Net Zero Cambridgeshire

What actions must Cambridgeshire County Council take
to reach net zero carbon emissions by 2050?

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Executive Summary

Cambridgeshire and Peterborough have a responsibility to do all they can to contribute to the 2050 target for net zero UK greenhouse gas emissions. This is a task for all levels of government, and this report sets out the shape of that challenge for Cambridgeshire and Peterborough: reducing emissions from the current 6.1 million tonnes (Mt) of carbon dioxide equivalent (CO_2e) per year to zero.

Domestic homes contribute 1280 thousand tonnes (kt) of CO_2e or 21% of current Cambridgeshire and Peterborough emissions, arising from energy used for heating and appliances. Under ambitious decarbonisation of heat and improvements to the energy efficiency of the housing stock, domestic emissions are forecast to fall by 91% by 2050. This would require swift roll out of low-carbon heating technologies, including hybrid heat pumps and district heating.

Transport accounts for 39% of emissions in Cambridgeshire and Peterborough and emissions have stayed constant for the last 10 years. An ambitious strategy that requires 100% of cars, LGVs, buses and motorcycles as well as 91% of HGVs to be electric by 2050 will reduce transport emissions to 81 kt CO_2e. Electrification of vehicles is not the only solution to decarbonising transport, and other measures that encourage shifting transport away from cars to walking, cycling and public transport must also be included.

Agriculture currently contributes 405.5 kt CO_2e per year, or 7% of Cambridgeshire and Peterborough's emissions, but much of the emissions in agriculture are difficult to abate. In the 2050 ambitious scenario emissions are estimated to be 239 kt CO_2, which is 40% of total residual emissions. Achieving the 2050 ambitious scenario involves a significant reduction of food waste, reduction of demand for red meat and dairy by 20%, and on farm measures such as increased fertiliser efficiency, breeding measures, and livestock food additives.

Commercial Services and Industrial emissions account for 27% of current emissions in Cambridgeshire and Peterborough, and have decreased from 2543 kt in 2005 to 1660 kt in 2016. The lowest emissions which could be achieved through an ambitious abatement strategy are 137 kt CO_2e. Implementation of low carbon heating and carbon capture and storage are vital for achieving this reduction.

Waste management contributes around 2% of current Cambridgeshire and Peterborough emissions (107 kt CO_2e) with emissions from the Waterbeach landfill and compost sites and Peterborough energy recovery facility. In an ambitious scenario net emissions are 29 kt CO_2e. Deployment of carbon capture storage, increasing capture of landfill and compost gas emissions and electrification of waste transport are considered and identified as priorities.

Afforestation as a means to reduce Cambridgeshire and Peterborough's net emissions has been explored extensively in this report. Land use, land use change and forestry (LULUCF) currently account for 4% of emissions. Abatement costs of £15-50 per tonne CO_2e and total CO_2 sequestration were calculated for various scenarios. Afforestation has the potential to play a role in helping to achieve net zero and the scale of afforestation required is calculated.

Peatland emissions are not currently counted in the emissions inventory, but could significantly affect Cambridgeshire's reported emissions - increasing them by as much as 90%. Whilst this is technically just a change in accounting, it does highlight the need for further research on peatland emissions and to prioritise the restoration and preservation of the area's peatland. In time and with the correct investment, peatland has the potential to change from a net emissions source to a net sink. Cambridgeshire has the opportunity to be a leader in the effective restoration of peatland, an activity which will be important for climate change mitigation efforts all over the world, and thus the county could potentially have an impact on climate change mitigation at an international level.

Projections show business as usual will lead to 2050 emissions of 3.5 million tonnes (Mt) of CO_2e. Under the ambitious decarbonisation strategy laid out in this report, emissions will still be 0.6 Mt CO_2e in 2050. In order to reach net zero, Cambridgeshire and Peterborough must offset these remaining emissions from the above sectors by some mix of afforestation, bioenergy with CCS, direct air capture with CCS, demand reductions, peatland restoration, and future unknown technologies.

This report provides an emissions baseline against which Cambridgeshire and Peterborough can measure their performance. In order to achieve net zero, Cambridgeshire and Peterborough must build on the existing support for climate action and go above and beyond their legal obligations. Importantly, both the district and county councils will need to consider the emissions impact of every future policy decision, from health to transport, and from buildings to waste. Now is the time for Cambridgeshire and Peterborough to be leaders in the global effort to tackle climate change.

Acknowledgements

We are all immensely grateful to have been given the opportunity to work on this really interesting project. Over the course of this project we have received assistance from a wide range of people from the County Council, District and City Councils and from others organisations.

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NOMENCLATURE

BECCS	Bio-energy with Carbon Capture and Storage
BEIS	Department for Business, Energy & Industrial Strategy
CCC	Cambridgeshire County Council
CCC RE	Cambridgeshire County Council Rural Estate
CCS	Carbon Capture & Storage
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CPCA	Cambridgeshire and Peterborough Combined Authority
DACCS	Direct Air Carbon Capture and Storage
DEFRA	Department for Environment, Food & Rural Affairs
EEFM	East of England Forecast Model
EEP	Energy and Emissions Projections
EFW	Energy From Waste
ERF	Energy Recovery Facility
GHG	Greenhouse Gas
GWP	Global Warming Potential
kt	Metric kilotonne (1 kt = 1000 t)
LFG	Landfill gas
LULUCF	Land Use, Land Use Change & Forestry
MBT	Mechanical Biological Treatment
MRF	Material Recovery Facility
Mt	Metric megatonne (1 Mt = 1,000,000 t)
N_2O	Nitrous Oxide
NAEI	National Atmospheric Emissions Inventory
NET	Negative Emissions Technology
PCC	Peterborough City Council
t	Metric tonne (1000 kg)

WCC	Woodland Carbon Code

Global Warming Potential

The Global Warming Potential (GWP) of a chemical species is a measure of how efficient the species is at trapping heat in the atmosphere relative to carbon dioxide. The main greenhouse gases (GHG) considered in this report were carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). For this report, GWP values for a 100 year time horizon were considered. By definition, CO_2 has a GWP value of 1 while methane and nitrous oxide have values of 34 and 298 respectively[1] which include atmospheric feedbacks. To allow for comparison between emissions of different GHGs, methane and nitrous oxide quantities were multiplied by the relevant GWP values to yield units of carbon dioxide equivalent (CO_2e). All final quantities of GHGs are quoted in terms of CO_2e.

Population Forecasts

A population growth forecast from Cambridgeshire Insight[2] (up to 2036) was used. The population projection from 2036-2050 was calculated from a linear fit from years 2031-2036 of the Cambridgeshire Insight projections.

Projections

The collation of data on the current situation, the future projections and the suggestions for mitigation discussed in this report have been done in the best possible faith and are accurate to the best of the authors' knowledge. However, unforeseen factors and circumstances in the present or future could change the accuracy of these statements. This report is intended to serve as a guide.

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[1] Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

[2] Cambridgeshire Insights https://cambridgeshireinsight.org.uk/population/

1. INTRODUCTION

The environmental impact of climate change raises concerns about greenhouse gas emissions at a global, national and local authority level. Forward-looking climate commitments in Cambridgeshire and Peterborough lay the groundwork for achieving significant emissions reductions by 2050, in line with contributing to the UK's fourth and fifth carbon budget. Cambridge City Council, South Cambridgeshire Dsitrct Council and Cambridgeshire County Council announced climate emergencies in May 2019 while Peterborough City Council did so in July. Furthermore, Cambridgeshire County Council recently signed the UK100 pledge to supply 100% of energy using clean sources by 2050. This successful track record of support for climate policies offers an opportunity for Cambridgeshire and Peterborough to be a trailblazer for county-led mitigation in the UK.

Emissions forecasts establish baseline predictions and provide a tool for assessing the impact of climate policies. The Department for Business, Energy and Industrial Strategy (BEIS) provides emissions predictions for the UK,[3]. However, there is no in-depth analysis at a local authority level. This report provides detailed forecasts for emissions arising in Cambridgeshire and Peterborough. The forecast includes the emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), which together contribute 97% of nationwide emissions, when weighted by global warming potential.[4] The remainder of nationwide emissions are from fluorinated gases.

Fluorinated gases ("F-gases") are a range of man-made compounds used in a variety of industries including refrigeration, air-conditioning and the manufacture of cosmetics, pharmaceuticals, electronics and aluminium. F-gases are extremely potent greenhouse gases with some having GWPs of several thousand or more[5]. Most emissions of F-gases in Cambridgeshire and Peterborough are hydrofluorocarbons (HFCs) which are used as refrigerants in the food industry. The biggest food company in Cambridgeshire and Peterborough, Hilton Food Group PLC (which contributes 61 % of employment in the food industry), have disclosed total emissions from "on-site processes" (which would include F-gas emissions - scope 1 from DEFRA[6])) of between 4,000 and 10,000 tonnes of CO_2e over the last 3 years[7]. Scaling the national F-gas emissions[8] based on the population yields 106,000 tonnes of CO_2e yet as Cambridgeshire does not have significant heavy industry, this figure is unlikely to be representative and the 2016 figure of 3,987 tonnes of CO_2e from Hilton is used (around 0.07% of total County emissions) and assumed to remain constant in future. It is possible that there are other sources but they are likely to be negligible compared to the Cambridgeshire and Peterborough's total emissions.

Forecasts are separated into sectors and districts where possible. They build from current data on emissions and demand, to provide an estimate of emissions in 2050. Two scenarios

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[3] BEIS. (2019). Energy and emissions projections. Retrieved from www.gov.uk/government/collections/energy-and-emissions-projections

[4] BEIS. (2019). 2017 UK Greenhouse gas emissions, final figures.

[5] BEIS. (2019). Greenhouse Gas Reporting Conversion Factors

[6] DEFRA. Environmental Reporting Guidelines Including Mandatory Greenhouse Gaas Emissions Reporting Guidance

[7] Hilton CSR Report 2018, P10)

[8] BEIS. (2019). 2017 UK Greenhouse gas emissions, final figures

are presented. Firstly, the 2050 Baseline Scenario projects emissions under business-as-usual. This scenario assumes no action is taken other than already legislated or planned at a national level. Secondly, the 2050 Ambitious Scenario assumes an aggressive decarbonisation at a national and local authority level. The specific assumptions for the Baseline and Ambitious Scenarios are given in the relevant sections below.

This report is structured as follows. The remainder of this section provides historic data for Cambridgeshire and Peterborough, and briefly reviews the national and county-level emissions reduction strategies. Sections 2 - 6 present Baseline and Net Zero emissions forecasts for the six sectors of the county economy: domestic buildings, commercial services and industry, transport, agriculture and waste. Section 7 explores options for achieving negative emissions through afforestation, and Section 8 describes how the county could close the gap between the Ambitious Scenario and net zero emissions by 2050.

1.1. EMISSIONS IN CAMBRIDGESHIRE AND PETERBOROUGH

Greenhouse gas emissions in Cambridgeshire and Peterborough were 6.1 megatonnes (Mt) CO_2e in 2016[9], 1.6% of the UK's total emissions. BEIS currently provides detailed emissions data on local authority emissions of carbon dioxide, but does not provide data on emissions of other greenhouse gases. Nationwide, emissions of CO_2 make up 81% of GHG emmissions, with the remainder from methane (11%), nitrous oxide (4%) and fluorinated gases (3%) [10].

Emissions of CO_2 in Cambridgeshire and Peterborough have fallen 26% since 2005, while nationwide emissions dropped 33%.[11]. Figure 1.1 shows historic emissions by district for the county. Emissions in all districts have fallen in the last 12 years, while the population of Cambridgeshire and Peterborough has increased by 14%.[12] A number of factors have contributed to these emissions reductions, including energy efficiency measures in building and homes, more efficient production and transport, and the falling carbon intensity of the national grid.

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[9] BEIS. (2019). UK local authority and regional carbon dioxide emissions national statistics. Retrieved from www.gov.uk/government/statistics/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics-2005-to-2017

[10] BEIS. (2019). 2017 UK Greenhouse gas emissions, final figures.

[11] BEIS. (2019). Final UK greenhouse gas emissions national statistics. Retrieved from data.gov.uk/dataset/9568363e-57e5-4c33-9e00-31dc528fcc5a/final-uk-greenhouse-gas-emissions-national-statistics

[12] Office for National Statistics. (2006). Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland 2005. Retrieved from www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates /datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland; Office for National Statistics. (2018). Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland 2017. Retrieved from www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates /datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland

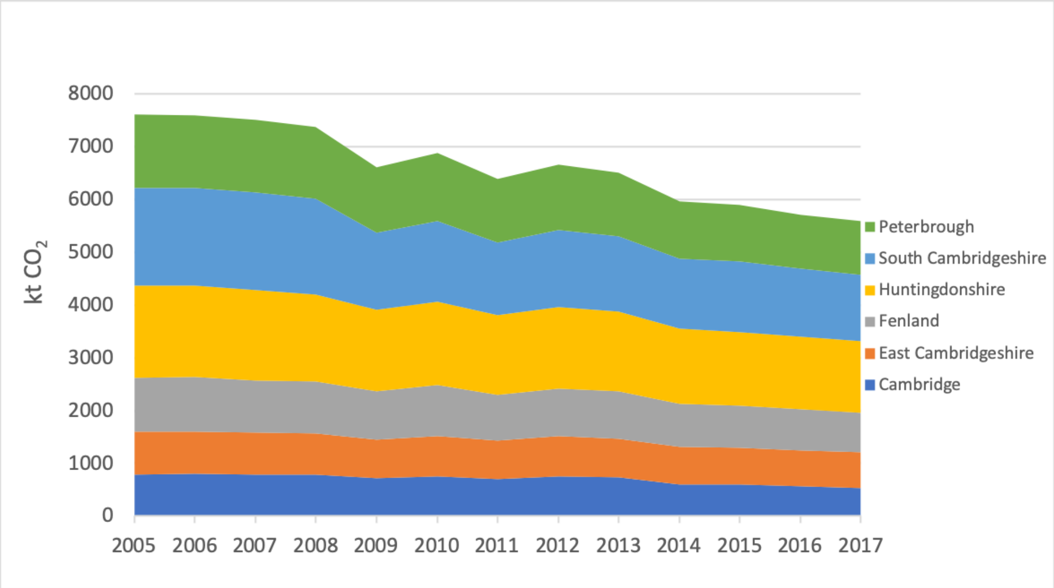

Figure 1.1: Cambridgeshire and Peterborough carbon dioxide only emissions, 2005-2017 (BEIS, UK local authority and regional carbon dioxide emissions national statistics, 2019)

Figure 1.2 shows CO_2-only county emissions in 2017 by sector. CO_2 emissions are dominated by transport and industry, which contribute 68% of total emissions. The remaining emissions come from domestic energy use, agricultural processes and waste collection and storage. These sectors are described in more detail in their respective sections below.

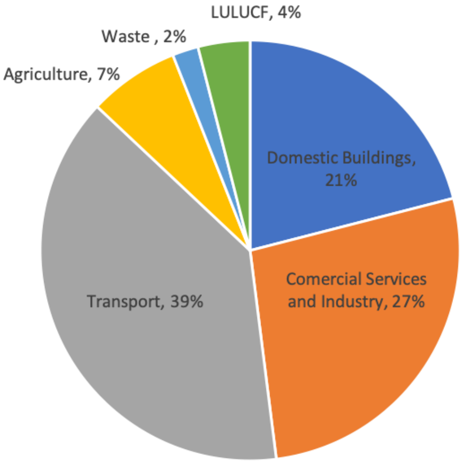

Figure 1.2: Cambridgeshire and Peterborough carbon dioxide emissions by sector, 2017

1.2. THE UK CONTEXT: NET ZERO 2050

The Committee on Climate Change recently recommended that the UK become a net zero emitter by 2050[13]. Any emissions must be balanced by negative emissions technology.

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[13] UK Committee on Climate Change. (2019). Net Zero - The UK's contribution to stopping global warming.

This ambitious target was adopted into UK legislation in June 2019, building on previous legislation which aimed for an 80% reduction in emissions by 2050. Nationwide Net Zero relies heavily on decarbonisation of the national grid, by replacing emitting resources like coal and gas with green energy sources. However, significant emissions reductions can be achieved by improving standards for processes and equipment, modernising the building stock, changing transport patterns and reducing energy demand which are all current CCC recommedations. It is in this context that Cambridgeshire and Peterborough can act to achieve significant emissions reductions.

2. DOMESTIC BUILDINGS

Author: Sarah Nelson

The domestic sector emits 21% (1280 kt CO_2e) of carbon emissions in Cambridgeshire and Peterborough. The main source of emissions is the generation of energy used in homes for heating and appliances. Figure 2.1 shows historic emissions arising from domestic use of electricity, gas and residual fuels (petroleum, coal and manufactured solid fuels).[14] Emissions fell by 31% between 2005 and 2016. There are two reasons for this. First, the decarbonisation of the national grid due to expansion of renewable energy sources alongside lower reliance on coal means that using electricity in 2017 emitted 27% less CO_2e emissions than in 2005.[15] Second, both electricity and gas demand has fallen since 2005. Energy demand trends are described in more detail in Section 2.1.

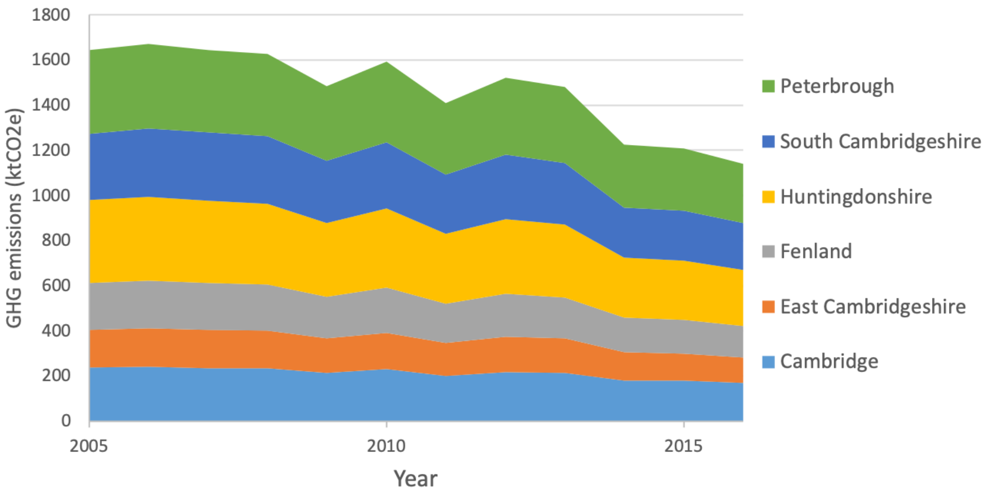

Figure 2.1: Domestic sector emissions by district, 2005-2016

The majority of domestic emissions in the county came from districts with the highest population density. Figure 2.2(a) shows that 56% of domestic emissions came from Peterborough, Cambridge and South Cambridgeshire.[16] Gas is the largest source of emissions for domestic buildings due to high demand for space heating requirements.

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[14] BEIS. (2019). UK local authority and regional carbon dioxide emissions national statistics.

[15] DEFRA. (2019). Government emission conversion factors for greenhouse gas company reporting.

[16] BEIS. (2019). UK local authority and regional carbon dioxide emissions national statistics.

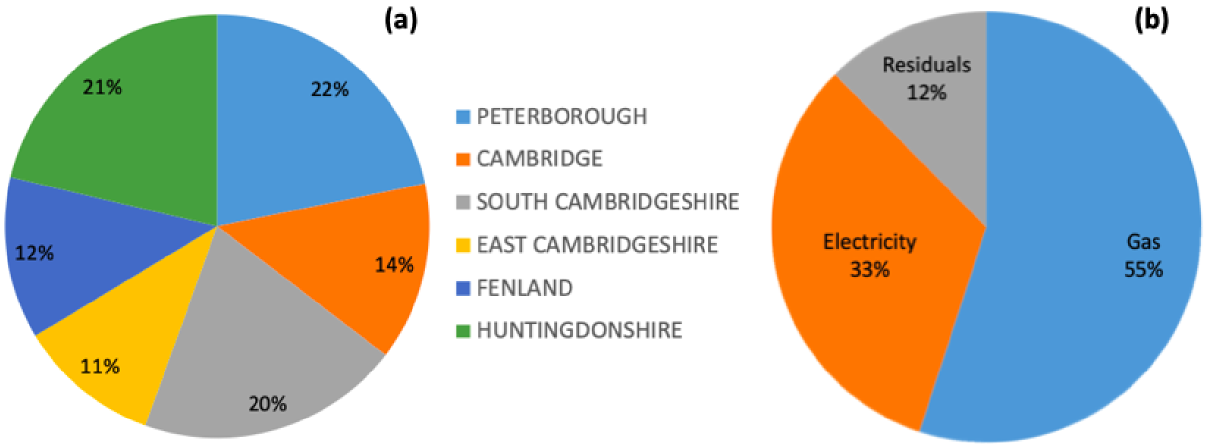

Figure 2.2: Domestic sector emissions by district (a), and source (b), 2017

2.1. ENERGY DEMAND

Energy demand is dominated by heating. Figure 2.3 illustrates the breakdown of energy demand by end use in the UK in 2013.[17] Space and water heating contributed 80% of total domestic energy demand, which have traditionally been supplied by the gas network. The largest sources of energy by supply are gas and electricity, which together supply around 90% of the county's domestic energy needs. The remainder is met by residual fuels, which is predominantly used in rural areas.

Energy demand in Cambridgeshire and Peterborough has fallen by 13% between 2005 and 2017,[18] even while population has risen by 14%.[19] The county's trend is reflective of national reductions in energy demand, which also fell by 14% over that period [20]. Electricity use in residential buildings decreased by 13% between 2005 and 2017, while electricity-based emissions fell by nearly 50%. Figure 2.4 shows the historical electricity demand in Cambridgeshire and Peterborough. Reasons for this reduction in electricity use include the following:[21]

- more efficient appliances;
- more efficient homes through insulation, double-glazing, etc;
- more conscious energy use by homeowners; and
- solar panels and other distributed generation sources reduce grid demand.

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[17] Department of Energy & Climate Change. (2014). United Kingdom housing energy fact file: 2013.

[18] Electricity: BEIS. (2018). Regional and local authority electricity consumption statistics. Retrieved from www.gov.uk/government/statistical-data-sets/regional-and-local-authority-electricity-consumption-statistics, Gas: BEIS. (2019). Regional and local authority gas consumption statistics: 2005 to 2017. Retrieved from www.gov.uk/government/statistical-data-sets/gas-sales-and-numbers-of-customers-by-region-and-local-authority.

[19] Office for National Statistics. (2006). Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland 2005.; Office for National Statistics. (2018). Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland 2017.

[20] BEIS. (2019). Energy Consumption in the UK.

[21] BEIS. (2019). Energy Consumption in the UK.

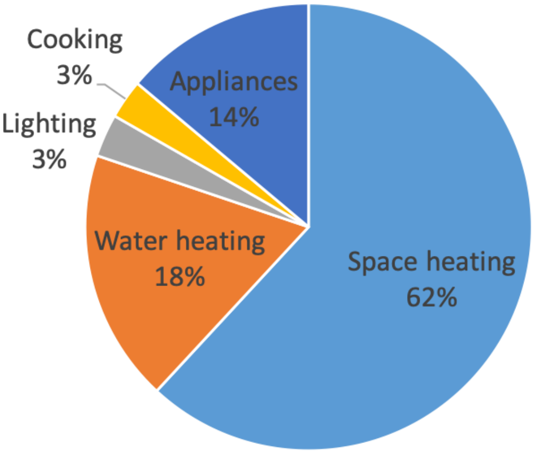

Figure 2.3: Domestic energy demand by end use, 2011

Gas has seen faster reduction in demand (14% between 2005 and 2017[22]) but slower decline in emissions (13%). There is very little flexibility in the emissions of gas usage, so the sole emissions reductions tactic is demand reduction, either by substituting to electrical heating sources, or reducing energy needs by improving household efficiency.

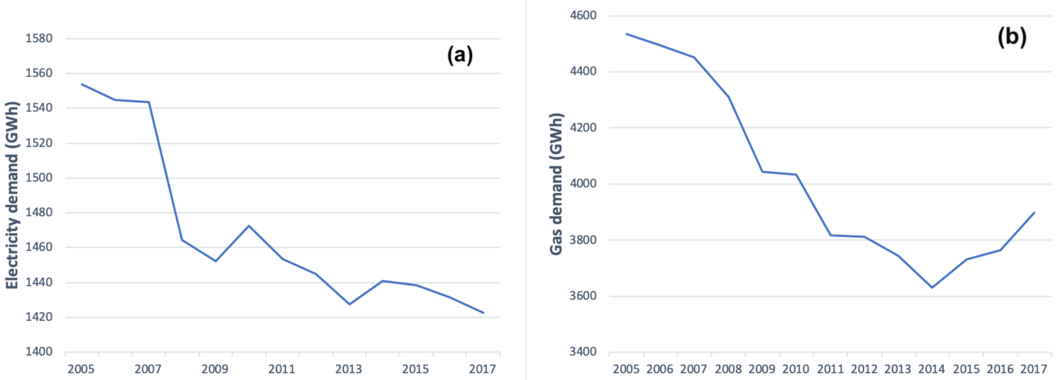

Figure 2.4: Electricity (a) and gas (b) demand trends in Cambridgeshire and Peterborough, 2005-2017

2.2. Projection Methodology

This section presents three projections to 2050: Baseline, Ambitious and Middle scenarios. Like for the other sectors, the baseline projection considers only currently implemented or planned policies, while the Ambitious scenario assumes aggressive mitigation strategy on a national and local scale. However, domestic housing is

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[22] Gas: BEIS. (2019). Regional and local authority gas consumption statistics: 2005 to 2017.

particularly difficult to decarbonise, because most investment decisions are made by price-sensitive homeowners rather than policymakers. Therefore, this section includes a projected Middle scenario, which considers how changes in household energy efficiency regulations - which are under the influence of local authorities - would affect domestic emissions.

There are several important factors to note before introducing the projection. Firstly, this projection includes emissions arising from residual fuels - petroleum, coal and other solid fuels. These alternative energy sources are currently predominantly used in rural areas, for heating and cooking, and make up around 12% of emissions in Cambridgeshire and Peterborough. Particularly important is the use of petroleum products in rural districts. This model has therefore included emissions in the county's domestic carbon account, which introduces some discrepancy between domestic emissions estimates from BEIS and these projections.

For the domestic sector, it is relevant to use projections over numbers of households. Other sections have used population-based projections from Cambridgeshire Insights. This section uses household projections for Cambridgeshire and Peterborough from the Office of National Statistics.[23] However, it should be noted that the Cambridgeshire Insights household projections come directly from the ONS projection, so this does not introduce an inconsistency into the model.

