DRAFT VERSION

The Economics of Low Carbon Cities: Achieving Net Zero in the City of Edinburgh

Summary Report

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Executive Summary

The Economics of Low Carbon Cities: Achieving Net Zero in the City of Edinburgh

Edinburgh has declared a 'climate emergency' and set ambitious targets for reducing emissions to zero by 2030, with a hard-target for 2037. The following summary report evaluates Edinburgh's specific potential for reducing emissions, in respect to these targets, for hundreds of interventions across 4 crucial sectors of Edinburgh's economy: domestic housing, public and commercial buildings, transport, and industry. These interventions could significantly reduce emissions and are modelled precisely to the particular characteristics of Edinburgh's economy, demography, infrastructures and built environment.

Our full analysis will follow this summary report and is informed by the 'Stern' methodology of evaluating the scale of cost, energy and emissions impacts these measures could institute when applied in Edinburgh. Interventions are 'ranked' on their cost- and carbon-effectiveness as investments and a case can be made for the prioritisation of certain interventions in a very specific context for Edinburgh. This report focusses on the city as a whole, and determines the emissions pathways and decarbonisation opportunities that the city can institute at a high-level; the investment observations here do not apply to any one institution or organisation (they do not focus on City of Edinburgh Council specifically), but to Edinburgh as a **collective**. We find that:

- Despite reducing emissions by 40.3% since 2001 to 2.51MtCO_2e, without significantly scaling-up climate action Edinburgh will still emit 2.23MtCO_2e in 2030 and 2.14MtCO_2e in 2037. These are reductions on present levels of only 11% and 15% respectively. Related to this, Edinburgh's current 'energy bill' across the city will increase from £831M at present to £1.03B in 2030 and £1.19B in 2037.
- Instead, Edinburgh's present emissions can feasibly be reduced by 56% in 2030 through cost effective measures that produce net returns over their lifetimes. This is an improvement of 45% on the 'Business as Usual' scenario whilst delivering £550M of annual energy cost savings across the city.
- 2019 emissions levels can be reduced by an increased 62% in 2030 through cost neutral measures which would deliver no net cost to the city economy over their lifetimes. This is an improvement of 51% and would deliver £566M in annual energy cost savings in Edinburgh as a whole.
- By exploiting the full technical potential of measures available to Edinburgh, irrespective of cost, present emissions levels can be reduced by 67% in 2030 and generate £586M in annual energy cost savings.
- These programmes of emissions reductions could feasibly produce between 7,000 and 18,000 new years of employment in the city whilst delivering multiple symbiotic benefits in cleaner air, reduced congestion, increased productivity, health benefits and stimulating innovation in Edinburgh's economy.
- However, even whilst exploiting its full technical potential in these sectors Edinburgh would still emit in excess of 821ktCO_2e in 2030. This shortfall, although greatly reduced from the 'Business as Usual' scenario, will likely require further innovation, policy development and investment mechanisms to ameliorate.

There is, in short, a clear evidence-based argument for progressive action on energy efficiency and emissions reductions in Edinburgh. The city can make significant progress towards its ambitious climate targets in a manner that delivers returns to the city economy, employment opportunities, and increased energy security; these actions also need to be taken swiftly and decisively, across many stakeholder groups and institutions in the city.

Introduction

Energy use, populations, and economies are concentrated in cities, meaning the opportunities for climate action often accumulate in cities too. Alongside with this concentration, local city stakeholders need reliable place-relevant evidence before they can decide which of the thousands of low-carbon options they should focus on. A lack of information and transparent, robust data limits the extent to which cities can generate a case for action spanning economic, social, political and environmental bounds.

This summary report sets out the longer term trends in energy use and carbon[1] emissions for different sectors in Edinburgh. It evaluates a long list of the measures that homes, businesses, communities and individuals could take to reduce carbon emissions. Ranging from changing light bulbs to upgrading factories, our analysis assesses both the economic and the climate case for interventions separately, and for wider programmes of implementation across the city. Individually, many of these actions have only a small impact on energy use and carbon emissions. Edinburgh after all, is a city of more than 500,000 people, with an economic output or Gross Value Added (GVA) of around £20 billion and total annual expenditure on energy of over £830M. Our analysis has even shown that by 2030 Edinburgh's 'energy bill' will rise to £1.027B and £1.194B in 2037. Collectively, however, thousands of small actions - and a few large ones - could generate substantive reductions in energy use, bills, and emissions. The collective, systemic effect of action at city-scale could also lead to significant benefits more broadly in Edinburgh as will be shown.

By evaluating the viability of these options, the following report highlights numerous opportunities facing Edinburgh; it also begins to clarify the challenges that will need to be overcome if these opportunities are to be realised. Low-carbon measures can require large investment, increased coordination and cooperation between city stakeholders, and (occasionally) transformative changes to the ways we live and work together. This analysis shows that the benefits of change can far outweigh the costs – a low-carbon future for Edinburgh will not just improve the global climate but create jobs, reduce energy bills, clean our air and fight fuel poverty. This vision of Edinburgh's future positively drives the city towards being a happier, healthier, more inclusive and more prosperous city. Our methodology provides hard-nosed evidence of this.

In the words of Edinburgh Council, the following investment case for low-carbon intervention can "…safeguard the health and wellbeing of current and future generations, as well as the sustainable prosperity of the city as a whole".

Edinburgh's Economy & Energy:

Edinburgh uses **9,955GWh** of energy costing around **£831.12M** every year.

This will grow to
£1.03B in 2030 and
£1.19B in 2037.

1 This report uses CO_2e as a measure of emissions combining a suite of 6 Kyoto Greenhouse Gases Edinburgh emits. Where the terms 'carbon', 'carbon emissions', 'emissions', etc. are used they refer consistently to the CO_2e measure as a unit of anlaysis.

Approach to the Analysis

Drawing on modelling techniques that were developed by the Centre for Climate Change Economics & Policy[1] and have been employed in multiple cities around the UK and in more than a dozen global cities, this analysis draws on both national and local information and data to understand the economics of climate action in Edinburgh[2]. The analysis proceeds in three steps:

First, data is collected to understand the landscape of energy use and emissions in Edinburgh, both in recent years and into the future. This involves understanding trends in both population and the economy in Edinburgh, as well as the state of current building stock and transport networks, using local and national data to project how these might change in the future. Second, a long list of the possible actions to reduce energy use and carbon emissions in the domestic, commercial, industrial, and transport sectors is refined for the local context; during this process some actions that are not locally relevant are removed whilst other new actions are added. Following this, the economic case for and the carbon impacts of actions are assessed individually using local costs and potential rates of deployment. Finally, actions are combined into scenarios to understand the extent to which the city as a whole can reduce energy use and carbon emissions. These scenarios take into consideration the complex interactions between measures, and between sectors.

