenario

Mitigation	Emissions (total to 2050, $ktCO_2$)
2018 Baseline	***8568***
BAU contribution	-2692
Transport	-1395
Domestic Buildings	-2027
Industry and Commercial Buildings	-1712
Total mitigated	**-7826**
Residual emissions	**741**

Note: * All figures are indicative estimates only.

13.4. Overview of scenarios

For buildings and industry, this study includes scope 1 and scope 2 emissions only. Upstream emissions are out of scope (see section 2). As the combustion of hydrogen releases no direct greenhouse gases and it has been assumed that hydrogen would be supplied from blue or green hydrogen, no CO_2 emissions were assumed in this study for hydrogen production nor for use in buildings. As heat pumps are assumed to use grid-supplied electricity, some emissions are assumed for the electricity they consume. This difference in emission factors leads to the high hydrogen scenario providing higher emission savings than the high electrification scenario for buildings sector. However, due to the factors not considered in this study (such as renewables built and electricity used to produce hydrogen would not be available for another sector and can lead to increase in emissions and reduce emission reduction opportunities of other sectors), an attempt has not been made to provide a comparison between the hydrogen and electrification scenarios in terms of emissions savings. This study thus aims to illustrate the level of interventions needed under each scenario.

For transport, the study has considered 'well to wheel' emissions, including the emissions associated with producing and distributing the fuel/energy used by transport. The emissions associated with the high hydrogen scenario were based on the assumption that green hydrogen is produced from electrolysis using electricity with the grid average emissions rates[67]. The difference in emissions relative to the high electrification scenario reflects the fact that more electricity would be required for each kilometre travelled by a hydrogen fuel cell HGV than if the electricity was directly used to power a battery HGV (as a result of the inefficiencies in converting the electricity to hydrogen and back to electricity in the fuel cell). The DfT's transport energy model[68] suggests the well to wheel emissions generated per kilometre by hydrogen fuel cell HGVs powered using green hydrogen would be about 2.3 times those generated per kilometre by a battery HGV (noting that neither technology yet exists). This leads to the minor change in emissions seen between the high electrification and high hydrogen scenarios.

For industry, the commissioning of HyNet North West, in particular, represents an opportunity for the county to receive a good supply of low-carbon energy for industrial processes, as well as for application in other sectors when the technology matures. It was assumed that 5% of the hydrogen energy from HyNet will become available to industry in Lancashire from 2030, rising to 10% by 2040 in both scenarios as part of BAU. Lancashire should consider partnering to ensure that even more low-carbon hydrogen energy is available to

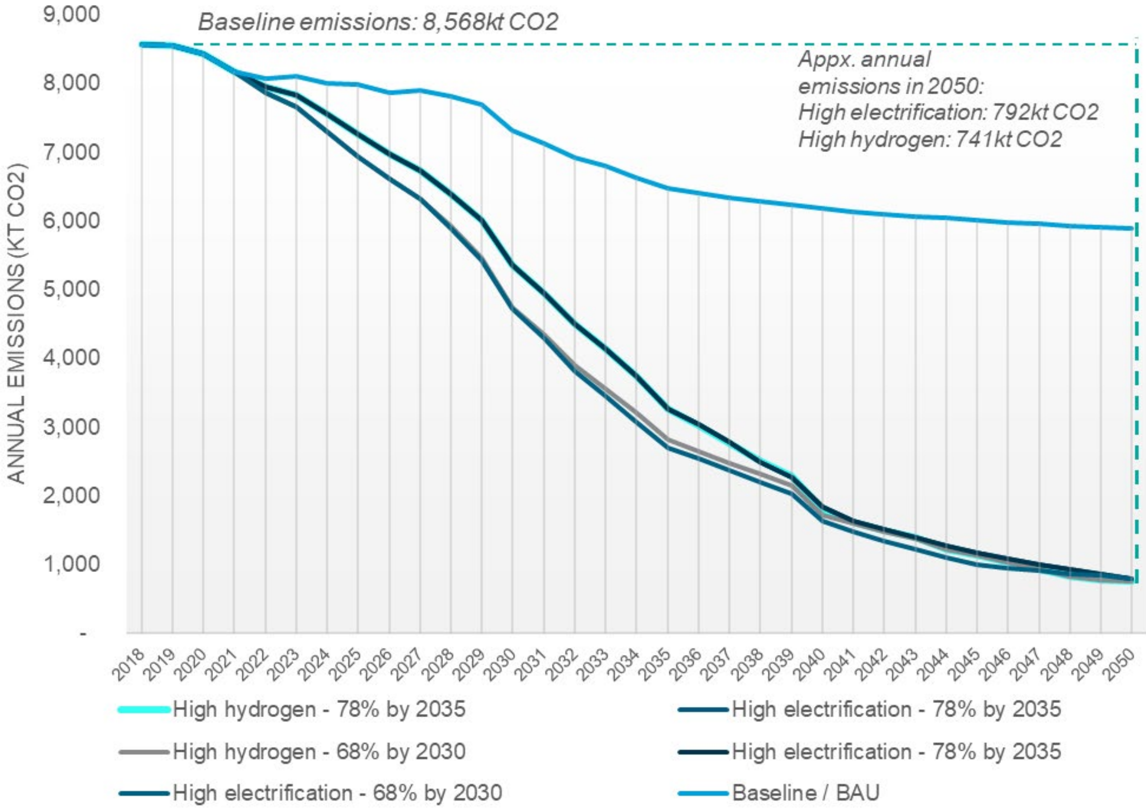
[67] This assumption was adopted to provide a straightforward indication of the potential scale of impact the use of hydrogen. In practice emissions would be different if the hydrogen was generated using renewable energy that would have been curtailed if the option to store the energy in hydrogen had not been available (reducing the emissions rate) or if it was blue hydrogen, involving a more energy intensive production process (increasing the emissions rate).

[68] Transport energy model (publishing.service.gov.uk)

industry during the 2030s and onwards in order to obtain further emissions reductions and take a role in regional leadership in hydrogen.

Emissions trajectories for 68% reduction by 2030 and 78% reduction by 2035 pathways under high electrification and high hydrogen scenarios are illustrated in Figure 13-3. As can be seen in the Figure, both high electrification and high hydrogen scenarios provide very similar trajectories to 2050 for the two pathways. This illustrates the importance of actions in the near term and implementing no-regret actions in the next decade such as energy efficiency, installation of heat pumps and electric vehicles to ensure the transition to Net Zero.

Figure 13-3: Extended pathways to 2050 under high hydrogen and high electrifications scenarios



14. Local authority pathways analysis

This section sets out representative pathway options for each local authority within Lancashire, including Blackburn with Darwen and Blackpool. These offer an indicative view of the emissions saving potential through mitigation measures that could be achieved in each authority for the 68% reduction and 78% reduction balanced pathways discussed in the previous sections. Further details on the methodology to calculate these pathways can be found in Section E.5 (within Appendix E).

The local authority pathways are set to show how forecast residual emissions year-over-year are broken down by sector. In each case, a proportional 'snapshot' of remaining emissions is shown at the target year. An indicative target for emissions is set from the local authority's baseline emissions: this shows what it would mean if each authority had to achieve the target pathway exactly for the region as a whole to fulfil the target savings in the scenario (See Table 14-1).

The analysis indicates that all but Ribble Valley, would be able to contribute proportionately to the 2030 and 2035 region-level target pathways across the three key sectors (Transport, Domestic Buildings and Industry and Commercial). This is because the distribution of emissions across these sectors for most local authorities is generally aligned with the average distribution considered for the regional pathways.

However, the presence of large industrial processes in Ribble Valley means that this local authority would not be able to meet both the 2030 and 2035 region-level reduction target pathways.

In the case of Fylde, Lancaster, West Lancashire and Wyre, the presence of high emissions from LULUCF results in these local authorities not being able to meet the 2030 and 2035 region-level reduction target pathways. The presence of LULUCF emissions in Chorley results in this local authority not being able to meet the 2030 region-level reduction target pathway (although it meets the 2035 reduction target).

Table 14-1: Local authority target emissions for pathway options

Local authority	68% reduction pathway target emissions ($ktCO_2$)	Target met?	78% reduction pathway target emissions ($ktCO_2$)	Target met?
Blackburn with Darwen	346	YES	238	YES
Blackpool	268	YES	184	YES
Burnley	207	YES	142	YES
Chorley	366	NO	252	YES
Fylde	277	NO	191	NO
Hyndburn	207	YES	143	YES
Lancaster	465	NO	320	NO
Pendle	233	YES	160	YES
Preston	400	YES	275	YES
Ribble Valley	507	NO	349	NO
Rossendale	200	YES	138	YES
South Ribble	376	YES	258	YES
West Lancashire	501	NO	345	NO
Wyre	385	NO	265	NO

14.1. Blackburn with Darwen

Figure 14-1: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Blackburn with Darwen

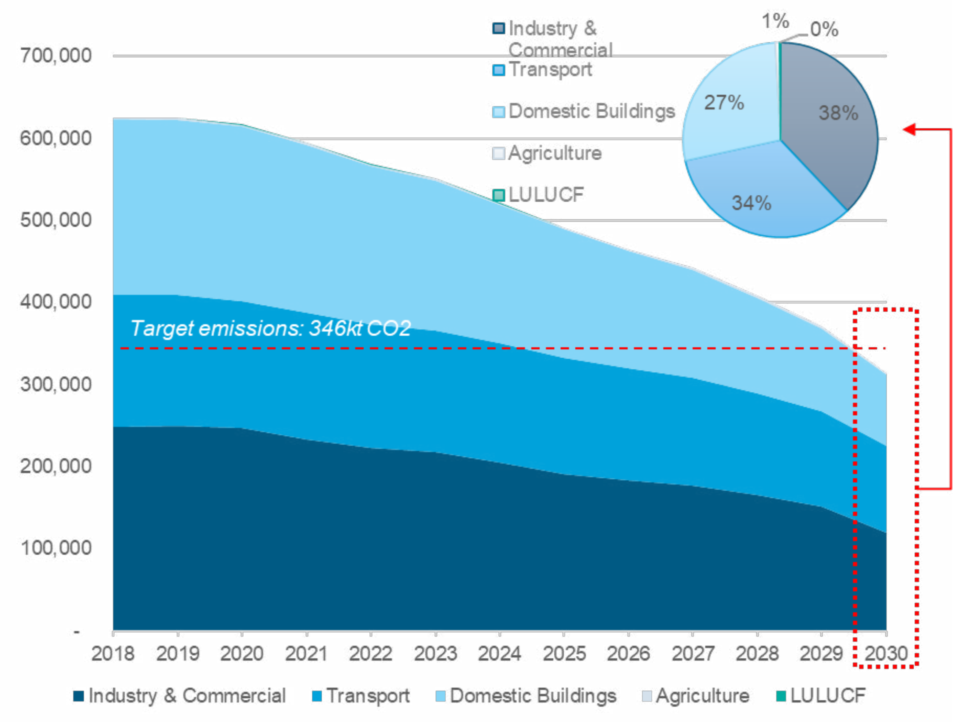


Figure 14-2: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Blackburn with Darwen

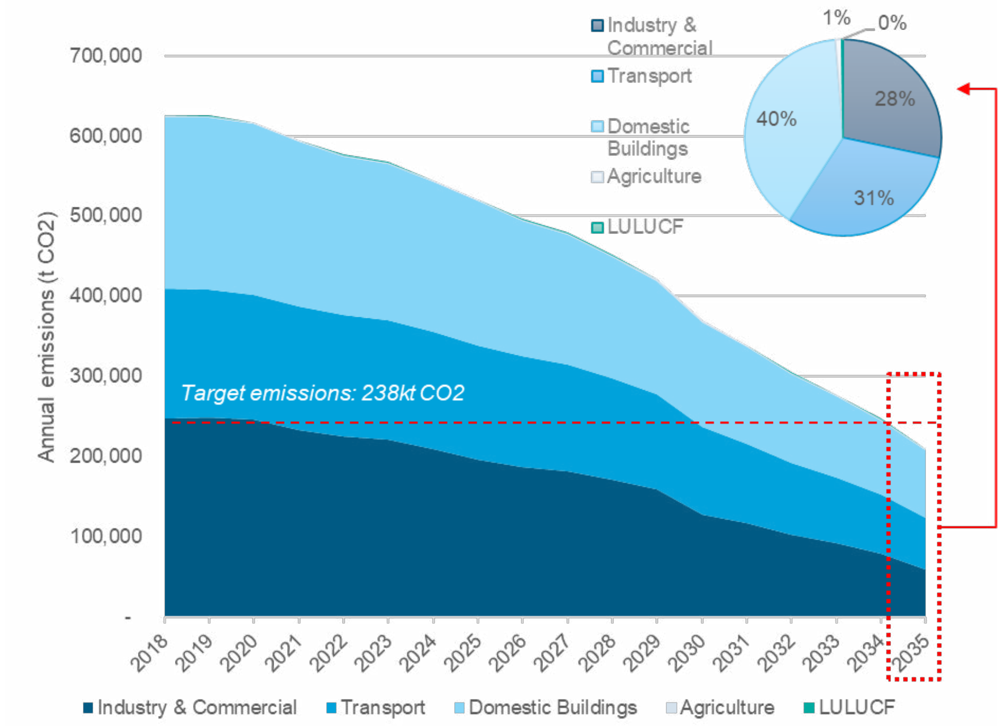
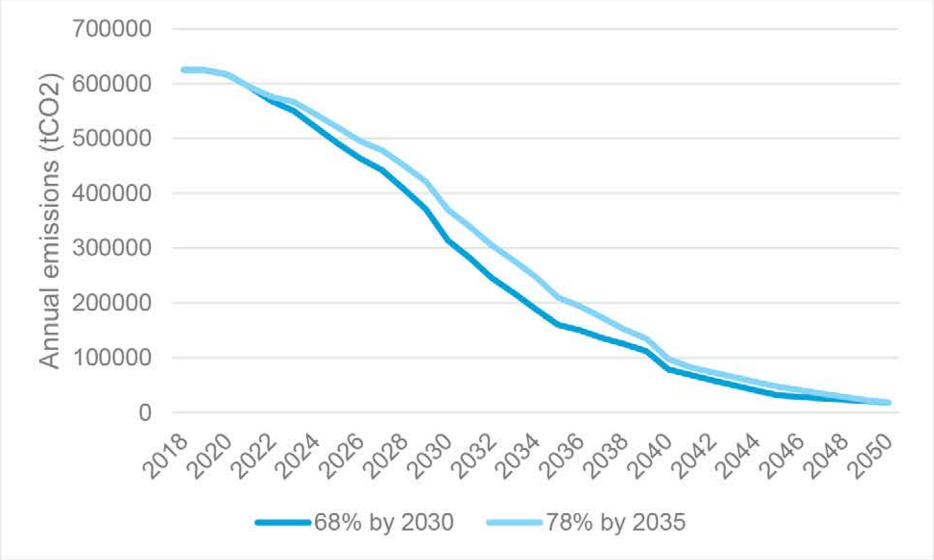
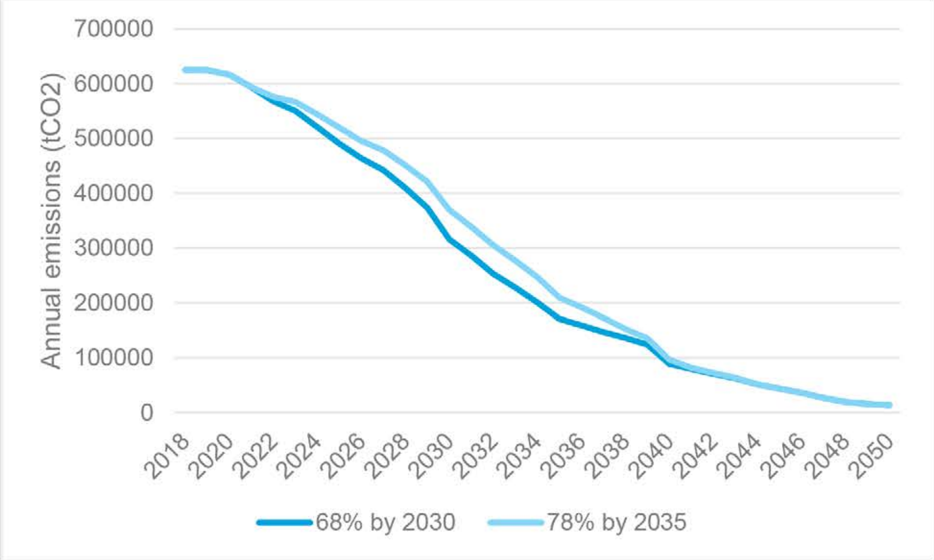


Figure 14-3: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Blackburn with Darwen



Remaining emissions in 2050 are 19ktCO_2 most of which is from Transport sector.

Figure 14-4: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Blackburn with Darwen



Remaining emissions in 2050 are 14ktCO_2 most of which is from Transport sector.