A detailed list of all modeling assumptions is provided in the Appendix for domestic emissions projection.

2.2.1. How is the Baseline Scenario built?

The 2050 baseline projection has two key elements: energy demand predictions and anticipated carbon intensity of the grid. Specifically, the projection considers four core factors:

- Electricity demand and gas demand, which were projected using the Steady Progression National Grid ESO Future Energy Scenario (FES) for national energy demand. The national trends (year on year % change) were applied to county-level energy demand from 2017.
- Residual fuel demands were assumed to follow the same trend as gas from the FES predictions (no national or county level projections were found).
- The carbon intensity of electricity was used to measure how much CO_2e was produced per unit of electricity drawn from the national grid. This figure changes over time as different energy sources are used.
- The carbon intensity of gas and residual fuels measure how much CO_2e was produced per unit of gas or residual fuels. Unlike electricity, these were assumed to be constant over time.

The National Grid's Future Energy Scenario projections are comprehensive, using a bottom-up model which considers trends in appliances, lighting, heating technologies,

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[23] Office for National Statistics. (2019). Household Projections for England.

insulation and home energy management systems. Crucially, the FES demand projection considers business-as-usual trends in the decarbonisation of heat sources, and the predicted changes in the Energy Performance Certificates of the housing stock. More aggressive county-level approaches are modelled in the Net Zero Ambitions and Middle scenarios presented below.

The carbon intensity of the national grid is assumed to follow projections from the Department for Business, Energy, and Industrial Strategy (BEIS). Their emissions factors until 2100 consider the planned decarbonisation of the grid at a national level. The county has little if any influence over the carbon intensity of the national grid.

2.2.2. How is the Ambitious projection built?

The county 2050 Ambitious Scenario is based on the Net Zero Further Ambitions scenario by the Committee on Climate Change. This projection assumes aggressive policy intervention to achieve emissions reductions. For the domestic sector, this means:[24]

- Gas and residual fuel demand is reduced by 90% by 2050 as homes move to low-carbon heat sources. The remaining 10% of demand comes from hard-to-decarbonise homes such as listed heritage buildings.
- Total energy demand is further decreased by 25% by 2050 due to wide-scale implementation of efficiency measures such as insulation and double glazing.

This scenario is deliberately ambitious: it illustrates where the county could be by 2050 if it pursued all possible avenues to mitigation. See the Assumptions Log for further details of the scenario assumptions.

2.2.3. How is the middle projection built?

This scenario is intended to take a central position on mitigation ambitions, and focuses on Energy Performance Certificates of domestic buildings. The assumptions for this projection are:

- All new homes are built to EPC Level A from 2020.
- All existing homes below EPC level C are retrofit to EPC level C over 10 years beginning in 2020.
- Local authority policies to improve housing stock affect energy demand over and above the national trend, which is still applied according to the National Grid's Future Energy Scenario.

2.3. 2050 Baseline Scenario

The baseline emissions projection shows a decline of 34% of CO_2e emissions in Cambridgeshire and Peterborough between 2017 and 2050. Figure 2.5 shows the baseline

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[24] UK Committee on Climate Change. (2019). Net Zero Technical report Committee on Climate Change, (May). Retrieved from www.theccc.org.uk/publications

emissions projection to 2050 broken down by district. There is no significant change in the shares of domestic emissions between different districts: variations in emissions shares are likely to arise in more concentrated sectors like agriculture or commercial.

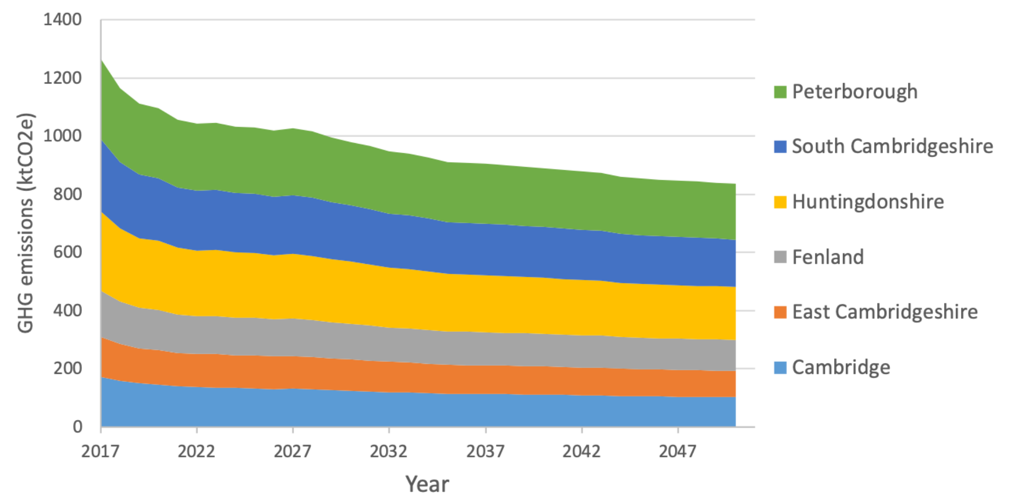

Figure 2.5: Baseline Scenario emissions by district, 2017-2050

Figure 2.6 shows the projection broken down by emissions sources. Emissions from energy use are expected to fall during this period, although electricity-based emissions will fall by a larger fraction than either gas or residual fuels. At the same time, total electricity demand for the county is expected to rise, as the electrification of heat transfers demand from gas and residual fuels to electricity. projection energy demand trends for gas and electricity are shown in Figure 2.7, and are based on nation-wide projections from the National Grid ESO.[25] The significant reduction in electricity-based emissions is attributable to the planned decarbonisation of the electricity grid,[26] which is expected to reduce by almost 90% in the next 30 years as renewable energy generation expands.

In the baseline scenario, emissions from domestic energy use contribute 24% of total county emissions in 2050, a slight increase from 21% in 2016. This reflects the relative difficulty of decarbonising the domestic sector. Electrification of heat is the core means by which emissions are reduced, supported by increases in the energy efficiency of the housing stock. However, under the baseline assumptions and without policy intervention, homeowners are slow to move off the gas grid. Because the carbon intensity of gas and residual fuels is constant, this means that emissions remain relatively high.

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[25] National Grid ESO. (2019). Future Energy Scenarios.

[26] BEIS. (2019). Electricity emissions factors until 2100.

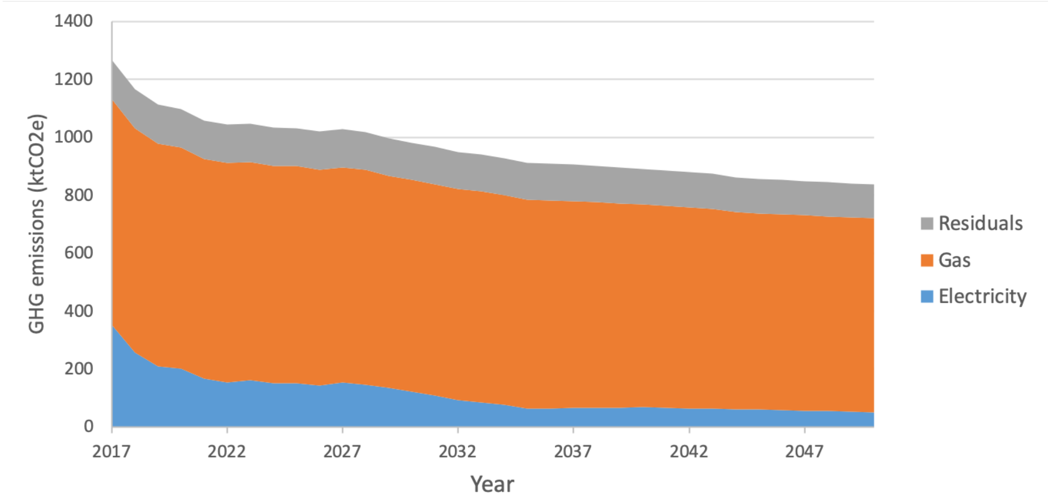

Figure 2.6: Baseline emissions projection by source, 2017-2050

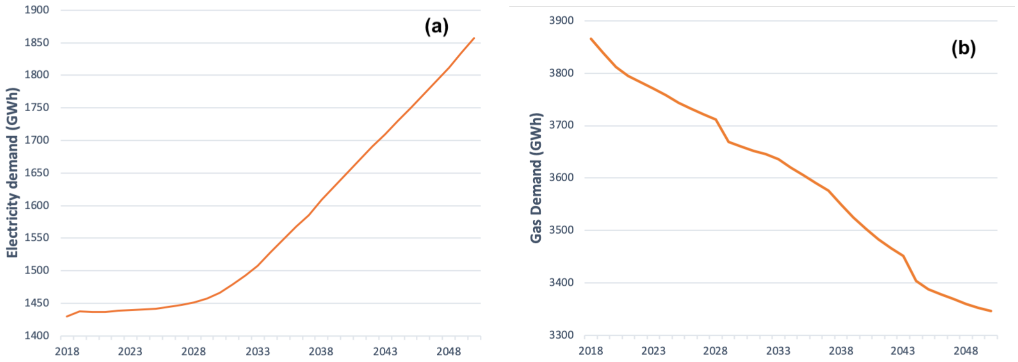

Figure 2.7: Baseline Scenario electricity (a) and gas (b) demand trends for the county 2017-2050, based on the National Grid's Future Energy Scenario trends.

2.4. 2050 Ambitious Scenario

The 2050 Ambitious Scenario shows a reduction of CO_2e emissions by 91% between 2017 and 2050, to 110ktCO_2e. In 2019, the UK government legislated a goal to reach net zero carbon by 2050.[27] What that might look like at a local authority level has not yet been determined, but Cambridgeshire and Peterborough in a position to support a low carbon region. This ambitious projection follows the guidelines of the Committee on Climate Change 2019 Further Ambitions scenario. The county's Ambitious Scenario emissions projection is given in Figure 2.8, separated by district. The projection by source is given in Figure 2.9. Figure 2.9 shows that the majority of emissions reductions come from reduction in gas demand due to aggressive policies to move homes off the gas grid. This assumption means that domestic energy use contributes 19% of total county emissions in the 2050 Ambitious Scenario, compared to 24% in the baseline.

There are two key aspects of the Net Zero Ambitions scenario: low-carbon heat and energy efficiency measures in homes. Reducing emissions by 92% by 2050 would require

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[27] UK Committee on Climate Change. (2019). Net Zero - The UK's contribution to stopping global warming.

roll-out of low-carbon technologies including heat pumps, hybrid heat pumps, district heating, hydrogen and smart storage heating.[28] No new homes should be connected to the gas grid from 2025. This scenario also requires extensive retrofitting to achieve high levels of energy efficiency in homes that would reduce energy demand.

The Committee on Climate Change estimates that installation of low carbon heat sources and energy efficiency measures in the Ambitious Scenario would result in abatement costing around £140/tCO2e. The projections above show that pursuing these measures would yield an additional mitigation of 723 kt CO_2e in 2050 above the baseline, giving an in-year cost of around £100m in 2050. Costs would likely be shared between homeowners and national or local funding bodies. This report has not attempted to estimate how the abatement costs would be shared.

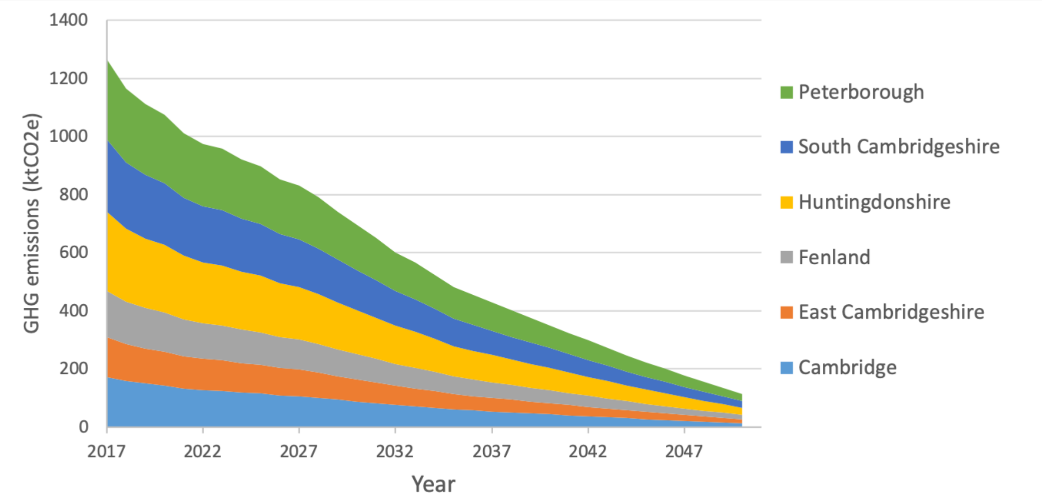

Figure 2.8: Ambitious Scenario emissions by district, 2017-2050

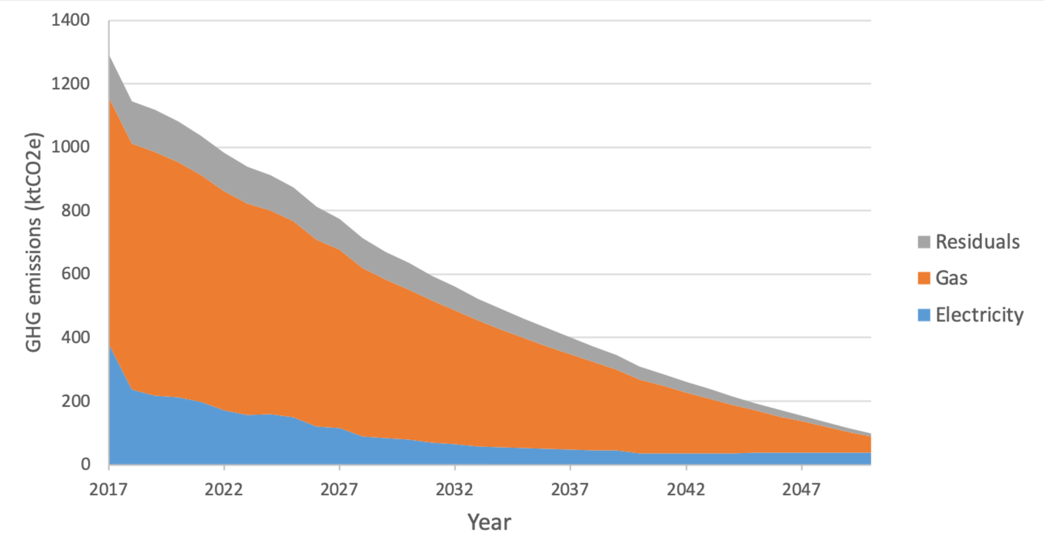

Figure 2.9: Ambitious Scenario emissions by source, 2017-2050

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[28] UK Committee on Climate Change. (2019). Net Zero - The UK's contribution to stopping global warming.

2.5. 2050 MIDDLE SCENARIO

The Middle Scenario is based on retrofitting homes to achieve given Energy Performance Certificate (EPC). EPCs rate the energy efficiency of households on a scale from A to G. The most efficiency homes (A) generally have the lowest energy needs.[29] Since 2007, EPCs have been required from homes that are purchased, rented or constructed. Not every home has an EPC but this projection assumes that the homes that do have EPCs are representative of the wider housing stock. BEIS provides up-to-date data on the number of EPCs by band in Cambridgeshire and Peterborough. This data has been used to construct a scenario based on domestic retrofits and new builds in the county.

The middle scenario achieves a reduction in domestic emissions of 46% between 2017 and 2050. This scenario yields lower cuts in emissions than the Ambitious Scenario, but is more plausible given the local authority's ability to influence district councils' EPC requirements for existing homes and new builds. Figure 2.10 illustrates the middle scenario by source (this scenario is not presented on a district level). The projection path of electricity, gas and residual fuel emissions is similar to the baseline scenario, but achieves more mitigation due to the more aggressive local action.

A caveat to this scenario is the difficulty of using the EPC level of a home to estimate its energy demand and therefore its emissions. EPCs are used to measure the energy efficiency of a home, but have no specific energy demand requirements so do not necessarily provide reliable estimates for modeling. The Middle Scenario is useful to show an estimate of mitigation the county could achieve by changing EPC requirements, but the uncertainty of this mitigation method should be recognised.

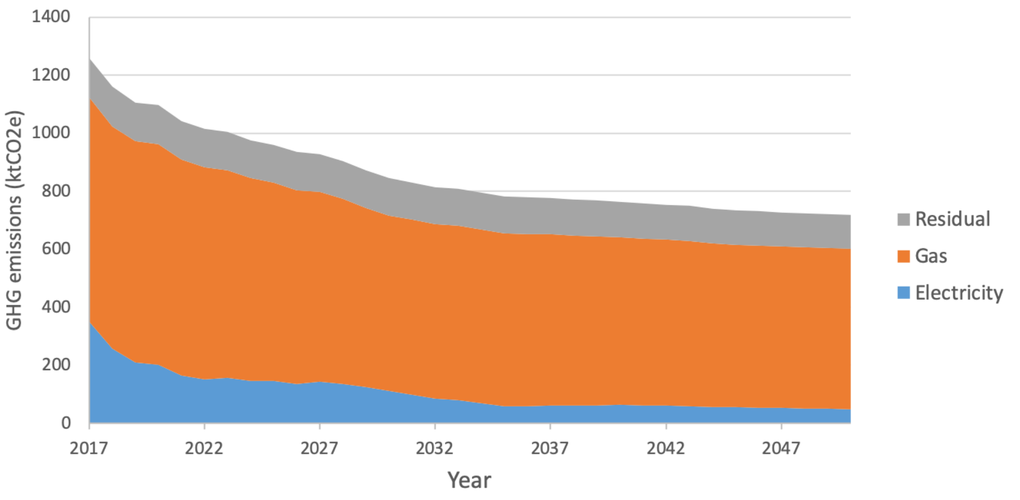

Figure 2.10: Middle Scenario emissions projection by source, 2017-2050

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[29] BEIS. (2017). Energy Trends: December 2017, special feature article - Domestic energy consumption by energy efficiency and environmental impact, 2015.

2.6. Domestic Sector Summary

Domestic sector emissions arise from the generation of energy used in homes for heating, appliances and lighting. Figure 2.11 shows the current emissions, contrasted against the three scenarios presented in this report. All scenarios include cuts in demand for gas and residual fuels, as well as a significant reduction in the energy intensity of electricity use. Even under the most ambitious assumptions, emissions from households cannot be reduced to zero due to electric heating requirements (even low-carbon heat sources draw from the grid), and hard to decarbonise homes that cannot be disconnected from the gas grid. To achieve net zero emissions would require negative emissions in other sectors, for example through afforestation or greenhouse gas removals.

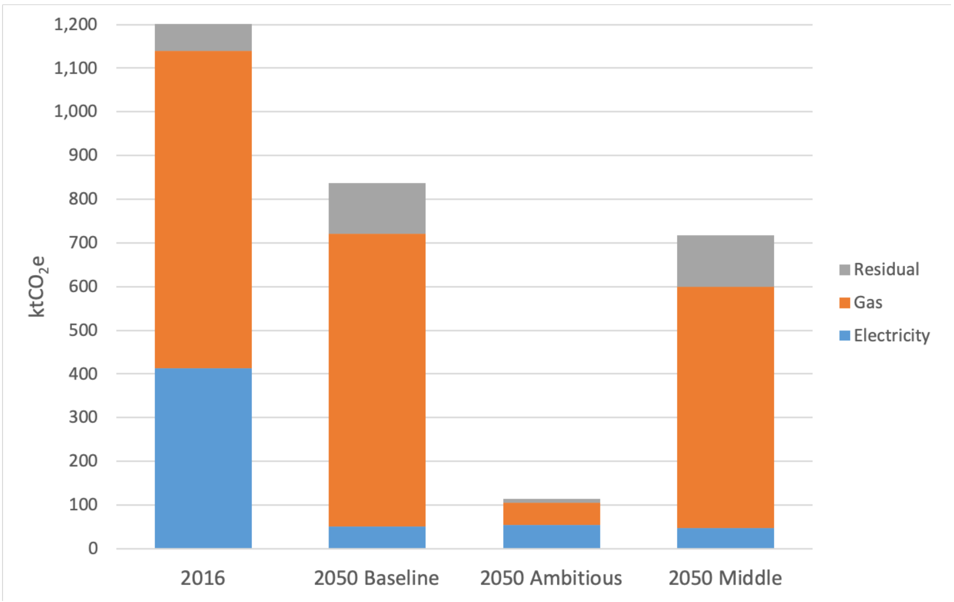

Figure 2.11: Comparing three emissions projections in the domestic sector, 2050

3. TRANSPORT

Author: Kieran Gilmore and and Matteo Craglia

In 2005, the transport sector accounted for 29% of all emissions in Cambridgeshire and Peterborough. This has risen to 39% of total emissions in 2016.[30] From 2005-2017 the total transport emissions for Cambridgeshire and Peterborough have stayed relatively constant (Figure 3.1). This results from a general increase in vehicle miles,[31] barring a small dip in 2008-09 following the global recession, offset by improvements in new car efficiency.[32]

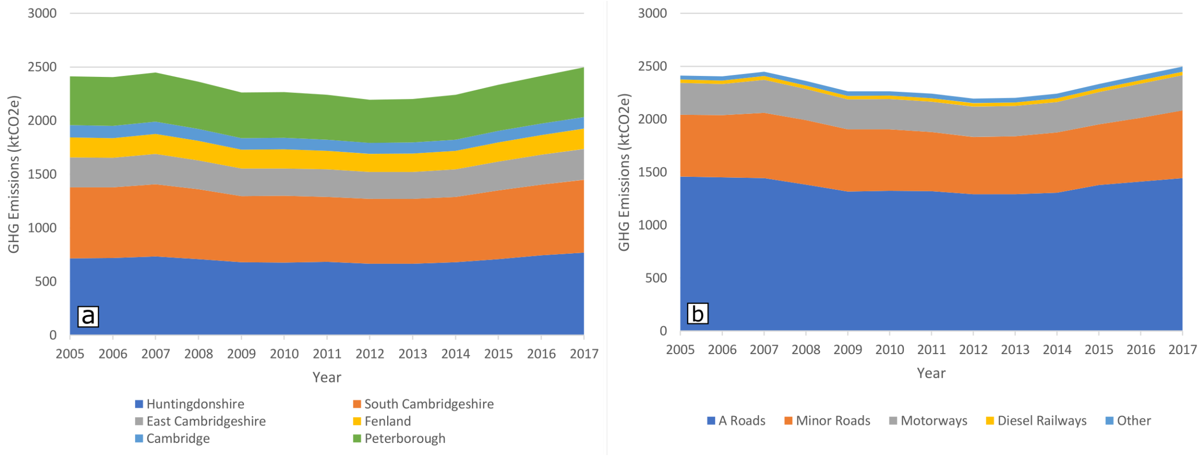

Figure 3.1: Total transport emissions from 2005 - 2017 split by district (a) and source (b).

The transport emissions per capita for Cambridgeshire and Peterborough are around 150% of the national average. Over half of the total emissions come from Huntingdonshire and South Cambridgeshire (Figure 3.1a), likely due to the major A roads which pass through these regions, and both of these local authorities have transport emissions per capita that are well above Cambridgeshire and Peterborough and national average (Figure 3.2). Cambridge is the only district with emissions per capita well below the UK average. 97% of transport emissions come from road traffic, with the major contribution from traffic on A-roads (Figure 3.1b).

Figure 3.3 shows the road transport emissions for Cambridgeshire and Peterborough by vehicle type.[33] Emissions are dominated by cars, with significant quantities coming from heavy goods vehicles (HGVs) and light goods vehicles (LGVs) as well. As the majority of transport emissions come from road transport and rail travel falling largely under national jurisdiction, this section will focus on road transport emissions within the Cambridgeshire and Peterborough area.

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[30] National Statistics, UK local authority and regional carbon dioxide emissions national statistics: 2005 to 2016

[31] Transport Statistics Great Britain, Roads and traffic (TSGB07), Table TRA8901 (TRA89) Motor vehicle traffic (vehicle miles) by local authority in Great Britain

[32] Transport Statistics Great Britain, Energy and environment (TSGB03), Table TSGB0303 (ENV0103) Average new car fuel consumption: Great Britain from 1997

[33] National Statistics, Final UK greenhouse gas emissions national statistics 1990-2017

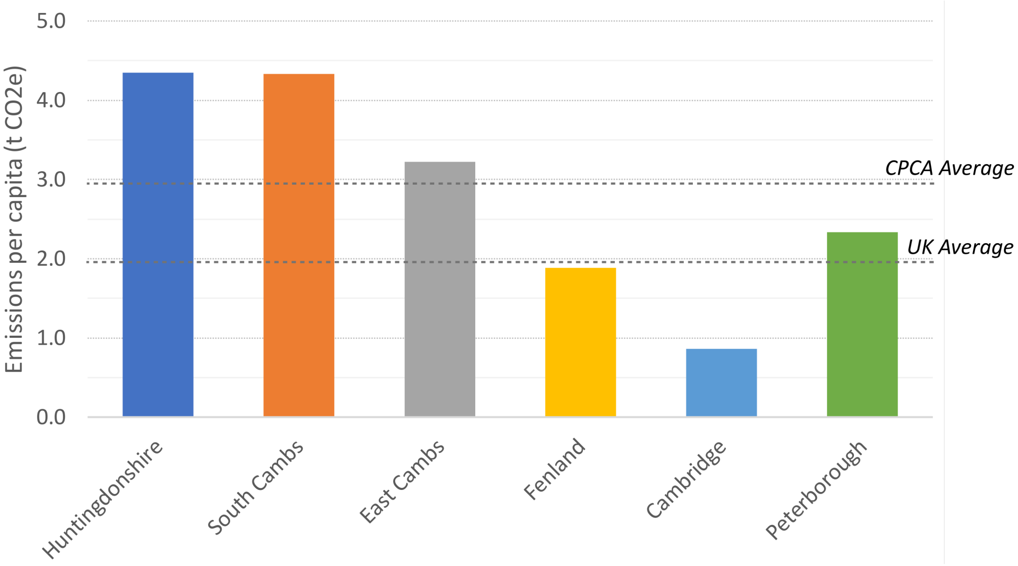

Figure 3.2: Total transport emissions per capita (2017) by district. The majority of districts are above the UK average.