Three scenarios are then developed. The 'Cost-Effective' scenario includes the set of profitable actions with a positive net present value, meaning their benefits more than offset their costs over their lifetime with discounting incorporated. The 'Cost-Neutral' scenario generates the largest carbon savings without generating a net cost; here, the benefits of all the measures equal their costs, so that the net present value is approximately zero. Finally, the 'Technical-Potential' scenario includes all measures that could generate carbon savings, regardless of their costs and benefits. While the economic case for this scenario is assessed, the scenario itself reflects what could technically be done to cut energy use and carbon emissions across the city of Edinburgh in the sectors presented here.

Our analysis includes both Scope-1 emissions, meaning those emitted by using fossil fuels within the city, and Scope-2 emissions that come from the use of energy within the city. Together, these are known as territorial emissions. For this analysis, we exclude Scope-3 emissions, or those emissions that come from the supply of goods and services consumed in the city, minus the emissions from goods and services produced in the city but consumed elsewhere. It is important to note that there are certain sources of emissions that this summary report does not currently build into its analysis, including the aviation sector. These emissions are known as consumption-based or extra-territorial emissions and are a significant source of Edinburgh's total CO_2e output but are complex in their modelling and presentation. Further analysis and our final report have the capacity to extend sectoral analysis of Scope-1 and Scope-2 emissions to waste and other sectors, but they are not considered here as the vast majority of territorial emissions are contained within the following sectors.

Importantly, this executive summary does not present the portfolio of recommended investments and interventions analysed on an attributional basis; there is no 'filter' here that discerns which assets The City of Edinburgh Council (or any other organisation situated within the city Local Authority) has control over. As such it represents a **high level**, **city-wide perspective** on the necessary suite of actions to decarbonise Edinburgh as an economy and society. Organisations and institutions across the city will necessarily have to increase present levels of collaboration, strategy formation and data-collection in efforts towards these targets; the full form of this analysis may help serve as an object document informing the 'pooled' efforts of stakeholders across the city.

[1] Gouldson AP, Colenbrander S, Sudmant A, McAnulla F, Kerr N, Sakai P, Hall S, Papargyropoulou E, Kuylenstierna J. 2015. Exploring the Economic Case for Climate Action in Cities. *Global Environmental Change*. **35**, pp. 93-105
[2] Available from: http://www.climatesmartcities.org/

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 -
	…	

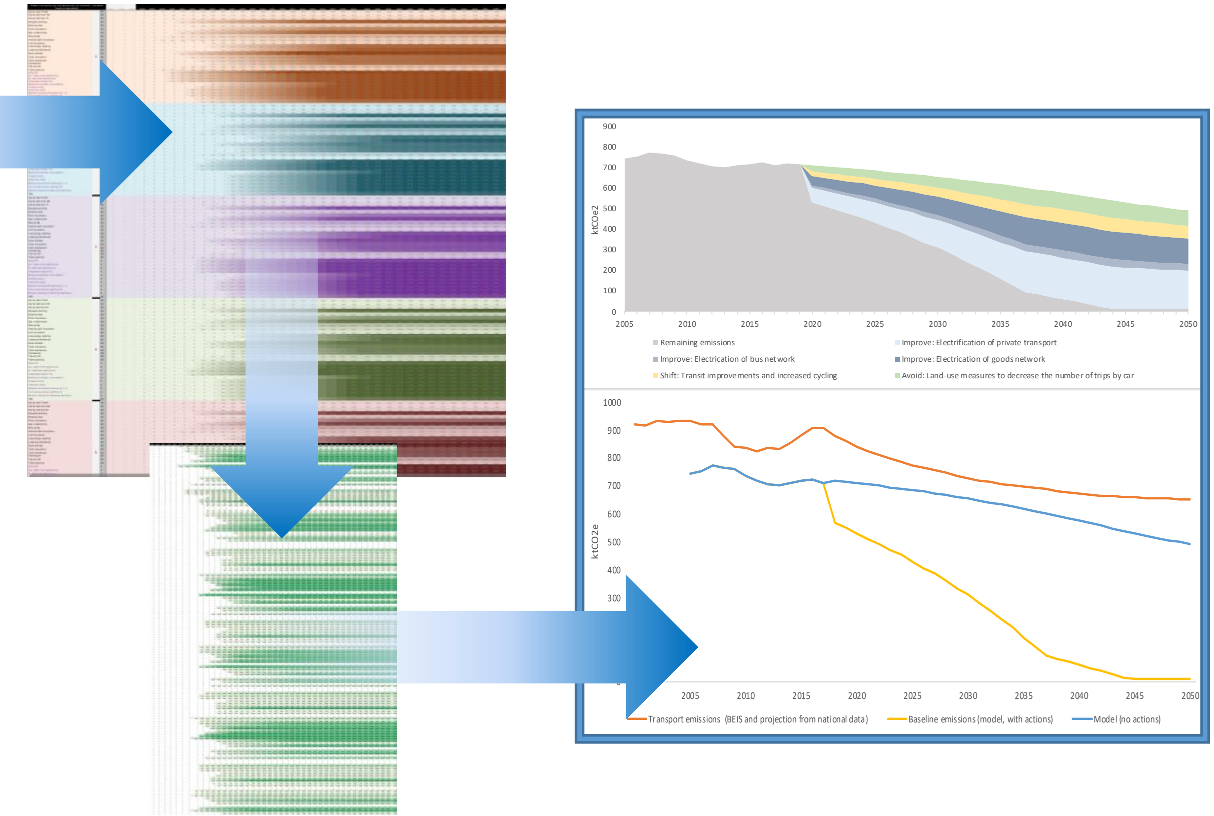


Figure.1: *Methodology Overview*

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 Edinburgh'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 Edinburgh) to be aggregated into the sectoral, and ultimately city-wide outputs, seen below.

Baseline Emissions: Sources and Targets

Our analysis shows that annual territorial emissions peaked in Edinburgh at 4.23MtCO_2e in 2001. Largely as a result of decarbonisation of the electricity grid, improving vehicle efficiencies and reduced energy use in homes and offices, this baseline has declined by 40.3% in the period between 2001 and 2019 where output reaches 2.51MtCO_2e. However, this rate of decrease is expected to diminish in the near future and without further action at the national or local levels, Edinburgh will not meet its carbon reduction targets. Edinburgh's target of net-zero emissions by 2030 will be missed by approximately 2.23 MtCO_2e, and the hard-target of net-zero emissions by 2037 will be missed by 2.14 MtCO_2e. In short, without significant additions of local actions the 'Business as Usual' projections hold Edinburgh to a course far off-target from the net zero aims.