14.2. Blackpool

Figure 14-5: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Blackpool

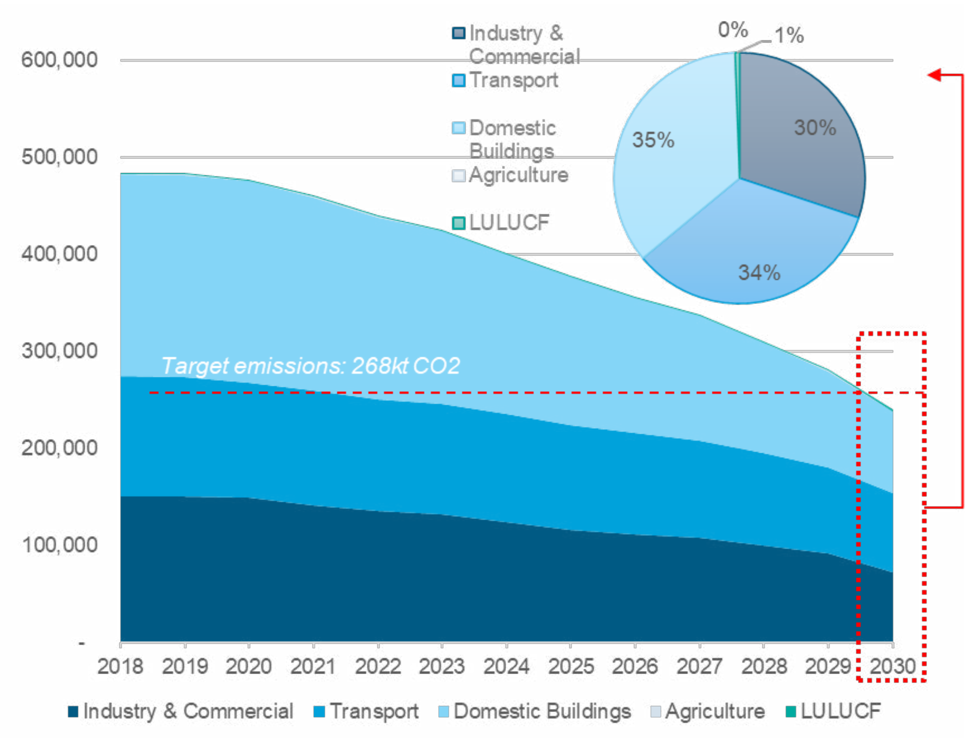


Figure 14-6: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Blackpool

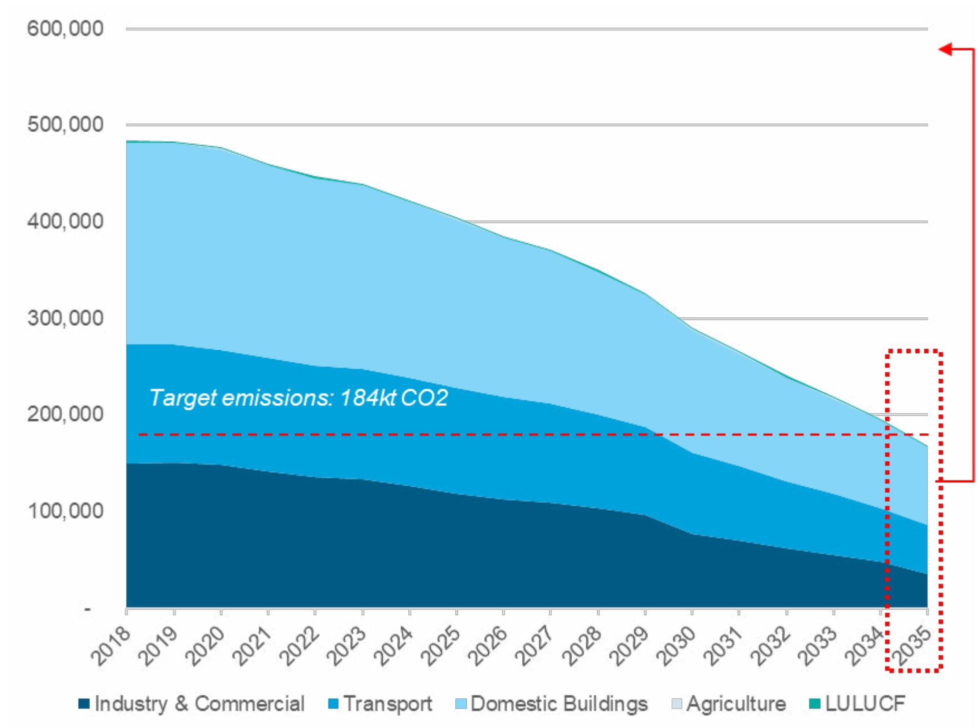
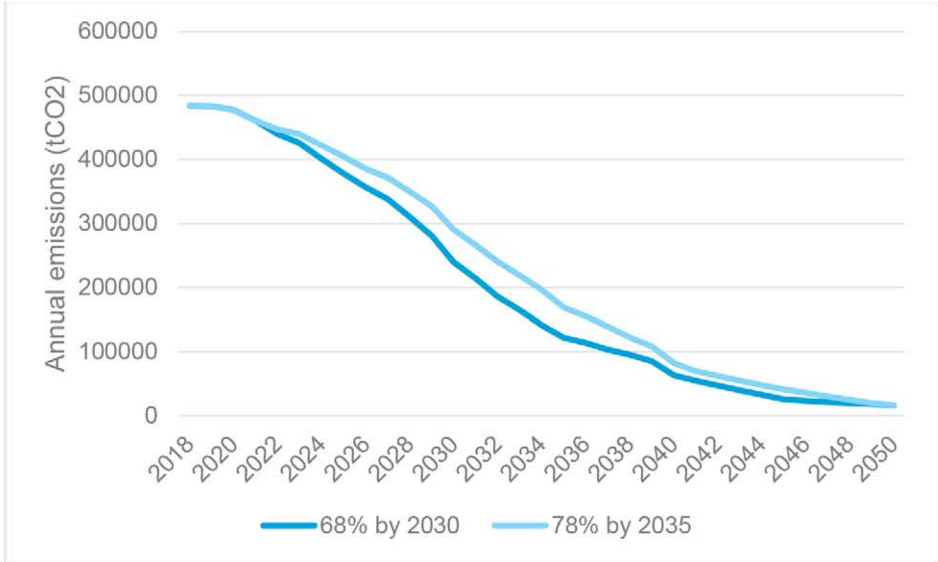
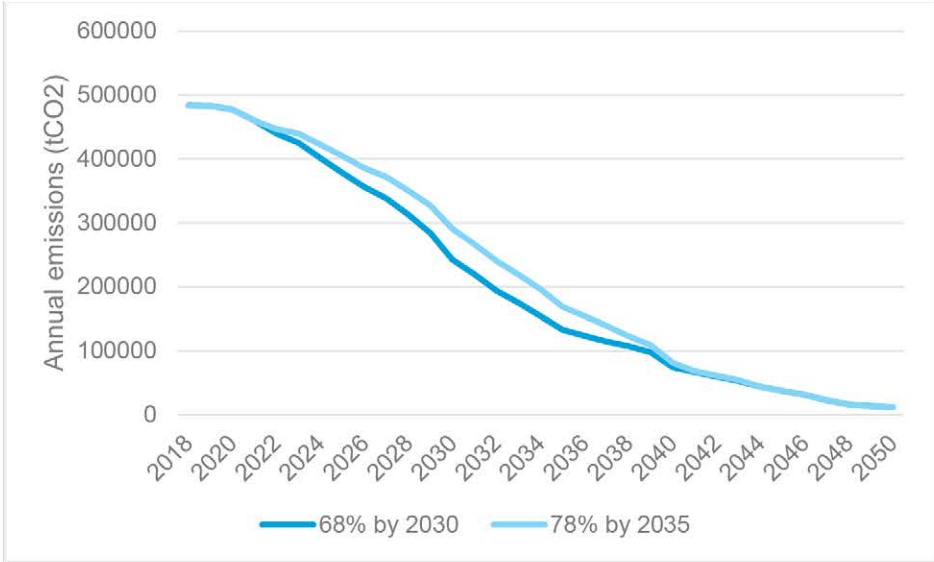


Figure 14-7: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Blackpool



Remaining emissions in 2050 are 16ktCO_2 most of which is from Transport sector.

Figure 14-8: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Blackpool



Remaining emissions in 2050 are 12ktCO_2 most of which is from Transport sector.

14.3. Burnley

Figure 14-9: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Burnley

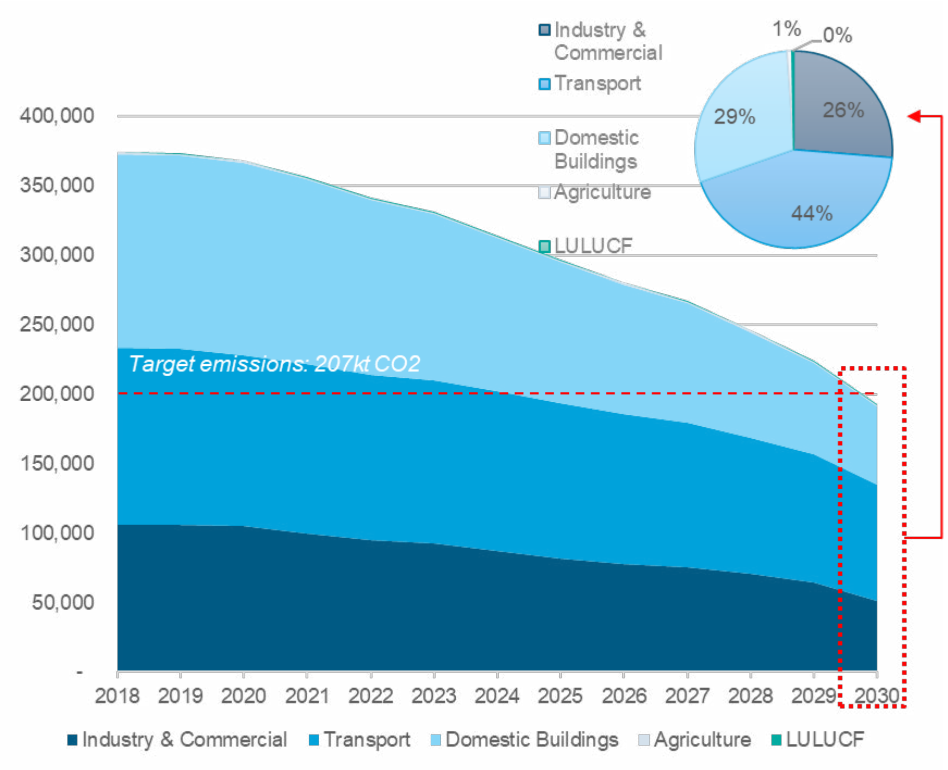


Figure 14-10: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Burnley

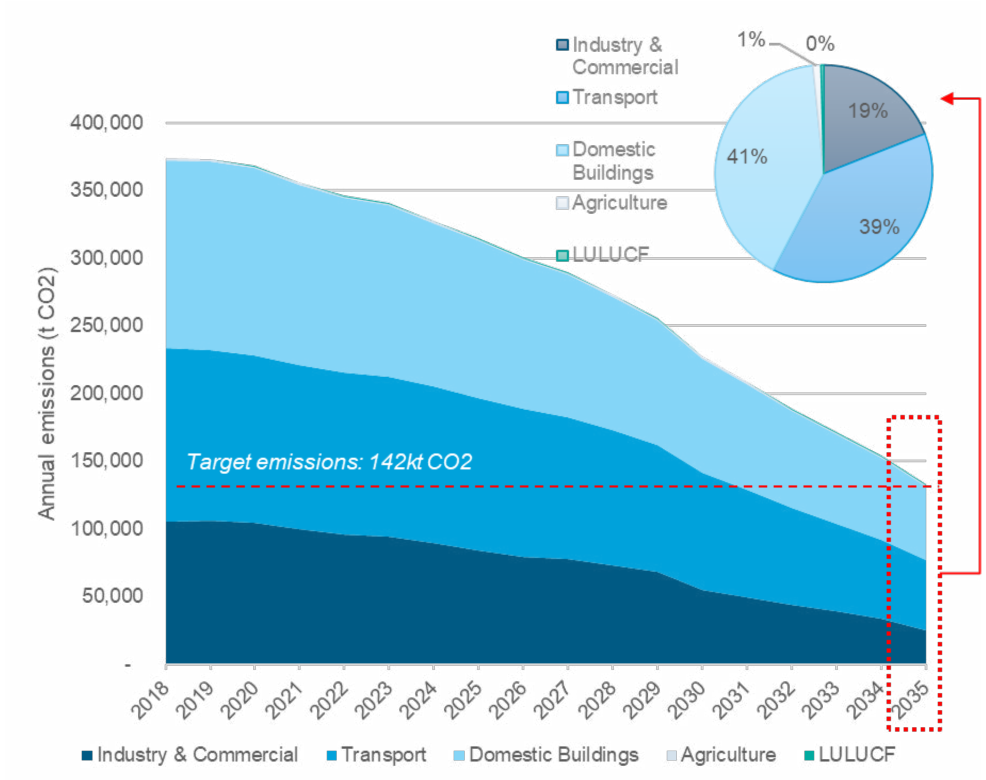
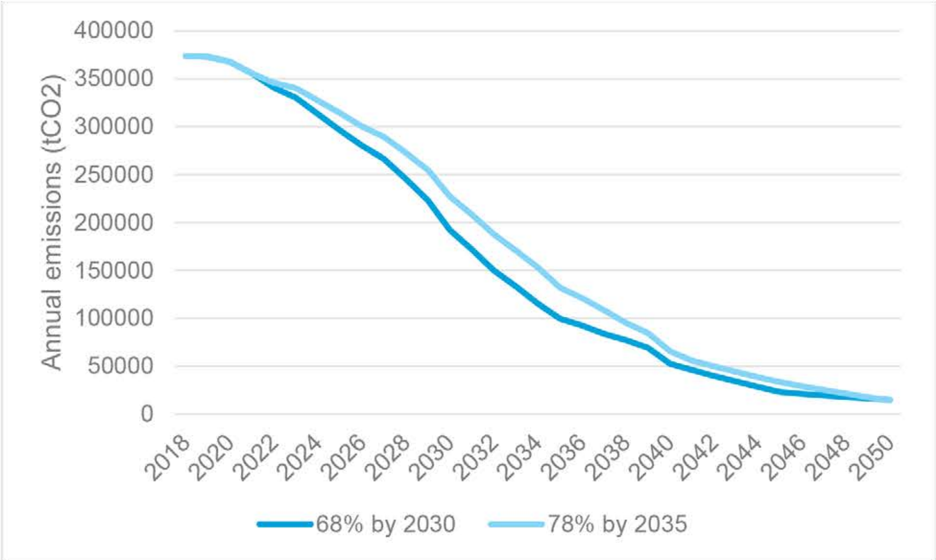
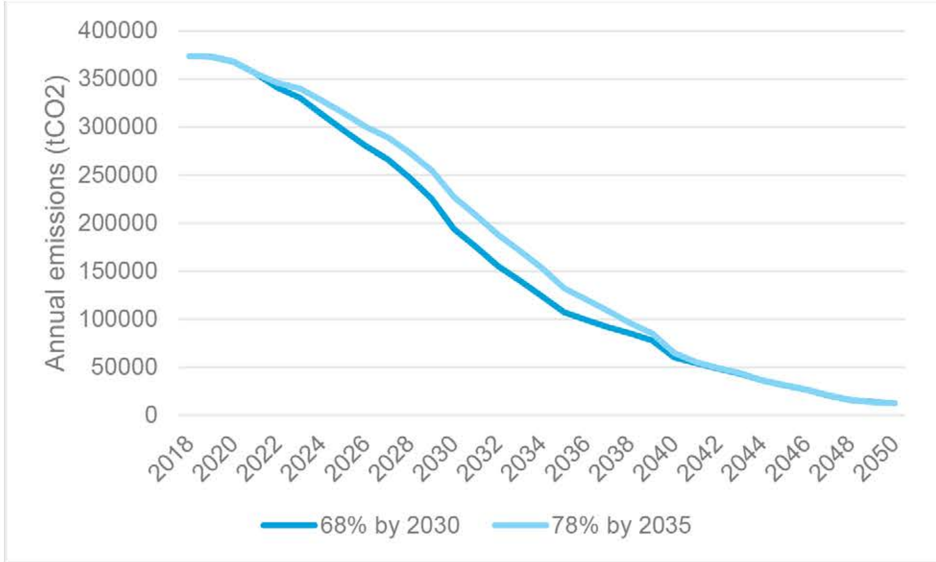


Figure 14-11: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Burnley



Remaining emissions in 2050 are 15ktCO_2 most of which is from Transport sector.

Figure 14-12: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Burnley



Remaining emissions in 2050 are 12ktCO_2 most of which is from Transport sector.

14.4. Chorley

Figure 14-13: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Chorley

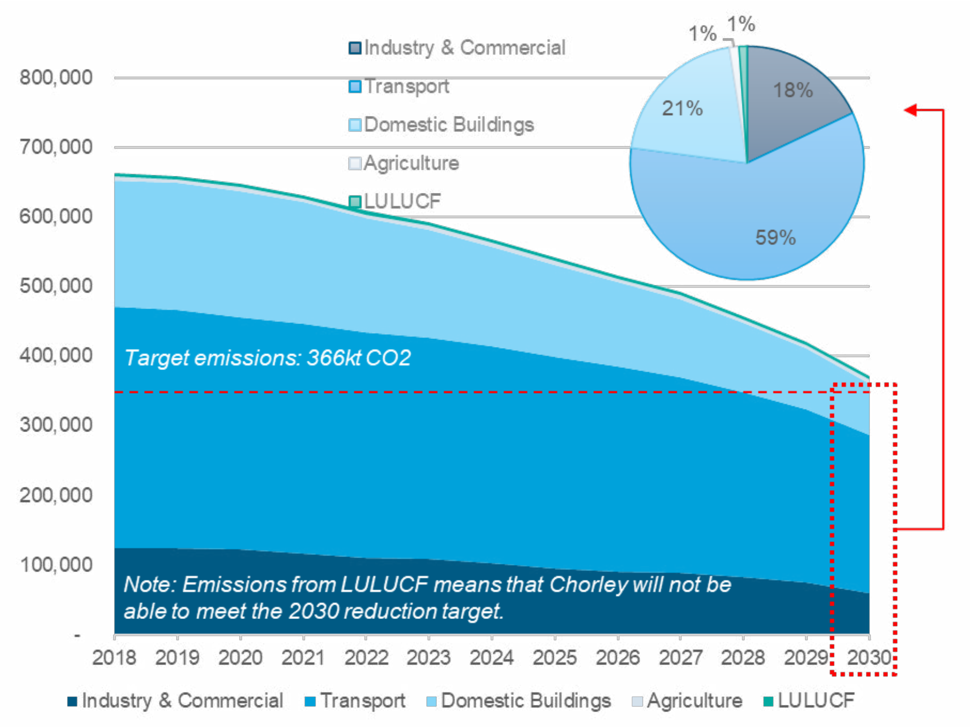


Figure 14-14: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Chorley

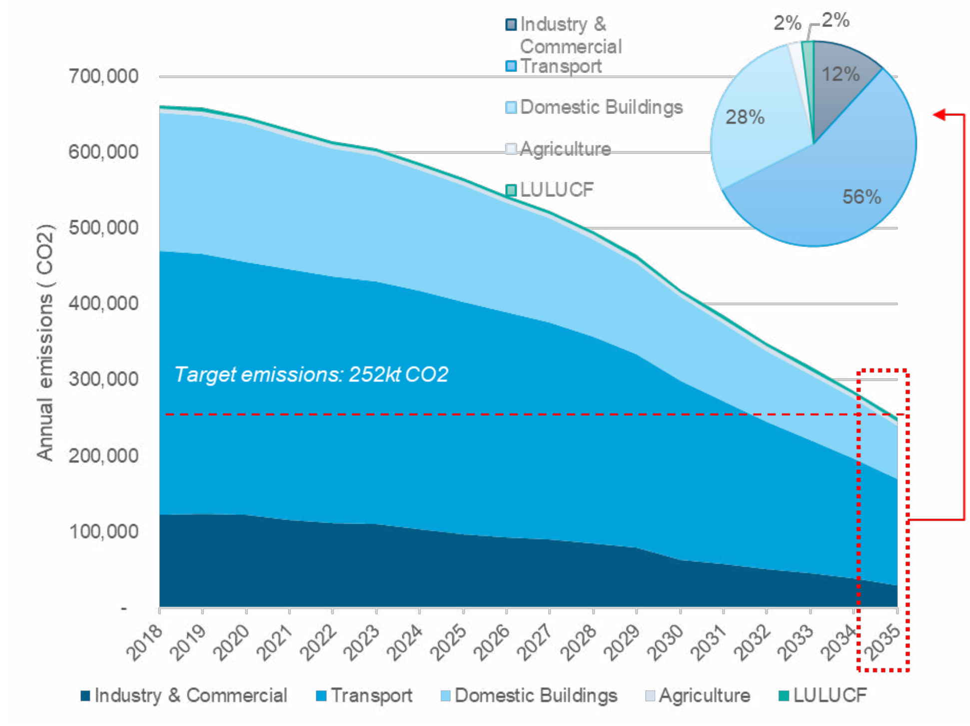
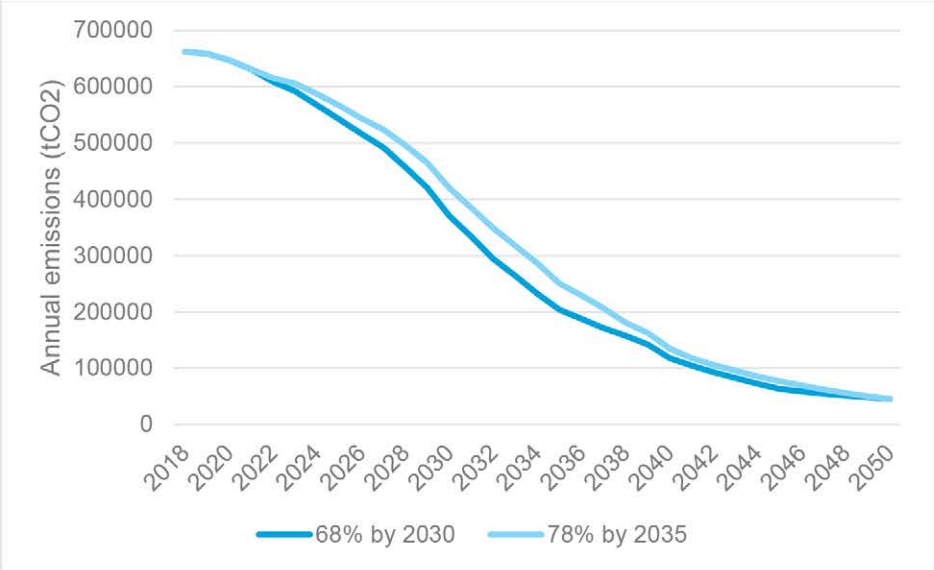
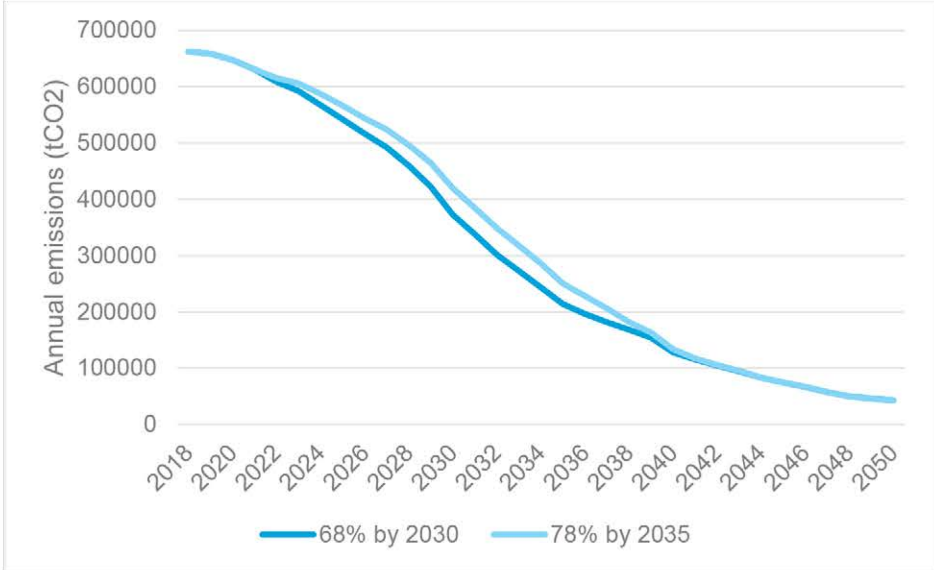


Figure 14-15: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Chorley



Remaining emissions in 2050 are 45ktCO_2 most of which is from Transport sector.

Figure 14-16: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Chorley



Remaining emissions in 2050 are 43ktCO_2 most of which is from Transport sector.

