Annex C

A Net Zero Carbon Roadmap for York

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Executive Summary

Background:

- Scientific evidence calls for rapid reductions in global carbon[1] emissions if we are to limit average levels of warming to 1.5°C and so avoid the risks associated with dangerous or runaway climate change.
- Globally, the IPCC suggests that we will have used up the global carbon budget that gives us a good chance of limiting warming to 1.5°C degrees within a decade. This science underpins calls for the declaration of a climate emergency.
- Dividing the global carbon budget up by population gives York a total carbon budget of just over 10 million tonnes from 2020. Based only on the fuel and electricity directly used within its boundaries (i.e. it's scope 1 and 2 emissions), York currently emits c.888,000 tonnes of carbon a year, and as such it would use up its carbon budget just over 12 years.
- This assessment does not include it's broader carbon footprint – for example relating to longer distance travel or the goods and services that are produced elsewhere but consumed within York (i.e. it's scope 3 emissions).

Baselines and Targets:

- Scope 1 and 2 carbon emissions from York have fallen by 44% since the turn of the millennium. With on-going decarbonisation of grid electricity, and taking into account population and economic growth within the city-region, we project that York's 2000 level of annual emissions will have fallen by a total of 51% in 2030 and 54% in 2050.
- If it is to stay within its carbon budget, York needs to add to adopt science-based carbon emissions reduction targets the build on the emissions reductions already achieved to secure 65% reductions on its 2000 level of emissions by 2025, 76% by 2030, 84% by 2035, 89% by 2040, 92% by 2045 and 95% by 2050.
- Without further activity to address its carbon emissions, we project that York's annual emissions will exceed its carbon budget by 802,000 tonnes in 2030, and 746,000 tonnes in 2050.

The Cost-Effective Options:

- To meet these carbon emissions reduction targets, York will need to adopt low carbon options that close the gap between its projected emissions in future and net zero emissions. This can be partially realised through cost-effective options that would more than pay for themselves through the energy cost reductions they would generate whilst often also generating wide social and environmental benefits in the area.
- More specifically, the analysis shows that York could close the gap between its projected emissions in 2030 and net zero emissions by 47% purely through the adoption of cost-effective options in houses, public and commercial buildings, transport and industry.
- Adopting these options would reduce York's total projected annual energy bill in 2030 by £287 million whilst also creating 3,570 years of employment in the city. They could also help to generate wider benefits including helping to tackle fuel poverty, reducing congestion and productivity losses, improving air quality, and enhancements to public health.
- The most carbon effective options for the city to deliver these carbon cuts include improved deep retrofitting of heating, lighting and insulation in houses, cooling and insulation in offices, shops and restaurants, and a range of measures across the transport sector including mode shift to non-motorised transport and the wider up-take of electric vehicles.

[1] For simplicity, we use the term 'carbon' as shorthand for all greenhouse gases, with all figures in this report relating to the carbon dioxide equivalent (CO_2e) of all greenhouse gases unless otherwise stated. Note that our assessment therefore differs from other assessments that focus only on CO_2.

The Need for Ambition and Innovation:

- The analysis also shows that York could close the projected gap to net-zero emissions in 2030 by 69% through the adoption of options that are already available, but that some of these options would not pay for themselves directly through the energy savings that they would generate. Many of these options would, however, generate wider indirect benefits both economically and socially in the city.
  This means that although it can achieve significant reductions in emissions by focusing on established cost-effective and technically viable measures, York still has to identify other more innovative interventions that could deliver the last 31% of shortfall between projected emissions in 2030 and a net zero target.
- Options identified elsewhere that could be considered in York include targeting a complete transition to net zero homes and public/commercial buildings by 2030, promoting the rapid acceleration of active travel (e.g. walking and cycling), tackling food waste, reducing meat and dairy consumption and reducing concrete and steel consumption/promoting adoption of green infrastructure including accelerated tree planting plans.
- As well as reducing York's direct (scope 1 and 2) carbon footprint, some of these more innovative measures (e.g. reducing meat and dairy or concrete and steel consumption) could start to focus on tackling York's broader consumption-based (i.e. scope 3) carbon footprint.

Next Steps:

- York needs to adopt a clear and ambitious climate action plan. The case for the adoption of such a plan is supported by the evidence that much – but not all - of the action that is required can be based on the exploitation of win-win low carbon options that will simultaneously improve economic, social and health outcomes across the city.
- The climate action plan should adopt science-based targets for emissions reduction. As well as longer term targets, it should adopt 5-yearly carbon reduction targets.
- The action plan should focus initially on York's direct (scope 1 and 2) carbon footprint as these emissions are most directly under the city's influence, but in time it should also widen its scope to consider its broader (scope 3) carbon footprint.
- The action plan should also set out the ways in which York will work towards achieving these science-based targets, drawing on the deployment KPIs listed in this report. Action should also be taken to monitor and report progress on emissions reductions.
- It is important to stress that delivering on these targets will require action across the city and the active support of the public, private and third sectors. Establishing an independent York Climate Commission could help to draw actors together and to build capacities to take and track action.
- Leadership groups should be formed for key sectors such as homes, public and commercial buildings, transport and industry, with clear plans for delivery of priority actions in each sector. All large organisations and businesses in the city should be asked to match broader carbon reduction commitments and to report back on progress.

1. Introduction

Climate science has proven the connection between the concentration of greenhouse gases in the atmosphere and the extent to which the atmosphere traps heat and so leads to global warming. The science tells us – with a very high level of confidence – that such warming will lead to increasingly severe disruption to our weather patterns and water and food systems, and to ecosystems and biodiversity. Perhaps most worryingly, the science predicts that there may be a point where this process becomes self-fuelling, for example where warming leads to the thawing of permafrosts such that they release significant quantities of greenhouse gases leading to further warming. Beyond this point or threshold, the evidence suggests that we may lose control of our future climate and become subject to what has been referred to as dangerous or 'runaway' climate change.

Until recently, scientists felt that this threshold existed at around 2 degrees centigrade of global warming, measured as a global average of surface temperatures. However, more recent scientific assessments (especially by the Intergovernmental Panel on Climate Change or IPCC in 2017) have suggested that the threshold should instead be set at 1.5 degrees centigrade. This change in the suggested threshold from 2 degrees to 1.5 degrees has led to calls for targets for decarbonisation to be made both stricter (e.g. for the UK to move from an 80% decarbonisation target to a net zero target), and to be brought forward (e.g. from 2050 to 2030).

Globally, the IPCC suggests that from 2020 we can only emit 344 billion tonnes of CO_2 if we want to give ourselves a 66% chance of avoiding dangerous climate change. We are currently emitting over 37 billion tonnes of CO_2 every year, which means that we will have used up our global carbon budget within a decade. It is this realisation – and the ever accumulating science on the scale of the impacts of climate change - that led to calls for organisations and areas to declare a climate emergency and to develop and implement plans to rapidly reduce GHG emissions.

2. Our Approach

2(a). Measuring an Area's Carbon Footprint

Any area's carbon footprint – measured in terms of the total impact of all of its greenhouse gas emissions - can be divided into three types of greenhouse gas emissions.

- Those coming from the fuel (e.g. petrol, diesel or gas) that is directly used within an area and from other sources such as landfill sites or industry within the area. These are known as Scope 1 emissions.
- Those coming from the electricity that is used within the area, even if it is generated somewhere else. These are known as Scope 2 emissions. Together scope 1 and 2 emissions are sometimes referred to as territorial emissions.
- Those associated with the goods and services that are produced elsewhere but imported and consumed within the area. After taking into account the carbon footprint of any goods and services produced in the area but that are exported and consumed elsewhere, these are known as Scope 3 or consumption-based emissions.

In this report we focus on Scope 1 and 2 emissions, and exclude consideration of long-distance travel and of Scope 3 or consumption-based emissions. We do this because Scope 1 and 2 emissions are more directly under the control of actors within an area, and because the carbon accounting and management options for these emissions are better developed. We stress though that emissions from longer distance travel (especially aviation) and consumption are very significant, and also need to be addressed.

2(b). Developing a Baseline of Past, Present and Future Emissions

Having a baseline of carbon emissions is key to tracking progress over time. We use local authority emissions data to chart changes in emissions from 2005 to the 2018. We also break this down to show the share of emissions that can be attributed to households, public and commercial buildings, transport and industry.

We then project current emissions levels for the period through to 2050. To do this, we assume on-going decarbonisation of electricity in line with government commitments and a continuation of background trends in *a*) economic and population growth, and *b*) energy use and energy efficiency. Specific numbers for the key variables taken into account in the forecasts are presented below. As with all forecasts, the level of uncertainty attached increases as the time period in question extends. Even so, it is useful to look into the future to gauge the scale of the challenge to be addressed in each area, especially as it relates to the projected gap between the forecasted emissions levels and those that are required if an area's emissions are to be consistent with a global strategy to limit average warming to 1.5 degrees.

2(c). Setting Science-Based Carbon Reduction Targets

To set science-based carbon reduction targets for an area, we take the total global level of emissions that the IPCC suggests gives us a 66% chance of limiting average levels of warming to 1.5 degrees, and divide it according to the share of the global population living in the area in question. This enables us to set the total carbon budget for an area that is consistent with a global budget. To set targets for carbon reduction, we then calculate the annual percentage reductions from the current level that are required to enable an area to stay within its overall carbon budget.

2(d). Identifying and Evaluating Carbon Reduction Opportunities

Our analysis then includes assessment of the potential contribution of c.130 [*] energy saving or low carbon measures for:

- households and for both public and commercial buildings (including better insulation, improved heating, more efficient appliances, some small scale renewables)
- transport (including more walking and cycling, enhanced public transport, electric and more fuel efficient vehicles)
- industry (including better lighting, improved process efficiencies and a wide range of other energy efficiency measures).

We stress that the list of options that is assessed may not be exhaustive; other options could be available and the list can potentially be expanded.

For the options included, we assess the costs of their purchase, installation and maintenance, the direct benefits (through energy and fuel savings) of their adoption in different settings and their viable lifetimes. We also consider the scope for and potential rates of deployment of each option. This allows us to generate league tables of the most carbon and cost-effective options that could be deployed within an area.

It is important to note that we base the analysis on current capital costs, although future costs and benefits are adjusted for inflation and discounting factors. This could be pessimistic if costs fall and benefits increase as some options become more widely adopted, or if the costs increase as the rates of deployment increase. It is also important to note that, although we consider the employment generation potential of different options, we do not consider the wider indirect impacts of the different options relating to their social, economic or environmental implications.