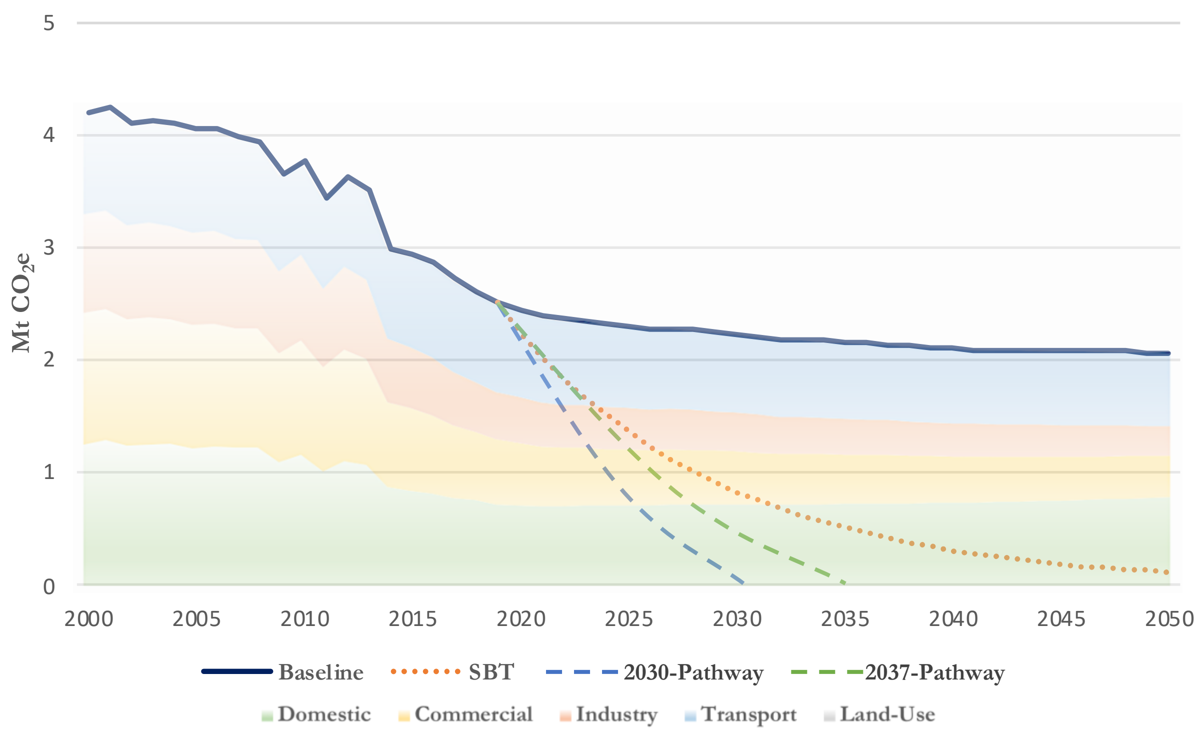


Figure.2: *Baseline & Sectoral Emissions with Future Target Pathways*

Baseline emissions (shown in *Figure.2* above in **dark blue**) aggregate Edinburgh's sectoral emissions from Scopes 1 & 2 on an annual basis (shown in shaded areas). They demonstrate an overall downward trend which flattens beyond 2030.

In contrast to the baseline, three future target pathways are presented above. A 'Science Based Target' (SBT) for Edinburgh is shown in **dotted-orange**, which projects Edinburgh's per capita contribution over time towards the IPCC's recommended target of a 66.7% chance of avoiding 1.5C warming in global temperatures[A]. It provides context to the scale of emissions reductions required at a global level. The **blue** and **green** dashed lines display projected emissions-pathways following Edinburgh's 2030 and 2037 net-zero

[A] Global Mean Surface Temperatures (GMST) targets. Visually, all three target-pathways provide a useful illustration of how far cross-sectoral decarbonisation in Edinburgh must intensify and of how ambitious the 2030 and 2037 targets are in absolute terms.

As mentioned above, between 2001 and 2019 the decarbonisation of Edinburgh's electricity supply has been a major contributor to overall emissions reductions; in fact, year on year percentage reductions in emissions from electricity supply are approximately 5 times greater than from any of the sectors considered in this report. Much of the progress in decarbonising Edinburgh has ultimately been achieved through this largely exogenous process, despite the many significant initiatives in sustainability across the city.

In 2019, the transport sector represented the largest sectoral contribution to emissions in Edinburgh, followed by the domestic and commercial sectors (see *Figure.3* below).

Edinburgh's Baseline Emissions:

Edinburgh's baseline emissions have declined by **40.3%** since 2001 to **2.51MTCO_2e** in 2019.

On this baseline Edinburgh will still emit **2.23MtCO_2e** in 2030 and **2.14MtCO2e** in 2037.

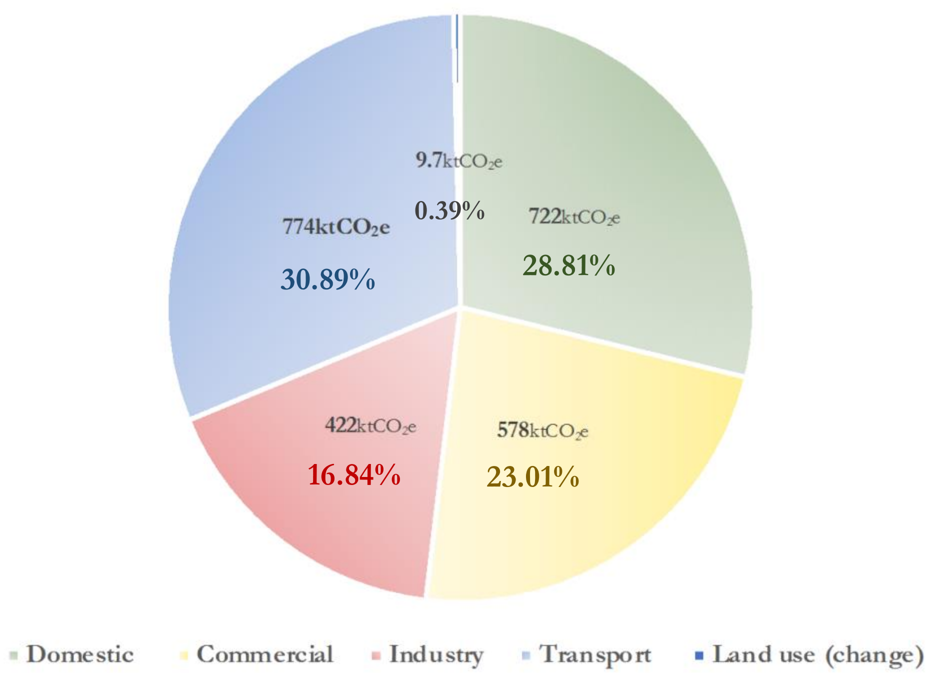


Figure.3: *Source of Emissions in 2019 by Sector*

For the purposes of this summary report, the focus of modelling has been on the **Domestic**, **Commercial**, **Transport** and **Industrial** sectors only. A full report potentially including additional sectors (*inter alia* Waste, Aviation, Land-Use, etc.) will proceed this draft analysis; the four sectors comprising Edinburgh's proposed carbon-reduction scenarios here represent the bulk of Scope 1 & 2 emissions in absolute terms, and as such the primary focus of efforts on decarbonisation.