14.5. Fylde

Figure 14-17: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Fylde

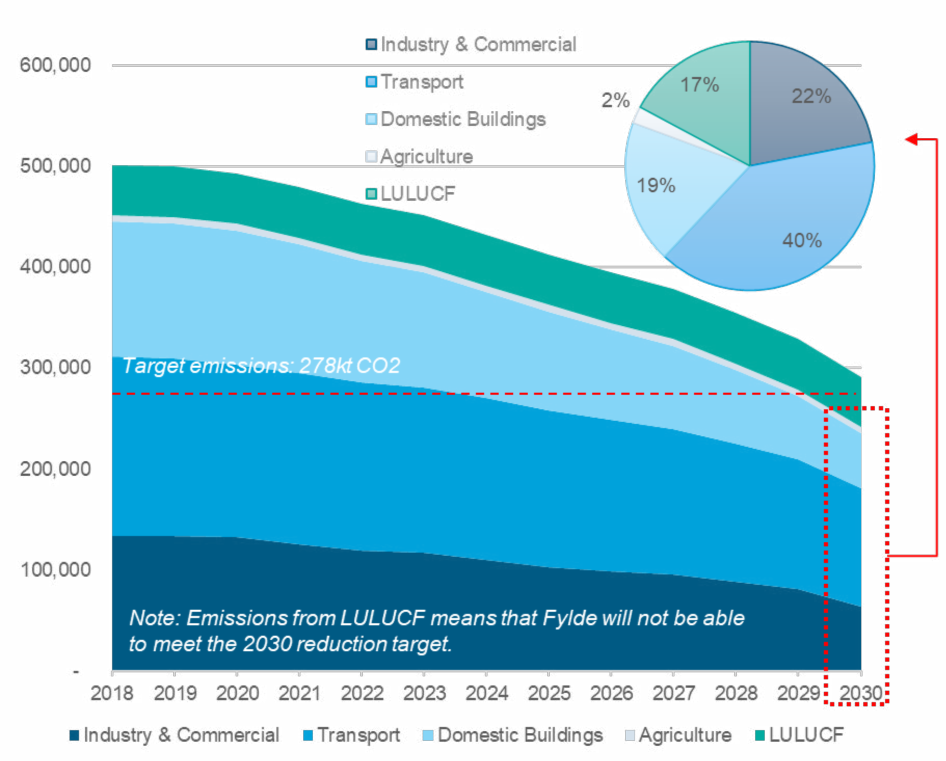


Figure 14-18: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Fylde

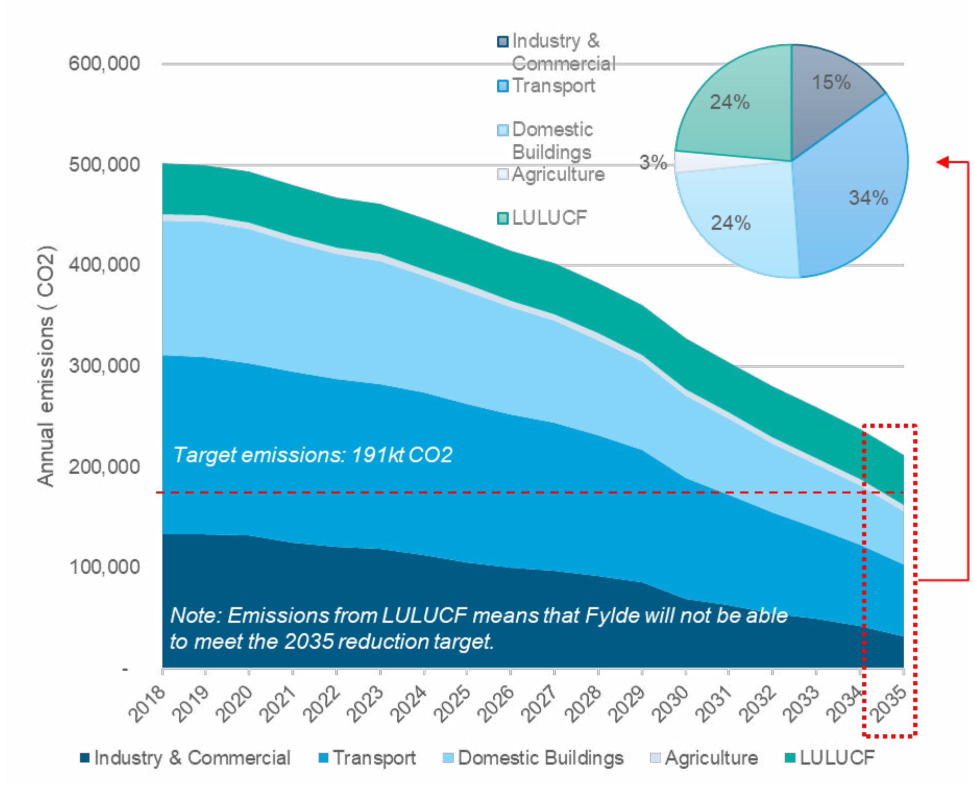
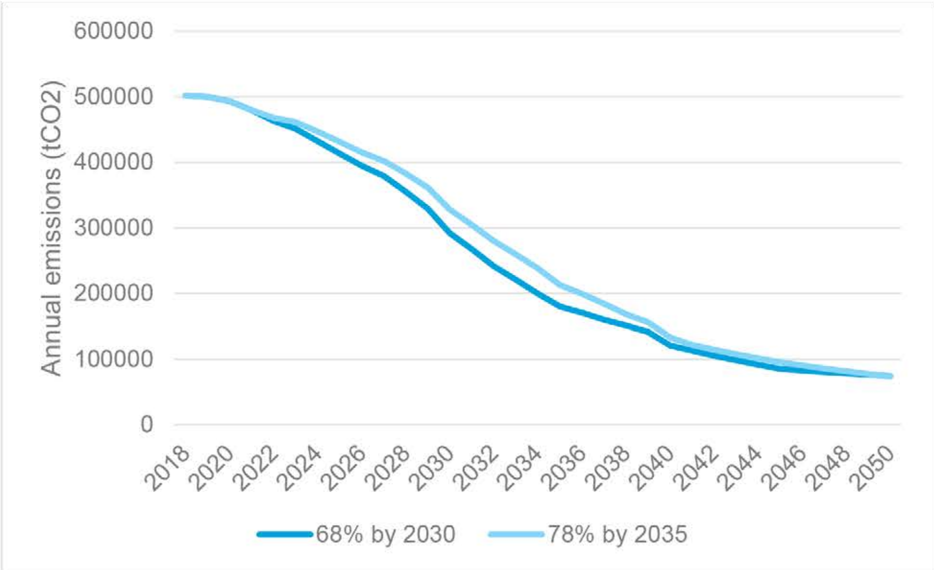
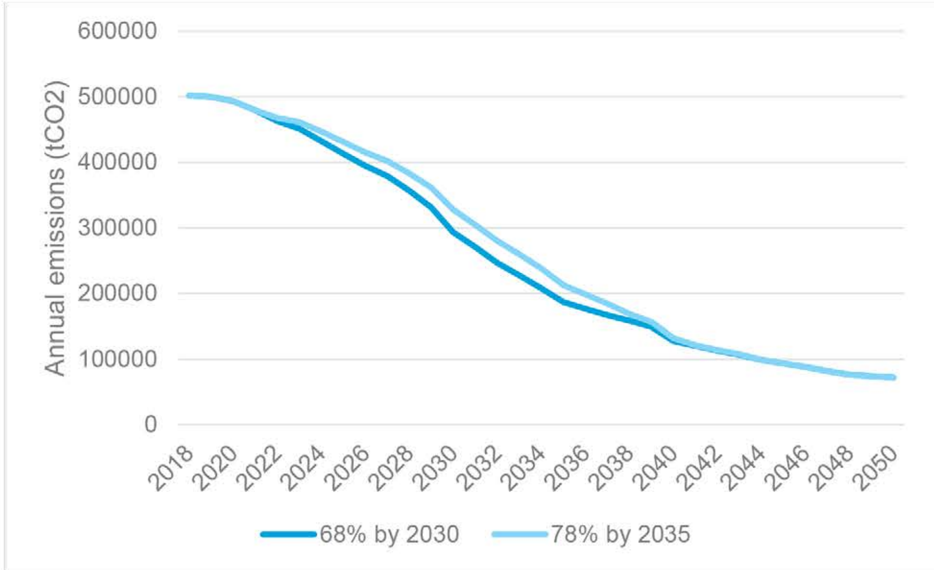


Figure 14-19: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Fylde



Remaining emissions in 2050 are 75ktCO_2 most of which is from Transport sector.

Figure 14-20: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Fylde



Remaining emissions in 2050 are 72ktCO_2 most of which is from LULUCF sector.

14.6. Hyndburn

Figure 14-21: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Hyndburn

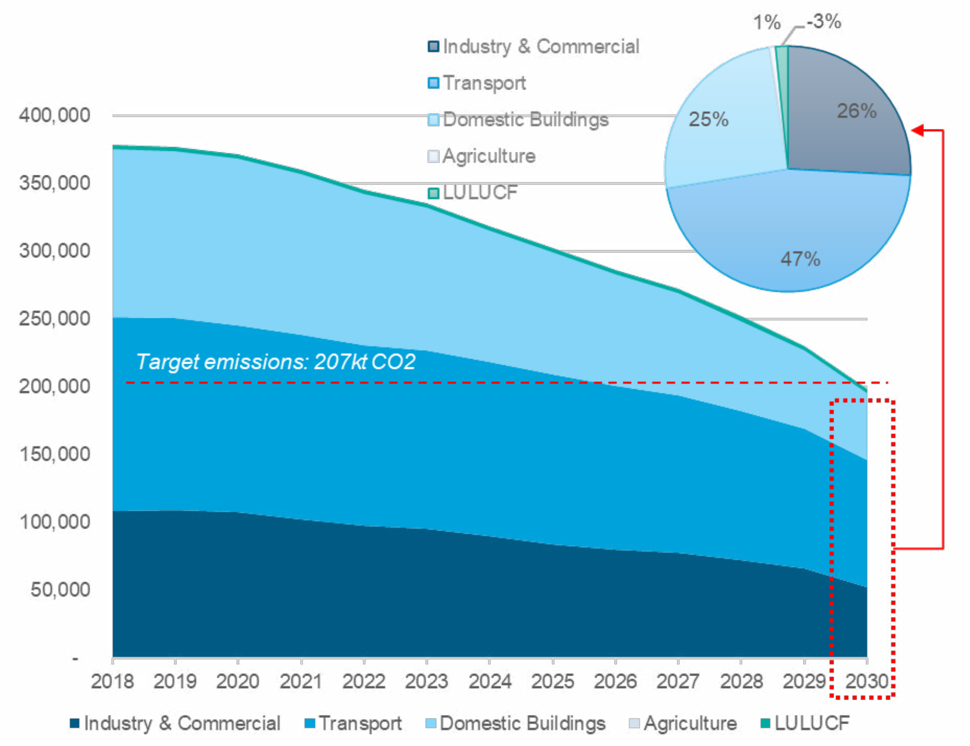


Figure 14-22: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Hyndburn

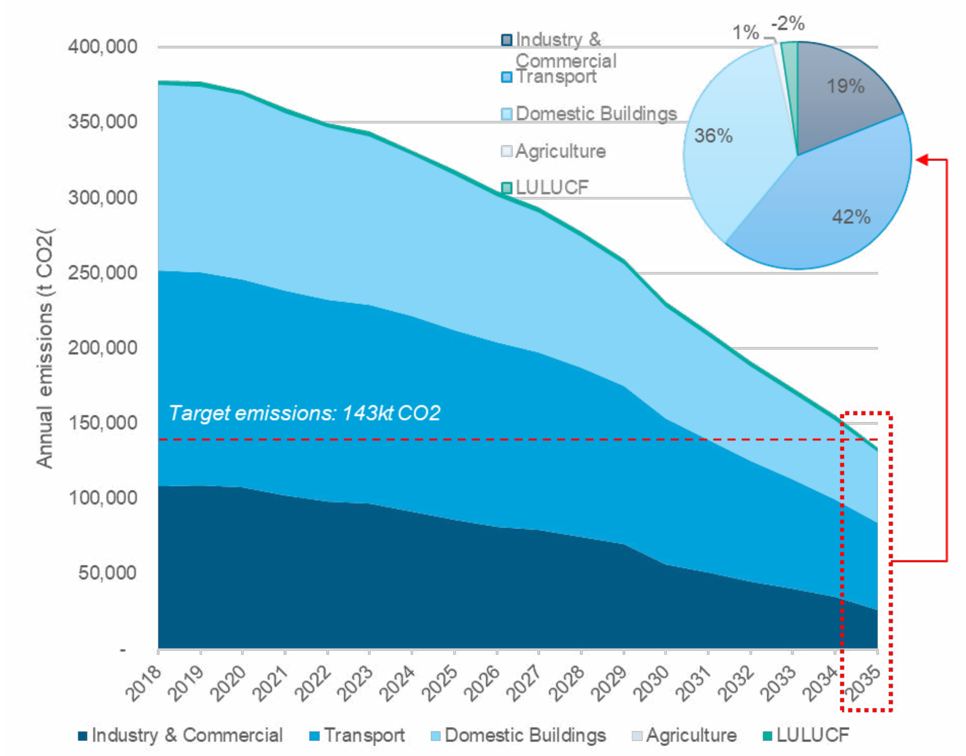
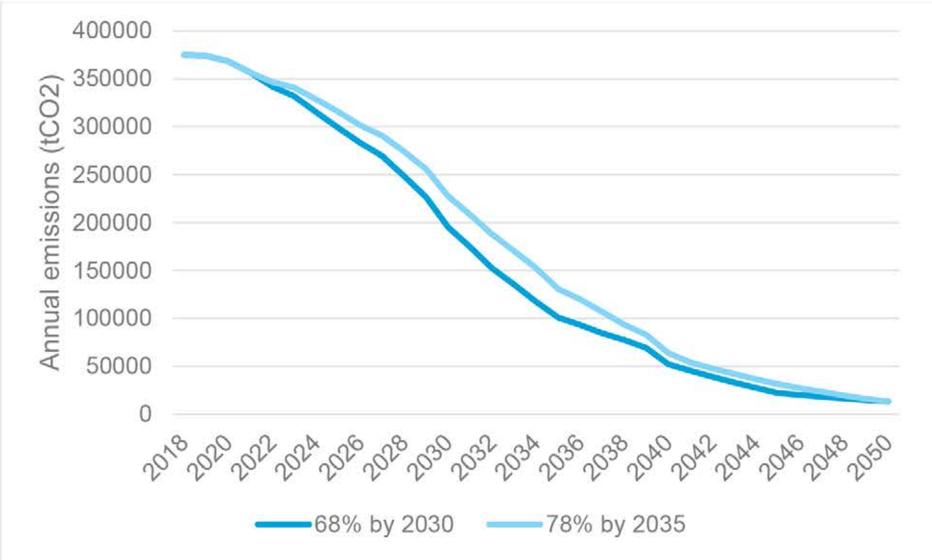
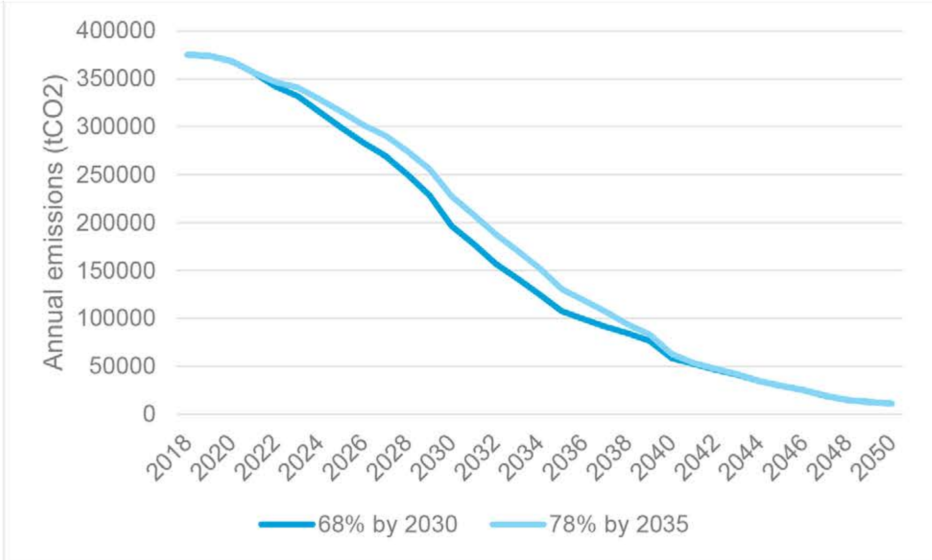


Figure 14-23: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Hyndburn



Remaining emissions in 2050 are 13ktCO_2 most of which is from Transport sector.

Figure 14-24: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Hyndburn



Remaining emissions in 2050 are 11ktCO_2 most of which is from Transport sector.

14.7. Lancaster

Figure 14-25: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Lancaster

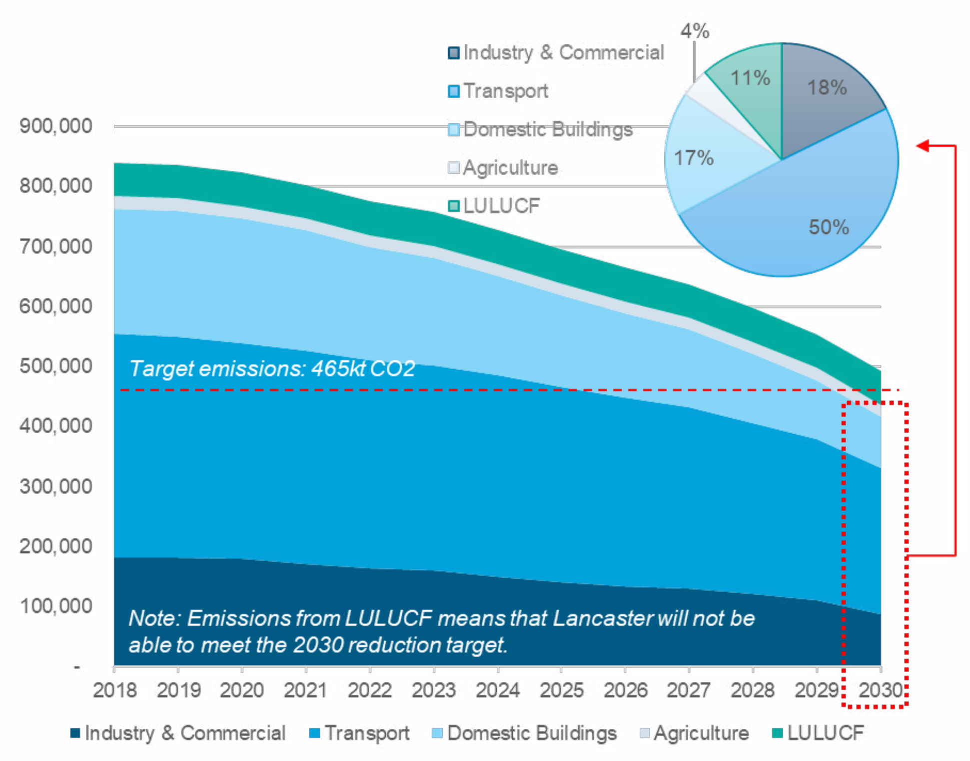


Figure 14-26: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Lancaster

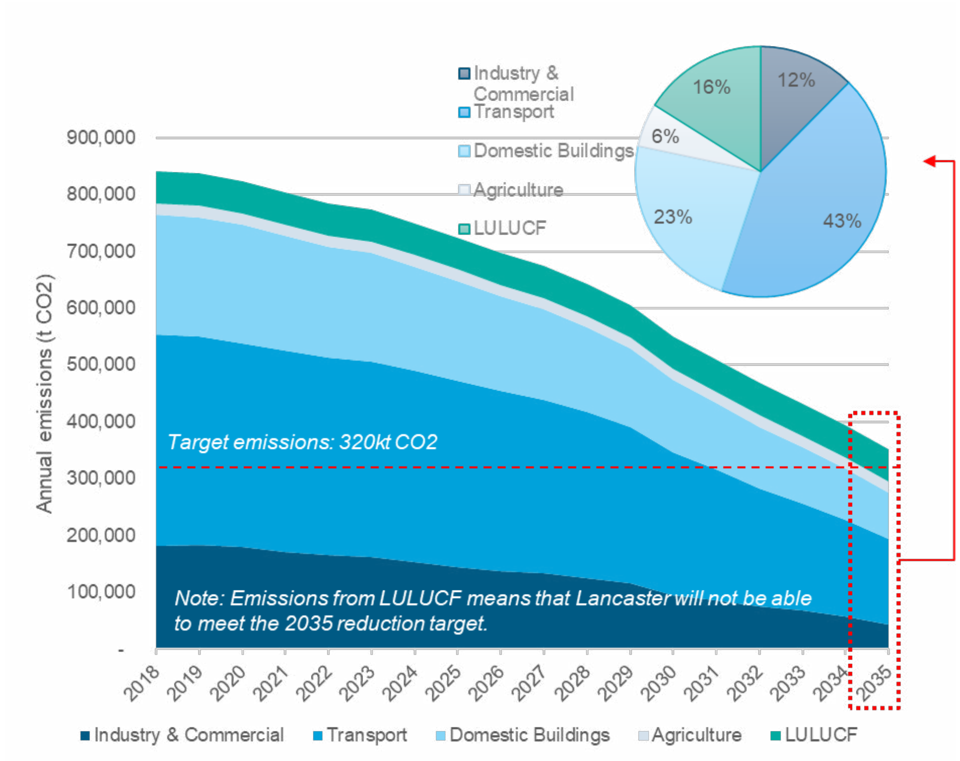
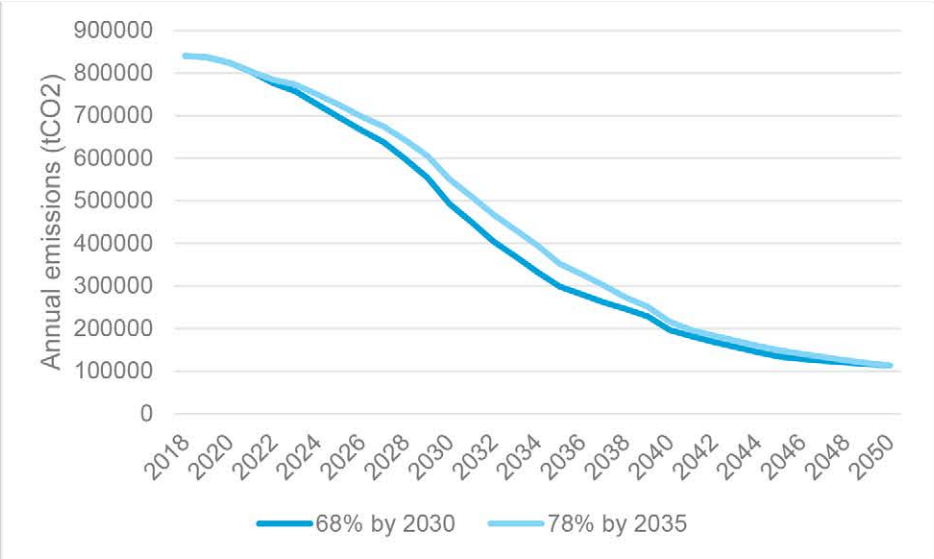
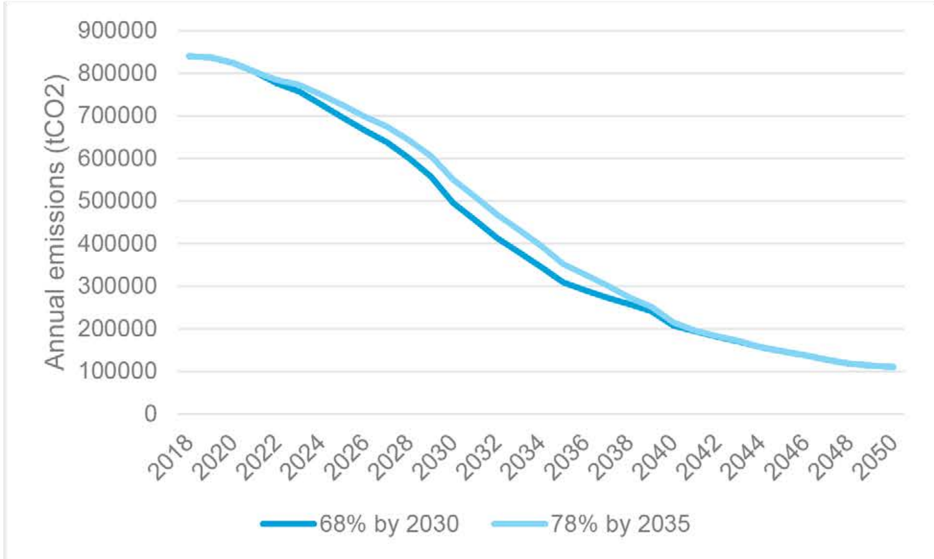


Figure 14-27: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Lancaster



Remaining emissions in 2050 are 114ktCO_2 most of which is from LULUCF sector.