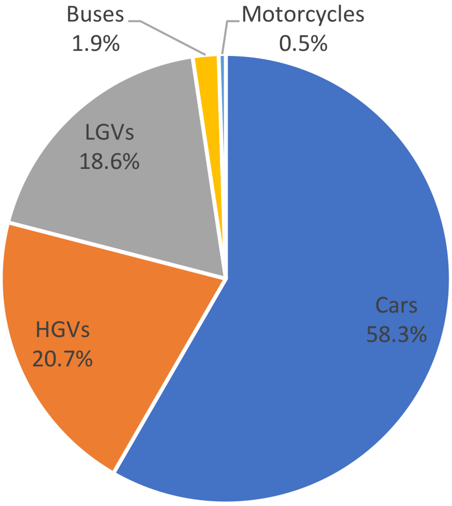

Figure 3.3: Breakdown of road transport emissions (2017) for Cambridgeshire and Peterborough by vehicle type. Cars, HGVs and LGVs are the major sources of emissions.

3.1. 2050 Baseline Scenario

The baseline emissions projection is a prediction of how emissions from the transport sector will most likely evolve to 2050 including all current national and local policies and targets in place and incorporating predicted growth (e.g. population growth, vehicle fleet growth).

The model covers the regions:

- Huntingdonshire
- South Cambridgeshire

- East Cambridgeshire
- Fenland
- Cambridge
- Peterborough

The model considers the following modes of transport:

- Car
- HGV
- LGV
- Bus
- Motorcycle

The model considers the following technologies:

- Petrol
- Diesel
- Hybrid
- Electric vehicle

3.1.1. Data and Methods

The model calculates the emissions from each mode of transport within each district. To calculate the emissions from each mode, total vehicle kilometres are combined with CO_2 emission factors to obtain the total CO_2 emissions.

The baseline projection incorporates predicted changes to a number of the different inputs into the model over time. These inputs are:

- **Mode technology shares** - The uptake of electric vehicles will have an important effect on transport emissions. The baseline scenario includes predicted electric vehicle uptake based on national sales targets.[34] See Appendix B.4 for full details on how mode technology shares are projected to 2050.
- **Vehicle kilometres** - Vehicle kilometres are projected to increase towards 2050.[35]
- **Vehicle Fuel Efficiency** - Fuel efficiency is projected to improve towards 2050.[36]
- **Electricity Emissions** - The emissions from electric vehicles depends on the emissions of the electricity source. The baseline uses government projections of emissions from electricity generation.[37]

Full details of the sources of data used and assumptions made during the modelling process can be found in Appendix B.

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[34] Brand and Anable 2019, 'Disruption' and 'continuity' in transport energy systems: the case of the ban on new conventional fossil fuel vehicles

[35] Department for Transport (2018), Road Traffic Forecast

[36] Department for Transport (2018), Road Traffic Forecast

[37] Department for Business, Energy and Industrial Strategy 2019, Electricity emissions factors to 2100.

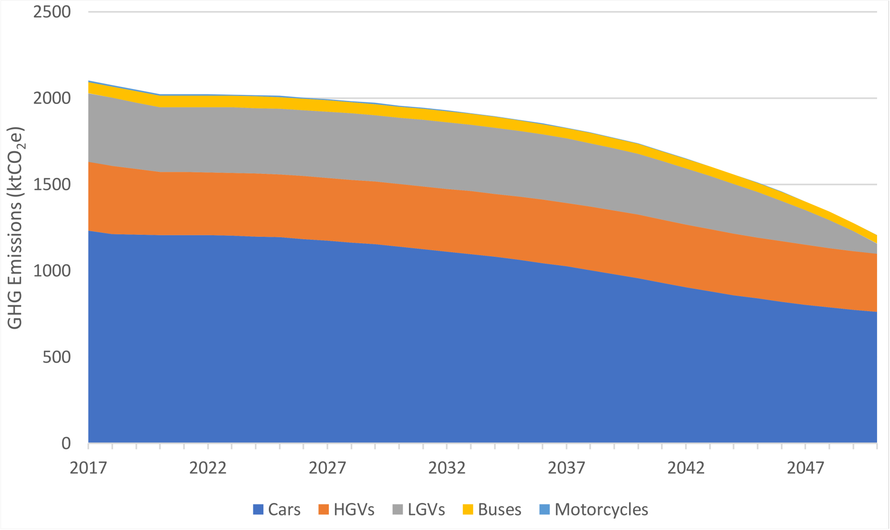

Figure 3.4: Baseline projection of GHG emissions to 2050 split by vehicle type. Emissions from cars and HGVs remain the biggest source of emissions.

The historical transport emissions data for Cambridgeshire and Peterborough from BEIS[38] have been calculated using a different methodology (see Appendix B.6), hence there is a small discrepancy between the BEIS data and the emissions output from this model. Although absolute values may differ slightly, the model still allows useful projecting of changes in emissions to 2050.

3.1.2. RESULTS

Figure 3.4 shows the baseline emissions projection of road transport to 2050 split by vehicle type. Total emissions drop from 2100 kt CO_2e in 2017 to 1200 kt CO_2e in 2050, mainly driven by electrification of the LGV fleet and some of the car fleet. Emissions from cars and HGVs remain the biggest source of emissions in 2050.

3.2. 2050 AMBITIOUS SCENARIO

The Committee on Climate Change Further Ambition scenario[39] lays out how the transport sector can achieve near net zero emissions by 2050. The policies they include are:

- End sales of non-zero emissions cars, vans and motorcycles by 2035.
- Zero emission HGV sales reach nearly 100% of sales in 2040, leading to a 91% fleet share by 2050.
- 10% of car miles are shifted to walking, cycling and public transport.

100% zero emissions bus fleets by 2035 are also necessary to reach net zero by 2050.[40]

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[38] National Statistics, UK local authority and regional carbon dioxide emissions national statistics: 2005 to 2017

[39] Committee on Climate Change (2019), Net Zero Technical report

[40] Energy Transitions Commission (2018), Mission Possible

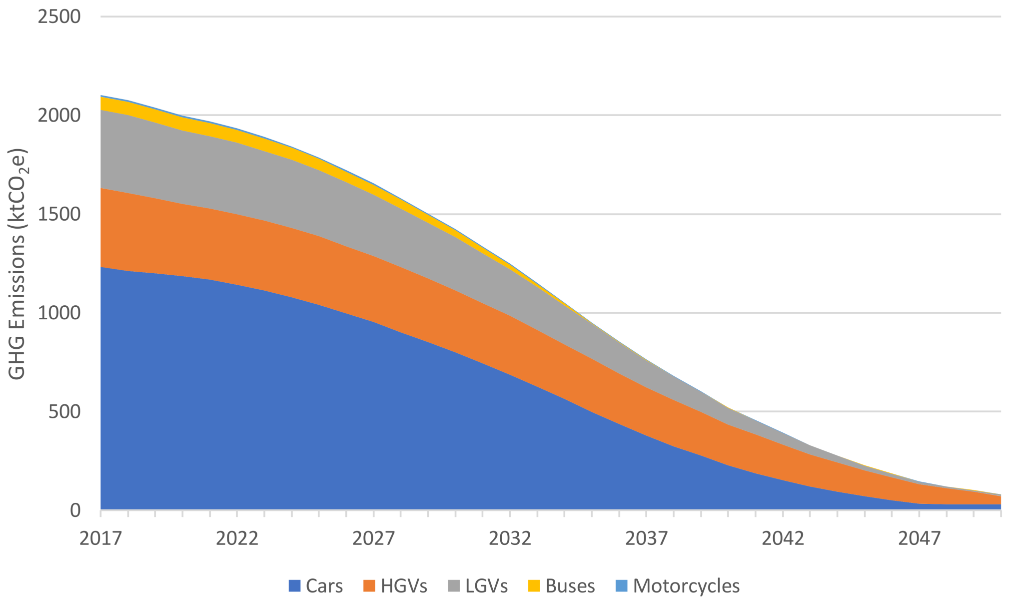

Figure 3.5: Net zero scenario projection of GHG emissions to 2050 split by vehicle type. Remaining emissions come from small fraction of HGVs which are not zero emission as well as a small contribution from electricity required to power electric vehicles.

Figure 3.5 shows the ambitious emissions projection which incorporates these policies to 2050 split by vehicle type. Total emissions drop from 2100 kt CO_2e in 2017 to 81 kt CO_2e in 2050, driven by full electrification of the car, LGV, bus and motorcycle fleets as well as the majority of the HGV fleet. Near full decarbonisation of electricity from the grid also means that the energy to power electric vehicles is low emission. Remaining emissions come from the fraction of HGVs which are non-zero emission as well as the small component of grid electricity that is non-zero emission. The total GHG emissions at 2050 for the baseline and net zero scenarios are plotted next to the 2017 GHG emissions breakdown in Figure 3.6.

3.2.1. Supporting uptake of electric vehicles

Although the local authorities of Cambridgeshire and Peterborough cannot directly control the sales and uptake of electric vehicles, there are supporting measures which can be put into practice.

A vital prerequisite to successful electric vehicle deployment is sufficient charging infrastructure. The European Union Alternative Fuels Infrastructure Directive[41] recommends that one publicly available charge point per 10 cars, as well as access to home charging and workplace charging is necessary to encourage significant electric

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[41] EC (European Commission) (2014), Directive of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure

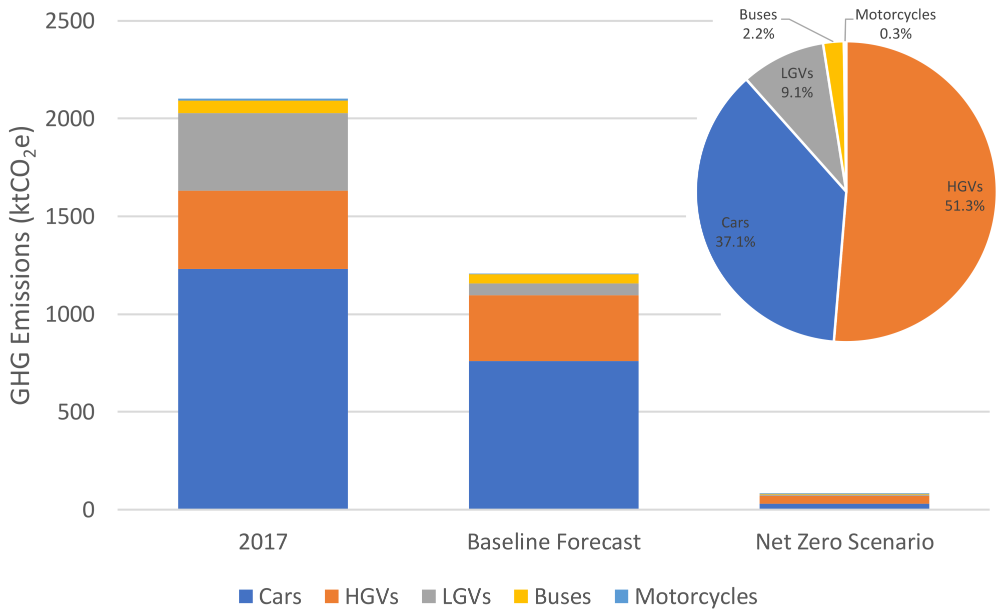

Figure 3.6: Total GHG emissions for road transport have been plotted by vehicle type. The three stacked bars show the emissions release in 2017, emissions in 2050 for the baseline projection and emissions in 2050 for the net zero scenario. The pie chart gives the breakdown of emission sources for the net zero scenario at 2050.

vehicle uptake. Analysis by the Committee on Climate Change estimated the number of public charge points in the UK that would be required by 2050.[42] 3500 public chargers in towns and cities, as well as 60 rapid chargers near main roads, are required in Cambridgeshire and Peterborough. On top of this, 11 hydrogen refueling stations and 1260 depot-based chargers for HGVs are also required. The report estimates that the total cost of a public electric refuelling infrastructure network in Cambridgeshire and Peterborough would be £150 million between now and 2050. A rapid charging network for longer journeys would cost around £5 million to 2050.

Local incentives for electric vehicle users that can also encourage uptake. Dundee has placed itself at the forefront of the Scottish Government's plans to phase out petrol and diesel vehicles by 2032. As benefits to electric vehicle users, the city offers free public charging and free parking for electric vehicle vehicles.[43] The key to Dundee's success consists of a focus on fleets, infrastructure, workplace charging, local incentives, and stakeholder engagement.

3.3. EMBODIED EMISSIONS OF ELECTRIC VEHICLES

Although the transition of the vehicle fleet to electric vehicles offers a straightforward solution for reducing emissions locally it is important to consider their wider environmental impact.

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[42] Committee on Climate Change (2019), Net Zero Technical Report

[43] https://drivedundeeelectric.co.uk/in-dundee/

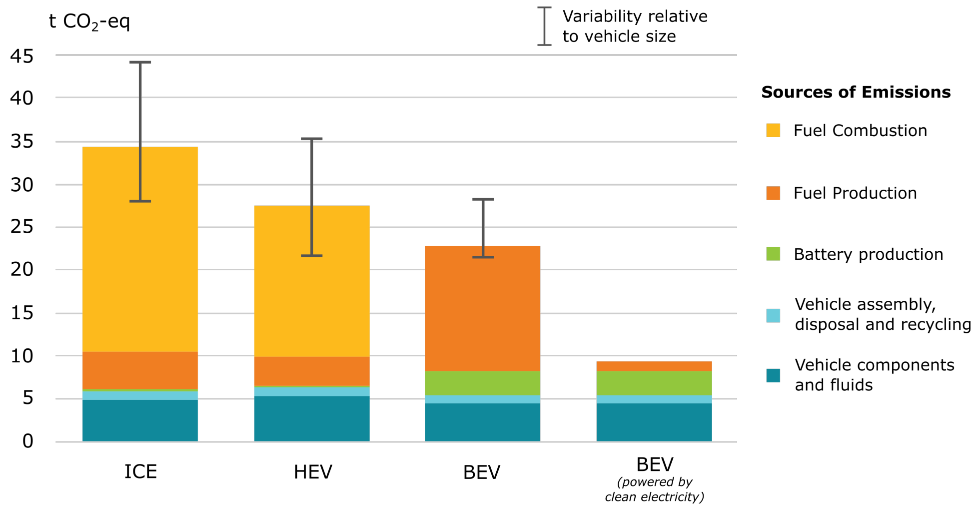

Figure 3.7: Comparative life-cycle GHG emissions of a global average mid-size car by technology, 2018. BEVs produce less overall emissions than ICE or hybrid vehicles but still have significant contributions from the electricity source and production emissions (IEA EV Outlook 2019). (ICE - Internal Combustion Engine, HEV - Hybrid Electric Vehicle, BEV - Battery Electric Vehicle)

Firstly, electric vehicles are only low emission if the electricity used to power them is clean. electric vehicles that are powered by electricity produced by coal or gas are still cleaner than petrol or diesel vehicles. However, for electric vehicles to be close to zero emissions, the electricity they run on must be produced using renewable resources such as wind or solar which is reliant on the decarbonisation of the UK grid as a prerequisite.

Secondly, the production of the vehicles generates significant, often termed "embodied emissions". For the purpose of the baseline in this study, we only consider emissions from the production of electricity used to power the vehicles. However, to fully account for the total emissions of an electric vehicle, the emissions generated during battery and vehicle manufacturing must also be considered. Figure 3.7 shows the comparative life-cycle GHG emissions of a mid-sized car powered by different technologies. Battery electric vehicles (BEVs) produce less overall emissions compared to internal combustion engine (ICE) and hybrid (HEV) vehicles, even when the electricity is produced using fossil fuels. It is important to note that even when an electric vehicle is powered by clean electricity, there are life-cycle emissions of the vehicle that come from battery production, vehicle components, as well as assembly and disposal.

The effects of factoring in life-cycle emissions of electric vehicles is shown in Figure 3.8. The total emissions in 2050 of the baseline and net zero scenarios have been plotted, with and without including the life-cycle emissions of cars. Shifting the car fleet to electric vehicles reduces emissions to nearly net zero within Cambridgeshire and Peterborough, but if the embodied emissions are taken into account, the distance is significant. Reaching net zero by 2050 ultimately needs to be a global goal, and although accounting for indirect (Scope 3) emissions[44] is not within the scope of this

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[44] Scope 3 emissions are all indirect emissions except emissions from electricity generation. Examples here would include emissions from raw materials, manufacture and transportation of goods used within

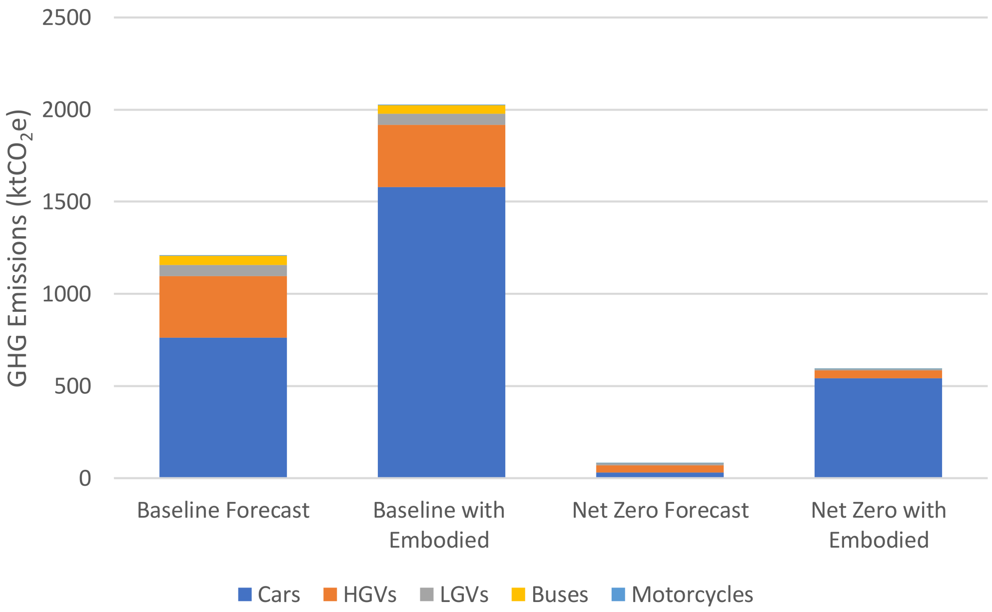

Figure 3.8: The GHG Emissions release in 2050 for the Baseline Porecast and Net Zero Scenario plotted with and without including the embodied emissions of cars that come from battery production, vehicle components and assembly and disposal. Shifting the car fleet to electric vehicles reduces emissions to nearly net zero within Cambridgeshire and Peterborough but emissions are still produced elsewhere as a result.

report, it is important to bear in mind that they can make up a significant fraction of a carbon budget.

Thirdly, transitioning the vehicle fleet to electric does not solve congestion. The Department for Transport has modelled traffic projections through to 2050.[45] The scenario that has the highest projection growth in traffic is the "Shift to Zero Emission Vehicles" scenario which incorporates a high uptake of electric vehicle vehicles. The traffic growth is partly driven by the low running costs of electric vehicles. The report estimates that there will be a 16% increase in congested conditions as a result of high electric vehicle uptake.

Finally, there are wider environmental impacts associated with the raw materials required for electric vehicles. Batteries require minerals such as cobalt, copper and neodynium, the mining of which can be associated with deforestation, soil and water contamination and human rights violations. A recent study concluded that if the UK's vehicle fleet were entirely replaced by electric vehicles by 2050, it would require almost twice the global annual supply of cobalt.[46] Battery disposal must also be carefully managed with specialist facilities as there is a risk to contaminate waterways, groundwater and soil if not properly handled.

Cambridgeshire and Peterborough, but produced elsewhere.

[45] Department for Transport (2018), Road Traffic Forecasts

[46] https://www.nhm.ac.uk/press-office/press-releases/leading-scientists-set-out-resource-challenge-of-meeting-net-zer.html

Electrification of the vehicle fleet is essential in achieving decarbonisation of the transport sector, but it cannot be the only solution. Electric vehicles running on 100% clean electricity still have emissions associated with them, so alternative measures that encourage mode shift of transport away from cars must also be explored. More than 50% of trips made in the UK are less than 5 miles; a switch from the car towards active travel can not only reduce emissions but also impact on air quality, traffic flow and improve public health. Efficient and reliable public transport and sufficient cycling and pedestrian infrastructure are necessary. This is possible when the private car is no longer made to be the priority on the road. Promoting the benefits of shifting towards these sustainable modes of transportation is essential. and policies from local authorities are necessary to encourage this behavioural change by making sustainable modes of transport the natural choice for all.

3.4. CONCLUSION

- The transport sector accounts for 39% of emissions in Cambridgeshire and Peterborough and emissions have stayed constant for the last 10 years.
- The baseline scenario predicts that transport emissions will fall from 2100 kt CO_2e to 1200 kt CO_2e from 2017 to 2050 due to some electrification of cars and LGVs.
- The net zero scenario requires 100% of cars, LGVs, buses and motorcycles to be electric by 2050 as well as 91% of HGVs. This reduces transport emissions to 81 kt CO_2e by 2050.
- There are an extra 500 kt CO_2 per year in 2050 if life-cycle emissions of electric vehicles are accounted for within the net zero scenario compared to if they are omitted.
- Electrification of the fleet cannot be the only solution to decarbonisation. Alternative measures that encourage shifting transport away from cars must also be explored.

4. AGRICULTURE

Author: Peter Budden

Agriculture currently only makes up 7% of emissions in Cambridgeshire and Peterborough, but the majority of these emissions are from livestock and fertiliser use, which are difficult to abate. Under the business as usual projection, these emissions will fall slightly but remain roughly stable, in contrast to other sectors where grid decarbonisation will make a big difference. Even in the ambitious scenario, it is projected that 239 ktCO$_2$e will remain, which is 40% of the total residual emissions from all sectors in the scenario. This still involves significant interventions: reduction of food waste, reduction of demand (and therefore production) of red meat and dairy by 20%, and on-farm measures such as electrification of machinery, increased fertiliser efficiency, breeding measures, and livestock food additives. Cambridgeshire and Peterborough have large areas of peatland, much of which have been drained and are currently used for agriculture, that are responsible for very large GHG emissions, up to 5.5 MtCO$_2$e. These will soon be included in the emission inventory, and peatland restoration must therefore be a high priority for Cambridegshire and Peterborough.

Agriculture emissions are significant in Cambridgeshire as the county contains large areas of farmland. As a proportion of total county emissions in 2016, agriculture was responsible for 7% of GHG emissions, through a combination of livestock methane emissions (enteric and manure), cropland N_2O from fertiliser use and CO_2 emissions from agricultural machinery which burn fossil fuels. Compared to the UK average ratio between crops and livestock, Cambridgeshire has much larger area of cropland and fewer livestock, which means current emissions from agriculture are relatively low, as livestock methane emissions can quickly add up. Figure 4.1 shows the breakdown in the CPCA area in 2016, the most recent year for which data is available on livestock numbers and crop areas from the Department for Environment, Food and Rural Affairs (DEFRA).[47] The livestock emissions factors (i.e. annual GHG emissions per animal) were taken to be the UK average from the most recent National Atmospheric Emissions Inventory (NAEI).[48]

4.1. METHODOLOGY FOR NON-CO_2 AGRICULTURE EMISSIONS

Emissions data is only reported at local authority level for CO_2, and not for other GHGs. Therefore a methodology for estimating the local non-CO_2 emissions was developed for this report. The methodology relies on the local data that DEFRA collects on livestock numbers and cropland areas. However, this local information does not provide a breakdown within the broad livestock categories of cattle, sheep, pigs or poultry. or a detailed breakdown of crop areas, which are categorised as either cereals,

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[47] DEFRA. (2019). Structure of the agricultural industry in England and the UK at June. `https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june`

[48] NAEI (2019). Emissions factors for 2017. `http://naei.beis.gov.uk/data/ef-all`

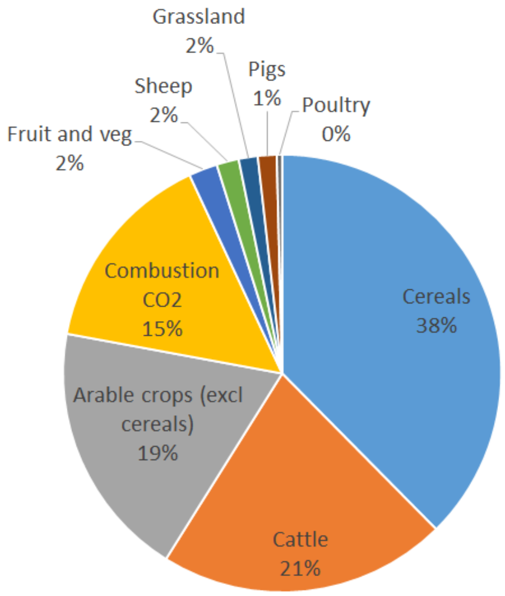

Figure 4.1: Breakdown of current (2016) Cambridgeshire and Peterborough GHG emissions from agriculture by emissions source

arable crops (excl. cereals), fruits and vegetables, or grassland. Different breeds of livestock and different crops can have very different emissions factors - for example each dairy cow emits approximately 2.6 times the annual emissions of a beef cow. As there is no data available to estimate the particular make-up of subcategories of livestock or crops in Cambridgeshire and Peterborough, in this methodology the national averages are used, taken from DEFRA statistics for June 2018.[49]).

For example, in the UK, 69% of cattle were non-dairy and 31% were dairy, so this ratio was applied to the number of cattle in the CPCA area to calculate the number of dairy and non-dairy cattle in the CPCA area. Then, the emissions factors from the NAEI were summed for all the different emissions sources associated with the subcategory of cattle - enteric, excreta, and manure management - to reach a total annual emissions factor per head of dairy cattle and non-dairy cattle. Multiplying these emissions factors by the number of livestock and applying the GWP of 34 for methane and 298 for N_2O. This same methodology - taking the UK average make-up of each category of livestock - was applied to cattle, sheep, pigs and poultry. Due to their negligible contribution, N_2O emissions from livestock have not been accounted for, but they are technically not zero. In CO_2e terms, UK N_2O emissions from livestock is 13 times less significant than UK methane emissions from livestock.).

For crops, a slightly modified method was used. The total reported N_2O emissions due

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[49] DEFRA. (2019). Structure of the agricultural industry in England and the UK at June. `https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june`

to cropland and grassland in the UK was taken from the NAEI and divided by the total cropland and grassland areas for the UK in the same year to estimate the average emissions factors.[50,51] Cropland CO_2 emissions are small in comparison to N_2O, and are assumed to already be counted in the local authority CO_2 data. There are no methane emissions attributed to crops or grassland in the inventory.