The Potential for Reducing Carbon Emissions

Looking forward, our results show that the Edinburgh could substantially reduce its energy use and carbon emissions. More specifically, we forecast that by 2030 Edinburgh could reduce its 2019 levels of emissions by:

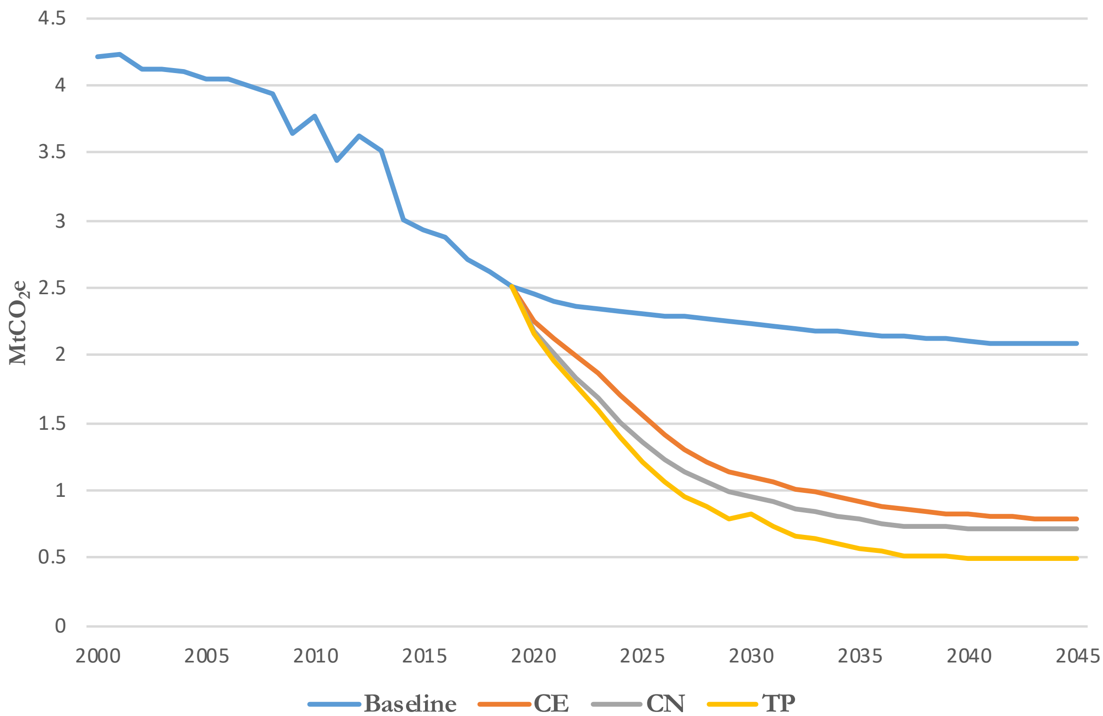


Figure 4: *Edinburgh's Emissions Under Baseline and Carbon-reduction Scenarios*

— 55.91% through **Cost-Effective (CE)** investments that would pay for themselves (on commercial terms) over their lifetimes. This would require an overall city-wide investment of £3.976 billion over the next 11 years, with these investments generating average annual savings of £550.173 million, paying back the investment in 7.455 years before generating further savings for the lifetime of the measures.

—61.83% through **Cost-Neutral (CN)** investments that could be realised at no net cost to the city's economy if the savings from Cost-Effective measures were captured and re-invested in further low Carbon measures. This would require a city-wide investment of £7.492 billion over the next 11 years, with these investments generating average annual savings of £566.285 million, paying back the investment in 12.538 years before generating further savings for the lifetimes of measures.

— 67.230% with the exploitation of the full **Technical-Potential (TP)** of the different measures. This would require a city-wide investment of at least £8.135 billion over the next 11 years generating approximate annual savings of £586.990 million, paying back the investment in 16.142 years and providing further savings over the lifetime of the measures. Even in this ambitious scenario, though, there remains a shortfall of around 821ktCO_2e in 2030 that needs to be mitigated by 'stretch options' - innovative new sectoral technologies, processes and efficiencies that are presently unavailable (or unreliable) to model here.

These results represent ambitious and internationally significant levels of investment into low-carbon and energy efficiency measures at city level, spanning several hundred separate interventions evaluated at similarly ambitious levels of penetration into each sector.

Reducing Sectoral Carbon Emissions

It is important to note that the results above represent the aggregation of sectoral outputs, and particular aspects of Edinburgh's economy and landscape are less obscured by evaluating each of the four sectors on its own terms; our final report will outline this sectoral breakdown in higher granularity. See page-12 for an overview and data on the performance of each sector.

Domestic Sector:
We find that Edinburgh's domestic sector remains (in relative terms) recalcitrant to emissions reductions efforts. Scotland's overall reliance on natural gas for heating provisions – and lack of substantive phasing and investment into the electrification and 'pooling' of heating resources – mean that provision of heat across the 8 domestic property categories modelled here is a consistent contributor to overall emissions. Cost-Effective and Cost-Neutral measures such as high efficiency combination boilers, insulation (wall, loft and floor) and thermostatic controls all reduce emissions significantly; there is however, a natural intrinsic emissions 'floor' to domestic heating without significant evolution in the sector.

The unique composition of Edinburgh's built environment also presents a challenge to decarbonisation. With approximately ¼ of Scotland's protected historic domestic building stock in-use, Edinburgh presents limits to the technical applicability of many cost effective energy-efficiency and energy production technologies. Indeed, 47.64% and 73.71% of domestic stock in Edinburgh was built before 1950 and 1985 respectively, inhibiting EPC recommendations for upgrades that could limit emissions attributable to heating provisions. For example, far less than half of domestic properties in Edinburgh can be applied effectively with cavity-wall, loft or floor insulation forms; 59.70% of properties currently have no wall insulation.