Beyond the range of currently available options, we also consider the need for more innovative or 'stretch' options to be developed and adopted within the area if it is to meet its carbon reduction targets. These need to be developed in each area, but the some of the ideas for innovative options identified elsewhere include targeting a full transition to net zero homes and public/commercial buildings by 2030, promoting the rapid acceleration of active travel (e.g. walking and cycling), tackling food waste, reducing meat and dairy consumption and reducing concrete and steel consumption/promoting adoption of green infrastructure.

2(e). Aggregating Up to See the Bigger Picture

Based on this bottom-up analysis of the potential for different options to be adopted within the area, we then aggregate up to assess the potential for decarbonisation within that area, and the costs and benefits of different levels of decarbonisation. We then merge the aggregated analysis of the scope for decarbonisation with the baseline projections of future emissions to highlight the extent to which the gap between the projected and required emissions levels that can be met through different levels and forms of action.

To break this gap down, we merge interventions into three broader groupings:

- ***Cost-Effective (CE)*** options where the direct costs of adoption are outweighed by the direct benefits that they generate through the energy savings they secure, meaning the portfolio of measures as a whole has a positive economic impact in present value. These options may also generate indirect benefits, for example through job creation, fuel poverty and improved air quality and public health.

[*] We evaluate over 130 separate low carbon technologies/interventions applied across sectors, with variable place-specific data on how their productivity and economics will change by application. This results in over 1000 unique data points customised to York's economy, infrastructures and demography.

- ***Cost-Neutral (CN)*** options where the portfolio of interventions mentioned above is expanded to consider investments that may not be as cost effective on their own terms, but where the range of measures as a whole will have near-zero net cost.
- ***The Technical Potential (TP)*** options where the direct costs are not (at present) covered by the direct benefits. However, the cost of many low carbon options is falling quickly, and again these options could generate important indirect benefits such as those listed above.

As it is unlikely that adopting all of the cost-effective or even technically viable options will enable an area to reach net-zero emissions, we also highlight the need for a fourth group of measures:

- ***The innovative or 'stretch' options*** that includes low-carbon measures that are not yet widely adopted. Some of the options within this group may well be cost and carbon effective, and they may also generate significant indirect benefits, but whilst we can predict their carbon saving potential, data on their costs and benefits is not yet available.

2(f). Developing Targets and Performance Indicators

Linked to the analysis detailed above, we extend our evaluation of potential emissions reductions across York's economy to substantive, real-life indicators for the levels of investment and deployment required to achieve targets. These Key Performance Indicators (KPIs) illustrate the scale of ambition required to reach the emissions savings presented in the Technical Potential scenario and are disaggregated by sector.

2(g). Focusing on Key Sectors

As well as presenting an aggregated picture, we also focus on the emissions saving potential in the housing, public and commercial buildings, transport, and industry sectors. We focus in on overall investment needs and returns, and present more detailed league tables of the most carbon and cost effective options that could be adopted in each sector.

3. Developing a Baseline of Past, Present and Future Emissions for York

Analysis shows that York's baseline (scope 1 and 2) emissions have fallen by 44% since 2000, due to a combination of increasingly decarbonised electricity supply, structural change in the economy, and the gradual adoption of more efficient buildings, vehicles and businesses.

With full decarbonisation of UK electricity by 2050, and taking into account economic growth (assumed at 2.5% p.a.), population growth (assumed at 0.1% p.a.) and on-going improvements in energy and fuel efficiency, we project that York's baseline (scope 1 and 2) emissions will only fall by a further 7% by 2030, 9% by 2040, and 10% by 2050. This is a total of just under 54% between 2000 and 2050.

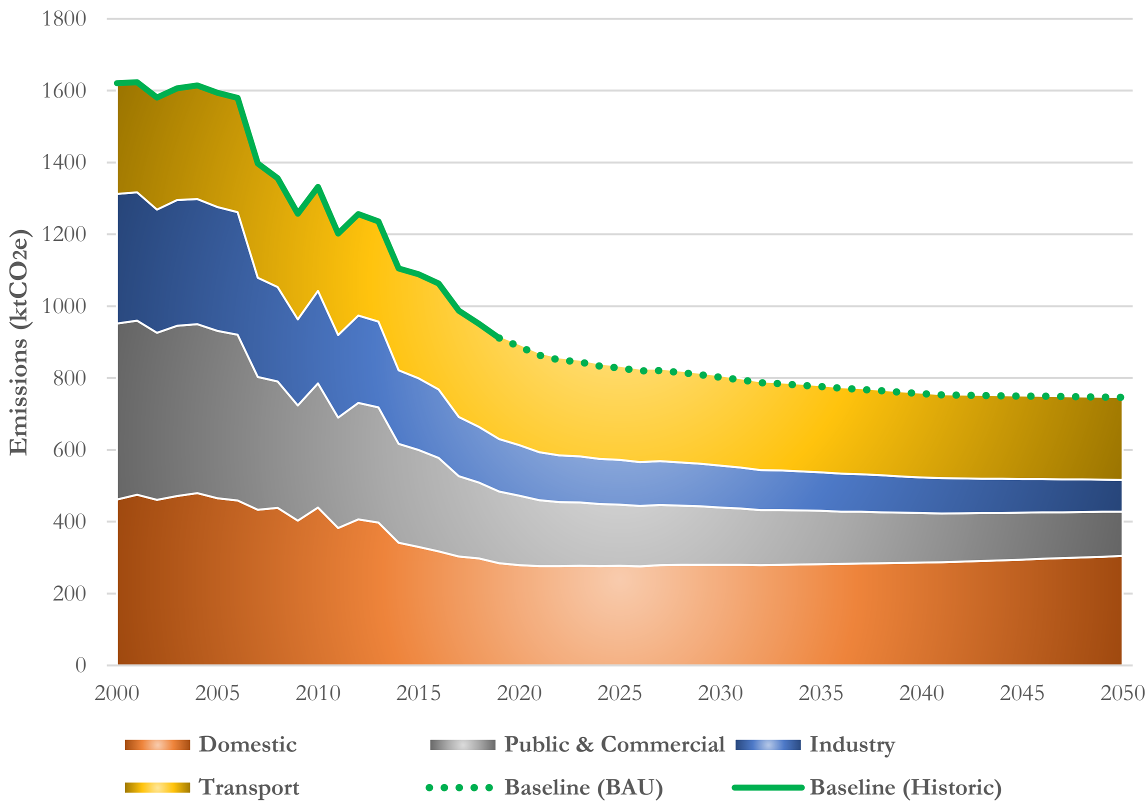


Figure.1: *York's Scope 1 and 2 GHG emissions (2000-2050)*

Currently, 32% of York's emissions come from transport, with the domestic housing sector then responsible for 31% of emissions, public & commercial buildings for 22% and industry 16%. Emissions related to land-use contribute c.0.5% and are not considered technically in this report. By 2050, we project emissions from transport will decrease very slightly (still producing c.31%) with a significant 10% increase in the proportion of emissions from housing. Small decreases are forecast in the proportion of emissions from public & commercial buildings and industry, largely a result of expansion in the output of the domestic buildings sector over this period.

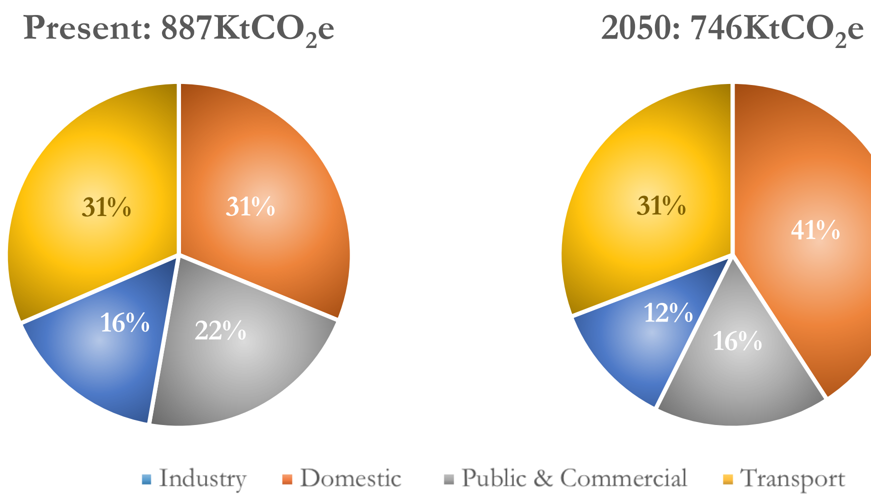


Figure.2: *York's Present and Projected Emissions by Sector*

Related to this emissions baseline, after evaluating the range of energy sources York consumes (spanning electricity, gas, all solid and liquid fuels across sectors) we find that in 2019 £299 million was spent on energy across the city. Transport fuels generated the majority of this demand (44%), followed by domestic buildings (35%) then public & commercial buildings and industry (13% and 9% respectively). By projecting demand and energy prices into future with reasonable baseline assumptions over population, inflationary measures and efficiency gains across the economy, we find that York's business as usual energy expenditure will likely grow to just under £320 million per year in 2030 and c.£435 million per year in 2050, with transport expenditure growing in its contribution to York's total (see Figure 3 below).

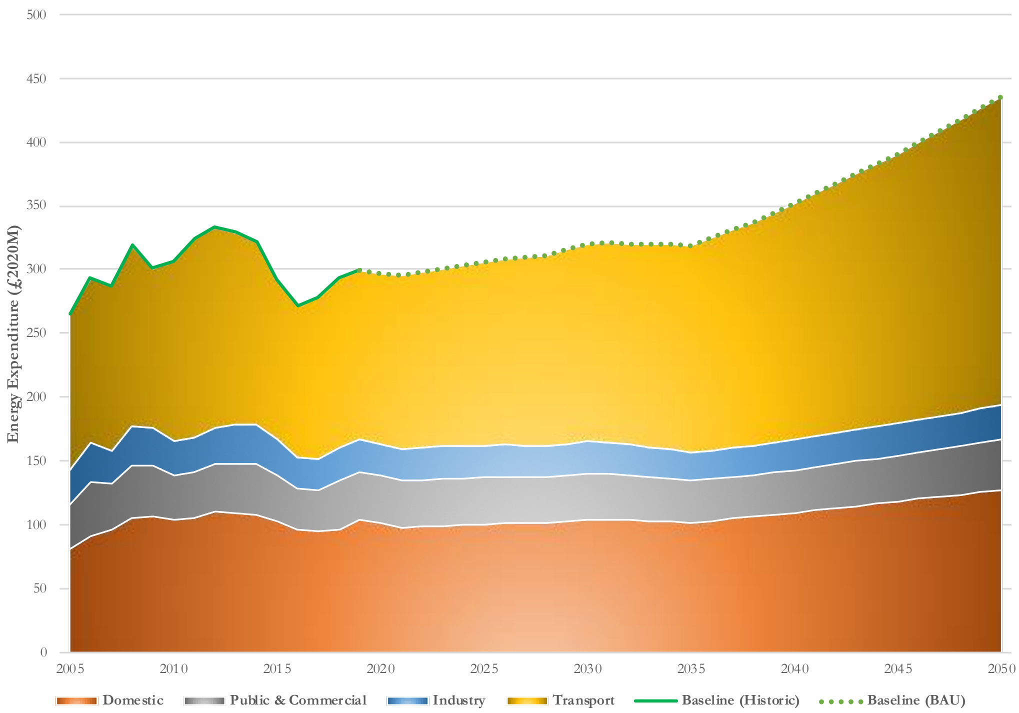


Figure.3: *York's Present and Projected Energy Expenditure by Sector*

4. Setting Science-based Carbon Reduction Targets for York

The Inter-governmental Panel on Climate Change (IPCC) has argued that from 2020, keeping within a global carbon budget of 344 gigatonnes (i.e. 344 billion tonnes) of CO2 emissions would give us a 66% chance of limiting average warming to 1.5 degrees and therefore avoiding dangerous levels of climate change. If we divide this global figure up on an equal basis by population, this gives York a total carbon budget of c.10 megatonnes (i.e. 10 million tonnes) over period between the present and 2050.