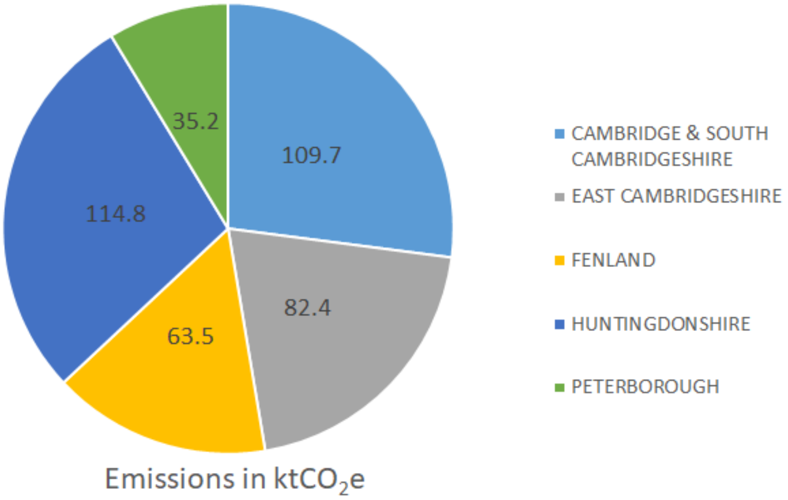

Figure 4.2: Breakdown of current (2016) CPCA area GHG emissions from agriculture by district council. DEFRA data on livestock numbers and cropland areas does not separate Cambridge and South Cambridgeshire in to separate areas, however it is likely that the vast majority of their combined agricultural activity is in South Cambridgeshire rather than Cambridge.

Local livestock numbers and cropland areas, as well as CO_2 emissions, are broken down to the district council level, allowing the above methodology to be carried out at district council level, and this is summarised in Figure 4.2.

4.2. EMISSIONS FROM PEATLAND

In line with current national reporting procedures, the methodology of this report does not include all GHG emissions from peatland. However, from next year, the national emissions inventory will be changing to include all peatland emissions, which will have a very large effect on Cambridgeshire in particular due to the large area of wasted peat in the county. Wasted peat is defined as shallow residual organic soils where much of the original peat has already been lost.[52] In England, 71% of this area is cropland, the majority of which is in Cambridgeshire, as seen in Figure 4.4. This has the potential to

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[50] National Atmospheric Emissions Inventory. (2019). `https://naei.beis.gov.uk/data/data-selector`

[51] DEFRA. (2019). Structure of the agricultural industry in England and the UK at June. `https://www.gov.uk/government/statistical-data-sets/structure-of-the-agricultural-industry-in-england-and-the-uk-at-june`

[52] Evans, C.; Artz, R.; Moxley, J.; Smyth, M.-A.; Taylor, E.; Archer, N.; Burden, A.; Williamson, J.; Donnelly, D.; Thomson, A.; et al. Implementation of an Emissions Inventory for UK Peatlands A Report to the Department for Business, Energy & Industrial Strategy; 2017.

increase emissions from Cambridgeshire by 4 - 5.5 million tonnes of CO_2e annually, equivalent to 65-90% of the current total reported emissions from the CPCA area. The relative importance of this change is illustrated in Figure 4.3.

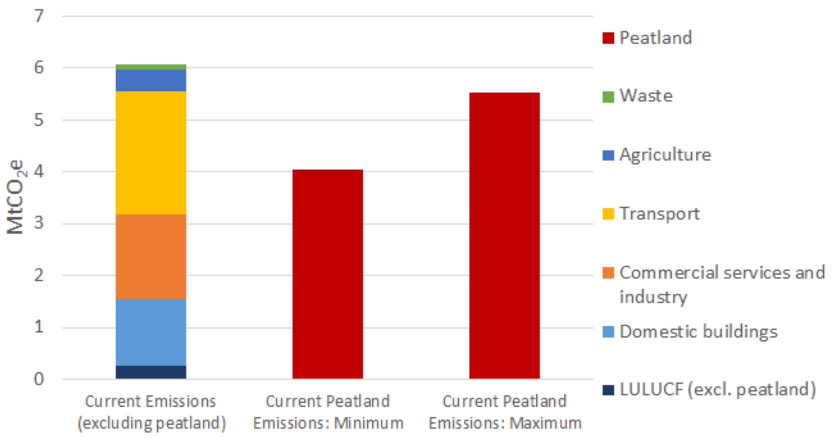

Figure 4.3: Estimated relative importance of the inclusion of peatland emissions to GHG emissions allocated to the CPCA area, after the change in inventory methodology next year.

Data on peatland emissions is scarce and subject to large uncertainties. The best resource at this time is a preliminary report outlining an estimation of the UK's current peatland emissions, which was commissioned by BEIS in anticipation of the upcoming change in inventory rules.[53] In this report, data is only provided on a devolved administration level (England, Scotland, Wales, Northern Ireland) however it is clear from figure 4.4 that a majority of the wasted peatland in England is located in Cambridgeshire, as well a small area of deep peat. Total England GHG emissions are currently estimated to be 6.4$MtCO_2$e and 4.5$MtCO_2$e from wasted and deep peat respectively, which leads us to estimate 4 - 5.5 $MtCO_2$e will be attributed to Cambridgeshire. These figures are reached by estimating that between 60 and 80% of wasted peat and between 5 and 10% of deep peat are within the CPCA area, and assuming the average wasted peat and deep peat emissions factors from the preliminary report: 9tCO_2e/year for deep peat and 34tCO_2e/year for wasted peat.[54]

Peatland emissions should be tackled at a national level, prioritising peatland restoration wherever possible. Given the large areas of peatland in the county, Cambridge County Council should take this in to account whenever considering land use policies. There are large uncertainties in the emissions from peatland, particularly wasted peat of which Cambridgeshire has such a large area.[56] The County Council should work to support the refinement of the data available, as peatland is the County's

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[53] Evans, C.; Artz, R.; Moxley, J.; Smyth, M.-A.; Taylor, E.; Archer, N.; Burden, A.; Williamson, J.; Donnelly, D.; Thomson, A.; et al. (2017). Implementation of an Emissions Inventory for UK Peatlands A Report to the Department for Business, Energy & Industrial Strategy.

[54] Evans, C.; Artz, R.; Moxley, J.; Smyth, M.-A.; Taylor, E.; Archer, N.; Burden, A.; Williamson, J.; Donnelly, D.; Thomson, A.; et al. (2017). Implementation of an Emissions Inventory for UK Peatlands A Report to the Department for Business, Energy & Industrial Strategy.

[56] Evans, C.; Artz, R.; Moxley, J.; Smyth, M.-A.; Taylor, E.; Archer, N.; Burden, A.; Williamson, J.; Donnelly,

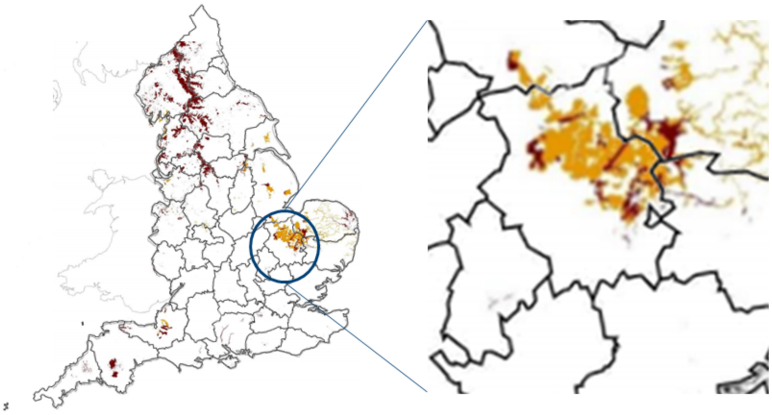

Figure 4.4: Map of deep peat (dark red) and wasted peat (yellow-orange) in England overlayed with the outline of the ceremonial counties of England. Insert shows the area in Cambridgeshire[55]

single biggest contribution to climate change as is the least well documented.

It should also be noted that emissions from peatland are an issue all over the world and the development of effective peatland restoration strategies, which turn the sources of GHGs into sinks, is vital. Cambridgeshire has the potential to become a world-leader in this field given the academic expertise that exists in the county and the UK in general. Thus an effective response to this issue in Cambridgeshire, supported by rigorous scientific testing and documentation, would enable the county's emission reduction efforts to have a much greater impact, potentially influencing policy internationally.

4.3. BASELINE FORECAST

Emissions from agriculture are effectively decoupled from local demographic changes as produce can be sold on a national and international level. Therefore, to model future emissions scenarios in this sector, national projections for agriculture emissions have been used. The Energy and Emissions Projections (EEP) published by the Department of Business, Energy & Industrial Strategy give projections for UK agricultural emissions by gas[57] for a business as usual scenario where only current policies are continues and there are no new climate-related policies. They are calculated using econometric equations which take in past behaviours and future predictions for economic output and efficiency changes. We apply the yearly reductions in each gas to the emissions from the CPCA area from combustion (CO_2), crops (N_2O) and livestock (methane). The EEP only projects to 2035, after we which we do not project any further changes in a business as usual scenario (in line with analysis by the Committee on Climate Change).

D.; Thomson, A.; et al. (2017). Implementation of an Emissions Inventory for UK Peatlands A Report to the Department for Business, Energy & Industrial Strategy.

[57] BEIS. (2019). Updated Energy and Emissions Projections: 2018 - Annex A: Greenhouse gas emissions by source. `https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2018`

Applying this methodology we see that all emissions sources are forecast to reduce incrementally out to 2035. We see that from a 2016 level of 406 $ktCO_2e$ in 2016, a business as usual scenario would lead to emissions stabilising at 351 $ktCO_2e$ by 2035. In reality there are many uncertainties in predicting emissions in a "no-further-policy" world, as there are many unknown factors that could affect demand for food and agricultural yields (including climate change itself).

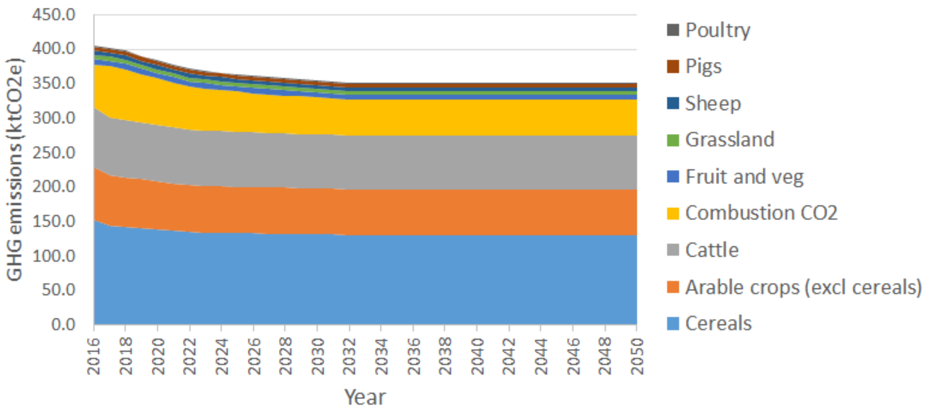

Figure 4.5: Projections for CPCA area agriculture emissions to 2050

4.4. 2050 Ambitious Scenario

Agriculture is one of the hardest sectors in which to abate emissions. There is no way that while maintaining an agriculture sector, non-CO_2 emissions can be zero.[58] However, there is still lots of potential to reduce emissions within the sector, through both on-farm measures and demand-side measures.

Stationary and mobile machinery currently running on fossil fuels such as tractors can be electrified on switched to run on hydrogen. Space heating and cooling can also be electrified or switch to hydrogen. Livestock emissions can be reduced by genetic breeding, ruminant feed additive 3NOP (3-nitrooxypropanol) which can reduce methane emissions by 4-40% (depending on the cattle type)[59], and diet change leading to a reduction in demand for meat and dairy. Emissions from crops can be reduced by improved nitrogen efficiency, the use of nitrification inhibitors which reduce N_2O emissions from fertiliser, and improved crop productivity. All agricultural emissions can be reduced by reducing food waste, thereby reducing demand for agricultural outputs.

All of these measures are combined to a package of measures by in the Committee on Climate Change Net Zero Technical Report to a realistic "Further Ambition" scenario, where UK agriculture emissions decrease by 42% on 2017 levels, or 32% relative to a 2050 business as usual scenario.[60] When this reduction is applied to Cambridgeshire's

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[58] CCC. (2019). Net Zero Technical Report

[59] Scotland Rural College, ADAS and Edinburgh University. (2019). Non-CO2 abatement in the UK agricultural sector by 2050 `https://www.theccc.org.uk/publication/non-co2-abatement-in-the-uk-agricultural-sector-by-2050-scotlands-rural-college-adas-and-edinbur`

[60] CCC. (2019). Net Zero Technical Report

agricultural sector, there are residual emissions of 239 $ktCO_2e$. This is then the largest residual sector of emissions in the 2050 Ambitious Scenario, making up 40% of the residual. This reflects the complexity and difficulty of reducing non-CO_2 emissions in the agricultural sector.

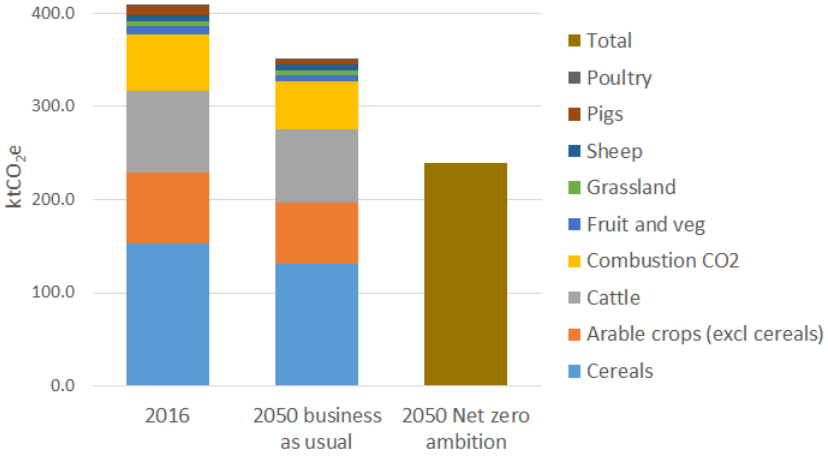

Figure 4.6: Comparison of current agriculture emissions, business as usual in 2050 and an ambitious net zero 2050 scenario in 2050 for the CPCA area

5. COMMERCIAL SERVICES AND INDUSTRY

Author: Yuchen Hu & Meena Matharu

The commercial services and industry (CSI) sector within Cambridgeshire and Peterborough comprises a diverse range of subsectors. Agriculture, an important part of the County's economy, is covered in its own section. Appendix C highlights the assumptions which have been made while the analysis of this sector in more detail. The uncertainty in economic predictions combined with the large emissions from this sector mean that further research should be a priority.

Commercial Services and Industry deliver a major contribution towards existing and future economic development within Cambridgeshire and Peterborough. However, unsurprisingly, industry, commercial operations and buildings contribute heavily towards existing daily energy consumption and demands. Therefore, meeting the UK and regional carbon emissions reduction targets by 2050 will require significant reductions in the consumption of energy within the CSI. This will require the deployment of low carbon heating and carbon capture and storage, (CCS).

The structure of this section is as follows:

1. Historical CO_2 emissions from Commercial Services and Industry (CSI)
2. Baseline emissions projection to 2050
3. Net Zero emissions projection to 2050

5.1. HISTORICAL EMISSIONS

Commercial and industrial emissions accounted for 27% of total emissions in Cambridgeshire and Peterborough in 2016[61]. Between 2005 and 2017 emissions decreased from 2980 kt CO_2e from to 1538 kt CO_2e (1644 kt CO_2e in 2016)[62] as shown in Figure 5.1. Emissions per capita also declined (Figure 5.2). Note the emissions data only considered CO_2 emissions.

Emissions in CSI come from four main sources: electricity, gas, large industrial installations and other fuels. Other fuels includes liquid fuels such as heating oil as well as solid fuels. Solid fuels include steam coal, anthracite, manufactured solid fuels, benzole, tar, blast furnace gas and coke oven gas. Analysis of emissions of large industrial installations from those three sources will not be included here as it is inseparable in UK Local Authority and regional carbon dioxide emissions national statistics. The pie chart (Figure 5.3) shows the percentage contribution from each source in 2017. Nearly 80% of the emissions in the CSI were indirect emissions through consumption of electricity (49%) and natural gas (30%). To reduce carbon emissions, a reduction in demand for each source and/or the reduction the carbon intensity of each

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[61] BEIS. (2018). UK local authority and regional carbon dioxide emissions national statistics: 2005 to 2016.
[62] BEIS. (2019). UK local authority and regional carbon dioxide emissions national statistics.

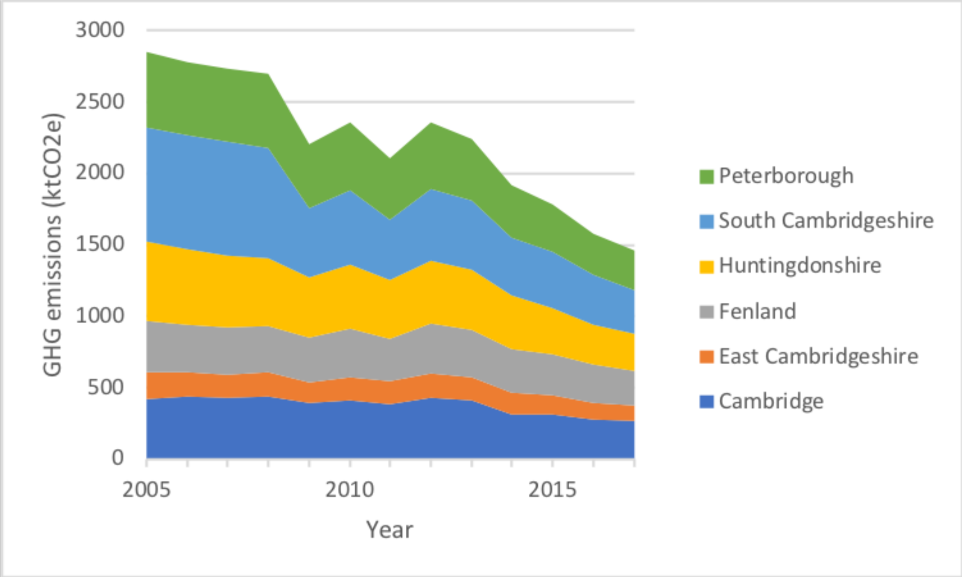

Figure 5.1: Historical emissions from CSI from 2005 to 2017

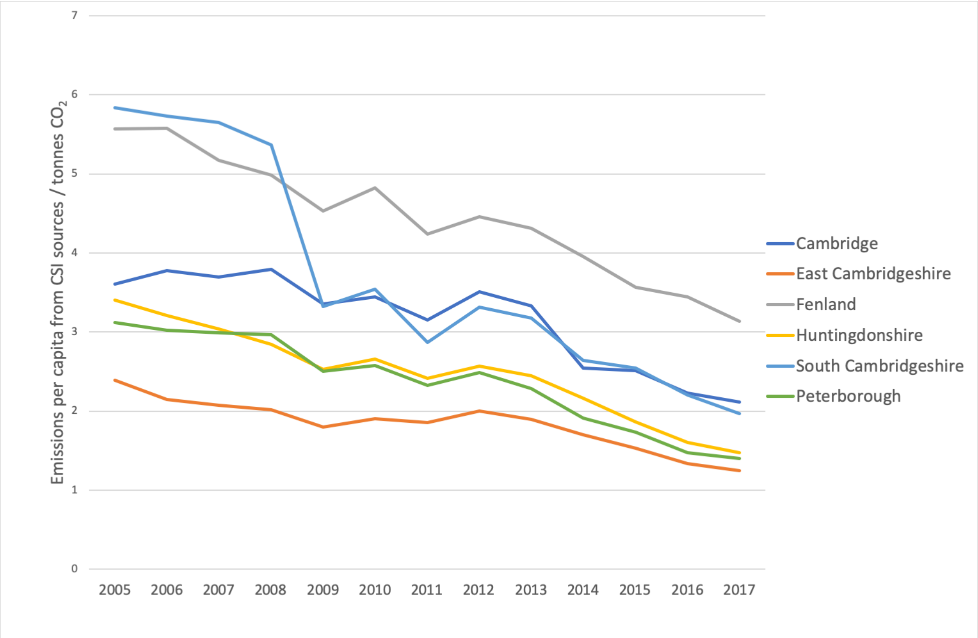

Figure 5.2: Historical emissions per capita from CSI from 2005 and 2017

source must be considered. The introduction of renewable sources of electricity generation and the reduction in coal have resulted in the emissions associated with electricity production steadily reducing[63]. Also, improvements in energy efficiency will temper the energy demand and emissions associated with local economic growth. Figure 5.4 shows the 2017 emission source breakdown for the districts. Fenland consumed more energy from gas than electricity. East Cambridgeshire, South Cambridgeshire and Huntingdonshire consumed more energy from solid fuels than that from gas.

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[63] BEIS. (2019). Electricity emissions factors until 2100

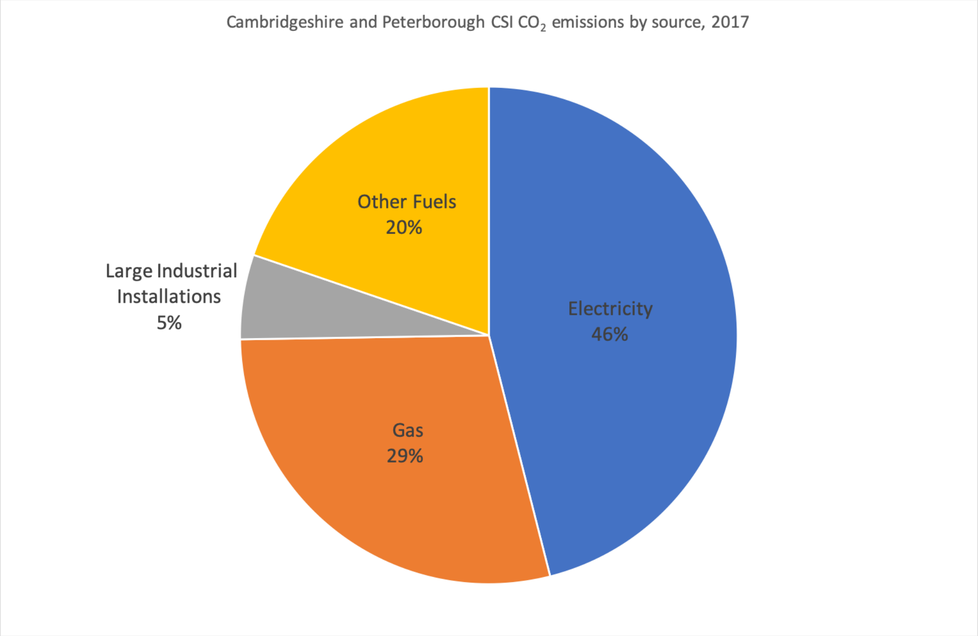

Figure 5.3: CSI emissions of CPCA in 2017 from source

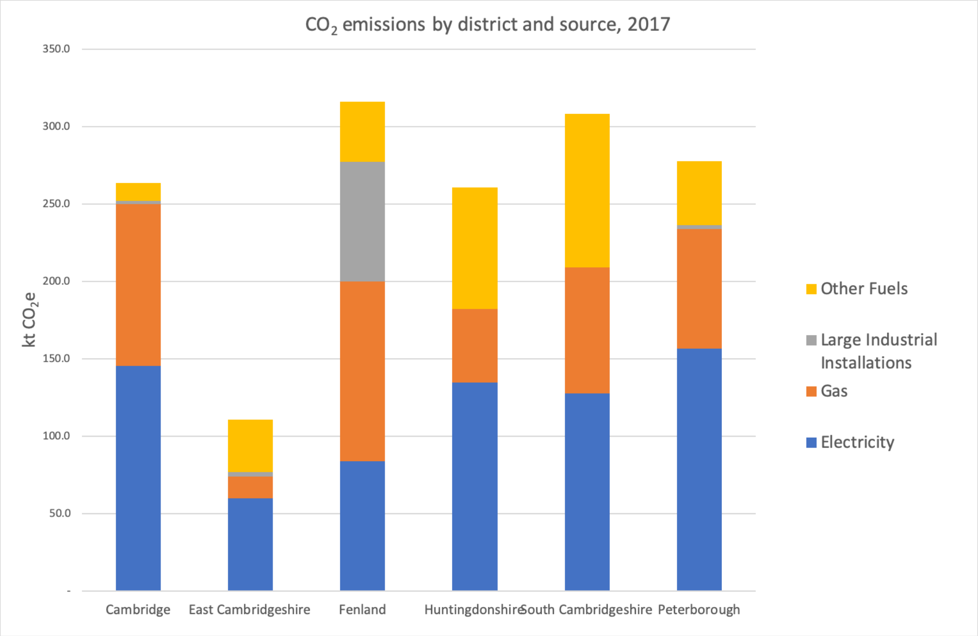

Figure 5.4: CSI emissions in 2017 by source and district

The breakdown in emissions sources in each district is related to the local economy structure and infrastructure. A breakdown of the employment in CSI is shown in Figure 5.5, this is from the model East of England Forecast Model (EEFM), 2017.[64] 53% of employment within the CSI in Cambridgeshire and Peterborough is in commercial services, while only 0.8% is in the metal industry. 58% of business in Cambridge and 72 % in Peterborough are commercial services. Fenland and Huntingdonshire has more industry than commercial services, with 36% and 31% of employment in the industrial

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[64] EEFM 2017 model variable spreadsheet: sheet Employment. https://cambridgeshireinsight.org.uk/eefm/

sector (Figure 5.6). In addition, among all the districts Fenland has the largest fractional contribution to employment by metal manufacturing (2 %), which may help to explain the higher emissions per capita figures seen in Figure 5.2.