In respect to the high capital, land and infrastructural investments linked to property, the domestic modelling here has been evaluated with 'phasing' programmes of interventions across stock that roll-out portfolios of energy efficiency measures realistically and in respect to Edinburgh's housing and population projections; this phasing delays the absolute annual emissions reductions in the domestic sector slightly. In addition to this, discounting rates applied to this portfolio of investments are realistically applied to future energy savings in respect to the varying capital intensity and property-application of 217 separate interventions.

Emissions Reduction Scenarios:

Through measures that pay for themselves over their lifetimes, Edinburgh can mitigate:

56% of annual emissions saving **£550M** per year in energy costs.

Through measures that maximise potential for emissions reductions, Edinburgh can mitigate:

67% of annual emissions saving **£587M** per year in energy costs.

At around 2030 there is a significant 'dropping off' of emissions reductions modelled, both in the nationally-derived baseline, and in our carbon-reduction scenarios. This is a combination of many factors (projected increases in absolute house numbers, relative stagnation in gas emissions factors, etc.) but is largely attributable to the realisation of all eminently available efficiency gains in heating and lighting provisions. Whilst out with the scope of this summary report to detail, many of Edinburgh's characteristics contribute to this function: Edinburgh has a low-density domestic sector (55% the population density and 53% the property density of Glasgow); a protected and significant historic property stock; a dominant reliance on natural gas for heat.

Commercial Sector:

The commercial sector – referring here to the stock of public and commercial buildings in Edinburgh - has a lower emissions output than the domestic sector in absolute terms, and can also be seen as a more fertile ground for cost effective interventions in energy efficiency and small scale microgeneration of heat and electricity resources. This analysis considered the near-entirety of Edinburgh's office stock, retail, industrial/warehouse and non-retail commercial buildings, along with hotels/accommodation, healthcare facilities, educational facilities and leisure/community centre building types. Whereas there remains a high proportion of historic & protected building stock in-use within the public and commercial sector (in a national context), this does not exert the same cost-implications or represent as high a percentage of total floorspace as in Edinburgh's domestic sector.

Where our analysis of Edinburgh's domestic sector takes a property-level evaluation (each property is the unit of analysis for interventions), the public and commercial buildings sector is evaluated by area floorspace across 11 building types and a total portfolio of 219 separate measures. Across the sector, improvements to building fabric and air-tightness, along with significant investments in cooling system efficiencies across Edinburgh's office and retail space, contribute to a number of highly cost- and carbon-efficient measures across the sector.

Only 27.04% of Edinburgh's 1.85M m_2 office floorspace has been built since the year 2000, and as such ingrained with construction and fabric technology with inherently improved cooling and heating characteristics. In contrast, this analysis has found that there remains significant scope for technologically and economically efficient investments in heating and cooling in the remaining 39.65% of floorspace built since 1950. Measures such as SFP2.0l/s, chilled-beam components and chiller mechanisms are all highly efficient investments in reducing the Edinburgh's commercial emissions over time. Additionally, improvements to building fabric and air-tightness measures across the sector could realise high levels of emissions reductions over time and yield reliable returns through energy cost savings.

Transport Sector:

Transport, as is the case at a national level in Scotland, remains an obstinate source of emissions; we find that the sector presents nearly one-third of the total emissions considered in this methodology. Despite this, our analysis finds that up to 73% reductions in present emissions levels are possible with an ambitious programme of investment and public engagement. This involves adding over 2,000 electric vehicles to the private road network on an annual basis, implementing aggressive standards on maximum vehicle emissions standards across built-up areas and the city centre, and rapidly phasing-up systems of mode shift between transport types. For example, we find that it is possible to increase the passenger kilometres travelled by private electric vehicle to 28% of car use in Edinburgh by 2037 whilst increasing the electrification of 'vehicle kilometres' by van and HGV in the city by approximately 13%. Our programme specifies various measures such as increases in the work-days per person spent working from home (increased to a maximum of 1 per week in some scenarios) and increasing the percentage of trips made by bus and bicycle (c. 10% increase in mode share) and directly modelling the effects these changes have on 'car trips avoided'.

It is important to note that the modelling of demand reduction from fossil-fuel driven transport modes has a profound and (often) highly cost effective impact on the function of emissions reductions over time in Edinburgh. The emissions factors applied to the transport sector are representative of particulates and non-CO_2 greenhouse gases that usually exert a far greater 'radiative forcing' effect than carbon dioxide per unit energy consumed, and hence contribute hugely toward overall emissions reduction pathways.

See *Figure.5* overleaf for an immediate visual demonstration of how Edinburgh's particular characteristics in each sector contribute towards starkly different programmes of investment and carbon-reductions over time.