At current rates of emissions output, York would use up this budget in just over 12 years at some point during the spring of 2032. However, York could stay within its carbon budget by reducing its emissions by just over 7% year on year. This would mean that to transition from the current position where emissions are 44% lower than 2000 levels to a local pathway that is consistent with the world giving itself a 66% chance of avoiding dangerous, runaway climate change, York should adopt carbon reduction targets (on 2000 levels) of:

- 65% by 2025
- 76% by 2030
- 84% by 2035
- 89% by 2040
- 92% by 2045
- 95% by 2050.

Such a trajectory would mean that the majority of all future carbon cuts needed for York to transition to a 1.5 degree consistent pathway need to be delivered in the next 10 years.

Figure.4: *York's Baseline and Science-Based-Target Emissions Pathways*

5. Aggregating Up: The Bigger Picture for York

a) Emissions reductions

Our analysis predicts that the gap between York's business as usual emissions in 2030 and the net zero target could be closed by 47 % (379ktCO_2e) through the adoption of Cost-Effective (CE) options, by a further 15% (118ktCO_2e) through the adoption of additional Cost-Neutral (CN) options at no net cost, and then by an additional 7% (53ktCO_2e) through the further adoption of all technically viable (TP) options. This means that York still has to identify the innovative or stretch options that could deliver the last 31% (252ktCO_2e) of the gap between the business as usual scenario and net zero in 2030.

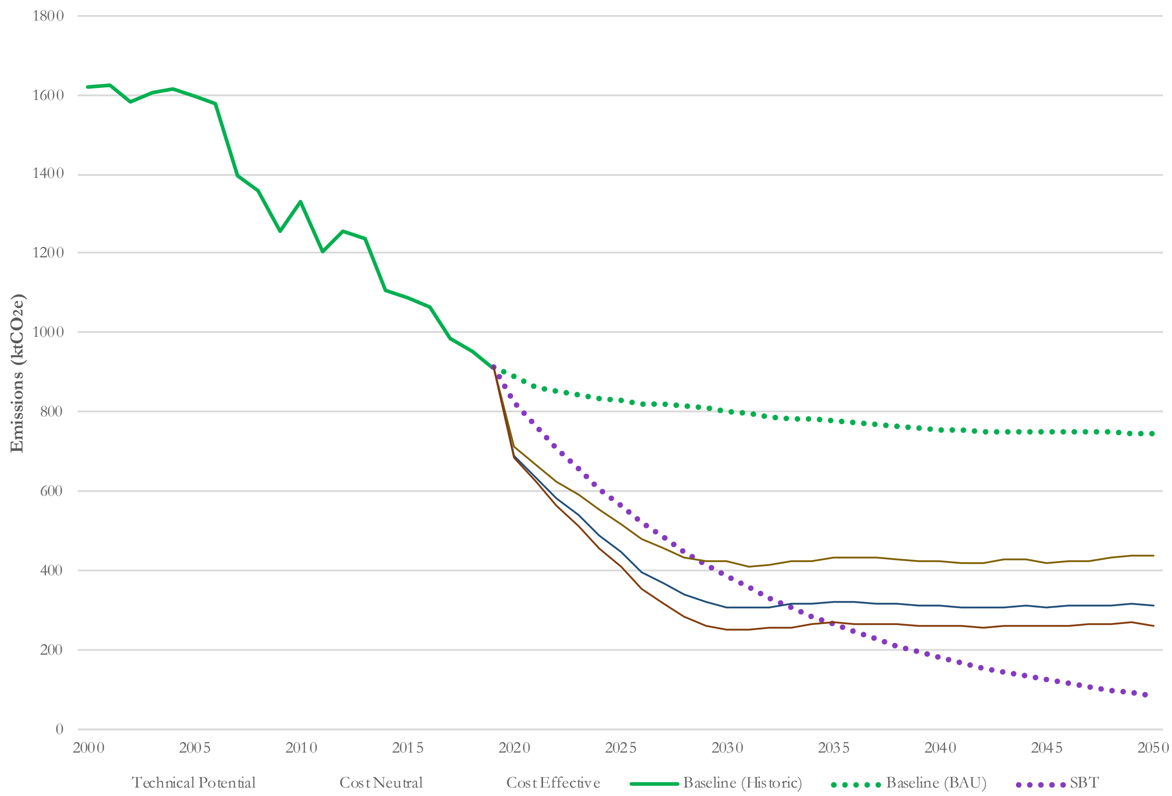


Figure.5: *York's BAU Baseline with Cost-Effective, Cost-Neutral, & Technical Potential Scenarios*

		2025	2030	2035	2040	2045	2050
Reduction on BAU Baseline	**CE**	38%	47%	44%	44%	44%	41%
	CN	46%	62%	59%	59%	59%	58%
	TP	51%	69%	65%	66%	65%	65%
Reduction on Present Emissions	**CE**	35%	43%	39%	37%	37%	35%
	CN	43%	56%	51%	50%	50%	49%
	TP	47%	62%	57%	56%	55%	55%

Table.1: *York's Potential 5-Year Emissions Reduction Percentages*

b) The most carbon and cost-effect options

Figure 6 below presents the emissions savings that could be achieved through different groups of measures in York. Appendices 1 and 2 present league tables of specific measures and their potential emissions savings over this period.

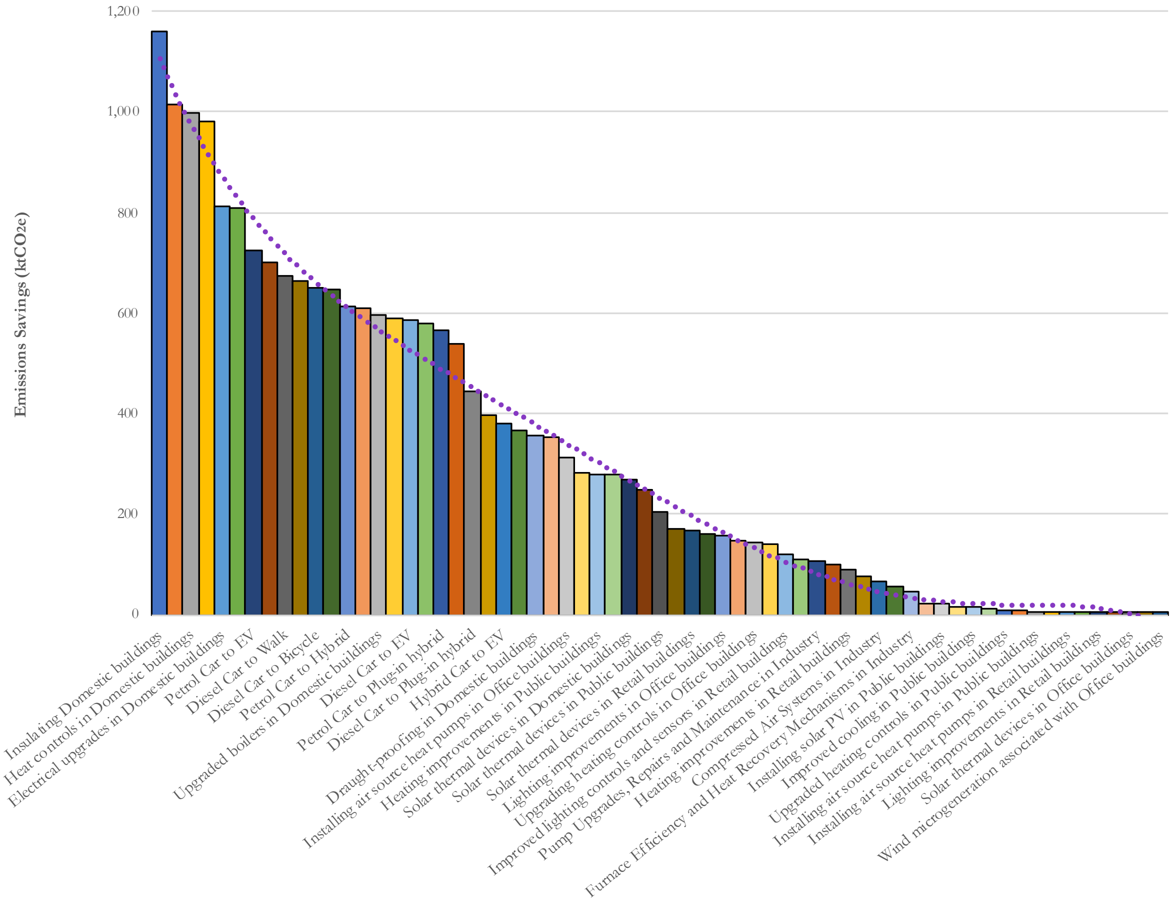


Figure.6: *Simplified Emissions Reduction Potential by Measure for York*

Simplified league tables of the most cost and carbon effective options in York are presented below (see Appendices 1 & 2 for more detailed league tables).