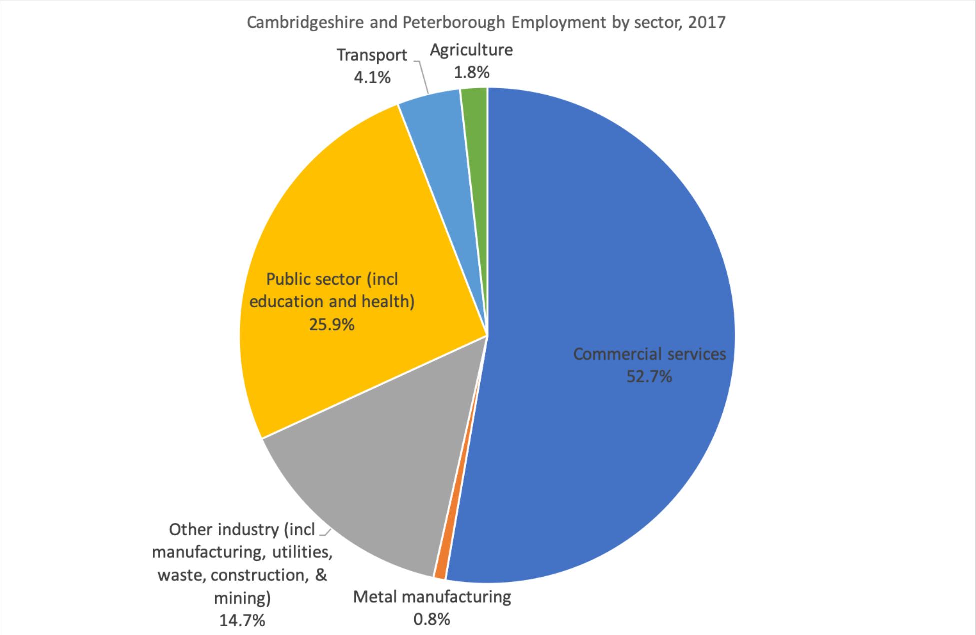

Figure 5.5: CSI job breakdown in 2017

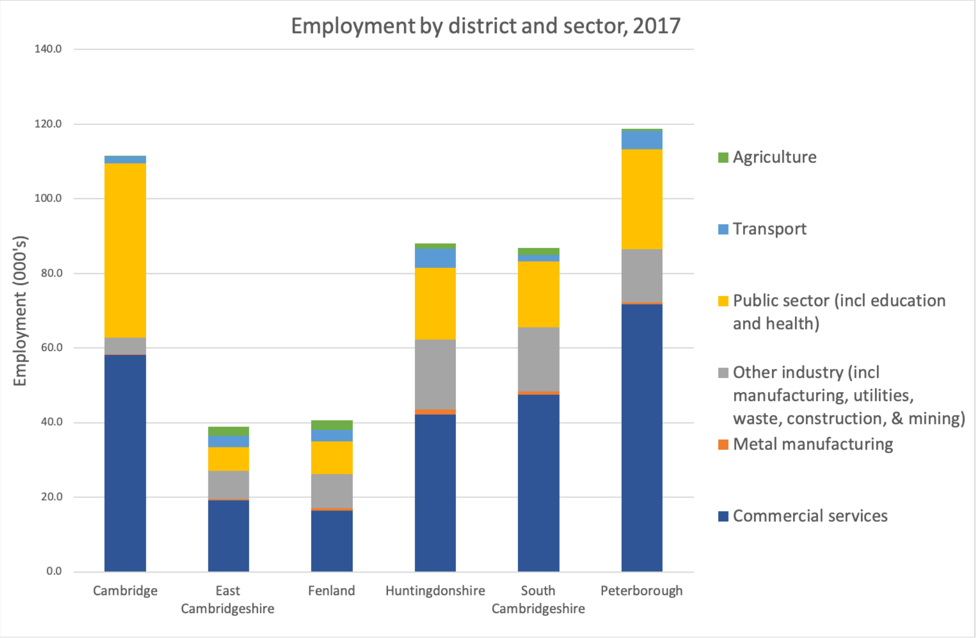

Figure 5.6: CSI job breaksown in 2017 in district councils

5.2. BASELINE EMISSIONS PROJECTION

The baseline emissions forecast utilises existing and planned policy scenarios. These are the national level regulations from National Grid for gas and electricity future energy base demands and carbon intensities. [65]

Emissions are calculated from the product of energy demand (GWh) and carbon intensity (ktCO_2e/GWh). The carbon intensity for electricity, gas and solid fuels are taken from BEIS. [66] The energy demand in the CSI sector considered in this scenario is from three areas: commercial services, the iron industry and other industry. Each consists of the following subsections:

- Commercial services: Wholesale, Retail, Accommodation and Food services, Publishing and broadcasting, Telecoms, Computer related activity, Finance, Real estate, Professional services, Research and Development, Business services, Employment activities, Art and entertainment, Other services.
- Iron industry: Metal manufacturing.
- Other industry: mining and quarrying, food manufacturing, general manufacturing, chemicals, pharmaceuticals, transport equipment manufacturing, electronics manufacturing, electronics, utilities, waters and remediation, construction.

Energy demand from public sector services, healthcare and education have been excluded from this projection.

Energy demand per capita in the UK was first calculated with BEIS EEP 2019 Annex F[67] and EEFM 2017 Employment[68]. The energy demand for each district in those three sectors was then obtained by multiplying UK energy demand per capita by the number of employees in the district, followed by adjustment based on the local economy breakdown. The modelling detail is presented in Appendix C.

The energy demand time-series plot is shown in Figure 5.7. The electricity demand increases to 3269 GWh in 2050 while the demand for gas remains relative unchanged at around 2000 GWh. The demand for solid fuels decreases by 65%, to 93 GWh in 2050.

Figure 5.11 shows the baseline emissions projections to 2050, with breakdown to districts.

Total emissions at 2050 are 684 kt CO_2e (Figure 5.9), 44% of the emissions in 2017 (1538 kt CO_2e). Despite a predicted increase in electricity demand, the emissions from electricity production drop from 707 kt CO_2e in 2016 to 95 kt CO_2e in 2050. This 87% reduction is driven by a reduction in the carbon intensity of electricity production of 90 % by 2050 relative to the 2107 level. As few techniques exist to reduce the carbon emissions from natural gas combustion, gas is predicted to become the largest contributor to emissions under baseline scenario by 2050.

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[65] National Grid Future Energy Scenario, http://fes.nationalgrid.com

[66] Electricity emissions intensity projections to 2100, BEIS

[67] https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2018

[68] https://cambridgeshireinsight.org.uk/eefm/

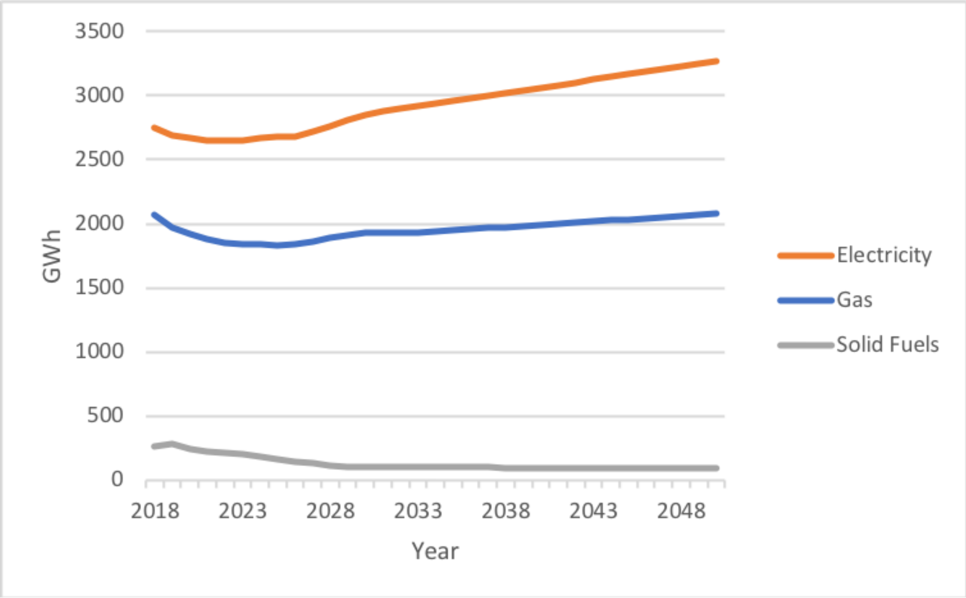

Figure 5.7: CSI baseline energy demand projections from 2018 to 2050.

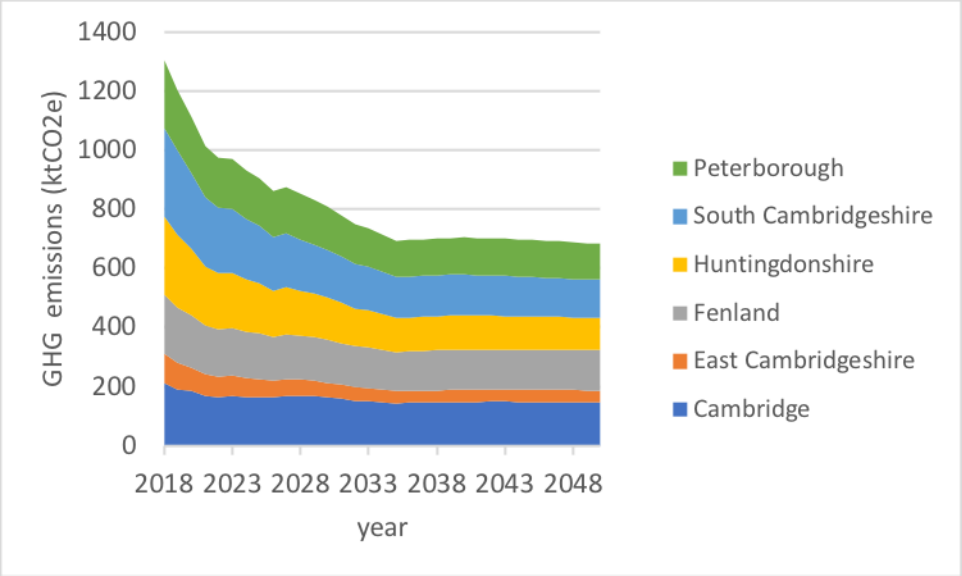

Figure 5.8: CSI baseline emissions projections from 2018 to 2050.

5.3. AMBITIOUS SCENARIO

The assumptions for the Net Zero Scenario are from the Committee on Climate Change report[69] as explained in Appendix C. This scenario is based on the same set of commercial services and industrial sectors as in the baseline scenario.

All the assumptions are implemented linearly on the baseline energy demand, as shown in Figure 5.10. In 2050, the energy demand will be 225 GWh from gas, 2486 GWh from electricity and 87 GWh from solid fuels.

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[69] Committee on Climate Change, 2019, Net Zero 2019

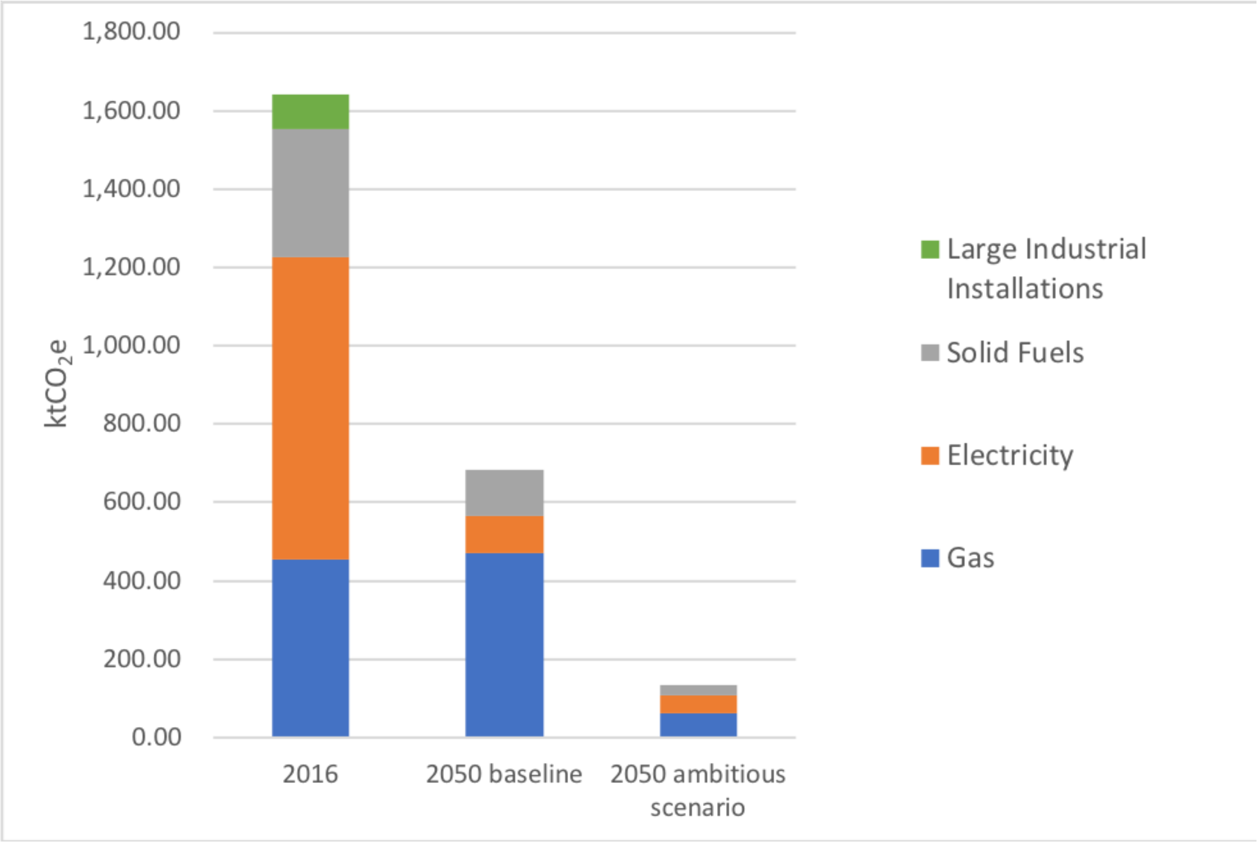

Figure 5.9: CSI emissions in 2050.

Figure 5.11 shows the emissions projections for each district to 2050.

The total emissions in the ambitious scenario are 103.2 kt CO_2e (Figure 5.9), around 20% of the total emissions under the baseline scenario and 8.6 % of 2017 emissions.

5.4. SUMMARY

The commercial services sector dominates demand for electricity. With the decarbonisation of the national grid, the emissions from electricity use will be reduced by 90% from the 2017 level. The key for local authorities in Cambridgeshire and Peterborough to reduce commercial and industrial carbon emissions is to decrease the use of natural gas and solid fuels. To achieve that, the implementation of low carbon heating is of paramount importance. However, even in the most ambitious scenario, i.e. 90% of gas demand reduction and complete cessation of solid fuel use, there will still be emissions from electricity use in 2050. Therefore, to reach net zero, CCS and afforestation must be deployed as well.

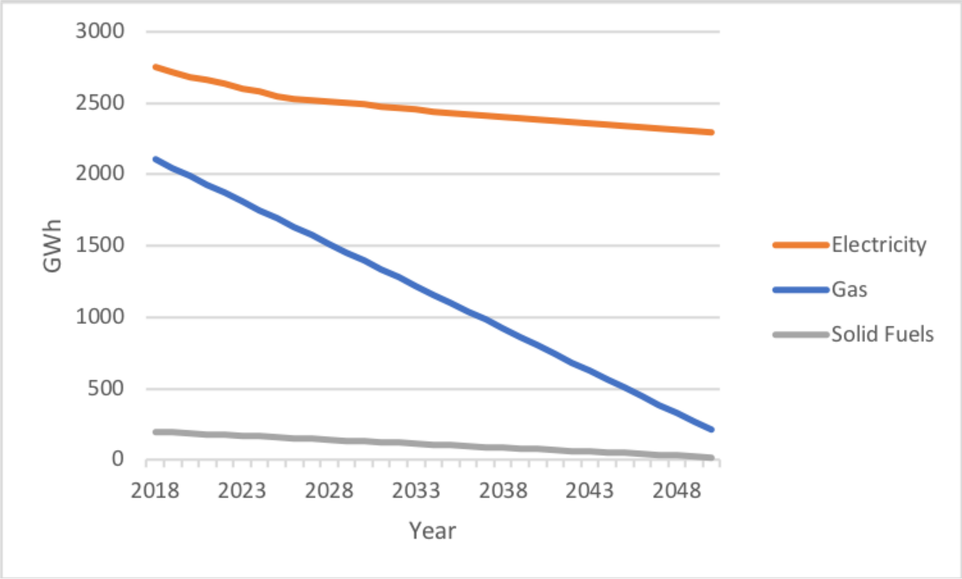

Figure 5.10: CSI ambitious energy demand projections from 2018 to 2050.

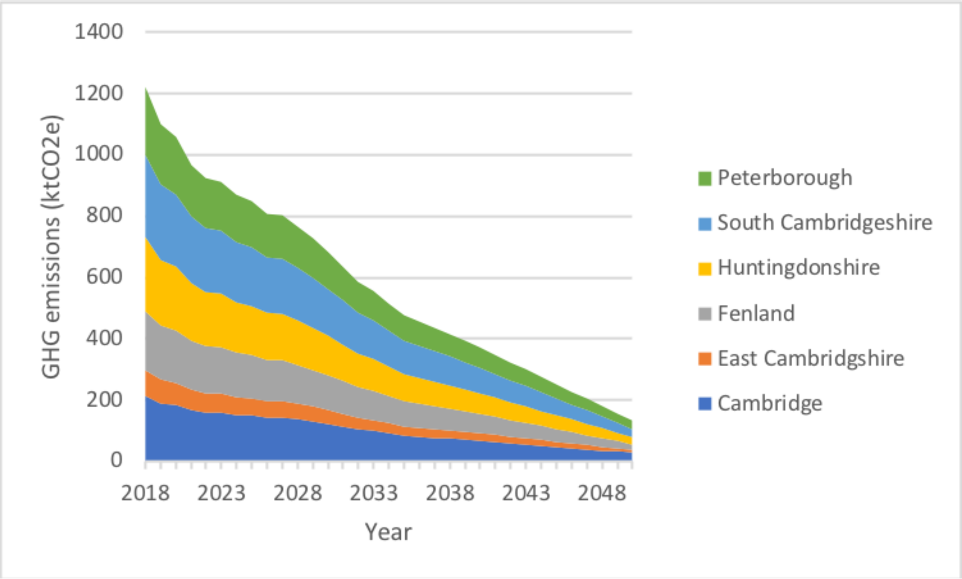

Figure 5.11: CSI ambitious emissions projections from 2018 to 2050.

6. WASTE MANAGEMENT

Author: James Weber

Deployment of CCS, electrification of vehicles and enhancement of methane capture at landfill and composting sites could see emissions from waste management drop from 130 kt CO_2e to around 25 kt CO_2e in 2050.

In relative terms waste management is a small source of carbon emissions, currently contributing 2% (130 kt CO_2e) of the County's total emissions. However, as emissions are dominated by a small number of sources, abatement efforts can be concentrated, enabling significant reduction in emissions to be achieved. Certain areas of waste management such as waste transport and industrial emissions also fall under the other categories covered in this report. Where this is case, it has been made clear and to avoid double-counting, emission estimates and projections have been added to County total only once. Nevertheless, a full breakdown of the emissions from waste management is believed to be helpful as it is an area where the Council has significant direct influence (e.g. waste transport) or indirect influence (e.g. by determining how landfill facilities are run). Given the small number of sources, this section is structured slightly differently with each source of emissions (see below) considered in turn with current emissions and projections to 2050 under baseline and ambitious scenarios (with the required policies and technologies) discussed.

The sources of emissions considered were:

1. Transport of waste collected by local authorities
2. Landfill at Waterbeach site in the form of landfill gas (LFG)
3. Recycling and composting activities
4. Energy Recovery Facility (ERF) in Peterborough
5. Other small facilities

The transport of third party (private) waste was not included (although rough estimates were made) and is assumed to be covered in the industry section. In addition, modelling work was performed to consider the effect of the proposed Waterbeach Energy from Waste (EFW) plant whose planning application is currently in the appeal stage.

Current emissions for each section were estimated using existing data and then a baseline projection and an ambitious emission reductions projection, including mitigation strategies, were considered.

6.1. OVERVIEW OF WASTE MANAGEMENT

The breakdown of waste in England, Cambridgeshire and Peterborough is shown in Figure 6.1. Cambridgeshire currently sends 55% (180 kt per year) of its domestic waste to recycling or composting with the remaining 45% (140 kt per year) sent to landfill[70]. In

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[70] Waste Data Summary Cambridgeshire County Council 2004-2019

addition, Cambridgeshire County Council deals with a small quantity of commerical waste (25 kt per year) of which 7-10 kt is sent to landfill.[71] These figures have remained roughly constant over the last 10 years. By contrast, Peterborough sends 44% of domestic waste (38 kt) to recycling or composting, 2% to landfill and 53% (44 kt) is incinerated[72].

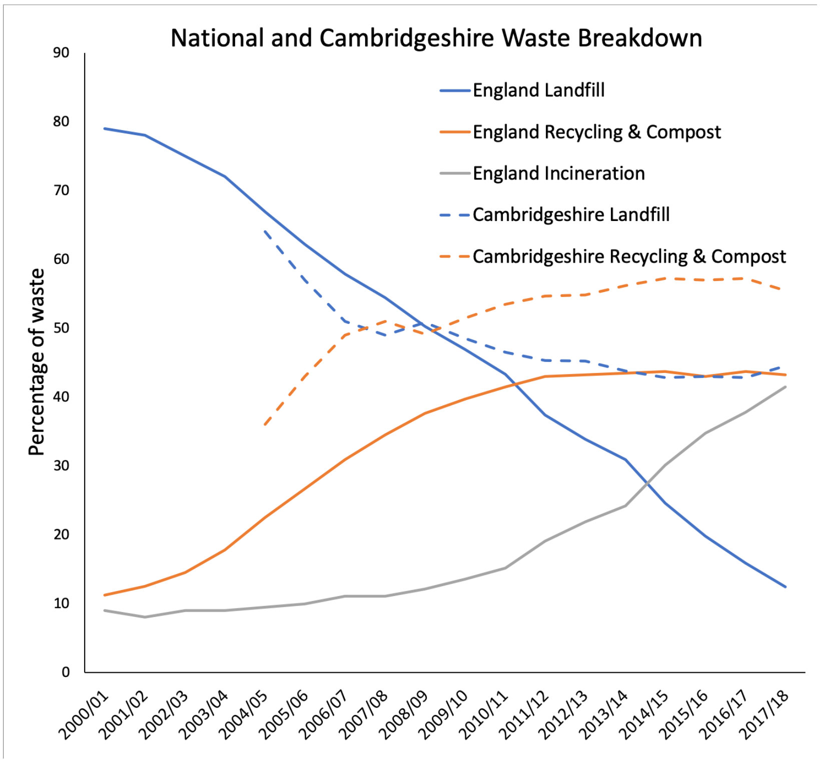

Figure 6.1: National & Cambridgeshire Waste Breakdown for waste collected by local authorities.

For context, the national recycling and composting rate is 42%. 40% of waste is incinerated and the final 10% sent to landfill[73]. The total waste per capita for Cambridgeshire is similar to the national average. The annual landfill per capita for Cambridgeshire is 200 kg and has decreased by 1.6% per year on average over the last 7 years[74].

6.2. TRANSPORT EMISSIONS

Emissions from waste transportation are estimated to be 4.9 kt CO_2e at present with reduction to 0.6 kt CO_2e by 2050 a reasonable target.

Emissions were calculated based on diesel fuel used by waste transport vehicles of the

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[71] Waste Data Summary Cambridgeshire County Council 2004-2019

[72] Management of local authority collected waste 2014 to 2017, Local Authority Collected Waste Management Statistics, DEFRA

[73] Management of local authority collected waste 2000 to 2017, Local Authority Collected Waste Management Statistics, DEFRA

[74] Waste Data Summary Cambridgeshire County Council 2004-2019

District and City councils. A conversion factor 2.59 kg CO_2e per kg diesel was used.[75] Only emissions from waste transport vehicles were considered; embodied emissions such as those from vehicle manufacture or maintenance were not included.

Data was obtained from Peterborough City Council, Fenland District Council, Huntingdonshire District Council and Cambridge and South Cambridgeshire Council. No data were obtained for East Cambridgeshire. Based on population comparisons[76], East Cambridgeshire (89,362) was assumed to have the same emissions as Fenland (101,491). The resulting quantity of 1,892,000 litres of diesel produced 4.90 kt CO_2e. To be clear, while this quantity was considered in terms of the emissions breakdown from waste management, it was not included the total County emissions figure as it is believed to be encompassed by the Transport emissions value. Additional information is provided in Sections D.1 and D.6.

Emissions from transport of waste to local household waste centres by private vehicles were not included as they were deemed to be within the emissions from transport section.

Private sector waste transport was not included this section as it was considered to be part of industrial emissions. A reasonable estimate would be 1.2 kt CO_2e because the quantity of private sector waste going to landfill (50 kt per year) is 1/4 of the amount sent to landfill/incineration by the County. This will probably be an upper bound as private waste transport distances are likely to be lower as they do not need to go "house to house".

6.2.1. FUTURE DEVELOPMENTS

Mileage/emissions will be increased by population growth (projected to be 23% between 2020 and 2050[77]) and more housing developments. While waste to landfill per capita has been dropping in Cambridgeshire, total waste per capita has remained unchanged over the last 5 years. Greater environmental awareness and a drive by district authorities to encourage lower waste production may reduce total waste per capita but here, a worst case scenario of a 23% rise in waste by 2050 is considered.

The actual relationship between total waste per capita and mileage will be complicated as it is affected by many factors such as route planning. A simple 23% increase in emissions would result in 6.3 kt CO_2e and this is considered to be the baseline scenario.

Three complementary emission reduction policies are proposed:

1. Partial or entire conversion of fleet to electric vehicles
In this ambitious scenario, analysis based on the predicted energy demand (23%

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[75] DEFRA. (2019). Government emission conversion factors for greenhouse gas company reporting.
[76] Cambridgeshire Insight. (2019)
[77] Cambridgeshire Insight

increase in diesel use) suggests emissions would be 0.6 kt CO_2e (10% of current emissions). A more detailed calculation is given in Section D.1. Realistically, improved efficiency of electric vehicles would reduce this value further. Again, embodied emissions are not included. Similar reductions are expected for waste transport by members of the public to household waste centres.

2. Analysis of routes to ensure maximum possible efficiency
While it is acknowledged this may already be standard practice, ensuring that the fleet drives the minimum number of miles and vehicles operate at maximum capacity is an inexpensive method of producing maximum efficiency.

3. Reduction in collection frequency
The challenges to implementation of this policy are acknowledged and it would need to be combined with a push to reduce total waste per capita. However, it would reduce transport emissions. One option would be to collect non-recyclable waste at the current frequency but collect recyclable waste, which is less likely to rot, on a less frequent basis thus reducing the demand for vehicle capacity and so vehicle mileage and emissions.

6.3. LANDFILL AT WATERBEACH

Current emissions are likely 57 ± 15 kt CO_2e per year with a large uncertainty in LFG capture. Ambitious increase in landfill gas (LFG) capture and halving of landfill waste per capita by 2050 would reduce emissions to 10 kt CO_2e.

The landfill at Waterbeach receives 200 kt of waste per year, of which 150 kt is from Cambridgeshire County Council (140 kt from domestic, 10 kt from commercial). The remaining 50 kt is from third party sources and, while the composition of the waste is unknown, it is suspected to consist primarily of aggregate waste and other byproducts of industry.