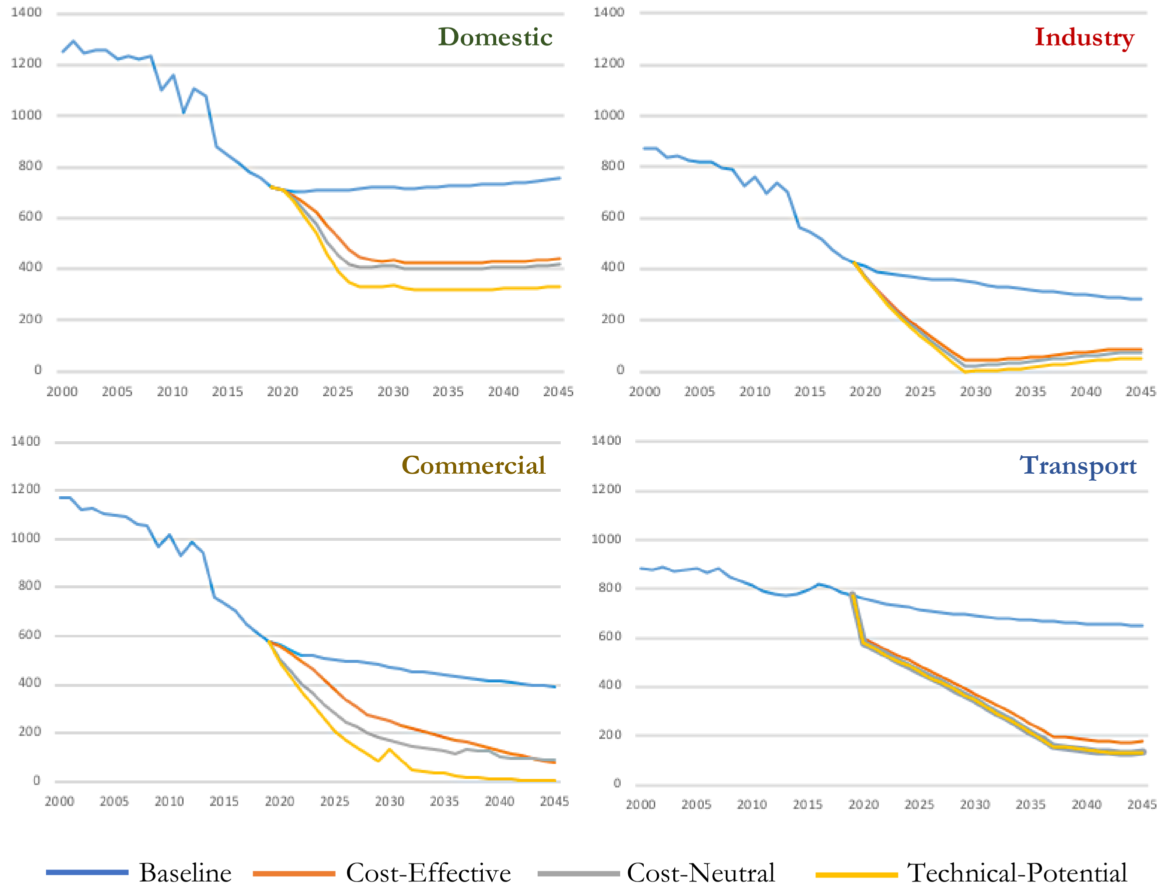


Figure.5: *Edinburgh's Sectoral Emissions Under Baseline and Carbon-reduction Scenarios*

Sector	**Carbon Reduction Scenario**	**% Reduction in Present Emissions by 2030**	**% Reduction in Present Emissions by 2037**
Domestic	Cost-Effective	39.04%	39.99%
	Cost-Neutral	41.97%	43.12%
	Technical-Potential	52.84%	54.60%
Commercial	Cost-Effective	55.31%	70.96%
	Cost-Neutral	66.04%	74.28%
	Technical-Potential	72.11%	96.73%
Industry	Cost-Effective	88.62%	83.02%
	Cost-Neutral	93.72%	87.27%
	Technical-Potential	99.83%	93.34%
Transport	Cost-Effective	37.77%	67.17%
	Cost-Neutral	40.64%	73.00%
	Technical-Potential	40.64%	73.00%

Table.1: *Edinburgh's Possible Percentage Reductions in Sectoral Emissions in 2030 and 2037*

The Scale of Challenge and Key Performance Indicators

It is important to note that the figures for deployment employed in this analysis are informed by multiple reliable sources determining the technical and practical scope for application of each intervention. Built-environment measures are guided by EPC recommendation percentages for each sub-category of sectoral building stock; transport values for penetration are informed by thorough literature review and previous analyses determining the latent capacity of urban transport infrastructures for decarbonising measures. The following table gives a small, general sense of the scale of deployment that our carbon-reduction scenarios envisage in practical terms **by the year 2037**:

Sector	Measure	Total Disaggregated Addition
Commercial	*T5 Lighting (conversions & new luminaries)*	1.926M m^2 *
	PIR Movement & Daylight Sensors	2.132M m^2 *
	Solar PV Installations	1.511M m^2 *
	Air tightness & Building Fabric Improvements	1.132M m^2 *
Transport	*Private EV Penetration*	38,633 (2,273 per year)
	EV Buses	3,391 (199 per year)
Domestic	*Cavity Wall Insulation*	22,278 homes
	Draught Proofing Measures	142,965 homes
	Low Energy Lighting Provisions	129,531 homes
Industrial	*Boilers/Steam Systems Upgrades*	13 measures **
	Furnaces/Process Heaters Improvements	7 measures **
	Cooling & Refrigeration Upgrades	7 measures **
	Motor-driven Equipment Upgrades	38 measures **

**Applies to GIA floorarea serviced by measure and not area of intervention itself*
***Applied city-wide involving 72 separate industrial processes*

Table.2: *Selection of KPIs Working Towards 2037 Carbon-reduction Pathways*

This is only a small sample of the scale of deployment required across hundreds of interventions, properties, and transport modes, achievable only through the combined efforts of multiple stakeholder groups (including the City of Edinburgh Council). In short, there is a hugely ambitious scale – and urgency – with which the recommended portfolio of cross-sectoral interventions must be instituted to even approximate an emissions reduction scenario close to the net zero targets for 2030 and 2037. Whilst the opportunities outlined here are all feasible and 'win-wins' for stakeholder groups across the city, they will require near-immediate and unequivocal support from institutions and the public.

Emissions-reduction Scenario	Cost per Tonne (£2018/tCO_2e)[1]
Cost-Effective scenario	-£125.53
Cost-Neutral scenario	-£44.21
Technical-Potential scenario	-£2.58

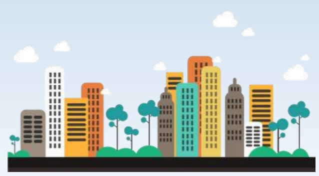
Table.3: *Summary of Emissions-Reduction Costs at City-Scale*

We predict that to meet its carbon reduction target for 2030, Edinburgh would have to at a minimum exploit the full technical potential of all of the energy efficiency and low-carbon options identified in this report, and also hope that a significant number of new options become available before 2030. Of course it is possible that new measures will be developed and become marketable in this period, along with new ways of unlocking existing potential, but this does highlight the scale of ambition that will be needed if Edinburgh is to meet its targets.

Scale of Challenge:

In order to maximise reductions of emissions in Edinburgh:

over **2,000 electric cars** need to be added to our roads every year
130,000 homes need to have energy efficient lighting fitted
over **1Mm^2** of commercial floorspace needs **fabric improvements**



[1] Discount rate applied to portfolio of measures averages approx. 5%. Arithmetic mean of cost per tonne applied across city-wide portfolio between sectors. Cost per tonne varies enormously across measures, hence the 3 programmes of carbon-reduction scenario outlined here (CE, CN & TP). Full analysis including discount-sensitivity programmes on application- and measure-specific basis will be outlined in full report.

Ranking Cost and Carbon Effective Options

The unique attributes of Edinburgh's building stock, transport network and socioeconomic demographics lead to a set of key opportunities for reducing emissions and generating economic returns. Among those opportunities to reduce emissions, heating and cooling in domestic, public and commercial buildings represent two of the areas with the largest potential. Among the opportunities where reducing carbon emissions generates net economic returns for investors, insulation of domestic buildings, investments in energy-efficient appliances and investments in the cooling of commercial buildings were found to present the largest opportunities, along with electrification of private car transportation in the city. A more explicit breakdown of these opportunities will be provided in the full version of this report – again, these measures are evaluated at city-level and not in respect to any individual organisation/institution.