Rank	Measure	Cost Effectiveness (£/tCO_2e)
1	Fabric improvements in Retail buildings	-571
2	Diesel Car to Bus (diesel) Journeys	-458
3	Improved cooling in Retail buildings	-393
4	Petrol Car to Bus (diesel) Journeys	-373
5	Diesel Car to Walk Journeys	-345
6	Diesel Car to Bicycle Journeys	-345
7	Petrol Car to Bicycle Journeys	-323
8	Petrol Car to Walk Journeys	-323
9	Fabric improvements in Public buildings	-276
10	Petrol Car to Plug-in hybrid Journeys	-214

Table.5: *York's Top-10 Most Cost-Effective Emission Reduction Options*

Rank	Measure	Emissions Reduction Potential 2020-50 ($ktCO_2e$)
1	Insulating Domestic buildings	906
2	Upgraded Heating controls in Domestic buildings	846
3	Electrical upgrades in Domestic buildings	669
4	Installing heat pumps in Domestic & Office buildings	653
5	Petrol Car to Bicycle Journeys	636
6	Petrol Car to Walk Journeys	636
7	Fabric improvements in Retail buildings	515
8	Petrol Car to Bus (electric) Journeys	485
9	Upgraded boilers in Domestic buildings	481
10	Electricity demand reduction in Domestic buildings	475

Table.6: *York's Top-10 Most Carbon Effective Emission Reduction Options*

Some of the ideas for innovative options identified elsewhere that could also be considered for York include targeting a full transition to net zero homes and public/commercial buildings by 2030, promoting the rapid acceleration of active travel (e.g. walking and cycling), tackling food waste, reducing meat and dairy consumption and reducing concrete and steel consumption/promoting adoption of green infrastructure. These are highlighted in section 8.

c) *Investment needs, paybacks and employment creation*

Exploiting the cost-effective options in households, public and commercial buildings, transport, industry and waste could be economically beneficial. Although such measures would require total investments of around £1.1 billion over their lifetimes (equating to investments of 110m a year across all organisations and households in the city for the next decade), once adopted they would reduce York's total energy bill by £287 million p.a. in 2030 whilst also creating 3,570 years of employment – or 357 full-time jobs for the next decade.

By expanding this portfolio of measures to at no net cost to York's economy (the Cost-Neutral scenario), investments of £2.3 billion over their lifetimes (or £230m a year for the next decade) would generate 5,887 years of employment (or 588 jobs for the next decade) whilst reducing York' emissions by 62% of projected 2030 levels.

Exploiting the all technically viable options would be more expensive (at least at current prices, c.£3 billion or £300m a year for the next decade) but realise further emissions savings – eliminating 69% of the projected shortfall in York's 2030 emissions, whilst saving hundreds of millions of pounds on an annual basis.

		2025	2030	2035	2040	2045	2050
Cumulative Investment (£M)	**CE**	763	1,160	1,162	1,163	1,164	1,164
	CN	1,442	2,223	2,254	2,256	2,257	2,257
	TP	1,934	2,964	2,995	2,997	2,997	2,997
Annual Energy Expenditure Savings (£M)	**CE**	203	287	284	285	281	284
	CN	188	258	256	248	239	233
	TP	187	255	252	245	235	227

Table.2: *Potential 5-Year Investments and Energy Expenditure Savings*

Sector	**Scenario**	**Investment (£M)**
Domestic	**CE**	584
	CN	924
	TP	1,170
Public & Commercial	**CE**	448
	CN	504
	TP	909
Industry	**CE**	17
	CN	198
	TP	287
Transport	**CE**	115
	CN	631
	TP	631

Table.3: *Potential Investments by Sector & Economic Scenario*

		Total	Domestic	Industry	Transport	Public & Commercial
Years of Employment	**CE**	**3,570**	1,250	58	157	2,106
	CN	**5,887**	1,975	676	864	2,371
	TP	**8,623**	2,503	982	864	4,274
Jobs (20-year Period)	**CE**	**179**	62	3	8	105
	CN	**294**	99	34	43	119
	TP	**431**	125	49	43	214

Table.4: *Potential Job Creation by Sector & Economic Scenario*

6. Developing Targets and Performance Indicators

To give an indication of the levels of activity required to deliver on these broader targets, the tables below detail total deployment across different sectors in York through to 2050. We also give an indication of the rate of deployment required in the city if it is to even approximate its climate targets. These lists are not exhaustive, and also apply by measure; any one building or industrial facility will usually require the application of several measures over the period. These figures effectively become Key Performance Indicators (KPIs) for the delivery of climate action across the city.

Domestic Homes:

Measure	Total Homes Applied	Mean Annual Rate of Installation (homes)
Lighting Upgrades	51,631	**2,963**
Floor Insulation	48,546	**2,732**
Glazing Upgrades	45,597	**2,589**
Gas Boiler Upgrades & Repairs	46,800	**2,506**
Solar PV	35,810	**2,055**
Thermostats & Heating Controls	35,116	**1,976**
Solar thermal	36,430	**1,955**
Loft insulation	32,283	**1,748**
Wall Insulation	23,111	**1,290**
Draught Proofing	18,401	**1,044**
Cavity wall Insulation	15,350	**856**
Heat Pumps	3,780	**215**

Public & Commercial Buildings:

Measure	Floorspace Applied (m^2)	Mean Annual Rate of Installation (m^2)
Lighting/Heating Controls and Sensors	1,450,231	**82,076**
Retail Heating Upgrades	1,420,740	**80,425**
Wind Turbines	795,241	**45,815**
Office Lighting Upgrades	398,040	**23,006**
Office Fabric Improvements	279,564	**15,595**
Office Heat Pumps	114,492	**6,328**
Office Solar PV	93,984	**5,168**

Transport:

Measure	Deployment
Additional EVs Replacing Conventional Private Cars	**1,536**
Additional Electric-Buses Procured and In-service	**85**
High Quality Protected Cycling Highways Built	**9** kilometres
Increase in Public Transport Ridership	**4M** trips per annum

Table.7: *York's Sectoral Emissions Reduction KPIs*

7. Focussing on Key Sectors in York

At full deployment (technical potential) across York, we calculate that there is potential to avoid over 14MtCO_2e in emissions that will otherwise be produced in the city between 2020 and 2050. The transport sector will contribute most significantly toward this total, with a decarbonisation potential of between 4MtCO_2e (cost-effective scenario) and 6MtCO_2e (technical potential) through the period. However, domestic housing , industry and public and commercial buildings also play a major role:; upgrading and retrofitting of York's built environment (including the domestic, public and commercial sectors) could reduce emissions by up to c.8MtCO_2e over the same period at full technical potential, with industry similarly showing the potential to decarbonise nearly 500ktCO_2e under the same conditions.

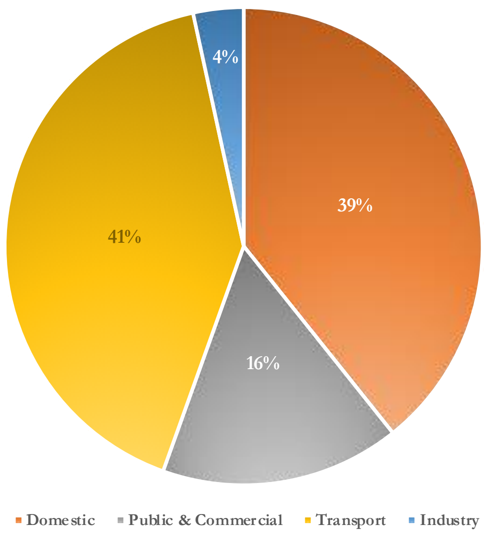


Figure.7 *York's Emissions Reduction Potential (2020-2050) by Sector*

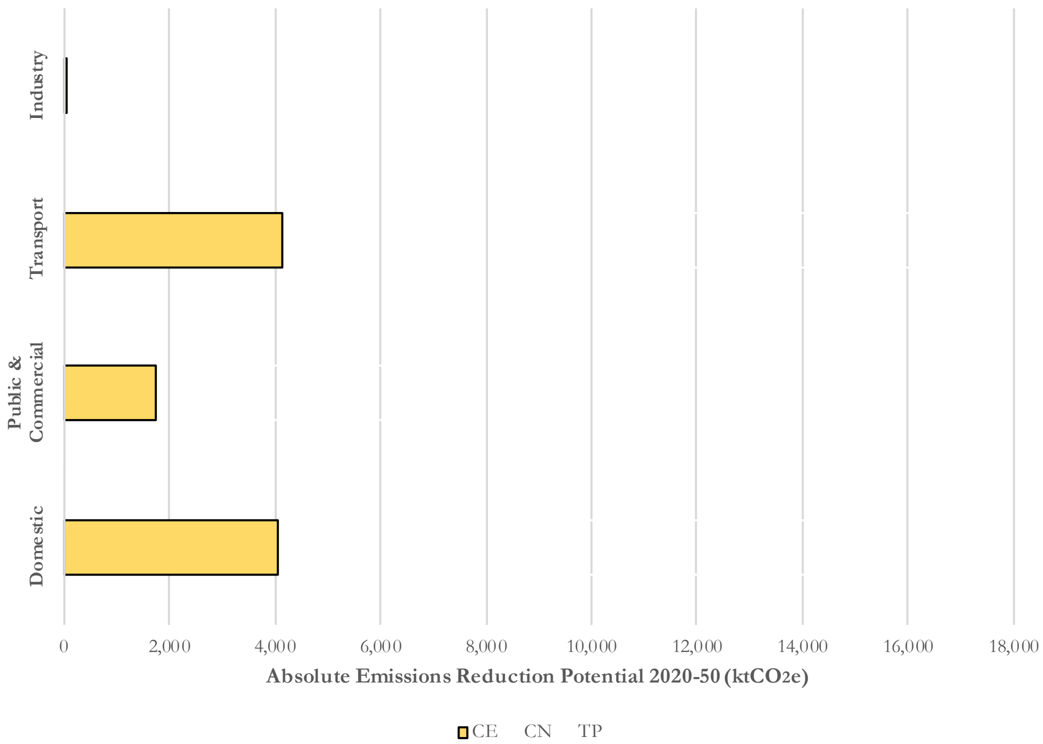
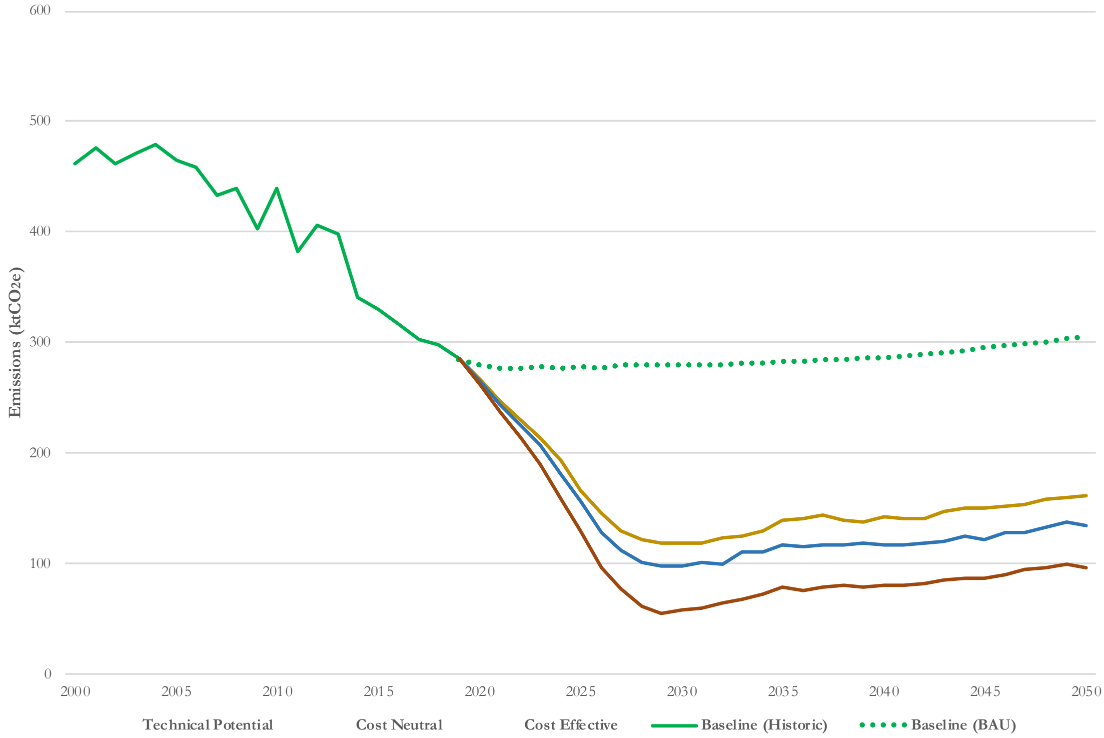