Figure 14-28: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Lancaster



Remaining emissions in 2050 are 110ktCO_2 most of which is from LULUCF sector.

14.8. Pendle

Figure 14-29: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Pendle

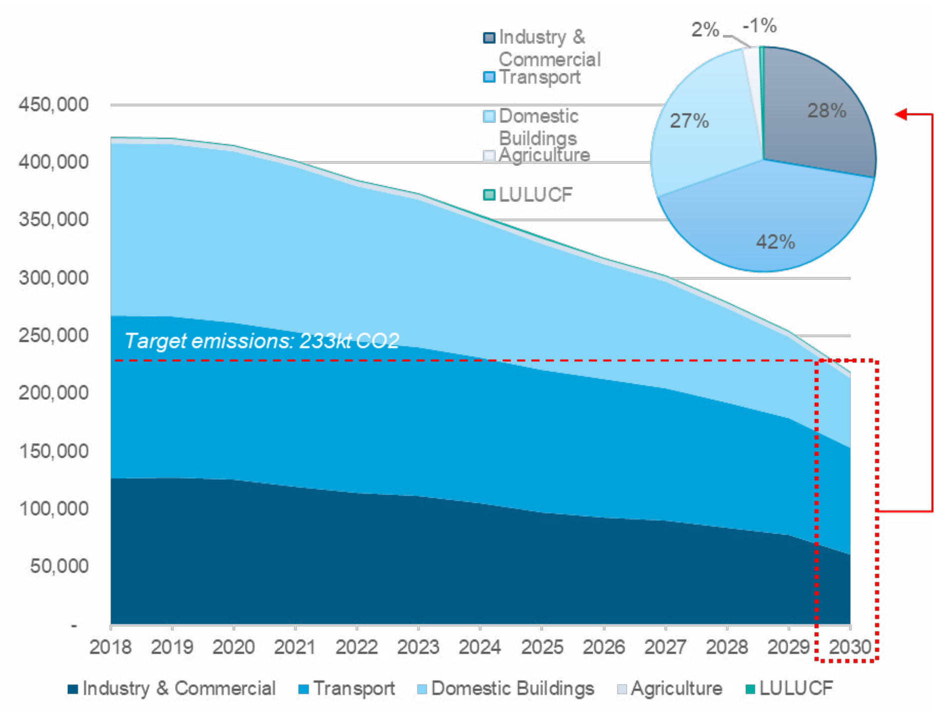


Figure 14-30: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Pendle

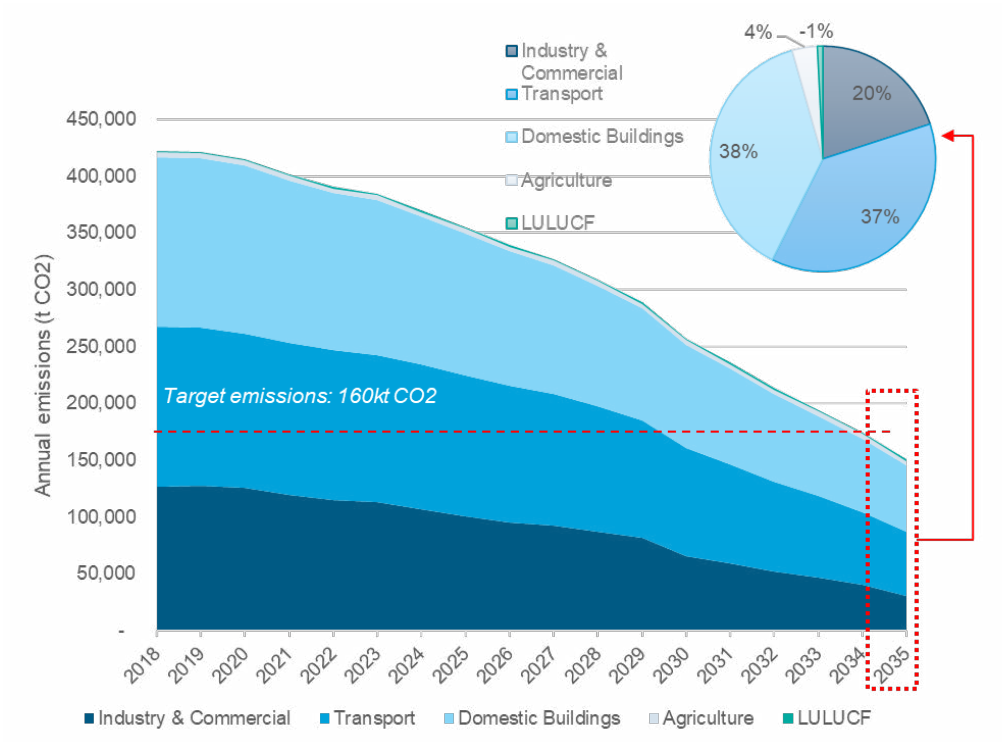
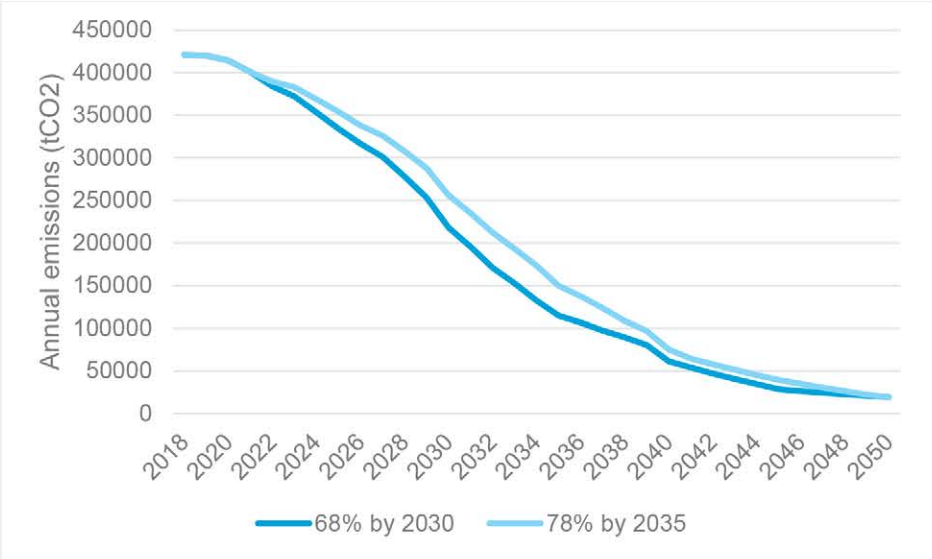
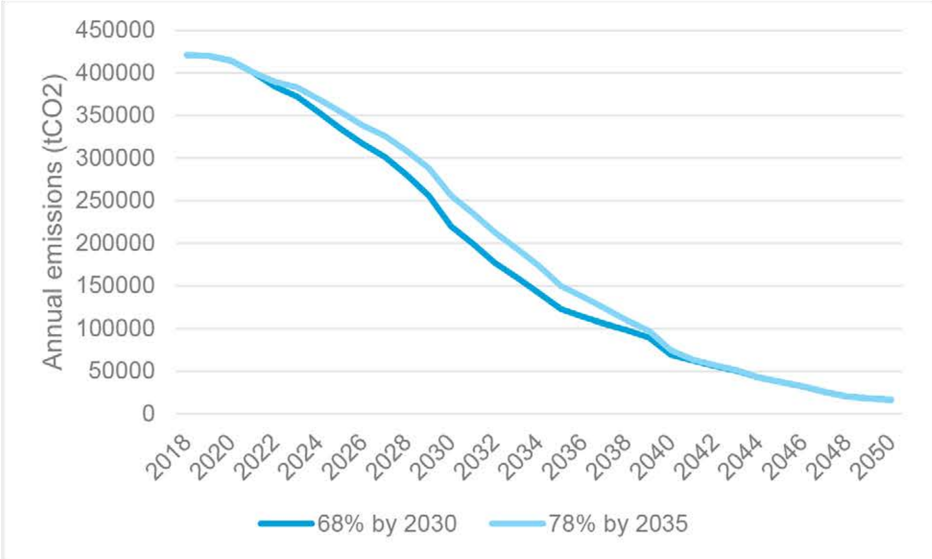


Figure 14-31: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Pendle



Remaining emissions in 2050 are 19ktCO$_2$ most of which is from Transport sector.

Figure 14-32: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Pendle



Remaining emissions in 2050 are 17ktCO$_2$ most of which is from Transport sector.

14.9. Preston

Figure 14-33: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Preston

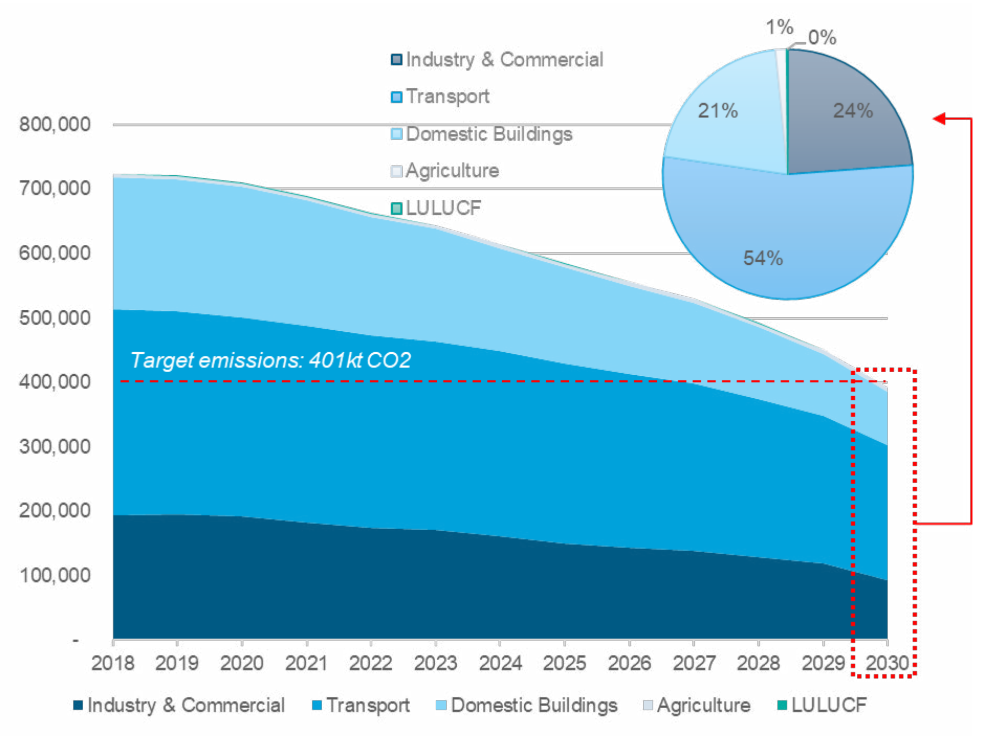


Figure 14-34: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Preston

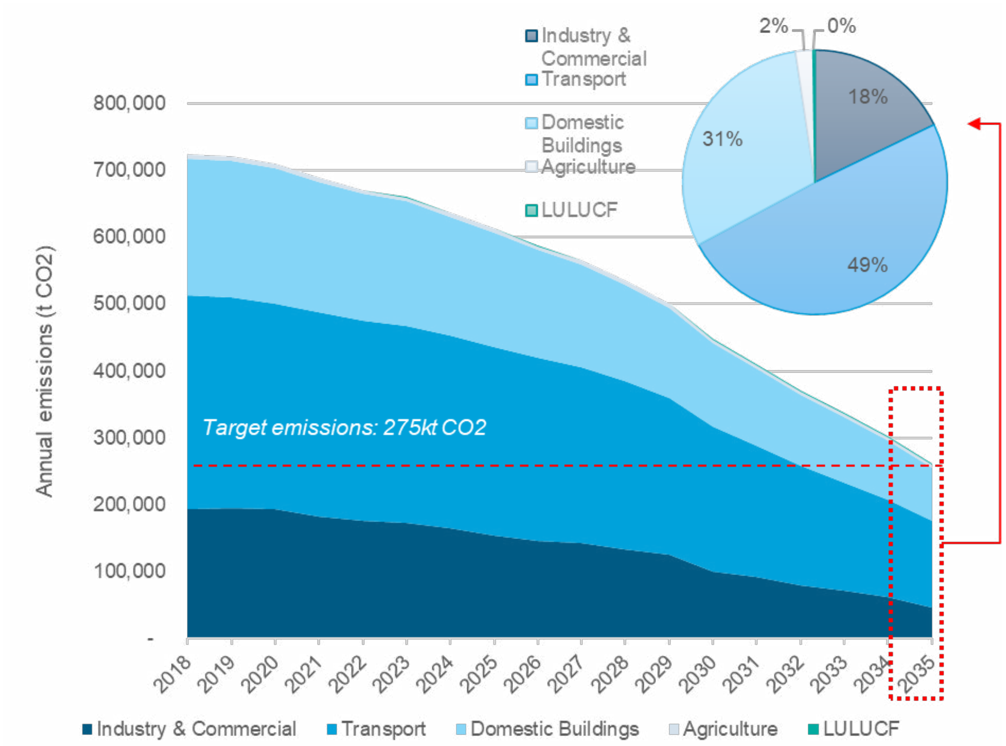
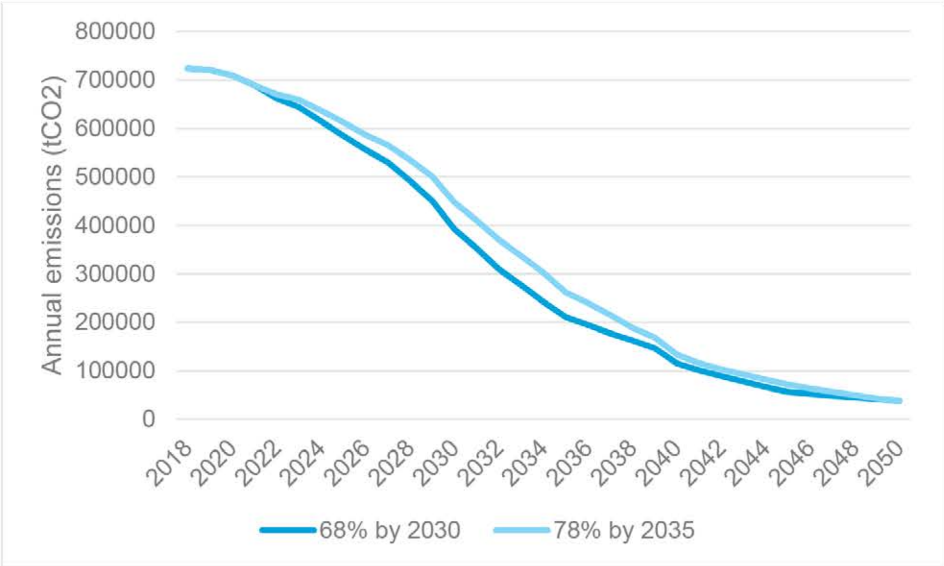
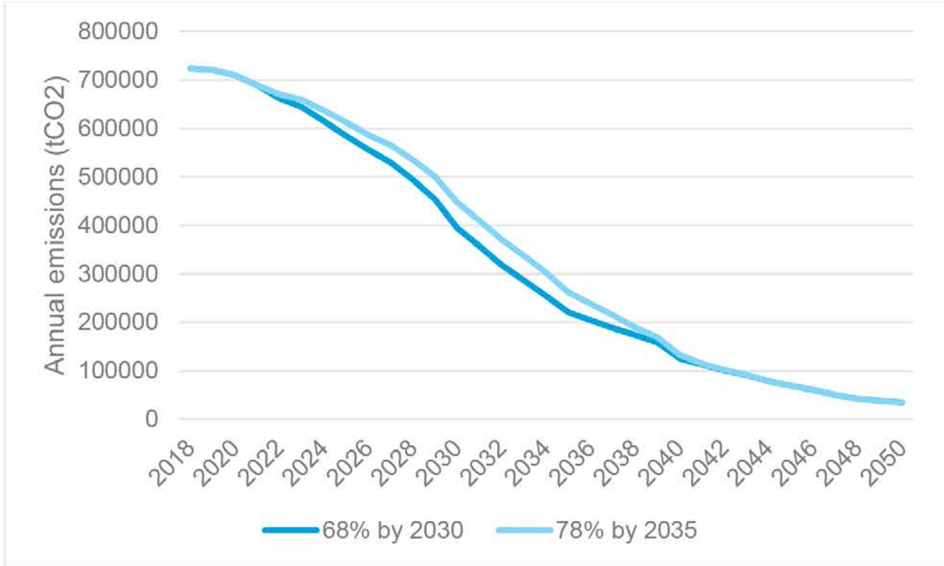


Figure 14-35: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Preston



Remaining emissions in 2050 are 38ktCO_2 most of which is from Transport sector.

Figure 14-36: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Preston



Remaining emissions in 2050 are 35ktCO_2 most of which is from Transport sector.