CO_2-only estimates for the Waterbeach landfill disclose a carbon footprint of 16.4 kt (2017)[78] which is likely to come from the waste transfer and site's electrical usage with the distribution unknown. As a baseline projection, the split was assumed to be 50:50 with vehicle emissions unchanged and electrical emissions declining with grid carbon intensity (0.226 and 0.025 kg CO_2e / kWh for 2017 and 2050 respectively[79]). This yielded emissions of 8.8 kt CO_2e in 2050; the baseline scenario. Full electrification of vehicles in the more ambition scenario resulted in emissions of 1.8 kt CO_2e by 2050. More detail is given in Section D.2. Again, this part of the landfill's emissions budget will be included in the total emissions of Industry and Commercial Services sector and so, to avoid double-counting, will not be included in the County's total emissions figure (see Section D.6).

However, an additional source of GHGs which is not considered in the Industry and

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[78] UK local authority and regional carbon dioxide emissions national statistics: 2005-2017, Ref BK5037IQ
[79] BEIS. (2019). Electricity emissions factors until 2100

Commercial Services sector is methane from the landfill. Decomposition of material in landfill produces landfill gas (LFG) which is composed of CO_2 and methane. The rate and quantity of LFG production depends on waste composition, landfill design and temperature among other things. Nationally, it is routine practice to capture LFG and burn it (which converts the methane to much less harmful CO_2) for energy generation.

Some information regarding methane capture has been obtained from the landfill operator, Amey Cespa Ltd.[80], see Figure D.4. This data is believed to refer to the landfill and composting (see Section 6.5) together and discloses 5.24 "Teq CO2" (Tonnes equivalent CO_2) of avoided GHG emissions via methane capture from landfill and the generation of 19,252,010 MWh of electricity from the methane. The definition of "Teq CO2" is uncertain at present. It was interpreted as the quantity of methane captured in units of tonnes of CO_2e. However, as 5.24 kt is around the same quantity of methane (within ~1 kt) predicted to be emitted in the modelling work in this report and by Fitchner[81], "Teq CO2" could refer to the quantity of methane captured in tonnes of methane. This needs to be clarified as a matter of urgency.

Under the assumption that 5.24 kt refers to CO_2e, this corresponds to a total reduction in emissions of 7.0 kt CO_2e (captured methane and offset of emissions from grid electricity production using 2018 carbon intensity [82]). The data discloses the "Proportion of methane burnt in torch and used for generating electricity with regard to the amount potentially emitted" as 99.9%, far higher than industry standards which are in the range 52%-75%.[83] [84] Furthermore, as is shown in Section 6.3.2, the amount of 5.24 kt CO_2e is a very small fraction of the predicted quantity of methane emitted from the landfill.

Clarification of the LFG capture rate should be sought as this information is crucial for producing an accurate carbon footprint of the landfill and further enquiries should be made to determine it as a matter of urgency. In a worst case scenario (no LFG capture), annual emissions could be as high as **130 kt CO_2e**, dwarfing the other emission sources in the sector and making the landfill a key area to focus abatement efforts. To explore the implications of the uncertainty in the LFG, several different LFG scenarios were considered. DEFRA guidance for LFG capture calculations recommends a capture rate of 75% but large landfills are estimated have a capture rate of 68% and the national collection efficiency is estimated to be 52%.[85]

To calculate the possible LFG emissions, an approach very similar to that used in the carbon assessment report for the proposed Energy From Waste facility at the Waterbeach site was used[86]. Domestic waste was asssumed to have a biogenic carbon fraction of

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[80] Waterbeach Information Request & supporting docuements, from Amey Cespa and made available to Cambridgeshire County Council

[81] Waterbeach Energy From Waste Facility Carbon Assessment, Fitchner Consulting Engineers Ltd

[82] BEIS. (2019). Electricity emissions factors until 2100

[83] Waterbeach Energy From Waste Facility Carbon Assessment, Fitchner Consulting Engineers Ltd

[84] Appendix B, Review of Landfill Methane Emissions Modelling, Report for DEFRA by Golder Associates, 2014

[85] Waterbeach Energy From Waste Facility Carbon Assessment, Fitchner Consulting Engineers Ltd

[86] Waterbeach Energy From Waste Facility Carbon Assessment, Fitchner Consulting Engineers Ltd

15%[87] and a more detailed explanation of the calculation is provided in Section D.2.

6.3.1. LFG SCENARIOS

Several waste reduction scenarios were considered. For each, the waste per capita as a function of time was multiplied by the projected population to produce a value for total waste. The recycling/composting and landfill fractions remained unchanged and LFG emissions were calculated. Year-on-year reductions of landfill waste per capita of 0% (fixed), 2.28% and 7.39% were considered. The latter two were chosen as they result in a 50% and 90% reduction in waste by 2050 respectively (for reference, waste to landfill has decreased by 1.6% per year over the last 7 years). A fixed value of 10 kt of waste was added to the total to account for commercial landfill contributions; it was assumed that commercial landfill would not decrease with time and that it would have the same composition as the domestic waste.

The extra 50 kt of waste from third parties was not considered in this analysis as its composition is unknown. Given that it is likely to consist of byproducts of industry such as aggregates, the biogenic carbon content will likely be lower than that of the 15% of domestic waste. A tentative estimate of a 5% biogenic content resulted in emissions (under a 68% LFG capture scenario) of 4.2 kt CO_2e, about 10% of the Cambridgeshire County Council waste emissions. However, given the uncertainty in this figure and the fact that the council have little direct control over third parties, LFG emissions from third parties were omitted.

6.3.2. RESULTS

The results of the scenarios are shown in Figure 6.2. The "No capture" scenario indicates that the landfill has the potential to be a considerable source of emissions (130 kt CO_2e which is more than the rest of the waste management sector combined). Using the figure of 5.24 kt CO_2e from Amey Cespa for captured emissions, the resulting emissions are 125 kt CO_2e, again very high with an apparent capture rate of 4% which is significantly below the industry standard.

Given the uncertainty surrounding the figures from Amey Cespa, a "middle of the road" scenario with a LFG capture rate of 68% was considered. This resulted in current annual emissions are 41±15 kt CO_2e with the uncertainty reflecting the likely range of LFG capture percentages of 52% - 75%.

The modelling also shows the significant impact that reduction of waste of to landfill and increase in LFG capture has on the emissions. At present a 5% increase in LFG capture will abate 6.5 kt CO_2e, more than the emissions from the entire waste transport fleet.

A baseline projection situation with the current drop of 1.6% in landfill waste per capita per year will yield 2050 emission of 31±10 kt CO_2e while an ambitious emission

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[87] Waterbeach Energy From Waste Facility Carbon Assessment, Fitchner Consulting Engineers Ltd

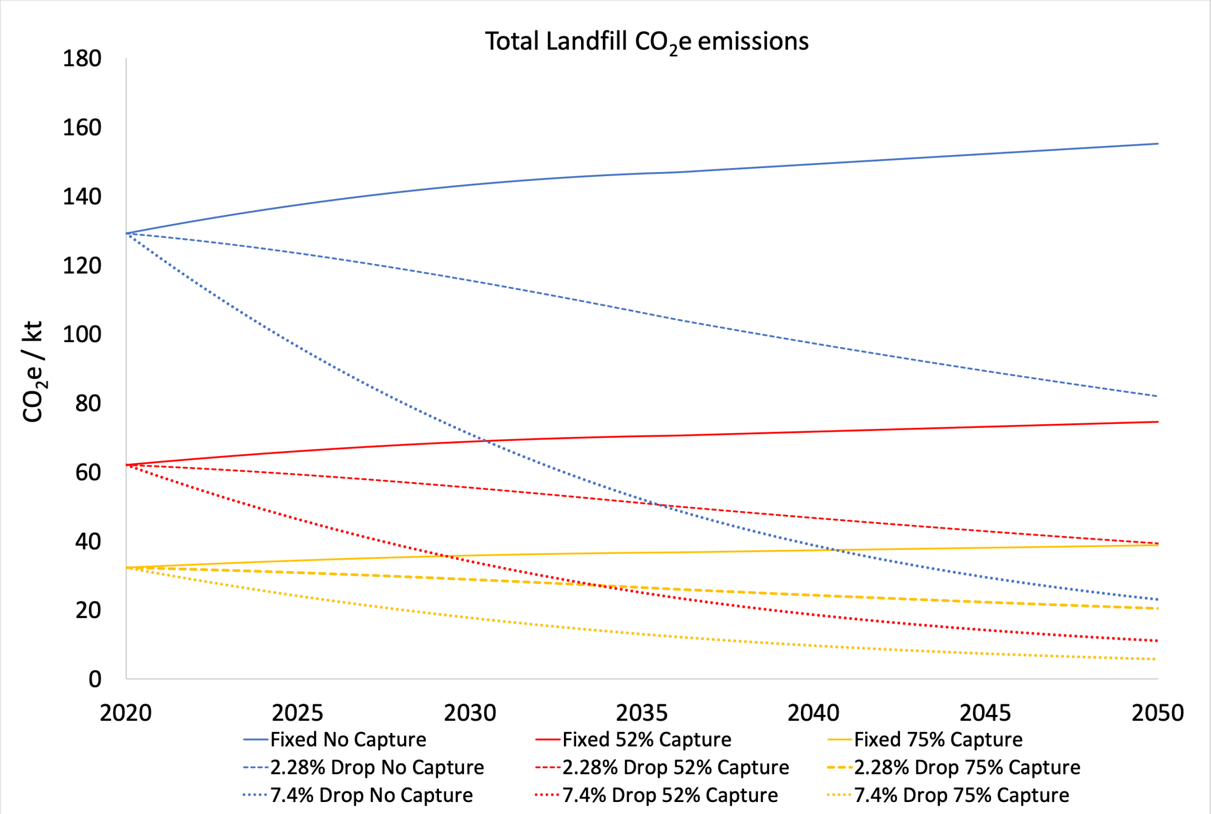

Figure 6.2: Emissions from landfill under different waste reduction scenarios and LFG capture rates. The 75% and 52% capture rates represent the likely upper and lower bounds. Decreasing landfilled waste and increasing LFG capture will both significantly reduce emissions.

reduction scenario (not shown) where LFG capture rises to 85% (the upper bound estimate for current LFG capture rates[88] and landfill waste per capita is halved by 2050 (2.28% drop per year) results in annual emissions of 14.8 kt CO$_2$e.

A further consideration is the financial benefit of reducing the amount of waste sent to landfill. Every tonne of waste sent to landfill costs £91.35[89] meaning the halving of waste per capita to landfill envisaged in the ambitious scenario would save on average £2.59 m per year from 2020-2050 (£0.1 m in 2020 rising to £5.17 m in 2050, assuming no change to tax). This incentive has not been explored in this report but warrants further research as it could release capital for investment in other mitigation technologies.

6.3.3. Inclusion of Energy From Waste Facility

The proposed Energy From Waste (EFW) facility at Waterbeach could produce emissions of up to 90 kt CO$_2$e per year by 2050. However, these emissions could be substantially reduced (by 80%) with use of CCS and, provided waste is diverted from the Waterbeach landfill to the EFW, such a facility could offer an

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[88] P.3 Review of Landfill Methane Emissions Modelling, Report for DEFRA by Golder Associates,2014
[89] Landfill Tax: increase in rates, HMRC, Published 29 October 2018

alternative to increasing LFG capture rates.

The proposed EFW facility has a capacity of 230 kt per year and so could take all the waste currently sent to landfill by Cambridgeshire County Council, even accounting for population growth. There is however no guarantee of this and therefore, to assess the impact on net carbon emissions three scenarios have been considered where the EFW takes none of the Cambridgeshire County Council waste, 50% of it or 100%.

Operating at full capacity, the net emissions will be 75.8 kt CO_2e in 2025 rising to 89.7 kt CO_2e in 2050. The increase is due to decreasing grid carbon intensity and a detailed explanation of the calculation is given in Section D.3. Implementation of CCS at an 80% capture efficiency (a reasonable level[90]) would reduce the 2050 emissions to 18 kt CO_2e. It should be noted that not all of the emissions will be derived from waste collected by the council, a significant fraction will come from third party sources.

In the scenario where the no county waste goes to the EFW, the EFW's emissions are simply added to the landfill emissions. At the other end of the scale, when 100% of Cambridgeshire County Council waste goes to the EFW, landfill emissions go to 0 and so total emissions simply rise gradually from 75.8 kt in 2025 to 89.7 kt CO_2e in 2050, regardless of efforts to reduce landfill waste. Under 50% scenario, emissions plateau at 118-144 kt CO_2e depending on LFG capture rate. The plots showing the effect of different diversion to the EFW are shown in Appendix D.4 and illustrate the fact that, should the EFW be built and take a significant quantity of waste, CCS will become an ever more important technology while landfill gas capture rate will be of diminished importance.

The optimal solution, from a carbon emissions perspective, would be the diversion of all waste to an EFW fitted with CCS or significant increase in LFG capture.

6.4. PETERBOROUGH ENERGY RECOVERY FACILITY

Net annual emissions are currently 14 kt CO_2e and are expected to rise to 21 kt CO_2e by 2050. CCS at 80% efficiency would reduce the 2050 annual emissions to 4.2 kt CO_2e.

Around 96% of Peterborough's waste which is not recycled or composted is incinerated in the Peterborough Energy Recovery Facility (ERF). The ERF handles 85 kt waste per year, of which 44 kt is currently waste collected by Peterborough City Council (PCC). Opened in 2015 and with a 30-year lifetime, the ERF will be operational until 2045 and, with no information available about a replacement, it is assumed it will continue until 2050 or be replaced by a similar facility.

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[90] [2005] IPCC special report on Carbon Dioxide Capture and Storage. Prepared by working group III of the Intergovernmental Panel on Climate Change. Metz, B., O. Davidson, H. C. de Coninck, M. Loos, and L.A. Meyer (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 442 pp

The ERF's net annual emissions were calculated to be 14.3 kt CO_2e in 2020 rising to 20.2 kt CO_2e in 2050 (again due to decreasing grid carbon intensity). A detailed explanation is provided in Section D.4.

The ERF's capacity was shown to be sufficient to cater for PCC under several different future scenarios. These included (i) a "worst case scenario" with no change to waste per capita, (ii) a "steady progression" case of 2.3% decrease per year (average annual drop over last 8 years) and (iii) a highly ambitious decrease of 7.4% per year resulting in a a 90% reduction in waste by 2050 relative to 2020 levels. Since waste from PCC has priority at the ERF, it can be safely assumed virtually all non-recyclable waste will be incinerated in the ERF.

6.5. Composting and Recycling Activities

Annual emissions were estimated to be 30 kt CO_2e, reducing under a baseline scenario to 22.5 kt CO_2e by 2050 and under an ambitious scenario to 3.0 kt CO_2e.

The emissions from composting and recycling, both direct and indirect via electricity, are very hard to constrain. The Waterbeach site handles the 180 kt of recycled and composted waste for Cambridgeshire while little information could be found regarding the much smaller quantity (36 kt) of recycled and composted waste for Peterborough.

The Waterbeach site includes a Materials Recovery Facility (MRF) which sorts recyclable waste into different categories and a Mechanical Biological Treatment (MBT) facility which sorts through black bag waste to find other materials which can be recycled. The MBT's CO_2-only footprint was estimated to be 14.4 kt CO_2e per year in 2017.[91] No information could be found for the MRF although it is possible the 14.4 kt CO_2 covers both.

The Waterbeach site has 2 composting facilities: open window composting and in-vessel composting, producing 42 kt of compost per year[92]. These processes involve the production of gases including methane and emissions are highly dependent on the conditions. Flaring of methane does appear to take place based on Environment Agency permit information[93] and information from Amey Cespa[94] but as the data from Amey Cespa requires clarification, it has not been used (further details are provided in Section D.5).

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[91] BEIS. (2019).UK local authority and regional carbon dioxide emissions national statistics.Ref AP3339XG.Retrieved from www.gov.uk/government/statistics/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics-2005-to-2017

[92] Amey Cespa https://wasteservices.amey.co.uk/where-we-work/cambridgeshire/waterbeach-waste-management-park/composting/

[93] Environment Agency Permit No EPR/NP3798VX

[94] Waterbeach Information Request & supporting docuements, from Amey Cespa and made available to Cambridgeshire County Council

Rather than use CO_2-only estimates where there is considerable uncertainty regarding what the data actually covers, emissions were estimated using comparison to national data on the assumption that the County's recycling and composting treatment is broadly representative of the national average. This yielded emissions of 30 kt CO_2e (a more detailed explanation is given in Section D.5).

The uncertainty associated with emissions arising from composting is large and this figure may be lower if significant methane capture and combustion from the compost is indeed in place at the Waterbeach site and this is something that should be investigated.

When considering the future projections, the origin of emissions was assumed again to be 50:50 between methane and electricity usage. The baseline projection increased with population while the electricity component decreased due to lowering carbon intensity yielding 20.45 kt CO_2e. The further ambition scenario also included 95% methane capture resulting in emissions of 2.96 kt CO_2e. The considerable uncertainty in the current emissions value results in uncertainty in these projections too. More detailed explanations are given in Section D.5.

6.6. Other facilities

While the Waterbeach waste processing site and the Peterborough ERF represent the largest waste management facilities, there exist other smaller facilities including several landfills which have been closed for 20 years. Information on these is scarce but their age means the emissions of LFG are will negligible by 2050 and so have not been included.

Milton landfill is a source of 23 kt CO_2e year[95]. This landfill accepts 96 kt of waste of unknown composition per year and captures an unknown fraction of the LFG produced and burns it for electricity generation[96]. Given the lack of further information regarding the landfill, emissions were assumed to remain fixed at 23 kt under the baseline future scenario emissions and were expected to decrease by 75% under the further ambition scenario as a result of a drop in landfill waste production and an increase in LFG capture to 85%. While there is significant uncertainty in this estimates, this source is small relative to other sources in the waste management sector.

6.7. Further work

The biggest sources of uncertainty remain the emissions from the landfill and composting at Waterbeach. Data on the quantity of methane/LFG collected and electricity generated from combustion does exists but, if taken to be correct, would suggest the capture rate is tiny (about 4%). Clarification of these data would significantly reduce the uncertainty in the current and projected emissions and allow decisions to be

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[95] BEIS. (2019).UK local authority and regional carbon dioxide emissions national statistics.Ref BV4584IU. Retrieved from www.gov.uk/government/statistics/uk-local-authority-and-regional-carbon-dioxide-emissions-national-statistics-2005-to-2017

[96] FCC Environment https://www.fccenvironment.co.uk/waste-processing/landfill/milton/

made regarding necessary abatement efforts. Therefore, these lines of inquiry should be renewed as a matter of urgency, particularly as the possible emissions could be very high.

Furthermore, any new contracts with landfill and composting operators should require a high level of LFG/methane capture as well as rigorous monitoring regimes to ensure these requirements are met.

It is also acknowledged that there may be other waste management facilities such as landfills in Cambridgeshire and Peterborough which would increase the total emissions from this sector. The analysis discussed in this section and the model which will be passed to CCC could be used to assess the impact such facilities. Furthermore, the suggested mitigation techniques of significant methane capture and rigorous monitoring standards would also be applicable.

6.8. CONCLUSIONS

- Current emissions in the waste management sector are 129 kt CO_2e per year (107 kt CO_2e when removing values counted elsewhere)
- Under a baseline scenario, where the dominant reduction mechanism is grid decarbonisation, emissions fall to 113 kt CO_2e per year by 2050 (90 kt CO_2e when removing emissions counted elsewhere.
- Under the ambitious scenario emissions fall to 29.3 kt CO_2e.

While there is considerable uncertainty in several areas, this assessment has provided a first estimate of the emissions of the waste management sector. The breakdown of the different emission sources and their possible values under Baseline Scenario and the 2050 Ambitious Scenario is shown below. The key areas for mitigation efforts are:

- Increase in LFG capture and compost methane capture at the Waterbeach landfill.
- Electrification of waste transport vehicles.
- Deployment of CCS for all incineration facilities.

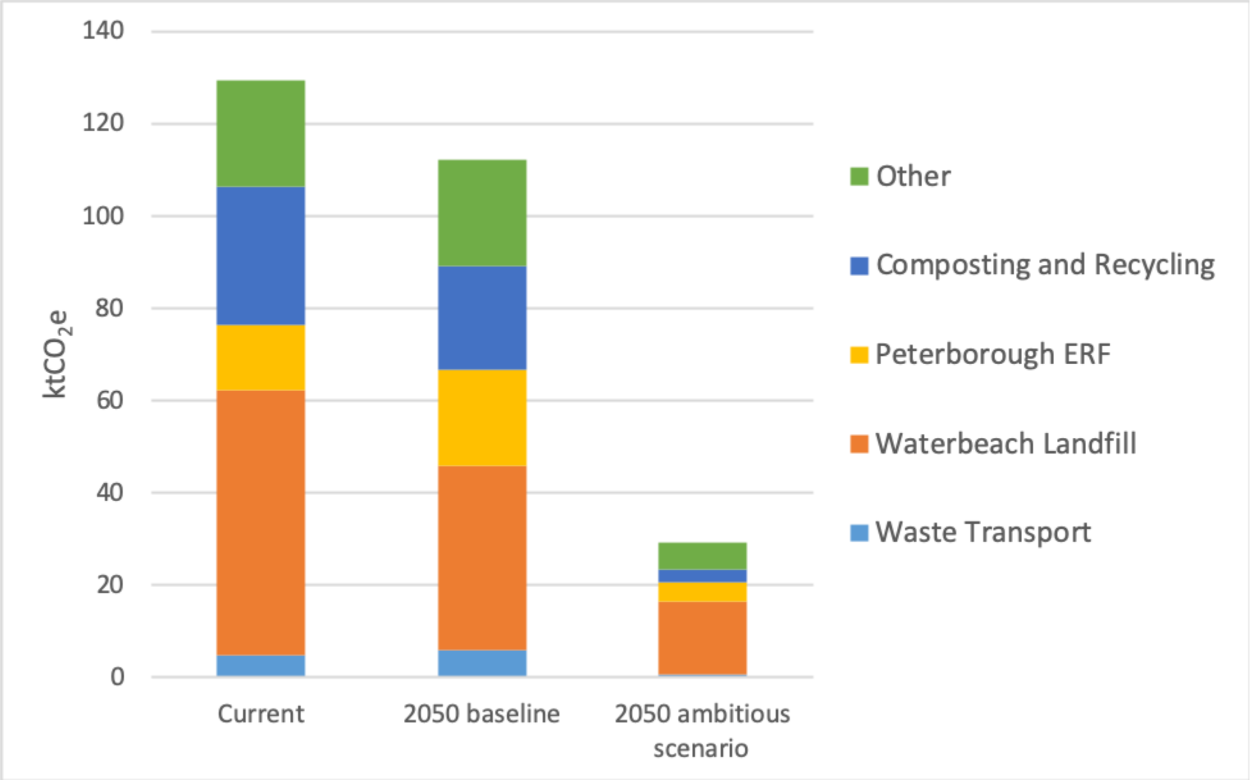

Figure 6.3: Breakdown of sources of emissions in waste management sector. To provide a comprehensive overview, this includes emissions which might fall under other categories (e.g. waste transport) and this does not include any contribution from the Waterbeach EFW

7. AFFORESTATION

Author: James Weber

Afforestation in Cambridgeshire has the potential to deliver abatement at a cost of £15-50 per tonne CO_2e and has the potential to play a significant role in ensuring the County reaches its net-zero target.

Afforestation has been identified as a key avenue for reducing net carbon emissions in Cambridgeshire. A recent paper in the journal Science stated "*The restoration of trees remains among the most effective strategies for climate change mitigation*"[97]. The Committee on Climate Change Net Zero report identified an afforestation target of 20,000 hectares per year increasing to 27,000 by 2025[98] while over the last 10 years, the UK has managed only 1/3 of that. Since 2000, around 250,000 trees have been planted in Cambridgeshire for reasons ranging from community benefit (e.g. community orchards) to Forestry Grant Schemes. In contrast to Direct Air Capture (DAR) and Carbon Capture and Storage (CCS), afforestation does not require infrastructure to transport captured CO_2. In addition to sequestering CO_2, afforestation, when properly planned, can enhance biodiversity and and inhibit soil erosion while also benefiting the public by providing places for exploration and recreation. Programmes in Scotland increasing the public's interaction have been shown to help contribute to positive mental health in a cost-efficient manner[99]. This section explores the ability of afforestation to contribute to Cambridgeshire's goal of reaching net zero carbon emissions by 2050.

The main conclusions from the study were:

- Over a 30 year period, average sequestration of 5-13 t CO_2 per hectare per year is possible (depending on tree species).
- The abatement cost over a 30-year period is competitive at £15-30 per tonne CO_2 (including revenue from timber sales) with further decreases possible in the case of increasing timber prices.
- The non-linear behaviour of tree growth means the sooner the trees are planted, the greater the annual sequestration will be in 2050 and the more sequestration can take place before then (the most climatically relevant metric is total sequestration, rather than just net zero by 2050).

7.1. AFFORESTATION METHODOLOGY

The key metrics for afforestation are abatement cost (cost per unit of CO_2 removed from the atmosphere) and cumulative sequestration (the amount of CO_2 removed from

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[97] Bastin et al., Science 365, 76-79 (2019)

[98] P.12 Committee on Climate Change. (2019) Net Zero Technical Report

[99] Branching Out, Scottish Forestry https://forestry.gov.scot/forests-people/health-strategy/branching-out

the atmosphere over a period of time less any CO_2 emitted by the act of afforestation). The method for calculating these values is presented below.

The approach taken in this study is relatively simple and includes several assumptions which are identified. All trees are planted in the year 2020. It is acknowledged that this may not be entirely practical but the differences introduced by planting over several years are within the calculations' uncertainty. The toolkit and data (hereafter "the model") used in the calculations will be provided to CCC separately along with instructions for its use. The model is designed to be easy to use and further complexity can be added (for example, the abatement cost and cumulative sequestration for a planting scheme which occurs over several years can be calculated); in short, it provides a framework for further exploratory work.

It should be noted that that the calculated abatement costs do not include the costs of finding suitable land, planning the planting and long term staffing costs (land management costs are included). Including an additional £75,000 a year for staffing raised abatement costs by around £2-3 per tonne CO_2e but, as staffing costs are unknown, this cost was not included in the following final values. However, all major costs have been included and, to offset additional unforeseen costs, a conservative approach has been taken overall.

The methodology was as follows.

1. A particular tree species or mixture of tree species was chosen for a given area of land. For this study an area of **3,000 ha** (30 km^2 or 11.7 sq. miles) was chosen. This area represents 1% of the land in Cambridgeshire and 1/3 of all agricultural land in the Cambridgeshire County Rural Estate. For context, if the 250,000 trees planted in Cambridgeshire had been spaced between 1.5m and 3m part (standard distances for afforestation), they would have occupied between 225 and 900 hectares.