Figure.8: *York's Emissions Reduction Potential By Sector & Economic Scenario (2020-50)*

In the following section, summaries of the emissions reduction potential and economic implications of investment are presented for the four main sectors. For display and continuity purposes, each sector is displayed with a summary of the same metrics: (*1*) emissions reduction potential over time in the three economic scenarios, (*2*) 5-year totals for cumulative emissions savings, investment requirements and annual energy expenditure reductions, and (*3*) a simplified table of the most cost effective low carbon measures applied in each sector across York.

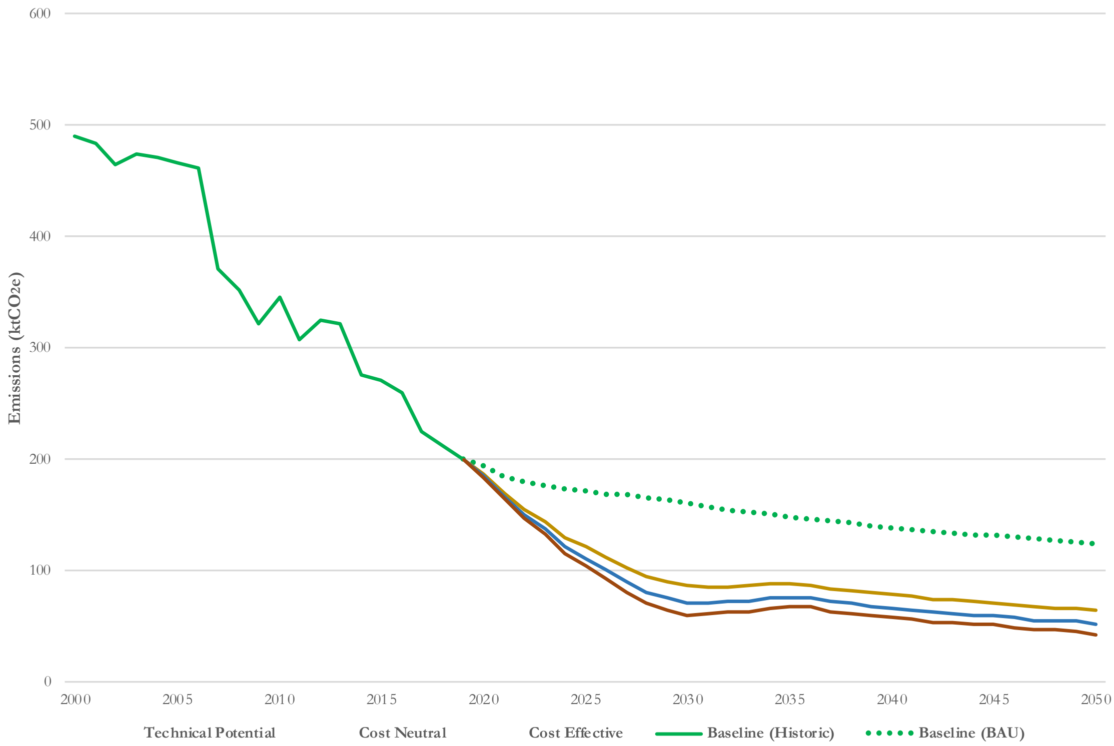
7(a). Housing



		2025	2030	2035	2040	2045	2050
Emissions Reductions ($ktCO_2e$)	**CE**	111	154	143	144	153	143
	CN	121	183	167	169	174	170
	TP	148	222	203	206	209	209
Annual Energy Expenditure Savings (£M)	**CE**	67	110	113	116	113	118
	CN	83	137	140	141	142	147
	TP	70	114	116	118	118	122
Cumulative Investment (£M)	**CE**	368	584	584	584	584	584
	CN	575	924	924	924	924	924
	TP	727	1,170	1,170	1,170	1,170	1,170

Rank	Measure	Cost Effectiveness (£/tCO_2e)
1	Electrical & Appliance upgrades in Domestic buildings	-208
2	Lighting improvements in Domestic buildings	-145
3	Electricity demand reduction in Domestic buildings	-137
4	Draught-proofing in Domestic buildings	-50
5	Installing heat pumps in Domestic buildings	-37
6	Upgraded Heating controls in Domestic buildings	-28
7	Glazing improvements in Domestic buildings	-27
8	Installing biomass boilers in Domestic buildings	-24
9	Solar thermal devices in Domestic buildings	-18
10	Upgraded boilers in Domestic buildings	-11

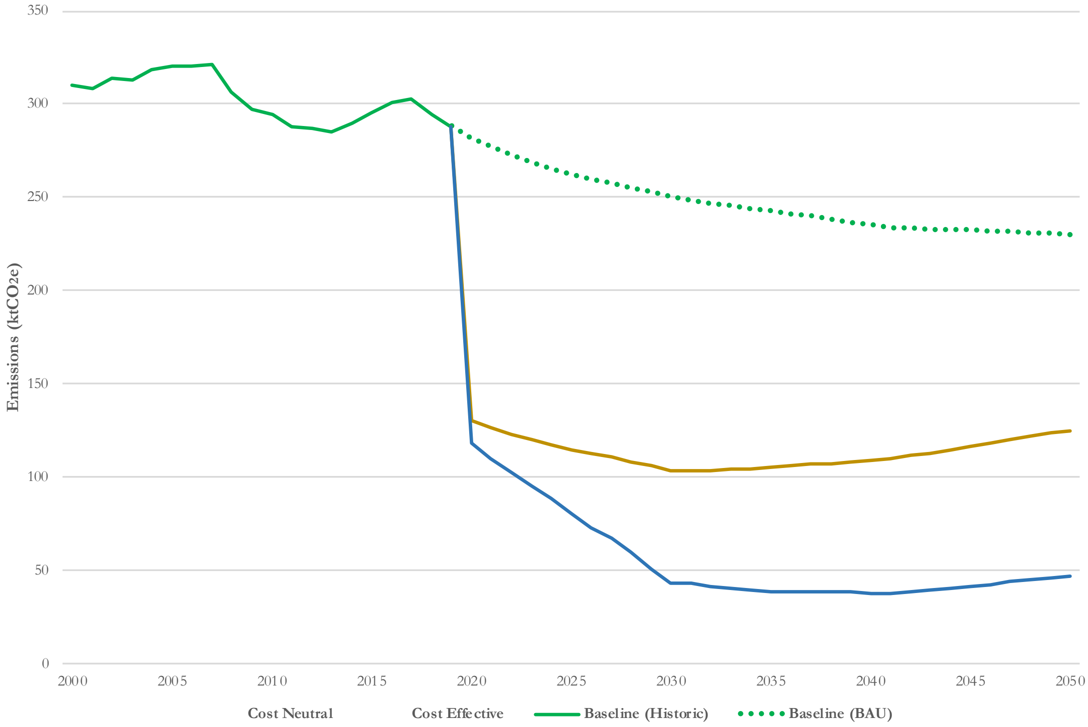
7(b). Public & Commercial Buildings



		2025	2030	2035	2040	2045	2050
Emissions Reductions ($ktCO_2e$)	**CE**	50	74	61	60	60	60
	CN	60	90	73	72	72	73
	TP	67	100	82	81	80	81
Annual Energy Expenditure Savings (£M)	**CE**	65	107	105	110	113	117
	CN	21	35	34	36	37	39
	TP	33	53	52	55	57	59
Cumulative Investment (£M)	**CE**	278	448	448	448	448	448
	CN	314	504	504	504	504	504
	TP	565	909	909	909	909	909

Rank	Measure	Cost Effectiveness (£/tCO_2e)
1	Fabric improvements in Retail buildings	-571
2	Improved cooling in Retail buildings	-393
3	Fabric improvements in Public buildings	-276
4	Lighting improvements in Public buildings	-200
5	Improved cooling in Office buildings	-198
6	Heating improvements in Public buildings	-139
7	Lighting improvements in Retail buildings	-132
8	Improved cooling in Public buildings	-97
9	Heating improvements in Office buildings	-82
10	Heating improvements in Retail buildings	-53