14.10. Ribble Valley

Figure 14-37: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Ribble Valley

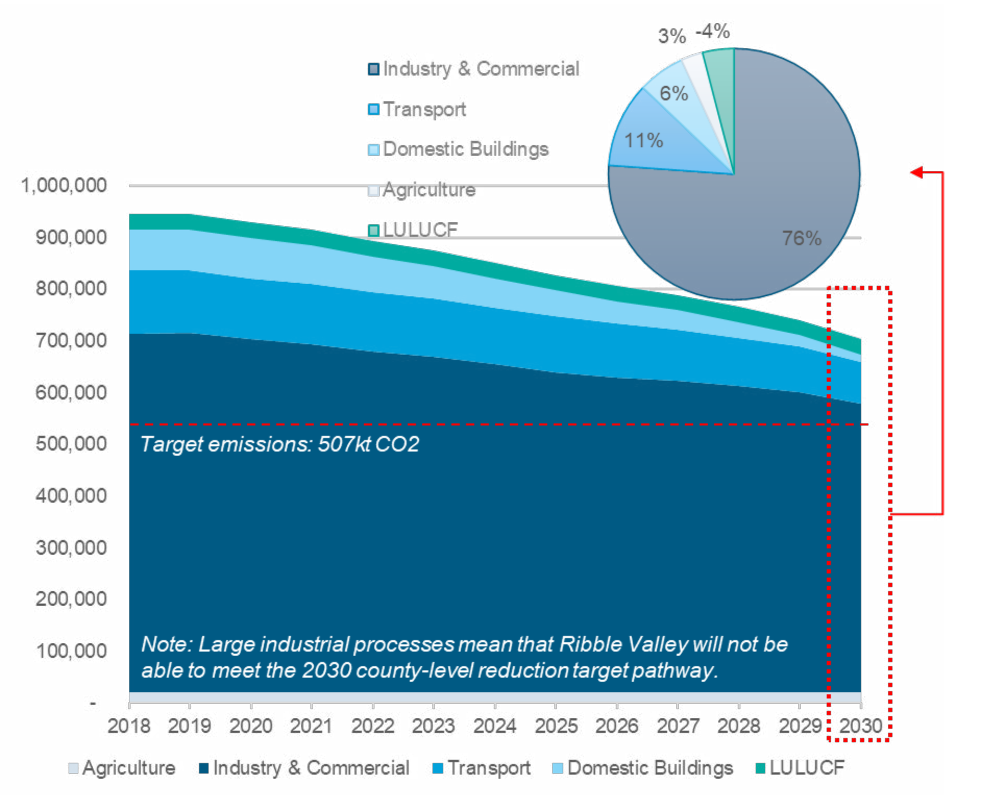


Figure 14-38: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Ribble Valley

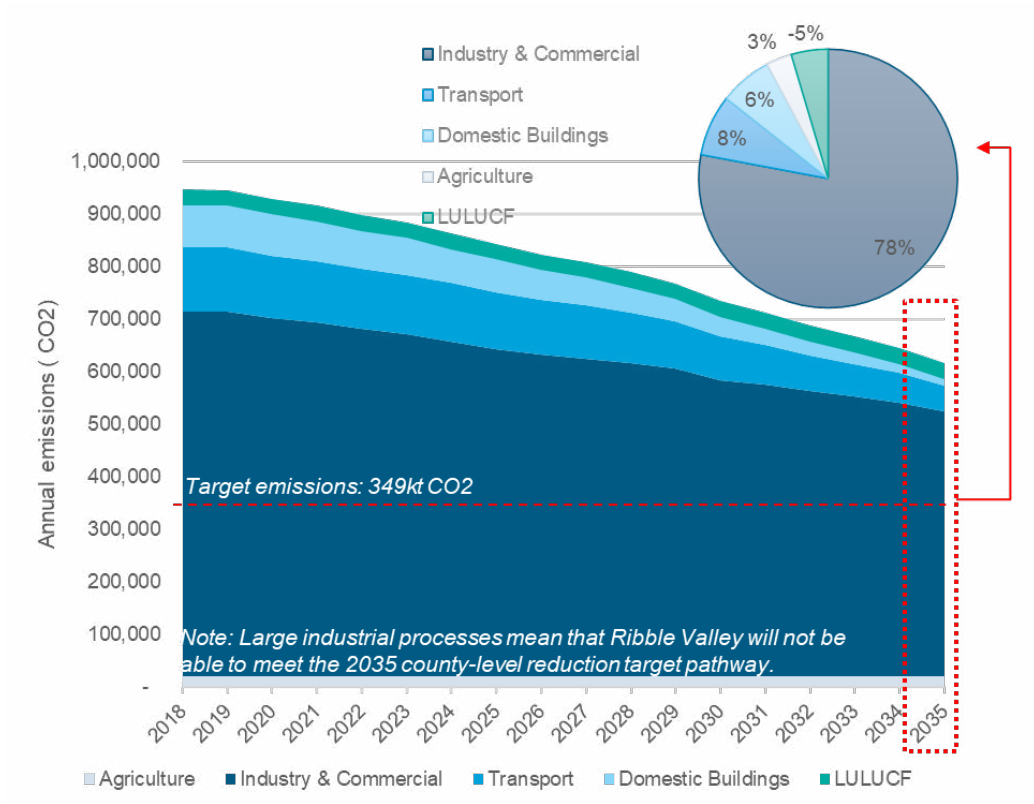
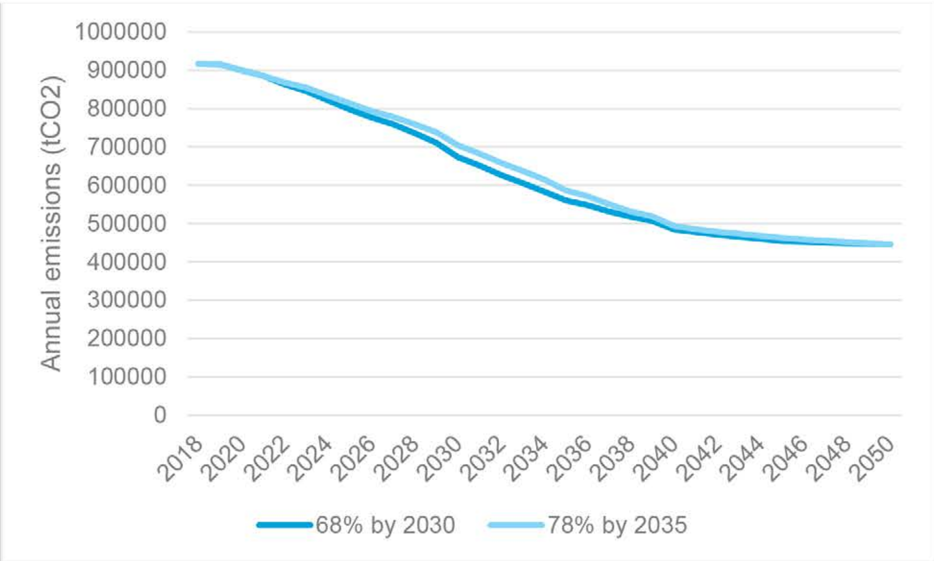
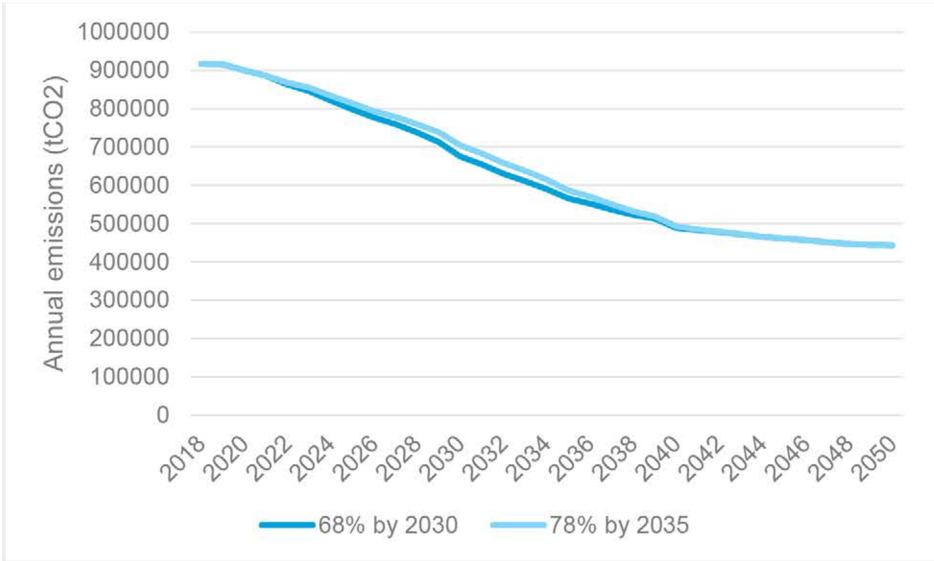


Figure 14-39: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Ribble Valley



Remaining emissions in 2050 are 446ktCO_2 most of which is from Industry sector.

Figure 14-40: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Ribble Valley



Remaining emissions in 2050 are 443ktCO_2 most of which is from Industry sector.

14.11. Rossendale

Figure 14-41: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Rossendale

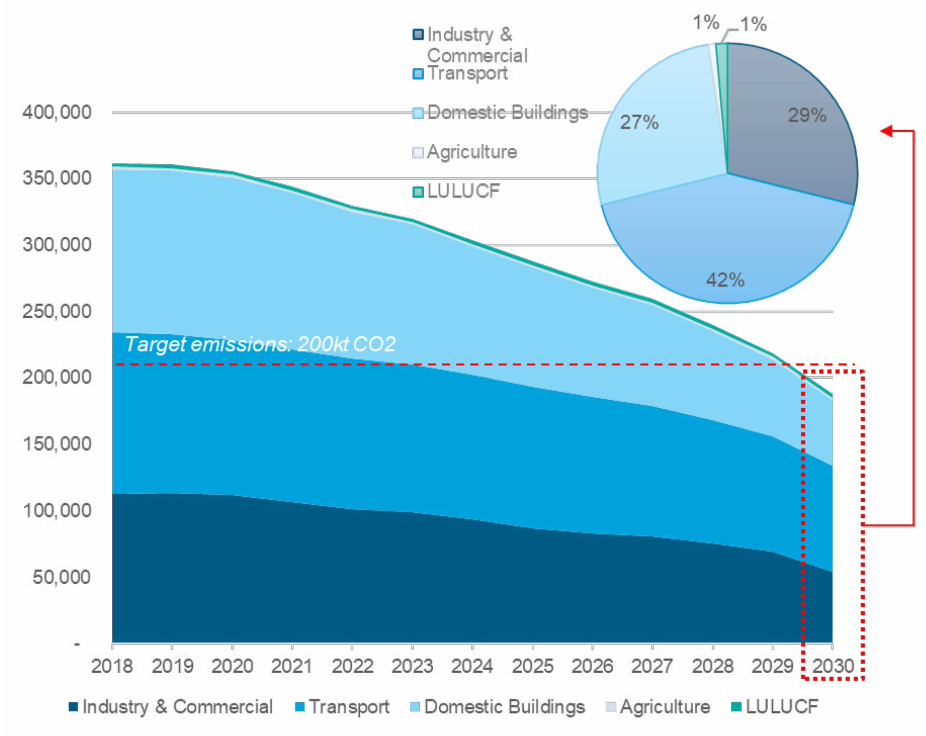


Figure 14-42: 78% emissions reduction by 2 035 pathway analysis, breakdown of CO_2 by emissions source – Rossendale

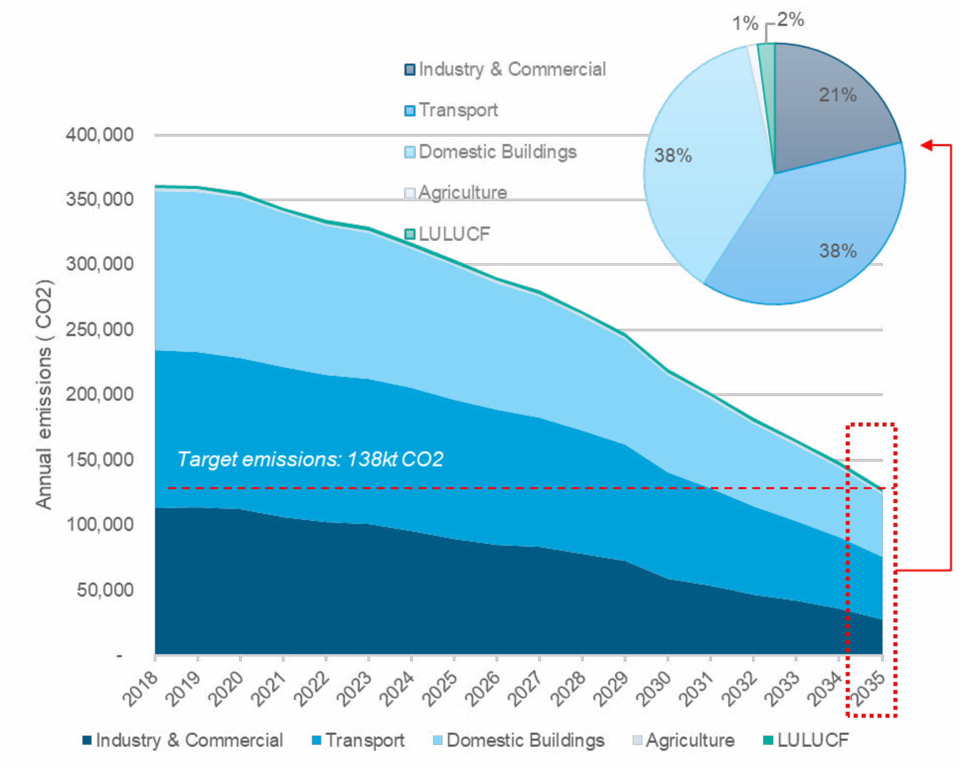
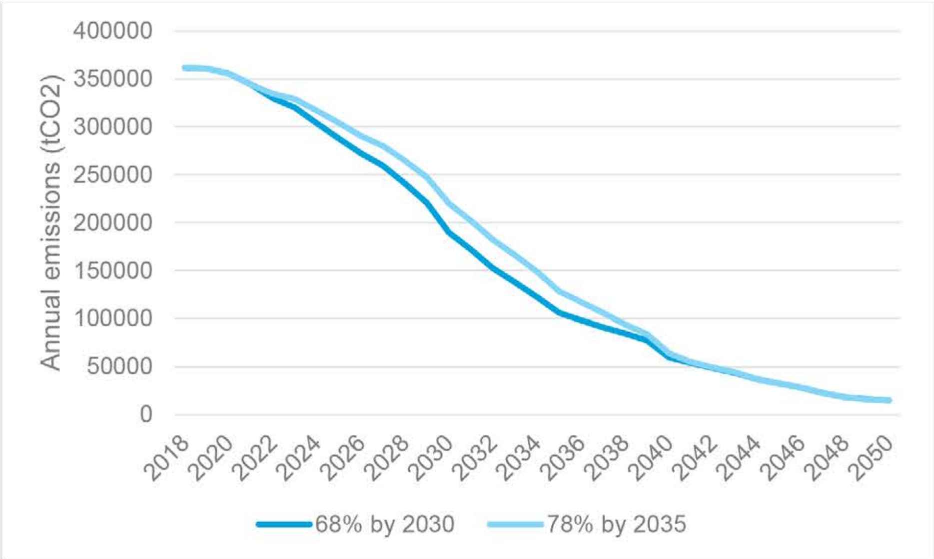
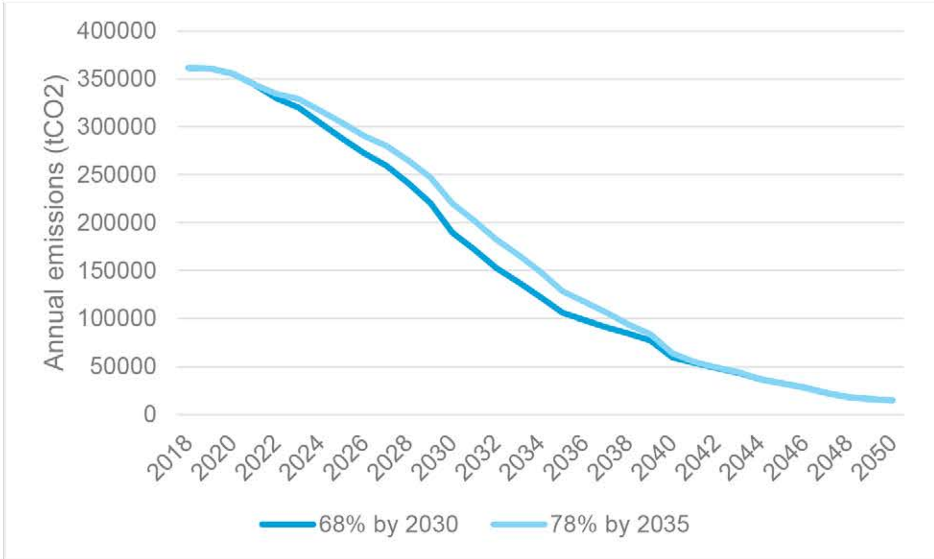


Figure 14-43: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Rossendale



Remaining emissions in 2050 are 17ktCO₂ most of which is from Transport sector.

Figure 14-44: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Rossendale



Remaining emissions in 2050 are 15ktCO₂ most of which is from Transport sector.

14.12. South Ribble

Figure 14-45: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – South Ribble

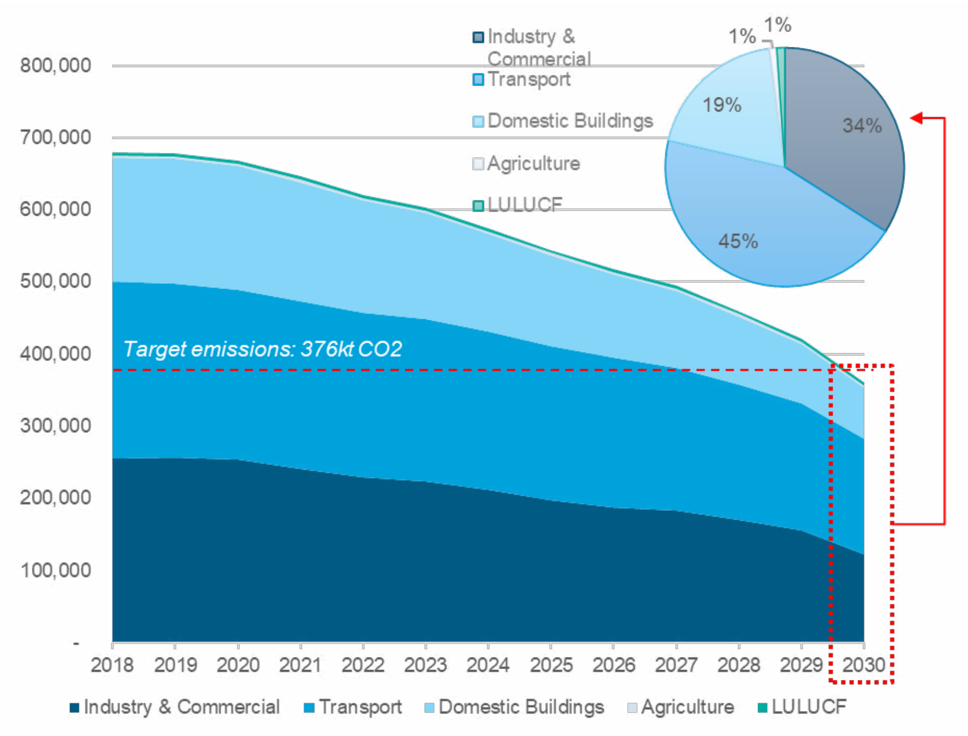


Figure 14-46: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – South Ribble

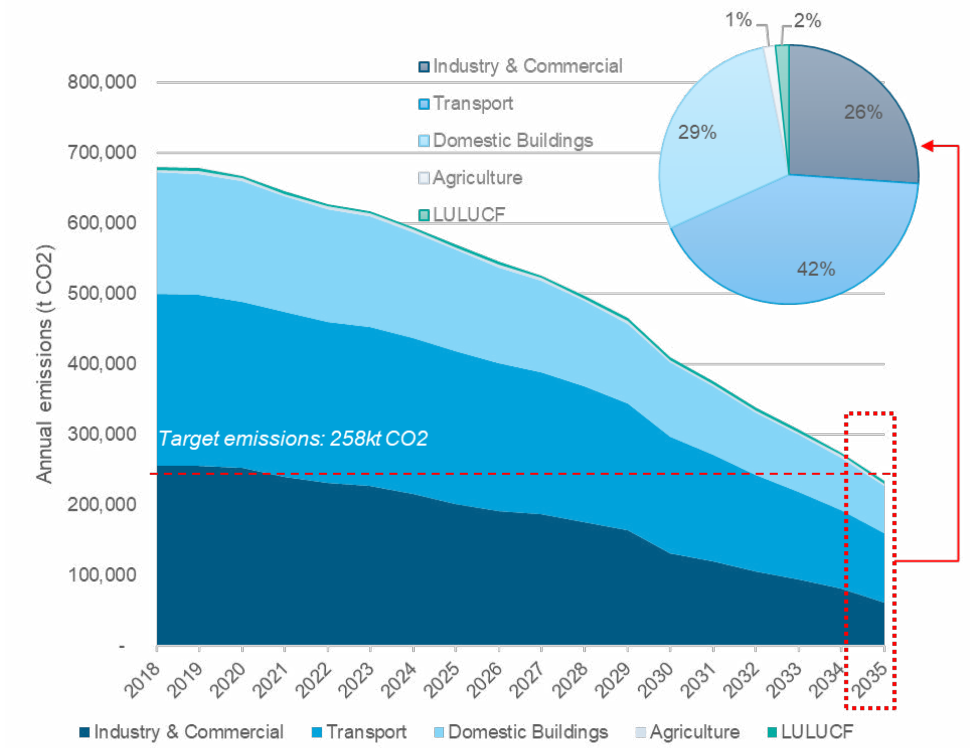
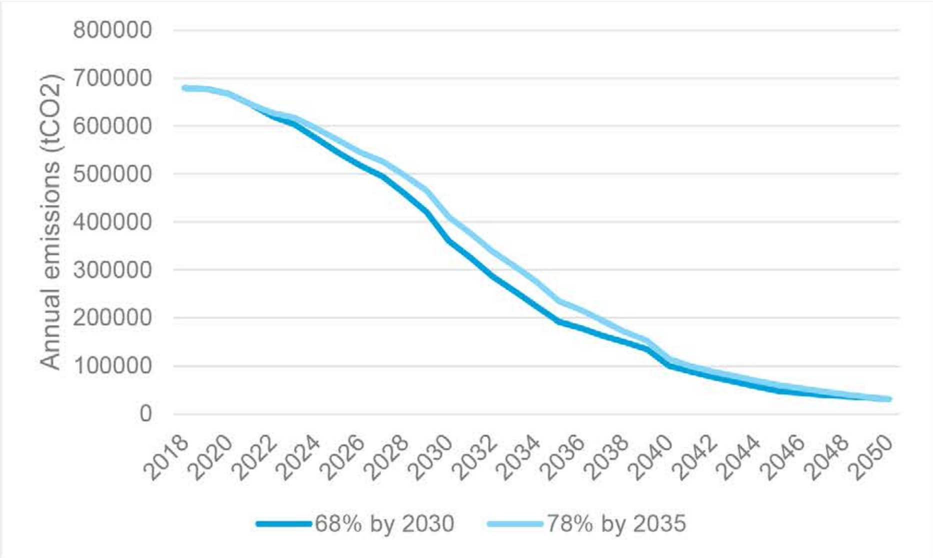
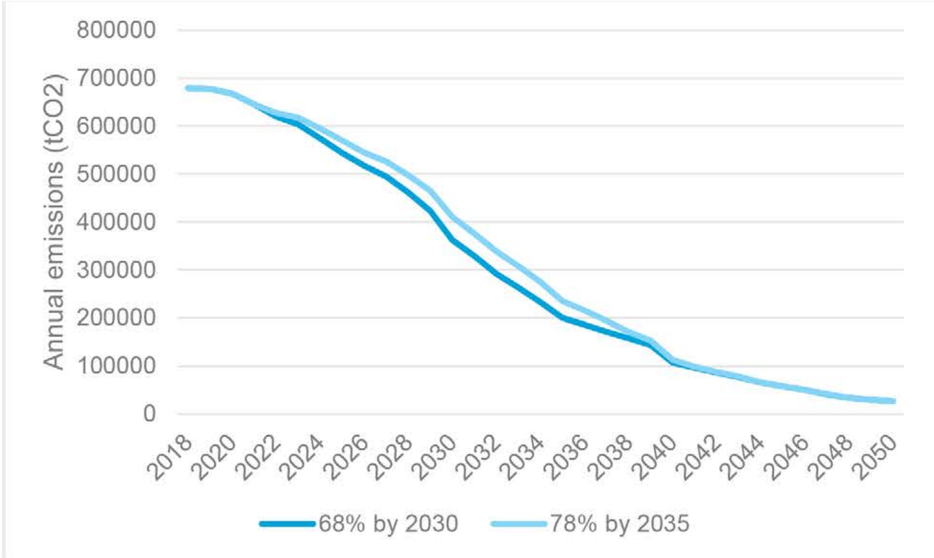


Figure 14-47: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – South Ribble



Remaining emissions in 2050 are 31ktCO_2 most of which is from Transport sector.