Carbon Effectiveness	Potential Aggregated Carbon Savings	Category	Measure
Highly Effective	*>2.4 Mt CO_2*	Domestic Insulation Improvements	*Cavity-Wall*
			External Wall
			Floor & Suspended Floor
			Internal Wall
			Loft & Loft Top-Up
		Domestic Heating Provisions & Controls	*High-Efficiency Combination Boilers*
			Air-Source Heat Pumps
			Thermostatic Radiator Valves
			Thermostat Controls
		Commercial Cooling Mechanisms	*SFP2.0l/s*
			Passive Chilled Beams
			Chiller CoP5.4
		Office Building Stock Fabric Condition	*Fabric Improvements*
			Air Tightness Improvements
		Transport Electrification	*Private-EV Penetration (100% in 2037)*
Very effective	*880kt to 2.3Mt CO_2*	Domestic Electricity/Heat Demand Reductions	*Turning Unnecessary Lighting Off*
			Reducing Internal Temperature by 1C
			A++ Rated Cold Appliances
			A+ Wet Appliances
		Commercial Heating Provisions	*Air-Source Heat Pumps*
		Domestic Lighting	*Low Energy Lighting*

Table.4: *Summary of Most Carbon-Effective Interventions at City-Scale*

Cost Effectiveness	Potential Cost Savings	Category	Measure
Highly Effective	*>250 £2018M*	Domestic Building Stock Insulation	*Cavity-Wall*
			Loft & Loft Top-Up
		Domestic Demand Reductions	*A++ Rated Cold Appliances*
			A+ Wet Appliances
			A Rated Ovens
			Induction Hubs
			Low Energy Lighting
		Commercial Building Stock Improvements	*SFP2.0l/s*
			Chiller CoP5.4
			Air Tightness
			Fabric Improvements
			Low Energy Retail & Office Cooling Systems
		Domestic Heating Provisions & Controls	*High-Efficiency Combination Boilers*
			Heat Pumps
			Thermostatic Valve Controls
			Tank Insulation
Moderately Effective	*<25 £2018M*	Domestic Electricity/Heat Demand Reductions	*Turning Unnecessary Lighting Off*
			Reducing Internal Temperature by 1C
			A++ Rated Cold Appliances
			A+ Wet Appliances
		Commercial Building Stock Heating Provisions	*Air-Source Heat Pumps*
		Domestic Lighting	*Low Energy Lighting*
		Transport Electrification	*Private-EV Penetration (100% in 2037)*
			Electric Bus Penetration
		Industrial Processes & Equipment	*Pumping Equipment Upgrades*
			Compressed Air Systems
			Fan Improvements
			Boilers and Steam Piping Upgrades
		Commercial and Domestic Fabric	*Draught Proofing Measures*

Table.5: *Summary of Most Cost-Effective Interventions at City-Scale*

Impact on Energy Bills

We calculate that Edinburgh currently spends approximately £830M on energy each year, representing approximately 4.17% of city GVA*; furthermore, we estimate that by 2030 Edinburgh's 'energy bill' will rise to £1.027B, and £1.194B in 2037. Given the precariousness of global fossil-fuel markets (and the inherent benefits brought about by commercial resource efficiency) these are extraordinarily large values that are largely exported every year from the city economy.

Fuel Type	**GWh Demand (2017)**	**Energy Expenditure (£2018M)**
Coal & Solid Fuels	8.395	831.12
Manufactured Fuels	7.301	
Petroleum Products	2965.588	
Gas	4684.348	
Electricity	2230.554	
Bioenergy & Wastes	79.280	
Total	*9975.466*	

Table.6: *Edinburgh's City-Scale Energy Consumption & Expenditure*

Through evaluating population projections, BEIS data on energy consumption and markets over time, and several other sources, we find that:

- With investment in Cost-Effective measures at city-scale, the 2030 annual energy bill could be reduced by over £532M, or £953 per capita based on population projections over time.

- With investment in Cost-Neutral measures at city-scale, the 2030 annual energy bill could be reduced by over £535M, or £959 per capita based on population projections over time.

- With investment in the full range of Technical-Potential interventions at city-scale, the 2030 annual energy bill could be reduced by over £597M, or £1,070 per capita based on population projections over time.

This indicates that the City of Edinburgh could significantly enhance its energy security through investments in energy efficiency and low-carbon options.

* BEIS data on 2017 final energy-consumption by City of Edinburgh local authority used in conjunction with BEIS Annex-M energy prices by year (2017). Costs inflated using compounded economic growth factors to 2019 values; final energy-consumption extended by linear function and in correlation with Local Authority growth from 2017-19.

Impacts on Employment

Investments in low-carbon options in Edinburgh would have wider effects on the local economy. In particular, a substantial body of research has shown that investment in a low-carbon economy can generate new employment opportunities[2]. Using established employment multipliers based on sector-specific investment outcomes, we find that:

- Investments in Cost-Effective measures between 2018 and 2030 would generate nearly 7,300 years of extra employment in the city of Edinburgh[3].

- Investment in Cost-Neutral measures would generate more than 16,000 years of extra employment across Edinburgh.

- Investment in Edinburgh's maximum Technical-Potential for interventions would generate more than 18,000 years of extra employment in Edinburgh.

Within the overall time span until Scotland's binding 2045 net-zero emissions target, these figures could translate to the direct positive externality from investment of **292**, 642 or **723** permanent positions within Edinburgh's economy. It is important to note that changes in labour market conditions, technologies and the specifics of individual investments mean that these figures, while appropriate at a high level, cannot be applied to specific interventions rather than generalised sectors.

Employment Generation:

Investing in these low-carbon interventions at city-scale could generate between **7,000** and **18,000** new years of employment in Edinburgh.

	Domestic	Industry	Transport	Commercial	Total
Cost-Effective investments	2,988	830	2,723	750	**7,291**
Cost-Neutral investments	4,984	2,085	5,816	3,169	**16,054**
Technical-Potential investments	6,430	4,593	5,062	1980	**18,065**

Table.7: *Net Jobs (years of employment) Created 2020-2030*

2 Blyth, W., Gross, R., Speirs, J., Sorrell, S., Nicholls, J., Dorgan, A., & Hughes, N. (2014). Low carbon jobs: The evidence for net job creation from policy support for energy efficiency and renewable energy. *London: UK Energy Research Centre*.
3 These are net jobs, after internalising losses within energy sectors; they include local jobs only, assumed to be 50% of the total employment generated.
5 (*Overleaf*) Von Stechow, C., McCollum, D., Riahi, K., Minx, J. C., Kriegler, E., Van Vuuren, D. P., ... & Mirasgedis, S. (2015). Integrating global climate change mitigation goals with other sustainability objectives: a synthesis. *Annual Review of Environment and Resources*, *40*, 363-394.