7(c). Transport



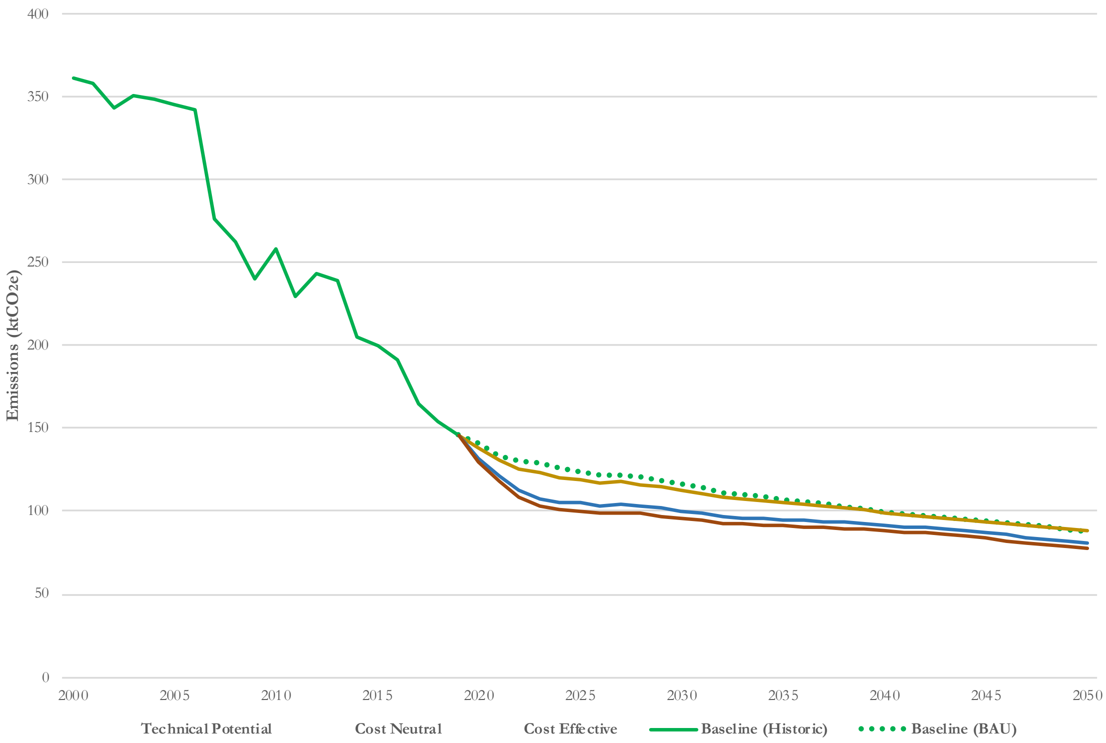
		2025	2030	2035	2040	2045	2050
Emissions Reductions ($ktCO_2e$)	CE	148	148	137	127	116	105
	CN	182	208	204	198	191	183
	TP	182	208	204	198	191	183
Annual Energy Expenditure Savings (£M)	CE	68	67	64	59	54	49
	CN	75	78	73	65	56	47
	TP	75	78	73	65	56	47
Cumulative Investment (£M)	CE	100	111	113	114	115	115
	CN	355	598	629	631	631	631
	TP	355	598	629	631	631	631

Rank	Measure*	Cost Effectiveness (£/tCO_2e)
1	Diesel Car to Bus (diesel)	-458
2	Petrol Car to Bus (diesel)	-373
3	Diesel Car to Walk	-345
4	Diesel Car to Bicycle	-345
5	Petrol Car to Bicycle	-323
6	Petrol Car to Walk	-323
7	Petrol Car to Plug-in hybrid	-214
8	Diesel Car to Plug-in hybrid	-136
9	Petrol Car to EV	-133

Note: Due to the high cost-effectiveness of many transport mode-shift options, the TP scenario has been removed and emissions pathways are covered by CE and CN only.
* Journey transitions

10	Petrol Car to Bus (electric)	-129

7(d). Industry



		2025	2030	2035	2040	2045	2050
Emissions Reductions ($ktCO_2e$)	**CE**	5	4	2	0	0	0
	CN	19	16	12	8	7	7
	TP	24	21	16	11	10	10
Annual Energy Expenditure Savings (£M)	**CE**	3	3	3	1	1	0
	CN	9	9	9	6	4	0
	TP	10	10	10	7	5	0
Cumulative Investment (£M)	**CE**	3	17	17	17	17	17
	CN	40	198	198	198	198	198
	TP	57	287	287	287	287	287

Rank*	**Measure**	**Cost Effectiveness (£/tCO_2e)**
1	Improving Efficiency of Boilers and Steam Piping in Industry	307
2	Fan Correction, Repairs, & Upgrades in Industry	663
3	Condensing & Insulation Measures to Boilers & Steam Piping in Industry	719
4	Pump Upgrades, Repairs and Maintenance in Industry	825
5	Compressed Air Systems in Industry	1,055
6	Furnace Efficiency and Heat Recovery Mechanisms in Industry	3,213
7	Refrigeration Efficiency and Technical Upgrades in Industry	15,656

* For display purposes interventions in industry have been aggregated here into the 7 relevant process types

8. Innovative Stretch Measures in York

Even with full delivery of the broad programme of cross-sectoral, city-wide low carbon investment described above, there remains an emissions shortfall of 31% between York's 2030 BAU baseline and the net zero target. Here we briefly consider the productivity of certain key technologies and interventions that may well be able to plug this gap into the future. Many of these so-called 'stretch options' are innovative by nature but they will be required to reach York's targets in future.

		2025	2030	2035
Annual Emissions Reduction Potential ($ktCO_2e$)	Zero Carbon Heavy Goods Transport	11	48	48
	Industrial Heat and Cooling Electrification	12	12	7
	870 Ha. Reforested Annually 2020-29*	47	120	148
	Electrification of Domestic Heat	6	33	48
	Electrification of Domestic Cooking	2	11	15
	Electrification of Commercial/Public Heating	3	8	3

Table.7: *Stretch Measures' Decarbonising Potential (* Sequestration Values)*

Figure 10 below shows the impact that the adoption of these stretch measures would have on York's carbon emissions, with the red dotted line showing the 'business as usual' baseline, the purple dotted line showing emissions after adoption of all technically viable options and the blue dotted line showing emissions after all technically viable and stretch options. This indicates that York would still have some residual emissions through to 2050. For illustration, the green dotted line shows that in theory York could offset is residual emissions through a UK based tree planting scheme, however this would require the planting of 39 million trees, which even with the densest possible planting would require 8,700 hectares of land, equivalent to 32% of the total land area of the city.

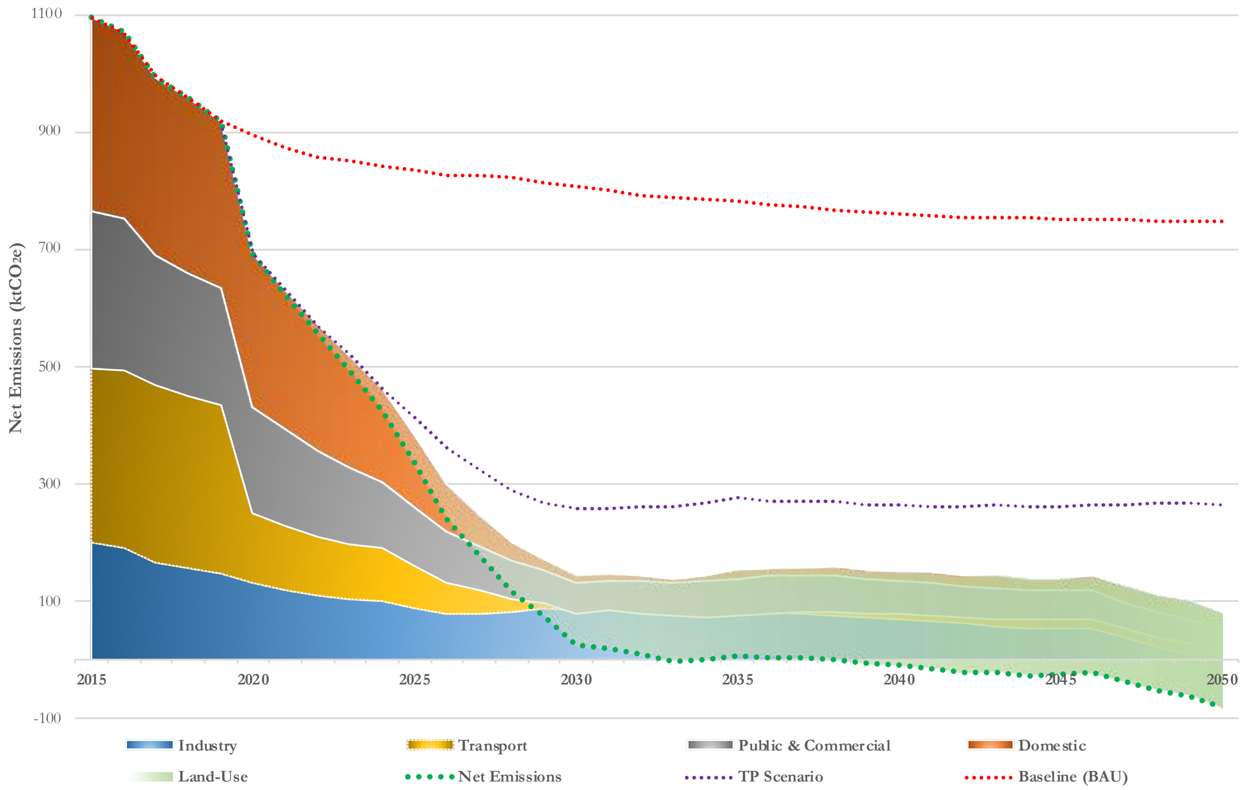


Figure.10: *Sectoral Emissions Shortfall Reduction with Stretch Measures*

9. Next Steps for York

Based on the analysis presented above, we recommend that if York wants to stay within its share of the global carbon budget, it needs to adopt a clear and ambitious climate action plan.

The case for the adoption of such a plan is supported by the evidence that much – but not all - of the action that is required can be based on the exploitation of win-win low carbon options that will simultaneously improve economic, social and health outcomes across the city.

A climate action plan for York should adopt science-based targets for emissions reduction, including both longer term targets and 5-yearly carbon reduction targets.

The action plan should focus initially on York's direct (scope 1 and 2) carbon footprint as these emissions are most directly under the city's influence, but in time it should also widen its scope to consider its broader (scope 3) carbon footprint.

The action plan should clearly set out the ways in which York will work towards achieving these targets, drawing on the deployment KPIs listed in this report. Action should also be taken to monitor and report progress on emissions reductions.

It is important to stress that delivering on these targets will require action across the city and the active support of the public, private and third sectors. Establishing an independent York Climate Commission could help to draw actors together and to build capacities to take and track action.

Such a Commission could act as a critical friend to the city, helping to promote stakeholder engagement and build buy-in and a sense of common ownership for the climate action plan, as well as in supporting, guiding and tracking progress towards its delivery.

Through such a Commission, cross-sectoral leadership groups could be formed for key sectors such as homes, public and commercial buildings, transport and industry, with clear plans for the delivery of priority actions in each sector. All large organisations and businesses in the city should be asked to match broader carbon reduction commitments and to report back on progress.