Figure 14-48: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – South Ribble



Remaining emissions in 2050 are 27ktCO_2 most of which is from Transport sector.

14.13. West Lancashire

Figure 14-49: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – West Lancashire

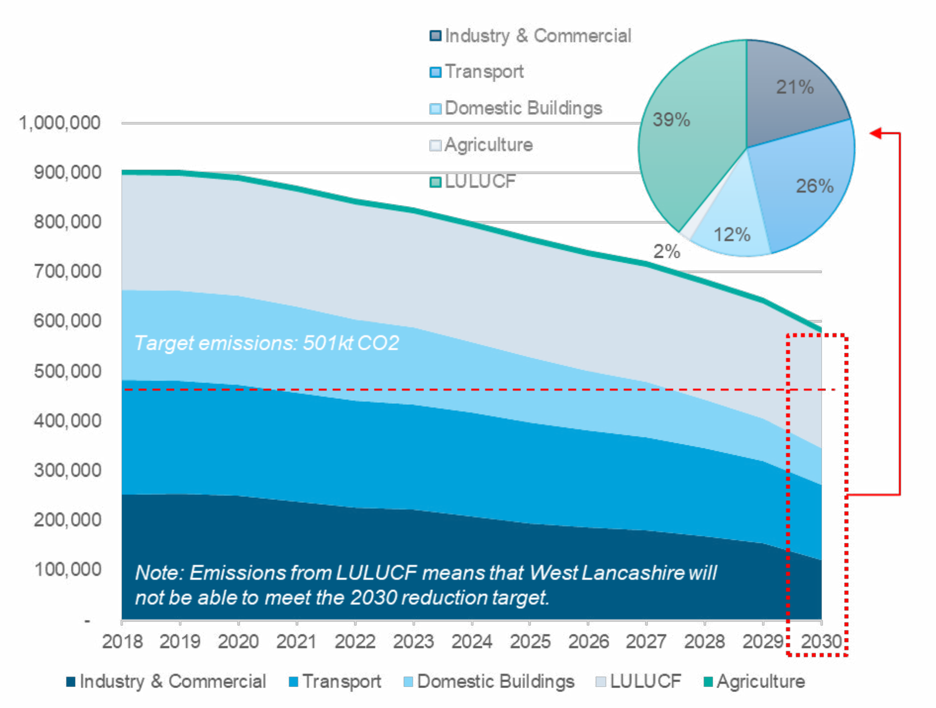


Figure 14-50: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – West Lancashire

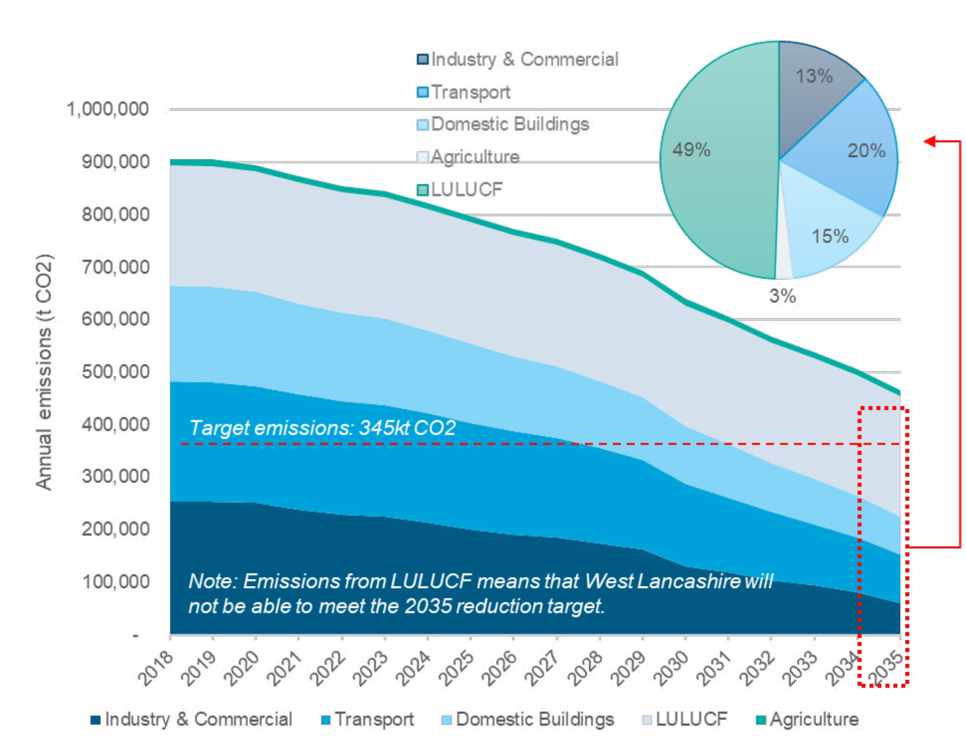
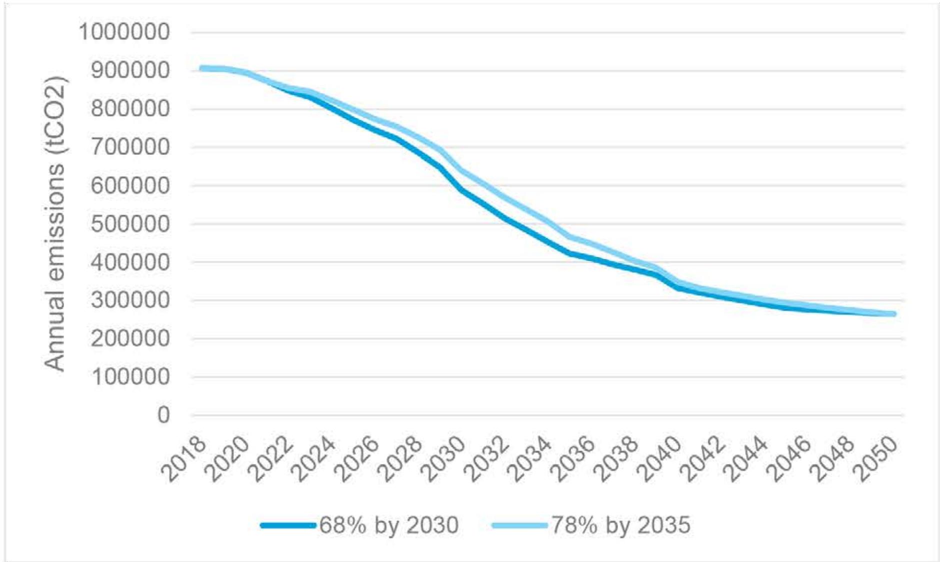
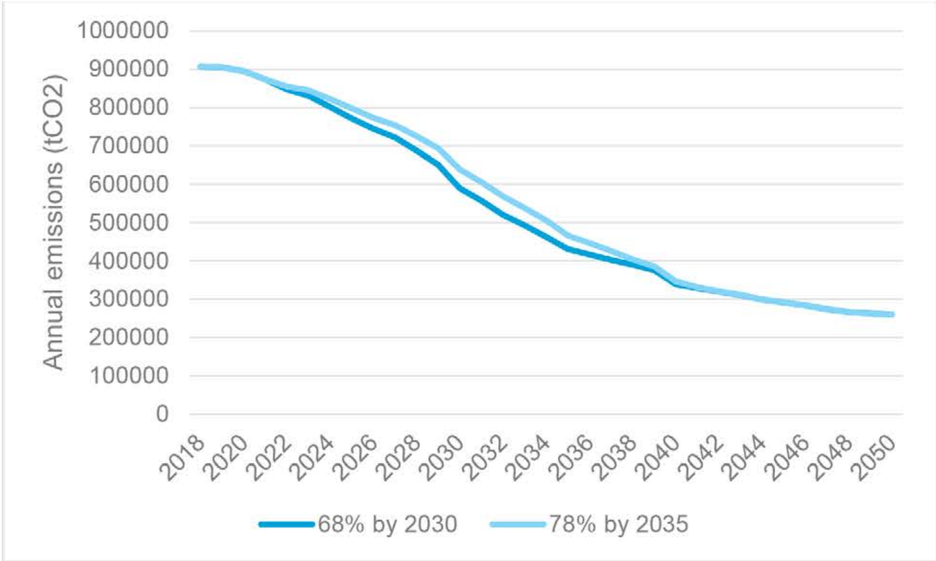


Figure 14-51: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – West Lancashire



Remaining emissions in 2050 are 265ktCO_2 most of which is from LULUCF sector.

Figure 14-52: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – West Lancashire



Remaining emissions in 2050 are 261ktCO_2 most of which is from LULUCF sector.

14.14. Wyre

Figure 14-53: 68% emissions reduction by 2030 pathway analysis, breakdown of CO_2 by emissions source – Wyre

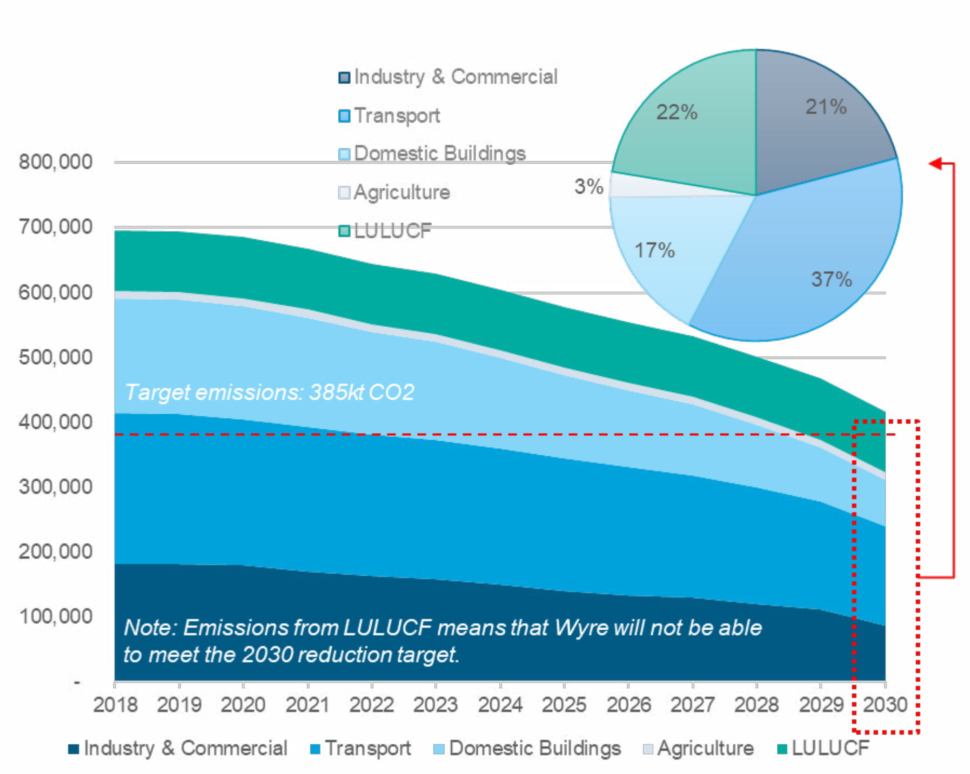


Figure 14-54: 78% emissions reduction by 2035 pathway analysis, breakdown of CO_2 by emissions source – Wyre

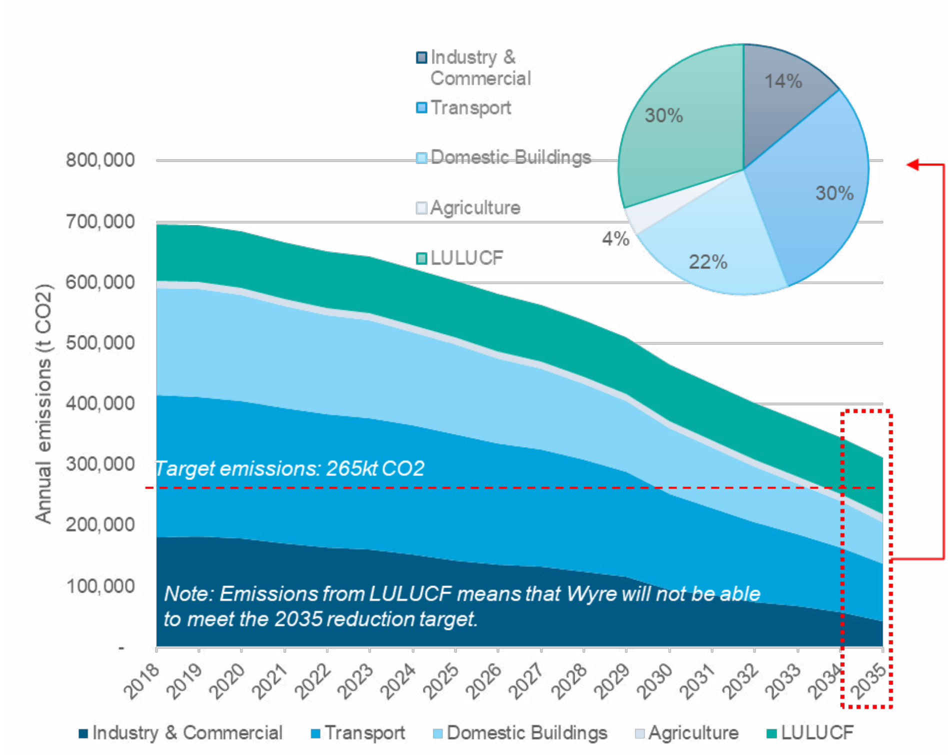
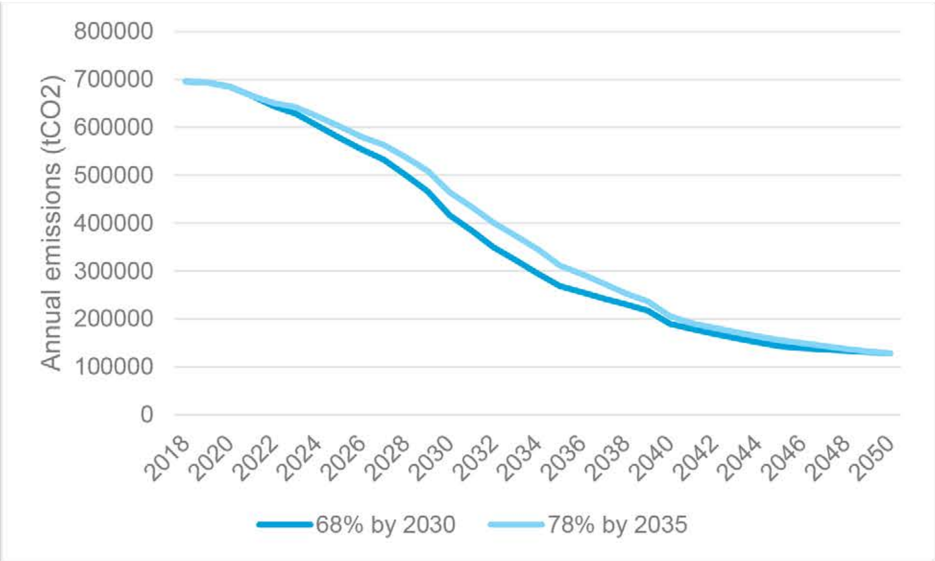
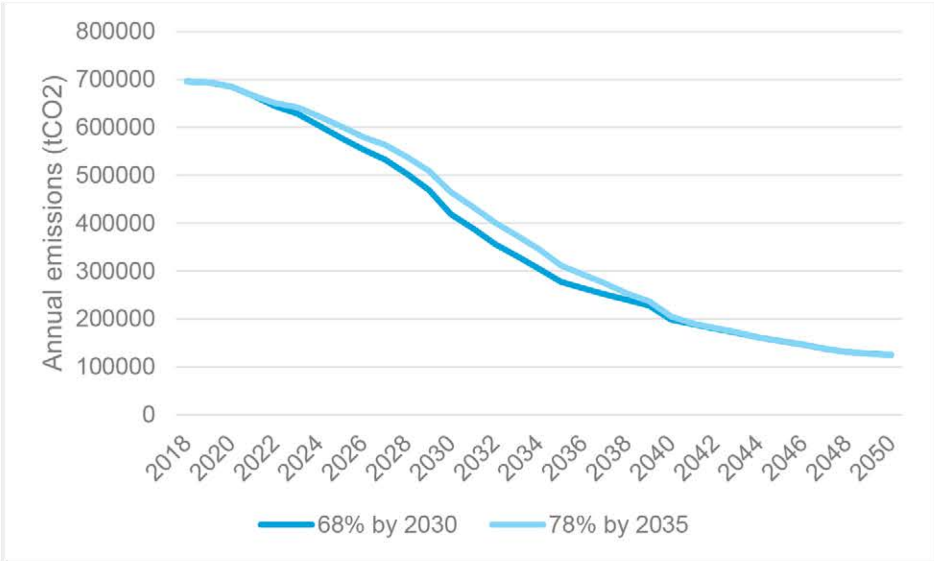


Figure 14-55: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high electrification scenario – Wyre



Remaining emissions in 2050 are 129ktCO_2 most of which is from LULUCF sector.

Figure 14-56: 68% emissions reduction by 2030 pathway and 78% reduction by 2035 pathways extended to 2050 under high hydrogen scenario – Wyre



Remaining emissions in 2050 are 125ktCO_2 most of which is from LULUCF sector.

15. Achieving Net Zero in the Lancashire region

15.1. Introduction

As already discussed, achieving 'Net Zero' emissions in the context of this study for Lancashire means that, following all efforts to reduce CO_2 emissions in the region, the total of active removals of CO_2 emissions from the atmosphere in the region offsets any remaining emissions from the economy.

In Section 10, it has been shown that the Lancashire region would be unable to reach the target of Net Zero by 2030 – ambitious local intervention would deliver only approximately a 65% reduction in emissions compared to the 2018 baseline (as opposed to the near 100% required) and nature-based solutions to remove emissions would not be available in territory within that timeframe. National action (for instance road pricing) would be needed to close the gap further.

The analysis in Sections 11 and 12 indicated that it is possible for Lancashire to achieve the two other targets under consideration: 68% reduction by 2030 (relative to 1990) and 78% reduction by 2035 (relative to 1990).

The analysis in Section 13 has shown that there are two alternative ways to reach Net Zero on or before 2050 when looking beyond 2030: high electrification and high hydrogen.

The results are summarised in Table 15-1 below.