Conclusions and Recommendations

From their peak in 2001, Edinburgh's emissions from using fossil fuels and electricity have declined 40.3%, or 6.12% per year on a per capita basis. This reduction, whilst undeniably a positive trend, is largely attributable to three factors: (*1*) exogenous decarbonisation of the national electricity grid, (*2*) improved energy efficiency in homes and vehicles, and (*3*) changes in the economic composition and social demography within Edinburgh. Looking forward to 2030, Edinburgh's emissions are projected to decline only modestly, with the economy and population growing substantially. Our analysis shows that Edinburgh could do more, that positive actions could generate significant economic benefits, and that *ceteris paribus* Edinburgh will need to rapidly and profoundly intensify investments in low-carbon technologies and energy efficiency if it is to meet its emissions targets.

Cost-Effective actions could reduce expenditure on energy by more than £532M in 2030 and generate hundreds of new long term jobs – many in areas that require specialised skills and that are well paid. Adoption of the energy saving and low-carbon options investigated here could also generate a large set of additional social, environmental and economic benefits, such as improved public health, reduced energy poverty and improved economic productivity. Investments in all of the Cost-Neutral and Technically-Possible measures would provide a smaller economic return, but could result in even greater reductions in expenditure on energy, larger numbers of new jobs, and an even greater impact on public health, energy poverty, and economic productivity.

Our results also demonstrate that Edinburgh can feasibly work towards its contribution to national (Scottish and UK) carbon reduction targets at low cost. At a national scale Scotland has evolved policy from UK commitments to 80% emissions reductions by 2050 from 1990 levels, to net-neutrality in 2045 guided by similarly progressed 5-year Carbon budgets. Whilst significant challenges remain in developing programmes of investment toward this goal, Edinburgh remains well placed to realise rapid cross-sectoral decarbonisation within the next 10 years through the portfolio of investments outlined here. This would leave the city economy in an appropriate stage of efficiency to plan and take future, more profound actions towards a net-zero target.

Meeting the more ambitious emissions targets set in conjunction with the declaration of a 'climate emergency', however, may be more challenging. Edinburgh's 2030 net zero emissions target would require in excess of 821ktCO_2e reductions beyond those identified in the maximum Technical-Potential scenario outlined here. To put this shortfall in context, it is greater than the current emissions outputs from Edinburgh's entire transport sector, and only marginally smaller than all industrial and commercial emissions in Edinburgh *combined*. Further reductions in emissions could be achieved with greater coordination between national government, businesses and citizens of Edinburgh, and other local authorities and regions. Emissions from commuters to Edinburgh from the central belt could be reduced if the regional transport network were improved, and minor changes in the emissions intensity of electricity and gas networks could substantially influence emissions in Edinburgh, but are only possible at the national level.

The challenge Edinburgh faces in meeting its 2030 target also emphasises the need for carbon reduction strategies to be dynamic and ongoing processes. Technological change will bring new options for reducing emissions, and may lower the cost of existing options. In the transport sector the effect of technological change on the price of electric vehicles is one area that could have a dramatic impact on emissions, as could the adoption of novel heating systems involving pooled resources and potential Hydrogen use within the city's domestic and commercial sectors. These new approaches, however, would benefit enormously from the investment stimulated and pathways forged by the lower risk, win-win measures outlined in this report.

Edinburgh needs to act – *swiftly* and *decisively* – if it is going to realise the economic, social and environmental potential of a low-Carbon transition.

Appendix: Example Table of Measures Considered

Domestic Sector	Wind turbines (5-20kW); Photovoltaic generation; Biomass boilers; Electronic products; ICT products; Integrated digital TVs; Reduced standby consumption; Reduce heating for washing machines; A++ rated cold appliances; A-rated ovens; Efficient lighting; A-rated condensing boiler; Insulate primary pipework; Glazing – old double to new double; Uninsulated cylinder to high performance; Glazing – single to new; Insulated doors; Reduce household heating by 10C; Induction hobs; Loft insulation 0 – 270mm; Cavity wall insulation (various types); Improve airtightness; DIY floor insulation (suspended timber floors); Loft insulation (varying depths & property types); Loft insulation (varying depths & property types); A+ rated wet appliances; Turn unnecessary lighting off; Installed floor insulation (suspended timber floors); Room thermostat to control heating; Thermostatic Radiator Valves; Paper type solid wall insulation; Modestly insulated cylinder to high performance; Air source heat pump with RHI; Micro wind turbines (1kW); Hot water cylinder thermostat; Solar water heating with RHI.
Public & Commercial Buildings	Energy Management of Various Commercial Appliances; Most energy efficient monitor PC only; Most energy efficient monitor; PIR Movement Sensors; Lights – turn off lights for an extra hour; Lights – sunrise-sunset timers; Lights – basic timer; Heating – more efficient air conditioning; Lights – light detectors; Stairwell timer; Compressed air; Presence detector; Heating – programmable thermostats; Heating – optimising start times; Heating – reducing room temperature; Biomass boilers with RHI; Most energy efficient fridge-freezer; Heating – TRVs fully installed; Most energy efficient flat roof insulation; Heating – most energy efficient boiler; Lights – IRC tungsten-halogen – spots; Air source heat pump; Ground source heat pump; Lights –replacement 26mm; Motor – 4 pole motor – EFF1 replace 4 pole; Solar thermal systems
Industrial	Burners; Drying and separation; Refrigeration and air conditioning; Lighting; Compressed air; Heat recovery with RHI; Design; Low temperature heating; Renewable heat with RHI; Building energy management; Space heating; New food and drink plant; High temperature heating; Fabrication and machining; Operation and maintenance; Controls; Energy management; Process improvement; Ventilation; Information technology; Motors and drives; insulation.
Transport	Mode-shift towards cycle trips; Private EV increased penetration; Park and ride; Express bus network; Bus priority and quality enhancements; Smarter choices; Cycling; Demand management; Mild hybrid; Plug-in hybrid; Full hybrid; Biofuels; Micro hybrid; Electric; New railway stations; Rail electrification.

* Industrial measures are based on the grouping of thousands of different measures into broader categories to aid analysis and presentation.
**Table is indicative and for illustrative purposes, omits certain measures.