Appendix 1. League Table of the Most Carbon Effective Options for York

Measure[*]	Emissions Reduction Potential ($ktCO_2e$)
Insulating Domestic buildings	906
Upgraded Heating controls in Domestic buildings	846
Electrical upgrades in Domestic buildings	669
Installing heat pumps in Domestic buildings	653
Petrol Car to Bicycle	636
Petrol Car to Walk	636
Fabric improvements in Retail buildings	515
Petrol Car to Bus (electric)	485
Upgraded boilers in Domestic buildings	481
Electricity demand reduction in Domestic buildings	475
Diesel Car to Walk	464
Diesel Car to Bicycle	464
Installing solar PV in Domestic Buildings	444
Petrol Car to EV	439
Petrol Car to Bus (diesel)	395
Petrol Car to Plug-in hybrid	375
Petrol Car to Hybrid	375
Diesel Car to EV	370
Diesel Car to Bus (electric)	341
Fabric improvements in Public buildings	338
Diesel Car to Plug-in hybrid	276
Lighting improvements in Domestic buildings	276
Draught-proofing in Domestic buildings	257
Installing biomass boilers in Domestic buildings	252
Hybrid Car to EV	240
Glazing improvements in Domestic buildings	228
Diesel Car to Bus (diesel)	224
Heating improvements in Public buildings	213
Solar thermal devices in Domestic buildings	193
Condensing & Insulation Measures to Boilers & Steam Piping in Industry	185
Installing air source heat pumps in Office buildings	163
Solar thermal devices in Public buildings	148
Lighting improvements in Office buildings	133
Improving Efficiency of Boilers and Steam Piping in Industry	131
Solar thermal devices in Retail buildings	125
Wind microgeneration associated with Public buildings	103
Improved lighting controls and sensors in Public buildings	89
Upgrading heating controls in Office buildings	86
Improved lighting controls and sensors in Office buildings	86
Improved cooling in Office buildings	85
Improved lighting controls and sensors in Retail buildings	72

[*] Measures listed here have been grouped and summed across multiple applications for display purposes; 'ICE' and 'NMT" refer to Internal Combustion Engine and Non-Motorised Transport respectively; Transport measures refer to transitions between travel modes.

Diesel Car to Hybrid	66
Lighting improvements in Public buildings	66
Compressed Air Systems in Industry	54
Pump Upgrades, Repairs and Maintenance in Industry	49
Heating improvements in Retail buildings	42
Fan Correction, Repairs, & Upgrades in Industry	34
Furnace Efficiency and Heat Recovery Mechanisms in Industry	34
Installing solar PV in Public buildings	13
Fabric improvements in Office buildings	10
Improved cooling in Public buildings	10
Refrigeration Efficiency and Technical Upgrades in Industry	7
Improved cooling in Retail buildings	7
Installing solar PV in Office buildings	5
Heating improvements in Office buildings	5
Installing air source heat pumps in Retail buildings	4
Upgraded heating controls in Retail buildings	4
Installing air source heat pumps in Public buildings	4
Lighting improvements in Retail buildings	4
Wind microgeneration associated with Retail buildings	4
Upgraded heating controls in Public buildings	4
Solar thermal devices in Office buildings	4
Installing solar PV in Retail buildings	3
Wind microgeneration associated with Office buildings	3
TOTAL	**14,306**

Appendix 2. League Table of the Most Cost Effective Options for York

Measure*	Cost Effectiveness (£/tCO_2e)
Fabric improvements in Retail buildings	-571
Diesel Car to Bus (diesel)	-458
Improved cooling in Retail buildings	-393
Petrol Car to Bus (diesel)	-373
Diesel Car to Walk	-345
Diesel Car to Bicycle	-345
Petrol Car to Bicycle	-323
Petrol Car to Walk	-323
Fabric improvements in Public buildings	-276
Petrol Car to Plug-in hybrid	-214
Electrical upgrades in Domestic buildings	-208
Lighting improvements in Public buildings	-200
Improved cooling in Office buildings	-198
Lighting improvements in Domestic buildings	-145
Heating improvements in Public buildings	-139
Electricity demand reduction in Domestic buildings	-137
Diesel Car to Plug-in hybrid	-136
Petrol Car to EV	-133
Lighting improvements in Retail buildings	-132
Petrol Car to Bus (electric)	-129
Petrol Car to Hybrid	-114
Improved cooling in Public buildings	-97
Heating improvements in Office buildings	-82
Insulating Domestic buildings	-76
Diesel Car to Bus (electric)	-63
Heating improvements in Retail buildings	-53
Lighting improvements in Office buildings	-53
Draught-proofing in Domestic buildings	-50
Diesel Car to EV	-41
Fabric improvements in Office buildings	-38
Installing heat pumps in Domestic buildings	-37
Upgraded Heating controls in Domestic buildings	-28
Glazing improvements in Domestic buildings	-27
Upgrading heating controls in Office buildings	-26
Installing biomass boilers in Domestic buildings	-24
Solar thermal devices in Domestic buildings	-18
Diesel Car to Hybrid	-12
Upgraded heating controls in Public buildings	-11
Upgraded boilers in Domestic buildings	-11
Upgraded heating controls in Retail buildings	-8
Installing air source heat pumps in Retail buildings	-1

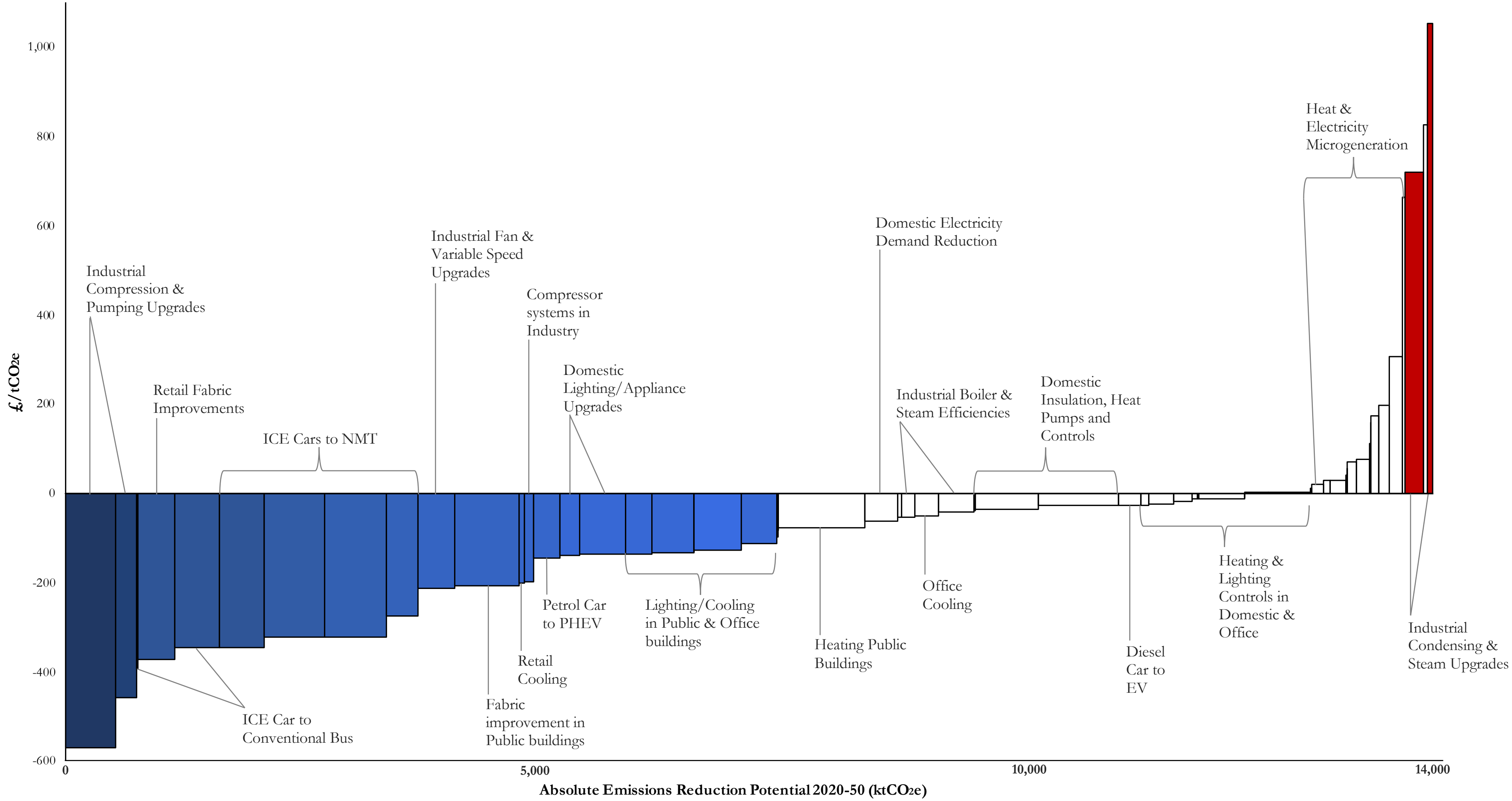
* Measures listed here have been grouped and summed across multiple applications for display purposes; the cost per tonne of emissions reduction displayed here are mean values across applications.

Hybrid Car to EV	3
Installing solar PV in Domestic Buildings	3
Installing air source heat pumps in Public buildings	10
Solar thermal devices in Retail buildings	19
Improved lighting controls and sensors in Retail buildings	29
Installing air source heat pumps in Office buildings	30
Installing solar PV in Public buildings	40
Installing solar PV in Office buildings	53
Installing solar PV in Retail buildings	55
Improved lighting controls and sensors in Office buildings	71
Solar thermal devices in Public buildings	76
Solar thermal devices in Office buildings	112
Wind microgeneration associated with Office buildings	158
Improved lighting controls and sensors in Public buildings	174
Wind microgeneration associated with Public buildings	196
Wind microgeneration associated with Retail buildings	307
Improving Efficiency of Boilers and Steam Piping in Industry	307
Fan Correction, Repairs, & Upgrades in Industry	663
Condensing & Insulation Measures to Boilers & Steam Piping in Industry	719
Pump Upgrades, Repairs and Maintenance in Industry	825
Compressed Air Systems in Industry	1,055
Furnace Efficiency and Heat Recovery Mechanisms in Industry	3,213
Refrigeration Efficiency and Technical Upgrades in Industry	15,656