Table 15-1: Summary of results for the pathway options/scenarios considered

Target Pathway Option/Alternative Scenario (targets based on 1990 baseline)	Target emissions compared with 1990 levels	2018 baseline	Reduction achieved from 1990 baseline	Reduction achieved from 2018 baseline	Residual annual emissions by target date	Target emissions met by target date?
100% reduction by 2030 (maximum ambition)	0 $ktCO_2$	8568 $ktCO_2$	79%	63%	3129 $ktCO_2$ (2030)	NO
68% reduction by 2030	4738 $ktCO_2$	8568 $ktCO_2$	68%	45%	4709 ktCO2 (2030)	YES
78% reduction by 2035	3258 $ktCO_2$	8568 $ktCO_2$	78%	62%	3258 ktCO2 (2030)	YES
68% reduction by 2030 extended to 2050 (high electrification)	Net Zero	8568 $ktCO_2$	94.7%	90.8%	792 $ktCO_2$ (2050)	NO (carbon removals necessary)
68% reduction by 2030 extended to 2050 (high hydrogen)	Net Zero	8568 $ktCO_2$	95.0%	91.3%	741 $ktCO_2$ (2050)	NO (carbon removals necessary)
78% reduction by 2035 extended to 2050 (high electrification)	Net Zero	8568 $ktCO_2$	94.7%	90.8%	792 $ktCO_2$ (2050)	NO (carbon removals necessary)
78% reduction by 2035 extended to 2050 (high hydrogen)	Net Zero	8568 $ktCO_2$	95.0%	91.3%	741 $ktCO_2$ (2050)	NO (carbon removals necessary)

This Section sets out to establish whether Net Zero could be achieved beyond the target dates of 2030 and 2035 for each of the three pathways considered (maximum ambition, 68% reduction by 2030 and 78% reduction by 2035). This analysis was undertaken by considering the residual emissions after implementation of interventions in each sector in each year after the target dates until 2050 for the two scenarios under consideration beyond 2030 - high electrification and high hydrogen. The assumed maximum carbon removal measures that could be implemented in territory in each year were then estimated to identify the date at which they would balance residual emissions and Net Zero could be achieved for both scenarios.

15.2. Available carbon removal interventions

Table 15-2 sets out the maximum carbon removal interventions available in territory that have been considered in the Net Zero pathways.

Peatland restoration is a key intervention as Peatland holds such a substantial carbon stock (14 million tonnes) that, without careful management, will become a large carbon emissions source. Restoration of Peatland, however, across 69,200ha has the potential to turn this land use type into a key carbon remover of around 800ktCO_2 by 2050.

Broad-leaved planting in 60% of the improved grassland, 30% of the arable fields and 90% of scrub lands in Lancashire by 2050 is factored into the pathway as forest land can remove large quantities of emissions from the atmosphere. This intervention targets around 95,000 ha to be turned into broadleaved woodland which could remove annually around 1300ktCO_2 by 2050.

Bioenergy with carbon capture and storage (BECCS) is factored into the pathway to account for large volumes of emissions coming from industry, specifically across 5 of Lancashire's cement and paper plants. This intervention has the potential to remove around 260,000 tCO_2 by 2035.

It is noted that nature-based carbon removals (Peatland restoration, Forest preservation and Broad-leaved woodland planting) require large up-front costs; there is also a lag-time between implementation and onset of carbon removals which occur at a much later date.

Table 15-2: Summary of carbon removals interventions with indicative roll-out rates and costs

Intervention	Extent of roll-out by 2025*	Extent of roll-out by 2030*	Emissions mitigated/removed*** (total to 2035; $ktCO_2$)	Emissions mitigated/removed (total to 2045, $ktCO_2$)	Units (ha)	Indicative costs** (capital expenditure cumulative by 2050)[69]	Comments
Peatland Restoration	20%	45%	-413 (This is emissions mitigated rather than removed from atmosphere. Peatlands being restored still emit carbon (for the first 16 years) however this is much less (around 4 times) than unrestored peatland in bad condition.	-723(These include both carbon removal and carbon mitigated as 40% of the peatlands will start yielding carbon removal while rest will still be emitting carbon.)	60,200	£160m[70]	100% of Peatland will need to be restored/ preserved as quickly as possible. Won't start yielding carbon removals until 2038. This is due to peatlands producing emissions for a certain time period (16 years assumed in this study) before starting to remove emissions, but they still lead to mitigated emissions.
Forest preservation	100%	100%	0	0	20,040	£0m	100% of Woodland will need to be restored/ preserved as quickly as possible. To preserve this carbon stock and prevent emissions, however this will not sequester any additional net atmospheric carbon.
Broad-leaved woodland planting	20%	45%	-260	-907	94,890	£2420m	Considerable upfront work/cost, won't yield carbon removals until 2032.
Bioenergy with carbon capture and storage (BECCS)	0%	100%	- 23	-278	N/a	£25m	Implementation of BECCS at 5 key sites across Lancashire.
Total			**-695 $ktCO_2$**	**-1908 $ktCO_2$**	**17,278**	**~£2.6bn**	

Notes:

* The extent to which carbon removal measures rolled out may be 100%; that does not mean that all emissions can be removed through intervention within the timeframe.

** Economies of scale not captured in this analysis; any costs represented are indicative and aggregated only to meet the target removal.

*** While the emissions are referred to as carbon removals, in the case of peatland this is a combination of carbon mitigation and removal as explained in table above.

[69] See Appendix E4.1 for costs and benefits per hectare for land use mitigation actions.
[70] Assumes lowland peatland restoration.

Evidence provided in CCC's[71] assessment of the wider economic and environmental impact of land use mitigation scenarios for Net Zero includes an estimation of the market and non-market impacts of implementing mitigation measures. Market impacts refer to the costs and benefits from changing land use that are reflected in market prices and exchange. Non-market impacts cover the wider set of ecosystem goods and services that flow from forestry, peatland restoration and low carbon farming for example. These goods and services generate benefits to society but are not generally priced in markets. These include wider benefits (ecosystem services in addition to carbon sequestration) such as increased recreational opportunities, improved health from increased physical activity, improved air quality, and improvements in flood alleviation, which is an important component of climate change adaptation.

Table 15-3 presents the private and wider social benefits for the key active sequestration and preservation measures as identified above for Lancashire.

Table 15-3 – Wider benefits of land use mitigation

Intervention	Type of benefit	Wider social benefits	Private benefits
New broadleaved planting	Carbon sequestration	£8 bn	£0.2 bn
	Recreation	£3 bn	
	Health	£0.5 bn	
	Air filtration	£0.2 bn	
	Flood management	£0.02 bn	
	Total	£11 bn	
Existing Woodland management	Total	£2 bn	£0.2 bn
Peatland restoration and preservation	Total	£14 bn	£0
	Total	**£27 bn**	**£0.4 bn**

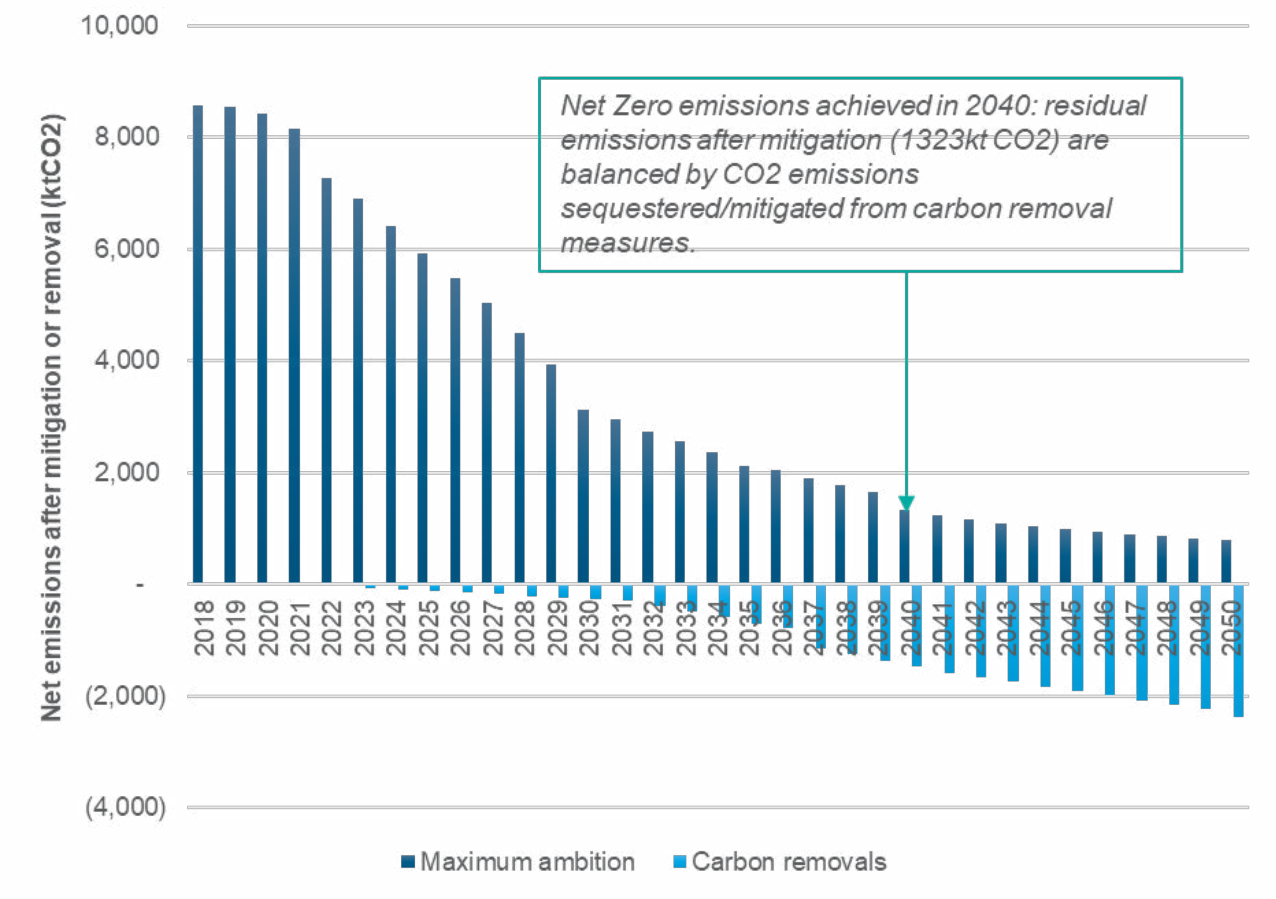
[71] Vivid Economics (2020), Economic impacts of Net Zero land use scenarios, https://www.theccc.org.uk/wp-content/uploads/2020/01/Economic-impacts-of-Net-Zero-land-use-scenarios-Vivid-Economics.pdf

15.3. Achieving Net Zero emissions through extending 100% reduction by 2030 pathway to 2050

Figure 15-1 shows the effect of the maximum ambition option (100% reduction by 2030), if the rates of intervention shown in Tables 10-2 to 10-4 continued to build up at a similar rate beyond 2030, until maximum local ambition has been reached, and extends the analysis to 2050. The continued trajectory to 2050 shows that Net Zero emissions are unlikely to be possible any earlier than 2040. By this date, an estimated further 2,337 $ktCO_2$ would be removed in addition to 4,439 $ktCO_2$ removed in 2030 (compared to 2018 baseline) with residual emissions after all mitigations being 1323 $ktCO_2$ in 2040 (dropping further to 792 $ktCO_2$ by 2050).

Net Zero could be achieved by 2040 if the assumed maximum intervention in carbon removals measures was also applied by this date (as set out in Section 15.2), including peatland restoration, woodland planting deploying BECCS technology and carbon removals measures. These measures would sequester an estimated 1471 $ktCO_2$ from the atmosphere in 2040.

Figure 15-1: Maximum ambition option extended to show feasible Net Zero emissions pathway

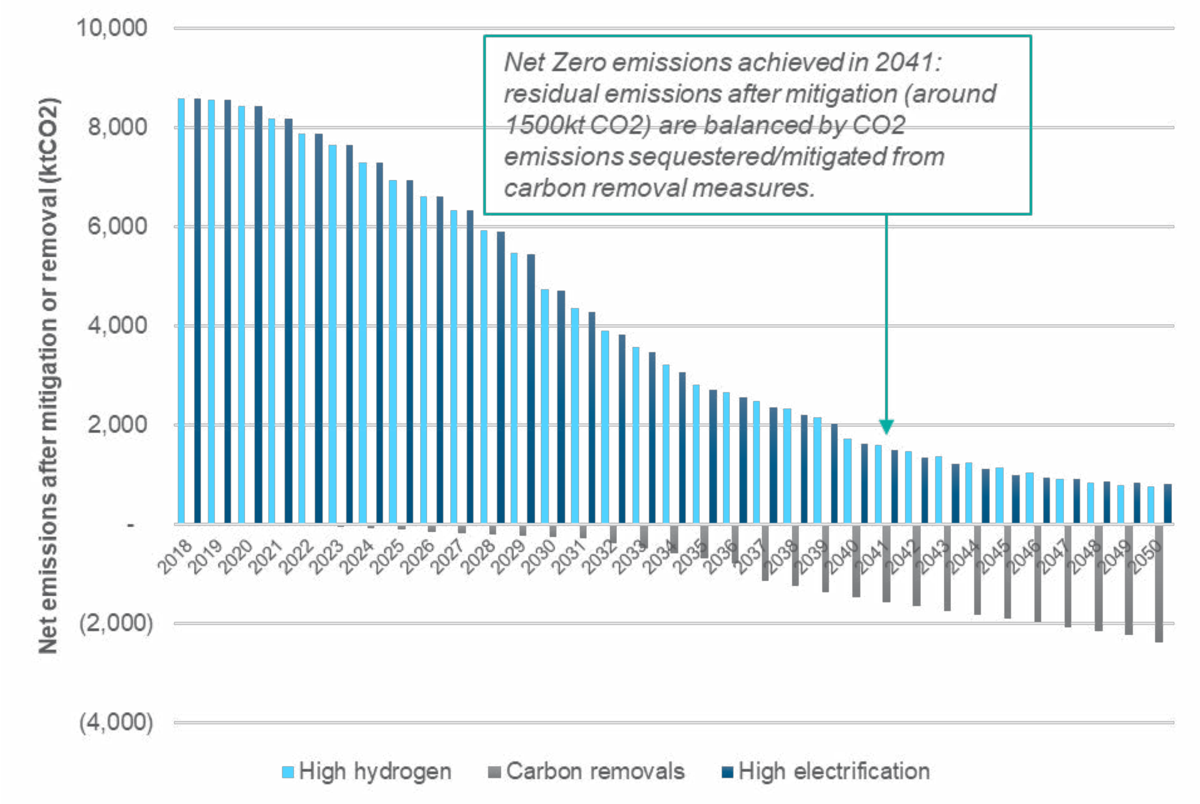


15.4. Achieving Net Zero emissions through extending the 68% reduction by 2030 pathway to 2050

Figure 15-2 shows the effect of the balanced option for meeting the 68% reduction target under high hydrogen and high electrification scenarios that are presented in Section 14. The continued trajectory to 2050 shows that Net Zero emissions are unlikely to be possible before 2041. By this date, an estimated 4,651 ktCO_2 would be saved by mitigation measures, in addition to BAU savings with residual emissions after all mitigations being around 1,500 ktCO_2 in 2041.

Net Zero could be achieved by 2041 if the assumed maximum intervention in carbon removals measures was also applied by this date (as set out in Section 15.2), including peatland restoration, woodland planting and deploying BECCS technology and carbon removals measures. These measures would sequester an estimated 1,582 ktCO_2 from the atmosphere in 2041.

Figure 15-2: 68% reduction by 2030 balanced option extended to show feasible Net Zero emissions pathway

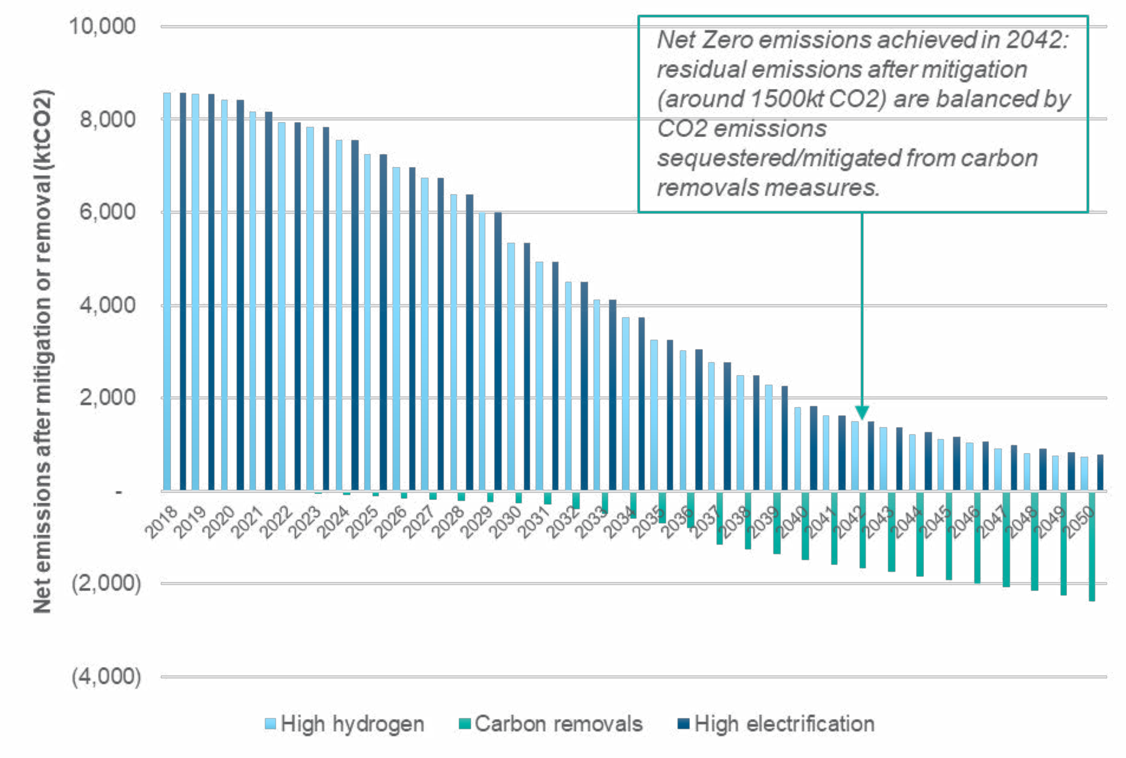


15.5. Achieving Net Zero emissions through extending the 78% reduction by 2035 pathway to 2050

Figure 15-3 below shows the effect of the balanced option for meeting the 78% reduction target under high hydrogen and high electrification scenarios that are presented in Section 14. The continued trajectory to 2050 shows that Net Zero emissions are unlikely to be possible any earlier than 2042. By this date, an estimated 4,495 ktCO_2 emissions would be reduced by mitigation measures with residual emissions after all mitigations being around 1,500 ktCO_2 in 2042.

This assumes that the maximum intervention in carbon removals measures has also been applied by this date, including peatland restoration, planting in low-grade agricultural land and BECCS technology sequestering 1,663 ktCO_2 from the atmosphere.

Figure 15-3: 78% reduction by 2035 pathway balanced option extended to show feasible Net Zero emissions pathway



15.6. The cost of achieving Net Zero

Sections 10 to 12 provide high level estimates of the capital costs of the mitigation measures included in the pathways for each of the targets considered. The estimates indicate total capital costs of between just below £30 bn and just over £40 bn for implementing the mitigation measures in each sector up to the target dates of 2030 or 2035. The costs provide a high level indication of the total capital costs of implementing the decarbonisation measures. They do not account for the savings associated with reference case spending avoided (e.g. replacement conventional boilers) and operating cost savings.

Continuing the pathways through the 2030s and 2040s to achieve Net Zero will increase the capital expenditure. Although uncertainties over costs are greater over longer timescales due to uncertainty over how technologies will develop and the impacts on costs, the CCC produced central estimates of cumulative capital costs for achieving their Balanced Pathway to Net Zero over the time period from 2020 to 2050[72]. Estimating the share for the Lancashire region on the basis of proportion of the UK population (2.3%[73]) suggests a total capital cost in the region of approximately £100 bn between 2020 and 2050[74] for the sectors considered in detail in this report (residential and non-residential buildings, surface transport, construction and manufacturing and LULUCF). These totals are included in the dataset made available with the 6th Carbon Budget[75]. However, in their reporting the CCC focus on net additional capital cost of achieving Net Zero. The comparison is made against a hypothetical counterfactual scenario in which no further climate action would be taken and investment would instead be made in high carbon alternatives (such as conventional boilers and diesel cars). The additional capital cost of achieving Net Zero reflects only the additional expenditure required to implement the decarbonisation measures rather than their high carbon alternatives. For the sectors that are the focus of this report, CCC estimate that the additional capital expenditure required is less than 20% of the total capital expenditure. Prorating the national total for Lancashire indicates a total of £15 bn to £20 bn additional capital expenditure in the region over the 2020 to 2050 timeframe.

The CCC highlight that decarbonisation measures are capital intensive and that the majority of costs will be incurred by the private sector and individuals. The CCC also highlight that a significant proportion of decarbonisation measures also deliver operating cost savings (particularly through energy savings). The surface transport sector will benefit particularly from savings because EVs have lower running and maintenance costs than petrol/diesel cars. In their estimates for the Balanced Pathway, the CCC estimate that operating cost savings would offset nearly 75% of the net additional capital costs for the sectors considered over the timeframe from 2020 to 2050 (pro-rated to an estimated £10 bn to £15 bn for Lancashire).