2. The parameters of tree spacing, soil type, yield class for each tree species for Cambridgeshire's climate (obtained using a reference location in rural Cambridgeshire[100]) and management regime (no thinning or 5-yearly thinning) were specified.

3. Using the data from the Carbon Trust Sequestration calculator[101], cumulative sequestration of CO_2 over time was calculated. To these values a 20% reduction was applied to account for model uncertainty[102]. Then a further reduction was made to account for the loss of CO_2 sequestration from the vegetation that the trees replaced

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[100] www.forestdss.org.uk/geoforestdss/

[101] Woodland Carbon Code - Carbon Calculation Spreadsheet `https://www.woodlandcarboncode.org.uk/standard-and-guidance/3-carbon-sequestration/3-3-project-carbon-sequestration#accountingforpcs`

[102] Woodland Carbon Code - Carbon Calculation Spreadsheet `https://www.woodlandcarboncode.org.uk/standard-and-guidance/3-carbon-sequestration/3-3-project-carbon-sequestration#accountingforpcs`

and the emissions from the process of establishing the trees. The result was the **total project carbon sequestration**.

4. As the quantity of CO_2 sequestered per year varied with tree age, an average abatement cost (£ per tonne CO_2) over a period of years was calculated. Given the focus of this report is CO_2 reduction to 2050, a 30-year period (2020-2050) was chosen.

5. To calculate the cost of the project, the following factors were considered:

- Planting (£1,250 per ha[103])
- Maintenance (£150 per ha per year in no thin, thinning scenarios had an additional £1000 per ha every 5 years (estimated))
- Tree costs are taken from a wholesale tree supplier Trees Please[104]
- Financial support available from the TE4 Woodland Capital Grants scheme[105] at the current rate of £1.28 per tree, up to £6,800 per ha.

In terms of land costs, 3 scenarios were considered:

I. Rental of CCC Rural Estate land where a rent of £327 per ha per year[106] (no inflation adjustment made) is assumed for 30 years. The CCC Rural Estate rental cost is higher than the East of England average rate (on a Full Agricultural Tenancy Agreement) at a cost of £240 per hectare.[107]
II. Purchase of Grade 3 farmland at a cost of £7,500 per acre.[108]
III. Purchase of grazing land at a cost of £4,950 per acre.[109]

It is acknowledged that a one-off purchase of a large quantity of land is unlikely without a loan. The effect to the abatement cost under such circumstances can be readily calculated if the interest rate, yearly repayments and length of loan is known. Therefore, the abatement costs for the land scenarios II and III are likely to be lower bounds. Other scenarios such as rental from private land owners can also be modelled very easily.

6. To offset the cost of the land and thus reduce the abatement cost, revenue from timber sales was calculated and factored into the abatement cost. To calculate the quantity of timber, the yield class of the trees (average volume of wood produced by a tree species per ha per year) was used. Multiplying the duration of tree growth by the yield class gives the volume of wood per hectare. To account for the fact that the annual yield will be lower than average for the early stages of tree growth and for other unforeseen costs, the total wood yield was *halved* to produce a more conservative estimate.

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[103] Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. and Snowdon, P. (eds). 2009. Combating climate change - a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change. The Stationery Office, Edinburgh.

[104] treesplease.co.uk

[105] www.gov.uk/guidance/woodland-capital-grants-2015-tree-planting-te4

[106] Hugo Mallaby, Cambridgeshire County Council

[107] Defra Farm Rents 2017-18 England

[108] Savills, GB farmland values 2017, Outlook and Historical Context

[109] Savills, GB farmland values 2017, Outlook and Historical Context

It is important to note that the overall abatement cost therefore assumes the trees are felled after 30 years and the wood is not burnt or allowed to rot. Using the wood in construction would be a good option. However, should the trees not be felled at 30 years, they will continue to sequester CO_2 and abatement costs for felling at a later date can be readily calculated.

There is considerable uncertainty in future timber price. Timber prices do fluctuate yet have shown longer-term growth.[110] Over the last 5 years average prices for coniferous wood sold standing (where the purchaser has the responsibility of felling the trees) rose by 85% in real terms and over the last 20 years they have risen by 130% in real terms. It is likely that other events in the future such as enhanced afforestation efforts on a national level driven by government incentives, a rising population and a greater drive to use more sustainable materials such as wood in construction over concrete will affect timber prices. To investigate the final abatement cost sensitivity to this uncertainty, calculations have been done for three scenarios:

I. Current timber price[111]
II. Double current timber price
III. Half current timber price

The timber prices referred to above are for softwood (pine, spruce etc.) which makes up 80% of the wood grown for industry in the UK. Information for standing sales prices of hardwood (oak, sycamore, aspen, birch etc.) was not found. Therefore, for this exercise, the hardwoods were assumed to have the same price as the coniferous wood (softwoods) as the actual difference between two is likely to be smaller than the model uncertainty.

Furthermore, in this approach it is assumed that the timber can be readily sold. Even with anticipated demand for more sustainable construction, it is uncertain whether national demand for timber will meet the large quantity of trees expected if afforestation becomes more popular. Markets overseas may be an good option, particularly where urbanisation is happening at a rate greater than in the UK. Of course, the transport of wood would bring with it carbon emissions and this is something would need to be considered in more detailed scenarios.

Therefore, the overall equation for calculating the abatement cost, AC, could be expressed as:

$$AC = \frac{\text{(trees + planting + land + management) - (government grant + timber sales)}}{\text{Cumulative net } CO_2 \text{ sequestration}}$$

In fact the land costs and timber sales were the most influential factors in the abatement cost.

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[110] Timber Prices Indices, Data to March 2019, Forestry Commission

[111] Timber Prices Indices, Data to March 2019, Forestry Commission

There are three further points about this abatement cost. Firstly, it should be noted that the abatement cost does not include any carbon price. It is not inconceivable that, under increasing pressure to mitigate climate government, the Government introduces a payment system where efforts to sequester of CO_2 are remunerated. Should this happen, the abatement costs would decrease further.

Secondly, in the case of renting land either from the CCC Rural Estate or other farmland, the difference between the cost of abatement or total net project cost and the annual cost should be noted. This difference arises because the revenue from timber sales is only received at the end of lifecyle. The annual cost is dominated by land rental and maintenance costs since the planting and tree costs are substantially reduced by the TE4 Government grant. Under a scenario of Sitka Spruce afforestation (see Scenario 1 below) on the CCC Rural Estate (£327 per ha per year) with a maintenance cost of £150 per ha per year, the annual cost is £477 per ha per year or £1.43 m per year, totaling £42.9 m over the 30 years. However, the net project cost is £25.8 m with the reduction arising from timber sales in at the end of the 30 years. While the costs of afforestation are more spread out compared to other mitigation strategies such as large scale infrastructure investments in transport, such a delay in final remuneration would make exploring other financing options worthwhile. These might include agreeing to sell the timber at fixed price several years before it is ready via an advance payment so some of the value can liquidised earlier. An another option would be instruments such as futures contracts which, while not providing funds at an earlier date, would provide greater certainty about the Council's long term planning.

The abatement cost for a longer period of time (for example a 40 or 50 year cycle) is likely to be similar, if not lower than the 30 year cost as annual abatement for years 30-50 is higher than for at least the first 10 years of a tree's life. However, employing a longer lifecycle would mean the revenue from sales would be realised at a later date.

8. In addition to the abatement cost, two further metrics were considered to assess the long term impact of afforestation and the impact in the year 2050:

- **Cumulative sequestration** - total net CO_2 sequestered over the period 2020 to 2050.

- **2050 sequestration** - net sequestration possible in the year 2050 assuming planting in 2020.

The **cumulative sequestration** provides information about term long term impact. As a measure of efficacy, the cumulative sequestration as a fraction of the county's total emissions over the period 2020-2050 was also calculated (see Table 8.1).

The **2050 sequestration** was used to assess the level of required afforestation to offset the remaining emissions from the other sectors. This is explained in Section 8. The toolkit from the Woodland Carbon Code (WCC) provided cumulative sequestration over 5 year periods (1-5, 6-10 etc) and so to calculate the annual sequestration in 2050, the value for the years 26-30 was divided by 5. Thus the 2050 sequestration is an average annual sequestration for the years 26-30 and so would provide an accurate value should tree planting commence as late as 2024.

7.2. RESULTS

Seven scenarios (S1-S7) were considered which spanned a range of different tree species and considered the management regimes of 5-yearly thinning or no thinning at all (full details in Section E).

S1 Sitka Spruce, no thinning
S2 Native woodland mixture*, no thinning (WCC Standard Example 2)
S3 Sitka Spruce, 5-yearly thinning
S4 Native woodland mixture*, 5-yearly thinning
S5 Corsican Pine, no thinning
S6 Oak, no thinning
S7 An equal distribution of Alder, Aspen and Sycamore, no thinning

*Native woodland comprises a mixture of Oak, Sycamore, Birch, Aspen, Alder, Rowan & Willow (see Section E)

Several other tree species were considered and the Woodland Carbon Code toolkit allows hundred of options (different spacings, tree mixtures, management regimes) to be considered. The trees chosen are reasonably amenable to Cambridgeshire's climate and the scenarios represent two general approaches to afforestation. The Sitka Spruce, Corsican Pine and Alder/Aspen/Sycamore mix represent high intensity CO_2 sequestration approaches; few species were able to produce more sequestration than the Alder/Aspen/Sycamore mix. However, planting monocultures can bring problems for biodiversity so a native woodland mixture of Oak, Sycamore, Birch, Aspen, Alder, Willow and Rowan was considered alongside an Oak-only scenario. The results from the scenarios are broadly additive and so trees from the different scenarios could be mixed.

The cumulative net sequestrations of the seven scenarios is shown in Section 7.1. The errors bars have been include for one species to provide a sense of the uncertainty in the model.

The key metrics for the different scenarios are shown in Table 7.1. For completeness, this table also shows the abatement cost if there were no sales of the timber. It also shows the approximate fraction of total county emissions from 2020-2050 which could be offset by afforestation should planting occur in 2020.

Scenarios S3 and S4 had the highest abatement costs due to the higher management costs of thinning and lower sequestration resulting from the removal of a fraction of the trees.

The abatement costs on CCC Rural Estate were very similar to those calculated base on the purchase of grazing land but Grade 3 farmland resulted in an abatement cost

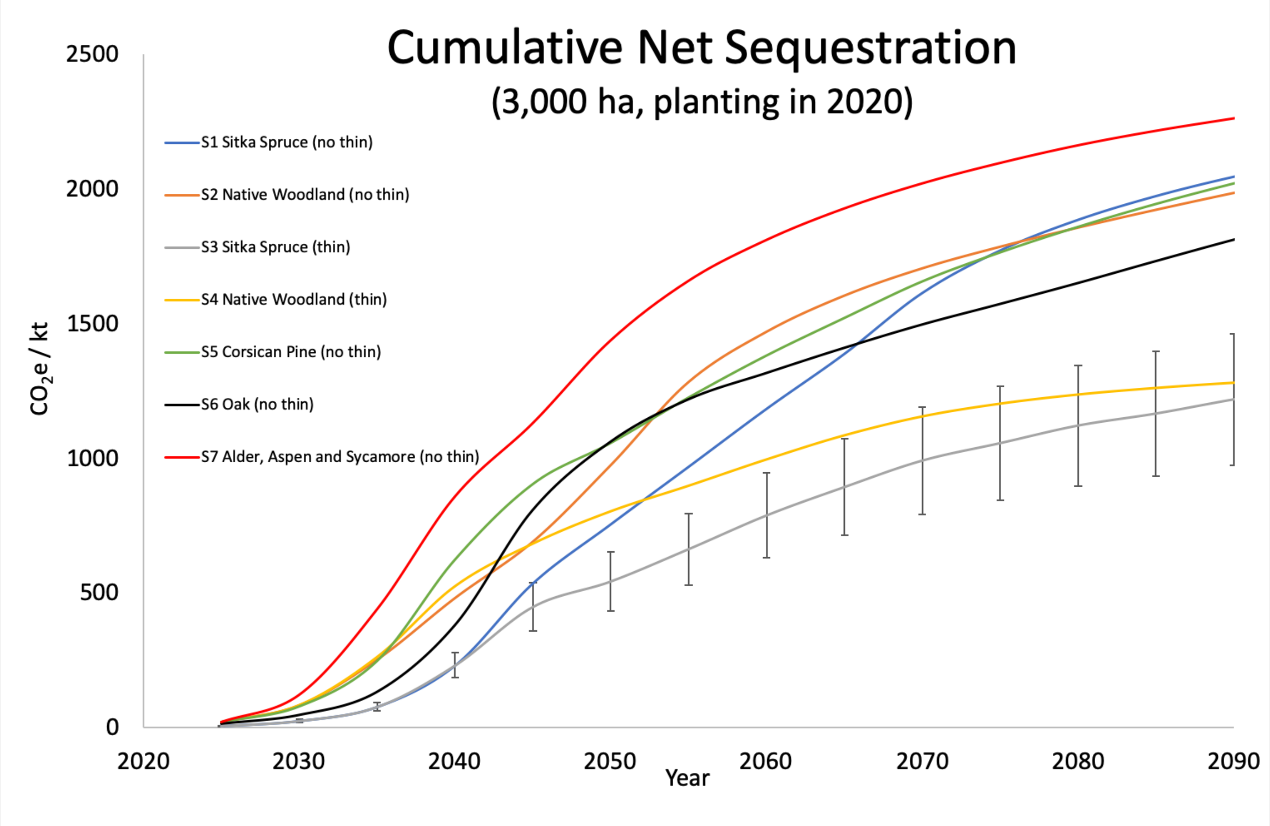

Figure 7.1: Cumulative net sequestration for the 7 scenarios without clearfell at 30 years. Sequestration is slow in early years but accelerates. Errors bars have been included for one scenario to provide an idea of the uncertainty in the model.

Table 7.1: Abatement cost, Cumulative Sequestration and 2050 Sequestration (* on CCC Rural Estate, ** total county emissions 2020-2050 assuming 5% year-on-year drop)

Scenario	**Abatement cost* / £ per t CO_2 (AC if no timber revenue)**	**Cumulative Sequestration / kt CO_2 (% of total emissions**)**	**2050 Sequestration / kt CO_2**
S1	34 (57)	755 (1.2%)	44
S2	35 (39)	975 (1.6%)	56
S3	80 (112)	542 (0.9%)	19
S4	65 (76)	753 (1.2%)	22
S5	22 (35)	1056 (1.7%)	30
S6	32 (34)	1061 (1.7%)	51
S7	20 (24)	1438 (2.3%)	61

roughly twice as large. It should also be reiterated that the CCC Rural Estate rental value of £327 per ha per year is larger than the East of England of average (£240 per ha per year) and so the abatement cost calculated for the EoE average is lower, ranging from **£15/ t CO_2e for S5 and S7 to £35/ t CO_2e for S4.**

The abatement costs (including effects of varying timber price), cumulative sequestration and 2050 sequestration are shown in Fig 7.2. Overall Alder, Aspen and Sycamore (planted at 3m spacing) produced the greatest cumulative sequestration and, along with Corsican Pine, the lowest abatement cost of around £20 per t CO_2. This is close to the value estimated in the Committee on Climate Change Net Zero Report of £12 per tonne CO_2e[112].

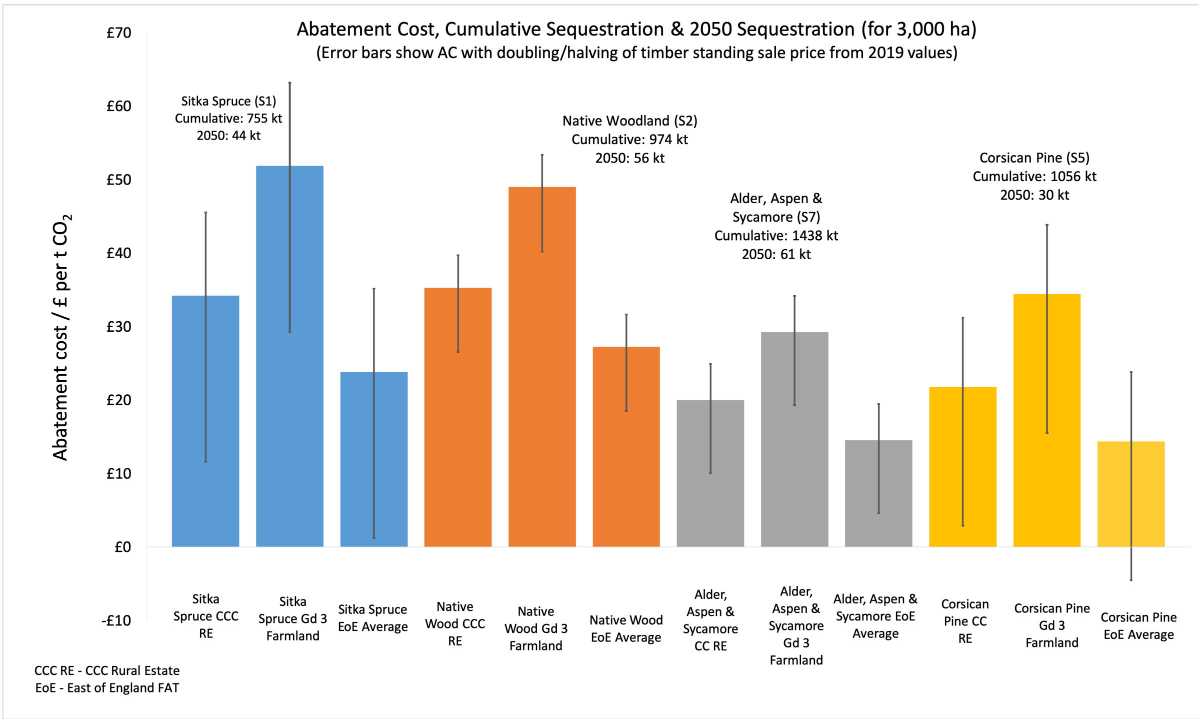

Figure 7.2: Comparison of 4 afforestation scenarios. The Alder, Aspen & Sycamore option delivers the greatest Cumulative and 2050 Sequestration.

7.3. Conclusions

Based on the results, the Alder/Aspen/Sycamore mix would appear to be the best option and should form a significant part of any afforestation effort. However, there are several other factors should be considered.

Any afforestation project should seek the advice of the **Woodland Carbon Code** (the supplier of the data used in this report) who will be able to provide further guidance regarding the best options for an afforestation strategy which maximises carbon sequestration but also preserves biodiversity and other important environmental aspects.

The sequestration of carbon in soil is also an important contributor to total sequestration and depends on the type of land used for planting and is generally higher when planting a mixture of native trees than mono-cultures. For example, following the guidance of the WCC, soil carbon sequestration is included in the sequestration totals

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[112] Committee on Climate Change. (2019) Net Zero Technical Report

for the native woodland mixtures S2 and S4.

To maintain biodiversity, a mixture of trees in at least some locations should be planted. Planting a diverse range of species can help mitigate against the effect of disease as some species may be resistant. The Native Woodland mixture scenario contains only 20% Sycamore; increasing the sycamore fraction at the expense of some of the other slower growing trees such as Oak would result in greater sequestration and lower abatement costs. Working with an ecologist to maximise biodiversity and carbon sequestration would be vital.

It would also be prudent to ensure a significant fraction of the trees planted are softwoods (Sitka Spruce, Corsican Pine etc.) since demand for such trees is more likely to be steady, if not increasing, given their importance in the construction industry and the drive for more sustainable construction where the substitution of steel and concrete for wood is expected to play a major role. A more detailed analysis of the potential revenue of from any trees planted is vital for any potential project.

It should also be noted that afforestation will need to compete with other land uses. Future climate change is likely to make land less productive[113] and increasing population will place a higher demand on land for agricultural output. Afforestation's effect on the water table, already an important an issue in parts of Cambridgeshire[114] must also be considered.

Finally, the modelling presented in this chapter is relatively simple but provides a strong basis for planning more realistic and sophisticated afforestation projects. Such projects could include mixing tree species, staggering planting and developing an efficient business plan to maximise return from timber sales. Furthermore, work could be done with other land users, such as farmers, to ensure afforestation brings them benefits as well; for example, selecting trees which will return more nutrients to the soil or reduce soil erosion. Further collaboration on exploring the potential afforestation would be welcomed by the author and the model created for this study, instructions for its use and all supplementary information will be provided to CCC.

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[113] IPCC. (2019).Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems

[114] Environment Agency Monthly Water Situation Report, East Anglia, August 2019

8. NET ZERO: CLOSING THE GAP

Even using ambitious assumptions, it is clear that certain sectors have emissions that are very hard to abate by 2050, which leaves a residual 594 $ktCO2_2$ of annual emissions from Cambridgeshire and Peterborough. The Committee on Climate Change also found this to be the case for the whole UK, noting that agriculture, aviation, heavy industry and certain hard-to-decarbonise homes remain as net GHG sources even in their "Further Ambition" scenario in 2050.[115] In Cambridgeshire, the breakdown for the 2050 Ambitious Scenario is shown in fig 8.2. As there is relatively little heavy industry and very little aviation in the county, the most significant remaining emissions are from agriculture, accounting for 40% of emissions in the 2050 Ambitious Scenario. This is followed by commercial services and industry (23%) and domestic housing (19%).

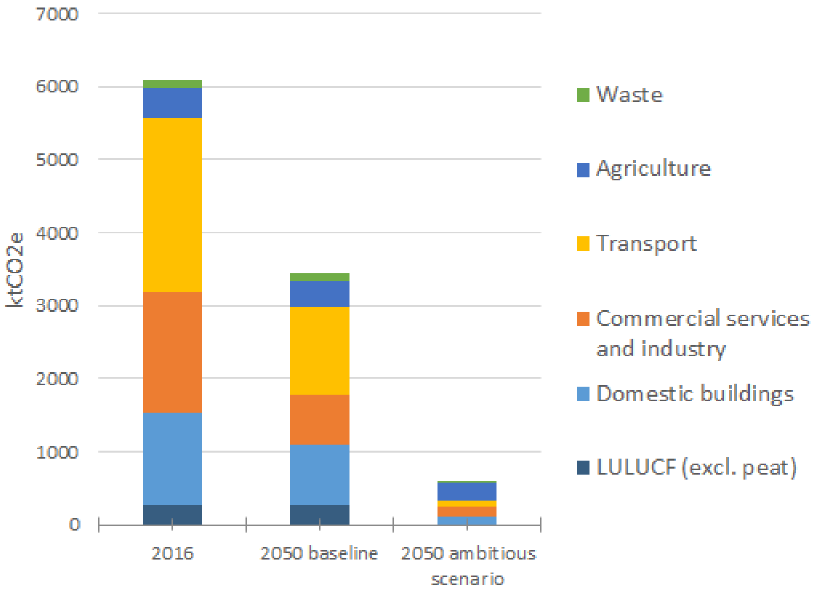

Figure 8.1: GHG emissions by sector in the 2050 Ambitious scenario. LULUCF is Land Use, Land Use Change, and Forestry

As per the methodology in the Committee on Climate Change Net Zero report, 4 pathways are proposed for Cambridgeshire to go further than the 2050 Ambitious Scenario and reach net zero or net negative GHG emissions by 2050: afforestation, carbon capture and ctorage (CCS), demand reduction and future technologies. In reality, any number of combinations of negative emissions technologies (NET) and more speculative abatement actions could extend the county to net zero or net negative emissions.

It is also necessary to highlight here the situation posed by peatland emissions, explored in detail in section 4.2. This could hugely change the magnitude of the problem in Cambridgeshire - emissions from peatland could double the current emissions inventory and completely dwarf the residual emissions in the 2050 Ambitious Scenario. This presents a very different and relatively unique challenge for Cambridgeshire, and it is inconceivable it could be tackled without intervention from national government. From

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[115] CCC. (2019). Net Zero: The UKs contribution to stopping global warming.

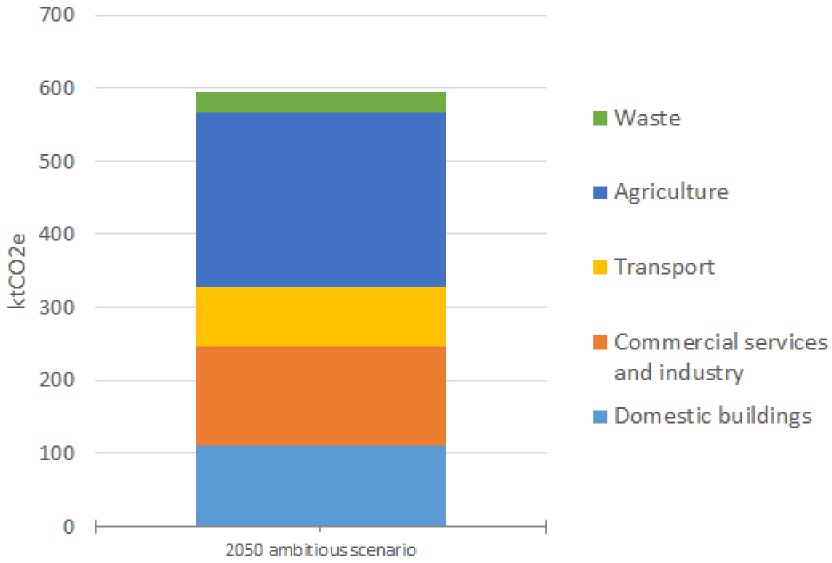

Figure 8.2: Ambitious sceenario breakdown by sector

here on it is assumed that the county is aiming for net zero by the current accounting methods, excluding peatland emissions. This being said, further research is urgently needed in this area and peatland preservation and restoration should be a top priority for Cambridgeshire and Peterborough.

8.1. AFFORESTATION

Abating 596.4 kt CO_2e in 2050 would require afforesting an area of around 34,000 ha, roughly 11% of all the land in Cambridgeshire and nearly three times the area in the CCC Rural Estate within the next 5 years. This has been calculated based on an equal split of scenarios S1 (Sitka Spruce), S2 (Native Woodland) and S7 (Sycamore). 34,000 ha of such a mixture would produce the abatement required in the year 2050 at an average abatement cost of £23.74 per t CO_2 (assuming planting 1/3 on CCC Rural Estate and 2/3 private farmland at the East of England average farmland rental value, no change to timber price). The annual cost of such afforestation would be around £14.3 m per year with the predicted revenue from timber sales upon clearfell resulting in a net project cost of £262 m. While a considerable cost, it is important to note that such a level of afforestation would sequester around 11,700 kt CO_2 over the 30 year period. To put this in perspective, this would be around 11% of the County's total emissions from 2020 to 2050 (based on a linear decrease in emissions to the 2050 ambitious target). Therefore, while more expensive overall than the Direct Air Carbon Capture and Storage (DACCS) proposed in Section 8.3, afforestation would sequester considerably more carbon in total (the most climatically relevant metric) and the cost to maintain net zero emissions in the years after 2050 would be much less than that for DACCS.