Appendix 3. Detailed Sectoral Emissions Reduction Potential by Scenario

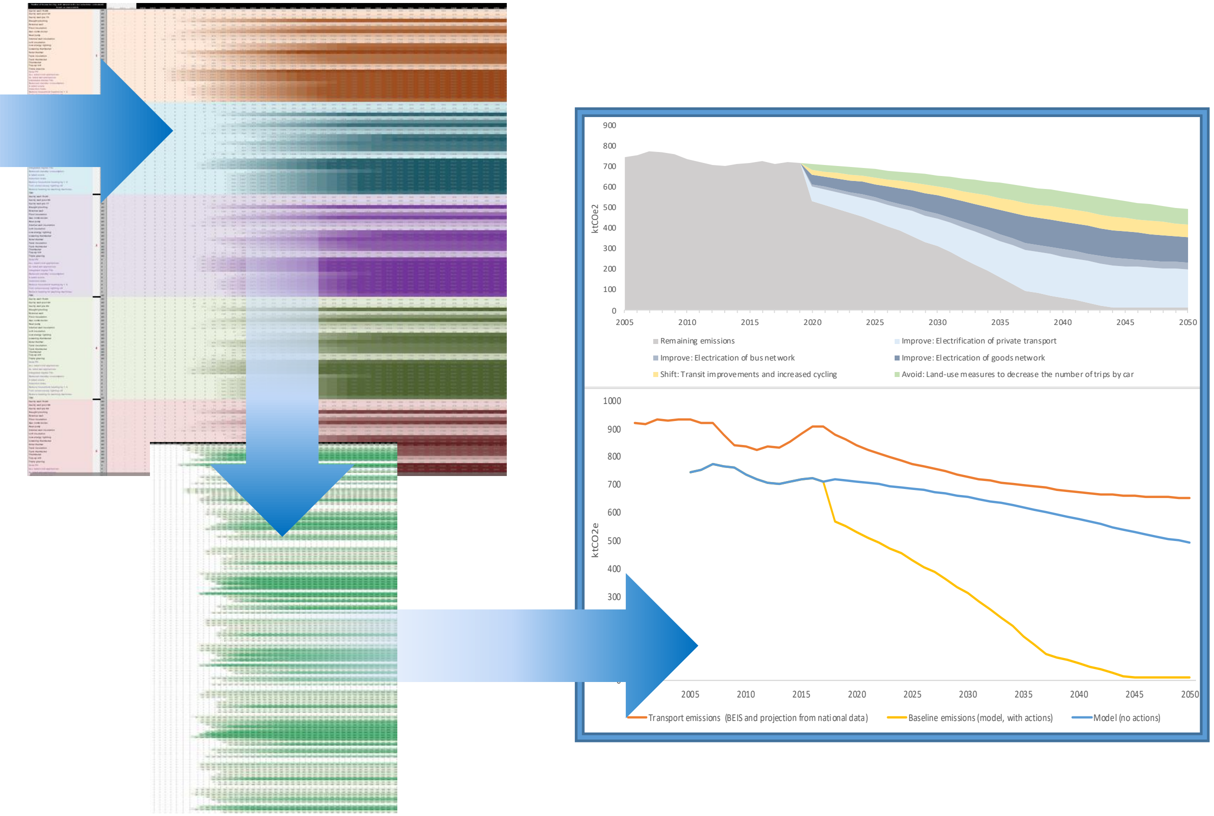
Sector	Measure	Scenario	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Domestic Housing	Reduction on BAU Emissions ($ktCO_2e$)	CE	5%	10%	17%	23%	31%	40%	47%	54%	57%	58%	55%	58%	56%	53%	54%	51%	50%	49%	51%	52%	50%	52%	52%	50%	49%	52%	51%	51%	48%	47%	47%
		CN	5%	12%	19%	25%	35%	44%	54%	60%	64%	66%	65%	64%	64%	61%	61%	59%	59%	59%	59%	59%	59%	59%	59%	59%	58%	59%	57%	57%	56%	55%	56%
		TP	7%	14%	23%	32%	43%	53%	65%	72%	78%	80%	79%	79%	77%	76%	75%	72%	73%	72%	72%	73%	72%	72%	72%	71%	71%	71%	70%	69%	68%	68%	69%
	Reduction on 2020 Emissions ($ktCO_2e$)	CE	5%	10%	17%	23%	30%	40%	47%	54%	57%	58%	55%	58%	56%	53%	55%	51%	51%	50%	52%	53%	52%	53%	54%	52%	51%	55%	55%	55%	51%	51%	51%
		CN	5%	11%	18%	25%	34%	43%	53%	60%	64%	66%	66%	64%	64%	61%	62%	60%	60%	60%	60%	60%	60%	61%	61%	61%	60%	62%	61%	61%	61%	59%	61%
		TP	7%	14%	22%	31%	43%	53%	64%	72%	79%	81%	80%	79%	77%	76%	75%	73%	74%	74%	73%	74%	74%	74%	74%	74%	74%	75%	74%	73%	73%	73%	75%
Public & Commercial buildings	Reduction on BAU Emissions ($ktCO_2e$)	CE	4%	8%	13%	19%	25%	29%	34%	39%	43%	45%	46%	46%	45%	44%	41%	41%	41%	42%	42%	43%	44%	44%	45%	45%	46%	46%	46%	48%	48%	48%	49%
		CN	5%	10%	16%	23%	30%	35%	40%	47%	51%	54%	56%	55%	53%	53%	50%	49%	49%	50%	51%	52%	52%	53%	54%	54%	55%	55%	56%	57%	57%	57%	59%
		TP	5%	11%	18%	25%	34%	39%	45%	52%	57%	61%	63%	62%	60%	59%	56%	55%	54%	56%	57%	58%	58%	59%	60%	60%	62%	61%	62%	64%	64%	64%	66%
	Reduction on 2020 Emissions ($ktCO_2e$)	CE	4%	8%	12%	17%	22%	26%	29%	34%	37%	38%	38%	38%	35%	34%	32%	32%	31%	31%	31%	31%	31%	31%	32%	31%	32%	31%	31%	32%	31%	31%	31%
		CN	5%	9%	15%	21%	27%	31%	35%	41%	44%	46%	47%	45%	42%	42%	39%	38%	37%	38%	37%	38%	37%	37%	38%	37%	38%	37%	37%	38%	37%	37%	38%
		TP	5%	10%	17%	23%	30%	35%	39%	45%	49%	51%	52%	50%	47%	47%	43%	42%	41%	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%	42%	41%	42%
Transport	Reduction on BAU Emissions ($ktCO_2e$)	CE	54%	54%	55%	55%	56%	56%	57%	57%	58%	58%	59%	59%	58%	58%	57%	57%	56%	56%	55%	54%	54%	53%	52%	52%	51%	50%	49%	48%	47%	47%	46%
		CN	58%	60%	63%	65%	67%	69%	72%	74%	77%	80%	83%	83%	83%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	83%	83%	82%	82%	81%	81%	80%	80%
		TP	58%	60%	63%	65%	67%	69%	72%	74%	77%	80%	83%	83%	83%	84%	84%	84%	84%	84%	84%	84%	84%	84%	84%	83%	83%	82%	82%	81%	81%	80%	80%
	Reduction on 2020 Emissions ($ktCO_2e$)	CE	54%	54%	53%	53%	53%	52%	52%	52%	52%	52%	52%	52%	51%	50%	50%	49%	48%	47%	46%	46%	45%	44%	43%	43%	42%	41%	40%	40%	39%	38%	37%
		CN	58%	59%	60%	62%	63%	65%	67%	68%	69%	72%	74%	73%	73%	73%	73%	72%	72%	72%	71%	71%	70%	70%	69%	69%	68%	68%	67%	67%	66%	66%	65%
		TP	58%	59%	60%	62%	63%	65%	67%	68%	69%	72%	74%	73%	73%	73%	73%	72%	72%	72%	71%	71%	70%	70%	69%	69%	68%	68%	67%	67%	66%	66%	65%
Industry	Reduction on BAU Emissions ($ktCO_2e$)	CE	2%	3%	4%	4%	4%	4%	4%	4%	4%	3%	3%	3%	3%	3%	3%	2%	2%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		CN	6%	10%	14%	17%	16%	16%	16%	15%	15%	14%	14%	14%	13%	13%	12%	12%	11%	10%	9%	9%	8%	8%	7%	7%	7%	7%	8%	8%	8%	8%	8%
		TP	8%	12%	17%	20%	20%	19%	19%	19%	18%	18%	18%	17%	17%	17%	16%	15%	14%	13%	13%	12%	12%	11%	11%	11%	11%	11%	11%	11%	11%	11%	12%
	Reduction on 2020 Emissions ($ktCO_2e$)	CE	2%	2%	3%	4%	4%	4%	3%	3%	3%	3%	3%	2%	2%	2%	2%	2%	1%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
		CN	6%	9%	13%	15%	14%	14%	14%	13%	13%	12%	12%	11%	11%	10%	10%	9%	8%	7%	7%	6%	6%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
		TP	8%	11%	15%	19%	18%	17%	17%	16%	16%	15%	15%	14%	13%	13%	12%	12%	11%	10%	9%	9%	8%	8%	7%	7%	7%	7%	7%	7%	7%	7%	7%

Appendix 4. Marginal Abatement Chart for York



Appendix 5. Methodology Explored

Sector	Measure	Application Data
Commercial	*Office T5 Lighting (conversions & new luminaries)*	kWh/m² - £2018 CAPEX/OPEX/EoL -
	Retail PIR Movement & Daylight Sensors	kWh/m² - £2018 CAPEX/OPEX/EoL -
	…	
Transport	*Private EV Penetration*	kWh/m² - £2018 CAPEX/OPEX/EoL -
	Public EV Buses	kWh/m² - £2018 CAPEX/OPEX/EoL -
	…	
Domestic	*Detached House Cavity Wall Insulation*	kWh/m² - £2018 CAPEX/OPEX/EoL -
	High-Rise Flat Draught Proofing Measures	kWh/m² - £2018 CAPEX/OPEX/EoL -
	…	
Industrial	*Boilers/Steam Systems Upgrades*	kWh/m² - £2018 CAPEX/OPEX/EoL -
	Furnaces/Process Heaters Improvements	kWh/m² - £2018 CAPEX/OPEX/EoL -
	…	



The figure above displays, at a high level, the methodology applied in this analysis. First, thorough evaluation of many hundreds of application-specific interventions was undertaken to develop data on what each measure will institute in energy savings (across several energy vectors), and the costs involved in its application and lifecycle. Next, lifecycle energy and cost savings are applied to reliable projections for market prices, costs, energy vector by type, emissions factor by source, and a variety of other economic and environmental variables over time. The ongoing productivity and savings of each intervention can then be then 'scaled-up' to the local conditions for deployment potential and place-specific penetration available in York's context – the number of houses (by type) recommended a certain measure year-on-year, area of commercial building judged suitable, possible percentage mode-shift in transport journeys, etc. This process enables the carbon savings attributable to each intervention (specific to York) to be aggregated into the sectoral, and ultimately city-wide outputs.

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PCAN PLACE-BASED CLIMATE ACTION NETWORK

UNIVERSITY OF LEEDS

Centre for Climate Change Economics and Policy

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