In summary, achieving Net Zero will require availability of funding to support significant capital expenditure. However, it will also provide the opportunity to avoid other forms of capital expenditure and deliver operating costs. Overall, the CCC estimate that the net cost of transition to Net Zero (including upfront investment, ongoing running cost sand the additional costs of financing, for all sectors) will be less than 1% of GDP over the 2020 to 2050 timescale.

15.7. Wider benefits of pursuing Net Zero

It is noted that the expenditure necessary to achieve Net Zero discussed in the previous section would deliver a number of wider benefits to the economy, employment, public health and the environment in Lancashire through:

- anchoring emerging industrial strengths to the region; growing regional capability in various technologies, including hydrogen, and new forms of energy efficiency/management.
- extensive 'green economy' investment opportunities, tying carbon reduction benefits to wider social value benefits, with both shorter term and longer term returns: new / enhanced services, products and solutions.
- enhancing opportunities for business, with substantial increased turnover/profit available to companies or organisations involved in delivering the recommended interventions.

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[72] CCC, 2020, 6th Carbon Budget Sixth Carbon Budget - Climate Change Committee (theccc.org.uk)
[73] Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland - Office for National Statistics (ons.gov.uk)
[74] CCC figures are in 2019, real prices
[75] CCC, 2020, 6th Carbon Budget. Supporting Data, Sixth Carbon Budget - Climate Change Committee (theccc.org.uk)

- creating many new skilled, higher income jobs across the green energy, transport and industry sectors in Lancashire. Some of these jobs will be transitions from other sectors so re-skilling will be extremely important. It will also be important to make sure that some green economy equipment and infrastructure is manufactured and constructed in Lancashire using locally based workers.
- improving overall health and wellbeing of residents, workers and visitors due to improved ambient and internal building air quality due to shift away from burning fossil fuels; less noise, vibration and disturbance from fossil fuelled vehicles. Also, by upgrading dwellings through retrofit programmes, there could be fewer cases of asthma and other illness due to reduced damp and avoided deaths from cold or heat in face of climate change. Increased levels of active travel would further support health improvements. Reduced traffic and increased focus on local areas would help to increase community connections and strength. Increasing the range of alternatives to accessibility by car would also help to improve equality by providing better options for those without access to cars.
- reduced energy costs for consumers, both organisations and residents.
- making electricity and heat more affordable for the population through local renewable energy production opportunities, both at household and community level.
- planting trees would provide a multitude of benefits alongside removing carbon from the atmosphere: enhance biodiversity, improve soils, ameliorate flooding and erosion, enhance air quality, improve overall wellbeing via access to green space and natural areas; and deliver economic benefits through the sale of timber and other forest produce (as already discussed elsewhere in this report).

15.8. Funding for local climate action

As outlined above Sections 10 to 12 include the identification of indicative total capital costs for the pathways considered. The CCC analysis on long term costs of Net Zero reported above highlights that a high proportion of the costs identified will be faced by the private sector and individuals. Local governments will only be looking to fund a proportion of the costs identified.

The recent government's Net Zero Strategy notes that funding for local climate action will come from a combination of the Local Government Finance Settlement, other government grants and support schemes, borrowing, and private finance including exploration of community bonds and crowdfunding. An important part of the funding landscape is the diverse range of grant funding schemes provided by HM Government to support local delivery. The recent National Audit Office (NAO) review into local government and Net Zero identified 22 dedicated grant schemes for net zero work from central to local government. Government recognise that longer term and more co-ordinated funding streams can enhance innovation and investment, reduce bureaucracy, and encourage more efficient and integrated decision making. Government will explore how to simplify and consolidate funds which target net zero initiatives at the local level where this provides the best approach to tackling climate change.

In addition to the above, the UK Infrastructure Bank (UKIB) will lend to local authorities for strategic and high value projects and invest in projects alongside the private sector, crowding in private sector capital. It has twin objectives of helping to tackle climate change, particularly meeting the UK's net zero emissions targets and helping to support regional and local economic growth across the UK. The UKIB will offer loans to local authorities for high value and strategic projects of at least £5 million. To complement this investment activity, over time, the UKIB will develop an expert advisory service to help local authorities develop and finance projects. The UKIB will build partnerships across the UK including with government departments, government sponsored bodies, local authorities and relevant representative organisations to foster collaboration and drive value for money. As it engages with the market, the UKIB will continue to learn and adapt, which will ensure that its loans to local authorities are as effective as possible.

We recommend that viable sources of funding are considered to fully inform a decision on the preferred pathway at the next stage of developing a workable net zero pathway for Lancashire.

15.9. Areas for further development

Whilst this study compares illustrative pathway options in terms of emissions reduction, application of interventions and indicative intervention costs, a pathway should not be chosen at this stage for the following reasons:

- The study is not detailed enough to have considered all factors which have implications in the identification of the 'optimal' pathway. For example, deliverability issues have not been considered in detail. Additionally, a detailed spatial infrastructure assessment would be needed, including high resolution temporal modelling of emissions reductions and emissions removals and the associated infrastructure costs, to have full visibility of some important costs and constraints. A number of the measures also rely on behaviour change (for instance changes in travel patterns) which is known to be challenging to forecast, bringing a number of uncertainties to the estimates.
- There is some crucial evidence not yet in place on certain technologies. For example, there are still research and demonstration steps required to prove the feasibility and viability of hydrogen for heat and for HGVs. It is noted that this study has excluded interventions in the power generation sector.
- An opportunity mapping exercise is recommended to explore the feasibility of a longer list of LULUCF interventions for reducing emissions and enhancing removals. This would include consideration of interventions listed by the Environment Agency in their 2021 review such as farm soil carbon capture, saltmarsh restoration and arable reversion, in addition to woodland creation and peatland restoration. Building on the initial LULUCF analysis in this report, a range of opensource datasets (see list in Appendix E.5.3) would be used to map Lancashire's natural capital assets (i.e. habitats) according to the UKHab classification system. Condition data would also be used, where available, as habitat condition can determine whether key habitat types are sources or sinks of carbon e.g. SSSI condition data for peatlands. This opportunity map could identify where it would be technically feasible in the Lancashire landscape to implement these measures and explore aspects of feasibility, such as site designations and agricultural land classification grades.
- Action will require inputs and coordination from a range of bodies. In particular, the pathway followed in Lancashire will be impacted by some important national decisions during the 2020s, in particular national government incentives and the availability of infrastructure and fuels. This means that the region should take all low regrets actions available locally which can support any pathway and continue to gather further evidence to support a final decision. It will also be impacted, and importantly, impact the development of the Greater Lancashire Plan which will need to have Net Zero at the core if the region is to pursue an economic model of development which leads to decarbonisation within the timeframes discussed in this report.

16. Conclusions and recommendations

16.1. Target pathway options

This study has modelled the application of national, regional and local emissions reduction interventions across three key sectors in Lancashire - Domestic Buildings, Transport, and Industry (including Large Industrial Installations) and Commercial (Non-Residential) Buildings. It has also considered measures to enhance removals of carbon emissions from the atmosphere in Lancashire. Measures have been considered for pathways to three target options, as follows:

- Net Zero (100% reduction relative to 1990) emissions by 2030;
- 68% reduction of emissions by 2030 (relative to 1990); and
- 78% reduction of emissions by 2035 (relative to 1990).

Current (2018) emissions in the region stand at 8,568 ktCO_2 according to BEIS data. Business as Usual would only deliver around a 31% and 60% reduction by 2050 (compared to 2018 and 1990 baselines respectively) with residual emissions of 5,876 ktCO_2; this would not be sufficient to meet the region's climate emergency goals. Further intervention at regional and local level would therefore be necessary to put the region on a pathway to Net Zero.

The analysis for the first pathway option examined the potential to reach the target of Net Zero by 2030 and indicated that:

- if the local emissions reduction interventions available to Lancashire starting from 2022 were implemented at an ambitious level, and currently expected national actions came into effect, Lancashire could not achieve Net Zero emissions by 2030, based on the measures and associated assumptions explored in this study (see Chapters 3, 5 and 6-9);
- the ambitious local action taken across sectors would achieve a substantial downward trajectory which would result in mitigated CO_2 emissions equivalent to nearly 80% of 1990 baseline emissions in 2030. However, it would not be possible to remove the residual emissions of 3,129 ktCO_2 p.a from the atmosphere in the 2030 timeframe. Nature-based interventions in territory would not be able to balance out these emissions.
- the actions taken would eliminate 98% of emissions from buildings; however, residual emissions would remain from transport and industry (approximately 60% and 30% respectively, compared with the baseline year), largely due to constraints on rates of uptake of measures in these sectors and the behaviour changes feasible in these sectors and on the availability of appropriate technology. For the transport sector, whilst more significant reductions in emissions could potentially be achieved, they would not be likely to be feasible through action at the regional/county level alone, without further national action (such as road pricing).
- Indicative total capital costs to implement this pathway to 2030 would be approximately £40bn at current prices. These costs provide a high level indication of the total capital costs of implementing the decarbonisation measures. As outlined in Section 15, net costs would be lower once the savings associated with reference case spending avoided (e.g. replacement of conventional boilers) and operating cost savings have been accounted for.

The examination of the two other pathway options has concluded that it is possible to achieve the target emissions reductions (68% and 78%) within the respective timeframes (2030 and 2035) in the region through a combination of emissions reduction interventions at varying rates of implementation. It has been found that:

- the 68% reduction by 2030 pathway (aiming for residual emissions of 4,738 ktCO_2 by 2030) would be reliant on ambitious rates of intervention for insulation and support to secure savings from national action on ULEVs and changes in travel patterns. Harder-to-deliver measures would be rolled out at slower rates, in particular heat pumps for decarbonisation of heat in buildings, which would track only slightly above current Government commitments. The interventions would be weighted, in terms of proportional contribution to emissions reductions, slightly towards Buildings where the technology is more mature and action can be taken more effectively in the nearer term, resulting in a higher weighting of residual emissions towards the Transport sector. This is predicated on the assumption that extensive mitigation of Transport sector emissions is challenging and takes time to build up as the fleet and travel behaviour change. Significant fleet change in particular is dependent on national action. Savings from large industrial processes would also be expected to be minimal. Indicative total capital costs to implement this pathway have been estimated as approximately £30bn at current prices.

- the 78% reduction by 2035 pathway (aiming for residual emissions of 3,258 ktCO_2 by 2035) would rely on some measures being applied at more ambitious rates of intervention. However, generally the pathway involves lower overall emissions reductions by 2030 than in the 68% reduction pathway, and harder-to-deliver measures are rolled out at slower rates compared with the 2030 target scenarios, in particular heat pumps for decarbonisation of heat in buildings, which would track current Government commitments only. Transport would still represent the highest proportion of residual emissions by 2035; but the effect of the national petrol/diesel car/van sales ban by 2030 would be more significant in this timeframe, as people and organisations replace petrol/diesel vehicles. Emission savings from large industrial processes (mitigation only) are almost double in 2035 compared with 2030. Indicative capital costs to implement this pathway have been estimated as c. £40bn at current prices.

When considering the application of the pathways for the 68% target reduction by 2030 and 78% reduction by 2035 for each local authority individually, key conclusions are:

- all local authorities would be able to contribute proportionally to the 2030 and 2035 region-level target pathways across the three key sectors under analysis (Transport, Domestic Buildings and Industry and Commercial), apart from Ribble Valley.
- the presence of large industrial processes in Ribble Valley means that this local authority would not be able to meet either the 2030 68% or 2035 78% region-level reduction target pathways.
- in the case of Fylde, Lancaster, West Lancashire and Wyre, the presence of emissions from LULUCF results in these local authorities not being able to meet the 2030 and 2035 region-level reduction target pathways. Similarly, Chorley is not able to meet the 2030 region-level reduction target due to the presence of LULUCF emissions, however, is able to meet the 2035 region-level reduction target.

16.2. Achieving Net Zero

The study has also concluded that Net Zero emissions could be achieved at a later date for the pathways associated with maximum ambition, the 68% reduction by 2030 and 78% reduction by 2035 targets, by 2040, 2041 and 2042 respectively. These dates have been estimated by modelling two future scenarios: high hydrogen and high electrification and extending pathways to 2050 where interventions continue to be deployed until the point in time where they could be balanced out by the maximum intervention in carbon removals that can be applied in territory.

As outlined in Section 15, achieving Net Zero will require substantial capital investment. The CCC estimates described in Section 15[76] imply total capital costs of the order of £100 bn between 2020 and 2050 for Lancashire, although a significant proportion of the cost would be offset by avoided capital expenditure on high carbon alternatives and operating cost savings.

Given the level of investment and change required, sustained action in line with the balanced pathway options should be continued after meeting the interim targets, in order to achieve Net Zero as efficiently as possible in territory. Under the assumptions on local and national action used in the current study, the indication is that achieving Net Zero is likely to require at least a further 5 years beyond 2035, even with high local ambition.

It is noted that, based on current study assumptions regarding rate of application / uptake of interventions, and broader policy context, achievement of Net Zero in the region at a date earlier than 2040 would likely only be possible if rates of emission reduction interventions were to accelerate in the late 2030s, national action was to accelerate, technological breakthroughs in emissions reductions and / or carbon removals were to occur and / or carbon removals were to occur outside as well as inside the region.

In identifying pathways to Net Zero it is important to recognise that whilst the Net Zero target date is a useful focus of attention, it can be misleading. The key issue in determining influence on climate change is the rate of decarbonisation and the cumulative emissions between now and 2050 (and beyond). Pathways are required that limit overall emissions over the time frame to the available carbon budget. Meeting the 68% and 78% reduction targets and achieving fairly steady rates of reduction in annual emissions before, between and after

[76] Estimates of the costs of achieving the Balanced Pathway to Net Zero provided by the CCC with their reporting on the 6th Carbon Budget, CCC,2020,Sixth Carbon Budget

the target dates would put Lancashire broadly in line with the rate of carbon reduction assumed in the CCC's Balanced Pathway for meeting the UK's carbon commitments. However, as outlined in Section 4, it is important to note other sources, including the Tyndall Centre, indicate that the carbon budget should be more limited and the rate of decarbonisation required is more rapid. This has been highlighted by the Tyndall Centre carbon budget pathways presented on the graphs in previous sections and provides important context when considering the levels of ambition required for decarbonisation pathways.

16.2.1. Recommendations

The analysis for the pathway options has highlighted the scale of change that will be required across all sectors in order to meet the identified targets associated with Government's commitments to carbon reduction and carbon budgets. Meeting the pathways consistent with other views of the Tyndall Centre and others on the more limited carbon budget available would require even more rapid and intensive action.

The pathway analysis has illustrated potential combinations of measures required to meet the identified targets, indicating the level of effort that would be involved in each sector. Whilst the pathway taken will evolve as more detailed work is undertaken on the cost and deliverability of measures, the clear recommendation from the analysis is that rapid action is needed in each sector, and that delivery of no regrets measures (that bring cost and other benefits as well as emissions reductions) should start as soon as possible.

The following sections summarise the measures included in the balanced option assessed for the 68% target reduction pathway as an illustration of the scale of action required across sectors. Whilst the detailed balance and phasing of uptake of different measures will change as further work on the cost and deliverability of measures is undertaken, the list of actions provides a good indication of the range and scale of change required.

General

The following actions to be pursued at regional/local authority level:

1) Rapid application of identified mature technology measures and rapid ramp-up of roll-out across sectors.
2) Rapid substantial, phased expansion of appropriate targeted capacity and skills base in territory across technologies and sectors.
3) Rapid sourcing and rapid mobilisation of sufficient resources and funds to pursue targets.
4) Further assessment of the cost and deliverability of mitigation measures to further develop pathway plans
5) To achieve the above, the region must continue to put pressure on central government regarding clarity of local authority roles and responsibilities, and funding available, to achieve Net Zero.

Transport

The following actions to be pursued at regional/local authority level:

6) Support national roll out of Zero Emission Vehicles through roll out of well planned and integrated charging and fuelling networks.
7) Encourage acceleration of ULEV uptake through measures including updates to public fleet, requirements for suppliers, support for car clubs and corporate fleet updates, with the aim to accelerate EV uptake to the point that it is 6 months ahead of the national average by 2030 and 12 months by 2035.
8) Support increased active travel / micro mobility use through measures to improve the range and quality of provision for walking, cycling and scooting and measures to encourage behaviour change, with the aim of achieving a 300% increase in cycling relative to reference levels by 2030.
9) Support increase public transport use through measures to improve the affordability, accessibility, reliability and quality of provision of public transport with the aim of achieving approaching a 20% increase in public transport patronage by 2030 (relative to 2019)

10) Change the balance of costs between modes to manage demand for road transport delivering the equivalent of a 35% increase in cost of car travel for approximately 50% of commuting/business trips, 35% of shopping trips and 25% of trips for other purposes by 2030.
11) Using data, communication and signal to achieve more efficient network management with an aim of increasing the average speed of 35% of the slowest links (<25mph) by at least 5 mph through congestion relief by 2030.
12) Plan land use to bring destinations closer to people, through approaches such as the 20-minute neighbourhood concept with the aim of reducing trip lengths and number (due to combined trips) and achieving a 5% to 10% reduction in car travel for shipping and personal business trips and up to 5% reduction for leisure trips by 2030.
13) Support improved digital connectivity to replace trips including providing digital hubs and increased options for online activity with the aim of reducing commuting and business trips by up to approximately 5% and reducing personal business and shopping and leisure trips by up to 5% by 2030.

Following the publication of the DfT's Transport Decarbonisation Plan in July 2021, the region should continue to put pressure on central government / transport authorities regarding:

14) Confirmation of regulatory framework to better enable the rapid transition to an Electric Vehicle (EV) car and van fleet
15) Confirmation of delivery plan bringing together all policies/funding support (including funding for charging points) for electric cars/vans
16) Confirmation of trials to identify the best route for decarbonising the HGV fleet, following the announcement in November 2021 of the ban on sales of diesel vehicles in 2035 (for vehicles <26 tonnes) and 2040 (vehicles >26 tonnes).
17) A clear steer on the need for demand management/road charging – to support LAs in trying to deliver it.
18) Funding to support the step change in provision of sustainable modes required.

Buildings

The following interventions to be pursued at local authority / industry level:

Domestic buildings

19) Insulation of existing building stock to reduce thermal energy demand – target 32% of potential emissions savings by 2025, 72% by 2030 and 100% by 2035.
20) Glazing of existing building stock to reduce thermal energy demand – target 32% of potential emissions savings by 2025, 72% by 2030 and 100% by 2035.
21) Installation of heat pumps for decarbonisation of heat in existing building stock – target 16% of potential emissions savings by 2025, 43% by 2030 and 63% by 2035.
22) Installation of LED lighting to reduce electrical energy demand in existing buildings – target 23% of possible emission savings by 2025, 60% by 2030 and 98% by 2035
23) Installation of solar PV panels to decarbonise electrical energy supply in existing buildings – target 23% of possible emissions savings by 2025, 60% by 2030 and 98% by 2035.

Industry and commercial (non-residential) buildings

24) Insulation of existing building stock to reduce thermal energy demand – target 32% of potential emissions savings by 2025, 72% by 2030 and 100% by 2035.
25) Glazing of existing building stock to reduce thermal energy demand – target 32% of potential emissions savings by 2025, 72% by 2030 and 100% by 2035.
26) Installation of heat pumps for decarbonisation of heat in existing building stock – target 16% of potential emissions savings by 2025, 44% by 2030 and 63% by 2035.
27) Installation of LED lighting to reduce electrical energy demand in both existing and new buildings – target 32% of potential emissions savings by 2025, 72% by 2030 and 100% by 2035.

28) Installation of solar PV panels to decarbonise electrical energy supply in both existing and new buildings – target 23% of potential emissions savings by 2025, 60% by 2030 and 98% by 2035.

Note: Although new development will represent a minimal proportion of emissions in comparison to emissions from existing development in the region, all new development should aim for Net Zero buildings from the outset and local plan policy should be set as such.

The region should continue to put pressure on central government regarding:

1) Funding for interventions to existing buildings to be made available.
2) Revised UK Building Regulations to promote new Net Zero buildings.

Large industrial installations

The following interventions to be pursued by industry in the region:

1) Resource efficiency and material substitution to reduce manufacturing emissions – target almost 100% of potential emissions savings by 2035.
2) Fuel switching to electrification (or hydrogen) - target almost 100% of potential emissions savings by 2035.
3) Bioenergy with carbon capture and storage (BECCS) as such solutions deliver carbon removals beyond emissions abated from the plant - target almost 100% of potential emissions savings by 2035.
4) The region should continue to work closely with industries in territory to achieve necessary rates of intervention.

Carbon removals

The following interventions to be pursued at local authority and regional level:

1) Restoration of peatland and conservation of existing woodland interventions to preserve existing carbon stocks – target 45% of carbon stocks by 2030 and 70% by 2035.
2) New woodland planting would need to start immediately as effects would only be felt in the long term – target 45% of possible removals by 2030 and 70% by 2035.
3) BECCS for industrial processes – 100% of possible removals by 2035.

The region must continue to put pressure on central government regarding:

4) An ambitious UK Tree Planting Strategy.
5) Further incentivise the development of BECSS as a negative emissions technology.

The measures outlined above illustrate the range of action required to meet carbon reduction targets in Lancashire. The detailed combination and phasing of measures will need to be tested through more detailed carbon, socio- economic, deliverability and environmental studies at the next stage of development of the preferred Net Zero pathway and action plan for the region and individual local authorities.

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