8.2. BIOENERGY WITH CARBON CAPTURE AND STORAGE

Bioenergy is the generation of electricity or heat from the burning of biogenic material. This includes the burning of waste from agriculture or industries such as the paper and pulp industry, or dedicated energy crops. In emissions inventories, the burning of biogenic material is considered carbon neutral, despite the fact the at the point of burning, there is CO_2 produced. This is because all the carbon in plants has all been sequestered from the atmosphere during the plant's life. The assumption that bioenergy is therefore carbon neutral relies on several conditions: the crops must be regrown continuously after being harvested, and must not displace a greater carbon sink such as primary forest or peatland.

Assuming that these conditions are met, it is possible to make bioenergy emissions net-negative if a bioenergy plant is fitted with CCS, which is then known as BECCS. The Committee on Climate Change estimates that BECCS (excluding biomethane) can be achieved at a total marginal cost of £158 / tCO_2 in 2050.[116] It is not clear how exactly the local emissions accounting will work - for example, the negative emissions from crops grown and burned at a bioenergy plant in Cambridgeshire, but stored in the north sea off Scotland, could be counted only in Scotland. Having said this, assuming that in this situation the negative emissions can be attributed to Cambridgeshire, this could be a part of the NET mix to offset the residual emissions in the 2050 ambitious scenario.

If the entire residual emissions in 2050 were offset by BECCS (excl. biomethane), then the marginal cost would be an estimated £90 million per year. However, this is highly unlikely to be either possible or advisable, due constraints on land use. It is estimated that 0.1-0.4 hectares of land for dedicated energy crops are required per tonne of CO_2 removed, which even at the lower bound is likely to give a worse return per hectare than afforestation.[117] Similarly to afforestation, bioenergy should not be deployed at the expense of food production, although if land is freed up by increases in efficiency, reduction in food waste, and diet change away from land intensive meat and dairy, this could present an opportunity. Land use change (LUC) emissions must also be considered: if it involves the degradation of existing carbon sinks such as peatland, which is a particular concern for Cambridgeshire. BECCS or indeed afforestation must not be carried out on land which could absorb the same or even more carbon by restoration and rewilding, which have the co-benefits of increased biodiversity. Having said this, BECCS from waste or sustainable biomass should not be ruled out from playing a part in the NET mix required to reach net zero.

8.3. DIRECT AIR CARBON CAPTURE AND STORAGE

Another strategy for CCS is Direct Air Carbon Capture and Storage (DACCS): rather than purifying CO_2 from waste combustion gases, it can be captured directly from the atmosphere. This is much more expensive and energy intensive, as CO_2 in the is currently only 0.04% of the atmosphere, compared to 70+% in oxy-fuel combustion waste

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[116] CCC. (2019). Net Zero: The UKs contribution to stopping global warming.

[117] Fern. (2018). Six Problems with BECCS. `https://www.fern.org/fileadmin/uploads/fern/Documents/FernBECCSbriefing_0.pdf`

streams.[118]. Nevertheless, if there are not sufficient combustion sources that CCS can be applied to, direct air capture is technically possible and is estimated by the Committee on Climate Change to have a marginal cost of £300/tCO_2e. [119] To abate the entire residual emissions in Cambridgeshire would then cost £178 m per year. DACCS is very expensive, requires vast amounts of clean energy, and has not been demonstrated at scale.

8.4. DEMAND REDUCTION

Another route to decrease emissions is by demand reduction. This can be achieved by better energy and resource efficiency, and societal behaviour change to decrease demand for emissions intensive products such as red meat. This second area is less directly linked to local emissions from Cambridgeshire as many products consumed in Cambridgeshire are manufactured elsewhere. However, emissions savings can be made through even more ambitious energy efficiency in homes and businesses, further diet change nationwide (and internationally) to reduce demand for red meat and dairy from Cambridgeshire. There is also the scope to reduce demand for land area which could allow increased peatland restoration.

8.5. FUTURE TECHNOLOGIES

Finally, it is not possible to foresee the extent to which technology will develop between now and 2050. Areas where new technology could reduce emissions beyond the 2050 Ambitious Scenario include higher CCS capture rates (currently assumed to be only 80-90%), and carbon-neutral synthetic fuels made from CO_2. Carbon capture is currently an emerging industrial sector and if deployed widely, there is the potential for the technology to develop to an efficiency at which higher capture rates are economically viable. Synthetic fuels produced from captured CO_2 are hugely expensive both thermodynamically and economically, making them at this time a less desirable option than other currently available abatement options. Huge advances in renewable energy and synthetic fuel production are required to make them more a more credible option.

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[118] Porter, R. T. J., Fairweather, M., Pourkashanian, M., & Woolley, R. M. (2015) The range and level of impurities in CO2 streams from different carbon capture sources. International Journal of Greenhouse Gas Control, 36, 161–174. `https://doi.org/10.1016/J.IJGGC.2015.02.016`

[119] CCC. (2019). Net Zero: The UKs contribution to stopping global warming.

Appendix

A. DOMESTIC BUILDINGS FORECASTING ASSUMPTIONS

There are several assumptions made in order to forecast the domestic energy demand and emissions. This appendix lists all assumptions, and identifies assumptions relevant to each of the three forecasting scenarios.

1 All domestic emissions arise from electricity, gas and residual fuel use. This forecast makes no attempt to capture the embodied carbon of the housing stock, or consumer goods in the domestic sector.

2 Household numbers increase linearly from 2041 (the final year of the ONS forecast).

3 New builds (or demolitions as the case may be) reflect the changing number of households.

4 Discrepancy factor between actual demand and EPC approximated demand calculation = (Actual demand 2017) / (EPC-based demand 2017).

5 EPC-based demand is calculated using the proportion of total buildings in each band, multiplied by the average energy demand in each band.

6 The national electricity and gas demand trend is the same as the Cambridgeshire and Peterborough energy demand trend.

7 Electricity and gas demand follow their respective FES Steady Progression forecast year-on-year trends.[120]

8 Residual fuel demand follows the FES Steady Progression forecast year-on-year trend for natural gas.

9 Carbon intensities of natural gas, petroleum products, coal and manufactured solid fuels do not change over time.

A.1. ASSUMPTIONS FOR SCENARIO 1: BUSINESS AS USUAL

1 Energy demand depends only on confirmed national policies; no local authority initiatives are implemented

A.2. ASSUMPTIONS FOR SCENARIO 2: NET ZERO

1 90% of all non-electric domestic heating is transferred to electricity - 10% of hard-to-decarbonise homes remain on the gas grid (in accordance with the Committee on Climate Change Net Zero Further Ambition scenario).[121]

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[120] National Grid ESO. (2019). Future Energy Scenarios.

[121] Committee on Climate Change. (2019). Net Zero – The UK's contribution to stopping global warming. Retrieved from www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/

2. All those homes with electric heating go onto low carbon heating, with an SPF of 3.58 (as assumed in Committee on Climate Change Further Ambitions).
3. The conversion to low energy heating is implemented in 2020 and progresses linearly to 2050.
4. Energy efficiency measures are deployed starting in 2026, representing a 25% decrease in total energy demand by 2050 as a result of fabric efficiency measures (as assumed in Committee on Climate Change Further Ambitions).
5. The energy efficiency of a gas boiler is 85% (as assumed in Committee on Climate Change Further Ambitions).

A.3. Assumptions for Scenario 3: Middle

1. All new builds are built to EPC level A starting from 2020
2. All existing homes below EPC level C are retrofit to EPC level C over 10 years beginning in 2020
3. Local authority policies to improve housing stock affect gas, electricity and residual demand over and above the national trend (based on FES forecasts).
4. No additional effort is made to reduce residual fuel demand.

B. Transport Modelling Methodology and Assumptions

B.1. Vehicle Kilometres

Car vehicle kilometres for Cambridgeshire and Peterborough from 2005-2018 are obtained from the Department of Transport.[122] LGV, HGV and Motorcycle vehicle kilometres for the East of England[123] from 2005-2018 are scaled for Cambridgeshire and Peterborough using total vehicle kilometres for Cambridgeshire and Peterborough.[124] Vehicle kilometers are projected to 2050 using forecasts from the Road Traffic Forecasts 2018, which gives car, LGV and HGV vehicle kilometers for the East of England to 2050.[125]

Car, LGV, HGV and Motorcycle vehicle kilometres have been approximated at the district level within Cambridgeshire based on the number of car registrations within that district.[126] Car registrations are assumed to remain proportional to population and have

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[122] Department for Transport, Table TRA8905 Car vehicle traffic (vehicle kilometers) by local authority

[123] Department for Transport, Table TRA0106 Road traffic by vehicle type and region

[124] Department for Transport, Table TRA8906 Motor vehicle traffic (vehicle kilometers) by local authority

[125] Department for Transport (2018), Road Traffic Forecast, Reference Scenario 1

[126] Department for Transport, All vehicles (VEH01) VEH0105: Licensed vehicles by body type and local authority: United Kingdom

been projected to 2050 using population predictions from Cambridgeshire insights.[127]

Bus vehicle kilometres have been predicted using mode shares of trips to work estimated from the 2011 census and scaling this with car vehicle kilometres.[128] This gives a breakdown of bus kilometres at a district level, which is important as bus kilometres are more variable across districts.

B.2. Passenger Kilometres

Passenger kilometres for cars and buses are obtained by scaling the vehicle kilometres by an average load factor which is the average occupancy within the vehicle. For cars the load factor is 1.6[129] and for buses it is 9.6.[130]

B.3. Vehicle Fuel Efficiency

- **Cars** - The types of passenger cars in Cambridgeshire and Peterborough and the fuel efficiency of petrol, diesel and hybrid cars is obtained using MOT and Vehicle Certification Agency (VCA) data as well as real world fuel consumption estimates.[131] It is assumed that fuel efficiency improves by 28% for petrol cars, 19% for diesel cars and 19% for hybrid cars between 2015 and 2050.[132] The fuel efficiency of electric vehicles is calculated using an average miles/kWh value from the VCA[133] combined with the energy intensity of the grid.
- **Buses** - Bus fuel efficiency is reported by Stagecoach.[134] It is assumed that fuel efficiency improves by 12% between 2015 and 2050.
- **LGVs** - Fuel efficiency comes from the UK Inventory report[135]. LGVs are assumed to have the same rate of fuel efficiency improvement as cars.
- **HGVs** - Fuel efficiency comes from the UK Inventory report. It is assumed that fuel efficiency improves by 12% and 21% for rigid and articulated HGVs respectively between 2015 and 2050.
- **Motorcycles** - Fuel efficiency comes from the UK Inventory report [136]. All improvements in vehicle fuel efficiency come from the Department of Transport Road Traffic Forecast 2018.[137]

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[127] https://cambridgeshireinsight.org.uk/population/

[128] Systra, CPCA Strategic Bus Review

[129] Department for Transport, Table NTS0905 Car/van occupancy and lone drive rate by trip purpose

[130] Department for Transport, Table BUS0304 Average bus occupancy on local bus services by metropolitan area status and country

[131] UK Informative Inventory report 1990-2017.pdf

[132] Department for Transport (2018), Road Traffic Forecasts

[133] Vehicle Certification Agency, Car and Van Fuel Consumption Database

[134] Stagecoach East Annual Report 2016-17

[135] UK Informative Inventory report 1990-2017.pdf

[136] UK Informative Inventory report 1990-2017.pdf

[137] Department for Transport (2018), Road Traffic Forecasts

B.4. BASELINE FORECAST

MODE TECHNOLOGY SHARES

- **Cars** - The UK government has made a commitment that 50-70% of new car sales are Ultra Low Emission Vehicles (ULEVs) by 2030[138] and has banned sales of diesel and petrol cars by 2040.[139] However, there is remaining ambiguity over the definition of an ULEV, and this target allows sales of hybrid electric vehicles after 2040. A recent study modelled the effects of UK government policy on EV shares of new vehicle sales, and how the EV share of the total car and van fleets evolve to 2050.[140] The baseline scenario selected from this study bans the sale of ICE vehicles from 2040 but allows sales of HEVs. The technology share used is plotted in Figure B.1.
- **Buses** - EU lawmakers have agreed that at least 25% of new buses will need to be hybrid or electric by 2025, and at least a third by 2030.[141] Based on these figures, in 2025 it is assumed that buses are 5% hybrid and electric in 2025, 15% in 2030 and 60% in 2050. The split between hybrid and electric buses is assumed to be equal.
- **LGVs** - The UK Government has set a target for up to 40% of total LGV sales being EV at 2030 has banned the sale of ICE LGVs by 2040. The LGVs fleet powertrain shares are assumed to follow the same trend as cars until 2040, where new vehicle sales are 100% EV.
- **HGVs** - HGVs are 100% diesel until 2040, where shares of electric HGVs rise linearly up to a 10% EV share at 2050.[142]
- **Motorcycles** - Fleet powertrain shares are assumed to increase linearly to 100% EV in 2050.

ELECTRICITY EMISSIONS

The baseline projection uses a Department for Business, Energy and Industrial Strategy electricity emissions projection to 2050 for the carbon intensity of electricity required by EVs.[143]

B.5. NET ZERO SCENARIO

MODE TECHNOLOGY SHARES

- **Cars** - The Committee on Climate Change Further Ambition scenario[144] suggests

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[138] Department for Transport, The Road to Zero: Next steps towards cleaner road transport and delivering our Industrial Strategy (July 2018)

[139] GOV.UK, Air quality plan for nitrogen dioxide No 2 in UK 2017 (26 July 2017)

[140] Brand and Anable 2019, 'Disruption' and 'continuity' in transport energy systems: the case of the ban on new conventional fossil fuel vehicles

[141] https://www.edie.net/news/11/Europe-agrees-sales-targets-for-clean–buses-in-cities/

[142] Kluschke et al. 2019, Market diffusion of alternative fuels and powertrains in heavy-duty vehicles: A literature review

[143] Department for Business, Energy and Industrial Strategy 2019, Electricity emissions factors to 2100.

[144] Committee on Climate Change (2019), Net Zero Technical report

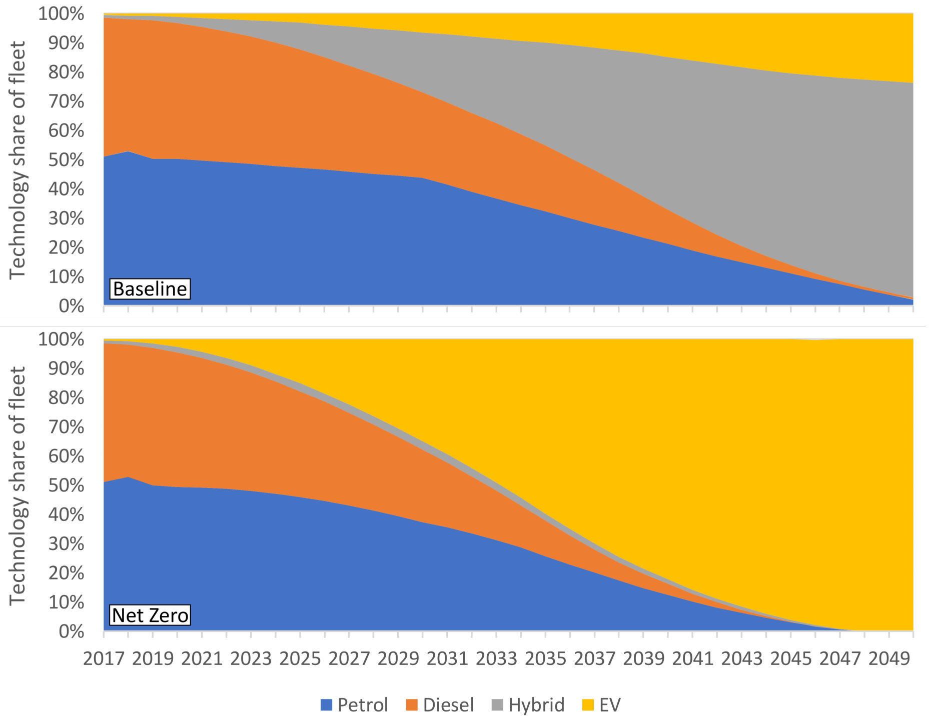

Figure B.1: The technology share of cars to 2050 used in the Baseline Forecast and Net Zero Scenarios are plotted. The baseline forecast bans sales of petrol and diesel vehicles from 2040 but allows sales of hybrid vehicles. The net zero scenario bans sales of petrol, diesel and hybrid vehicles from 2035.

the UK government end sales of non-zero emissions cars, vans and motorcycles by 2035. New sales of cars are assumed to be 100% EV by 2035 which results in 100% EV fleet share by 2050. The technology share used is plotted in Figure B.1.

- **Buses** - It is assumed that 100% of bus fleets are zero emissions by 2035.[145]
- **LGVs** - See cars above, 100% EV LGV fleet share by 2050.
- **HGVs** - It is assumed that zero emissions HGV sales reach 100% of sales in 2040, leading to a 91% zero emission fleet share in 2050.[146]
- **Motorcycles** - See cars above, 100% EV motorcycle fleet share by 2050.

VEHICLE KILOMETRES

10% of car miles have been shifted to walking and cycling in 2050, as per the Committee on Climate Change Further Ambition scenario,[147] and therefore produce no emissions.

ELECTRICITY EMISSIONS

The net zero scenario uses an optimistic Two Degrees National Grid Future Energy Scenarios projection for the emissions intensity of electricity that meets 2050 emissions

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[145] Energy Transitions Commission (2018), Missions Possible

[146] Committee on Climate Change (2019), Net Zero Technical report

[147] Committee on Climate Change (2019), Net Zero Technical report

targets.[148]

B.6. DIFFERENCES BETWEEN CUSPE TRANSPORT MODEL METHODOLOGY AND THAT OF BEIS

The CUSPE model (without lifecycle emissions) gives CO_2 emissions that are 13% lower than the BEIS estimates for 2014. This is most likely due to differences in the emissions caused by cars which make up the majority of emissions, we therefore focus our attention on this.

The BEIS model uses the network of UK roads split into three types, A roads, motorways and minor roads. Vehicle traffic estimates for different types of roads are used with speed dependent emissions factors to determine CO_2 emissions. Each type of vehicle is modelled to emit a certain level of CO_2 emissions when travelling at a certain speed. An average speed is estimated for the three types of road.

The CUSPE model uses publicly available data from the Department for Transport (DfT) on total vehicle kilometres travelled by mode and local authority. This is calculated by the DfT using traffic counts and types of roads in each local authority but is presented as an aggregate for all roads. We cannot therefore account for the type of road a vehicle is driven on. If Cambridgeshire has a higher than average share of travel on minor roads (where vehicles are typically less efficient) this would increase the BEIS CO_2 estimates relative to ours. Similarly, if Cambridgeshire has a higher than average amount of congestion this could increase the BEIS data but it's unclear whether the BEIS model is that detailed.

The emissions factors used by BEIS are more detailed than those used in our model because they vary by the speed of the vehicle. However, the emissions factors used in our model also have some strengths compared to the BEIS numbers. Real world emissions differ from type approval emissions (the values on the specs sheet that are tested in unrepresentative laboratory conditions). This is partly accounted for in the BEIS model using factors estimated by Ntziachristos et al. 2014.[149] However, these are slightly out of date and are not sales weighted. Our model uses the most up to date data available from Craglia Cullen 2019[150] and therefore addresses these issues.

Secondly, the BEIS model uses emissions factors for national average types of vehicles (i.e. the UK average diesel car). Our model uses MOT data[151] to determine the local vehicle stock in Cambridgeshire in much higher detail. This shows vehicles in Cambridge are newer than the national average.

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[148] National Grid 2018, Future Energy Scenarios

[149] Ntziachristos et al. 2014, In-use vs type-approval fuel consumption of current passenger cars in Europe, Energy Policy

[150] Craglia and Cullen 2019, Do technical improvements lead to real efficiency gains? Disaggregating changes in transport energy intensity, Energy Policy (under review)

[151] DVLA Anonymised MOT test data 2005-2017

The BEIS model does not account for embodied emissions but this is not the source of the difference as we can "turn off" lifecycle emissions.

C. COMMERCIAL SERVICES AND INDUSTRY

C.1. TECHNICAL DETAILS FOR BUSINESS AND INDUSTRY EMISSION MODEL IN CAMBRIDGESHIRE AND PETERBOROUGH

The model is based on the following equation:

$$\text{Emissions} = \text{energy demand} \times \text{carbon intensity}$$

Where energy demand was quoted in kWh and carbon intensity is quoted in kg CO_2e/kWh

- The predicted demand was different for the baseline and ambitious scenarios.
- The grid average carbon intensity from 2018 to 2050 was applied for both the baseline and ambitious scenarios.
- Energy demand from business and industry are considered in three sections, commercial services, iron manufacturing and other industry. Each consists of the following subsections:
  - Commercial services: Wholesale, Retail, Accommodation and Food services, Publishing and broadcasting, Telecommunications, computer related activity, Finance, Real estate, Professional services, Research and Development, Business services, Employment activities, Art and entertainment, Other services.
  - Iron industry: Metal manufacturing.
  - Other industry: Mining and quarrying, Food manufacturing, General manufacturing, Chemicals, Pharmaceuticals, Transport equipment Manufacturing: Electronics, Utilities, Waters and Remediation, Construction.

Energy demand from public sector services, healthcare and education have been excluded in this model.

Energy demand assumptions of the baseline scenario

- The District Council Energy was calculated as follows:

$$\text{demand} = \text{energy demand per employee} \times \text{number of employees in the district}$$

.

- UK energy demand is taken from the EEP energy consumption reference scenario, in which the existing and planned policies have been considered.
- Energy demand per employee = UK energy demand / number of employees in UK

- Emissions sources: electricity, gas and solid fuels. Emissions from road transport are not included. However, the electricity and demand from Agriculture is included
- The UK energy demand in three sections is presented with demand of gas, petroleum, electricity, renewable and solid fuels. Comprehensive data on the use of the renewable and solid fuels was hard to find and so the assumption was made they they were used to generate electricity (and so they were counted as electricity demand). While a simplification, the emissions from this source are small so the uncertainty caused is relatively small. Emissions from petroleum products have been excluded in this model.
- However, the projection is up to 2035. To get projection up to 2050, extrapolation has been made based on the trend of 2034-2035.
- Employment data is summed in three sections listed above, from the EEFM 2017 model. The EEFM 2017 employment only projects until 2045. Extrapolation has been made based on the trend of 2044-2045.

Based on the baseline scenario, the following adjustments are made for the net-zero scenario:

- 100% of commercial buildings will achieve low carbon heating (carbon neutral) by 2050.
- 85% of industry will achieve low carbon heating by 2050.
- Carbon Capture and Storage (CCS) will be implemented at 90% capture rate by 2050 to reduce process emissions and emissions from internal fuel use (fuels produced using the industries' feedstock) in the manufacturing sectors.
- All the assumptions are implemented linearly.

D. WASTE MANAGEMENT

D.1. WASTE TRANSPORT EMISSIONS

Diesel usage in litres was as follows:

- Cambridge and South Cambridgeshire 746,356 (scaled from data for 3 month period)
- Fenland 198,540
- Hungtingdonshire 385,788
- Peterborough 363,156 (scaled from data for 1 month period)

East Cambridgeshire's fuel usage was assumed to be the same as Fenland. The total diesel volume was multipled by the conversion factor 2.59[152] to produce 4.90 kt CO_2e.

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[152] Greenhouse gas reporting: conversion factors 2019, BEIS

To calculate the carbon footprint of a fully electrified transport vehicle fleet, the total energy content of the diesel used was calculated (1 litre of diesel provides 36.0 MJ[153]). The total energy demand under a 23% increase in fuel usage was calculated as 83.8 TJ (1TJ = 1m MJ). The carbon footprint of this quantity of energy was then calculated using the projected 2050 grid carbon intensity. As discussed earlier, this assumes the electrical vehicles will have the same efficiency as current HGVs. In reality, technological advances mean efficiency at 2050 are likely to be higher and the total energy demand lower.

D.2. LANDFILL CALCULATIONS

D.2.1. CO_2-ONLY EMISSIONS

The 16.4 kt CO_2e emissions were split in 8.2 kt CO_2e for vehicle transport and electricity usage each. In the baseline scenario, the vehicle emissions remained fixed and the electricity usage emission were reduced by a factor of 9.04 (the ratio of the 2017 and 2050 carbon intensities). In the ambitious scenario, the vehicles emissions dropped by the same factor assuming full electrification.

D.2.2. LFG CALCULATIONS

The average composition of waste sent to landfill in 2016 included a carbon fraction 25.6% and, of that, a biogenic carbon fraction of 58.7%[154]. This results in a biogenic carbon content of 15% and it is assumed that only biogenic carbon will produce methane. the assumption that 50% of biogenic carbon is converted to LFG and the composition of LFG is 32.5% methane* (on a mass basis[155]), the amount of methane emitted from the landfill was calculated and converted to CO_2e. The CO_2 in the landfill gas is ignored as the carbon was sequestered from the atmosphere during the material's growth. 50% of the biohenic carbon was assumed to decompose into LFG[156]. Therefore 1 tonne of landfill waste is expected to produce 0.076 t of methane or 2.58 t CO_2e. The results of various capture rates and declines in waste sent to landfill were then calculated.

Matters are further complicated as decomposition takes time; the waste from one year can take several years to decompose. However, as the landfill has been operational for over 10 years, emissions from it are assumed to have reached a steady state.

The methane captured is assumed to be flared with no electricity generation. This is carbon neutral as the CO_2 was originally sequestered from the atmosphere. If electcrity generation is employed, this would reduce the net emissions further. Assuming a generation efficiency of 50%, 1 tonne of methane would produce 50,000 MJ[157] which

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[153] Engineering Toolbox https://www.engineeringtoolbox.com

[154] Waterbeach Energy From Waste Facility Carbon Assessment, Fitchner Consulting Engineers Ltd

[155] Appendix B, Review of Landfill Methane Emissions Modelling, Report for DEFRA by Golder Associates, 2014

[156] Waterbeach Energy From Waste Facility Carbon Assessment, Fitchner Consulting Engineers Ltd

[157] Thomas, George. Overview of Storage Development DOE Hydrogen Program. Livermore, CA. Sandia National Laboratories. 2000

would offset 1.8 t CO_2e in 2019 and 0.35 t CO_2e in 2050.

* Note that the commonly quoted figure for LFG is 57% methane and 43% CO_2. However, this is on a volume (and therefore mole) basis and for GWP, it is necessary to use a mass basis since the GWP of any species is defined in terms of the global warming potential of 1 kg of the species of interest releative to 1 kg of CO_2. To convert to a mass basis, we note that in one mole of LFG, 57% of the molecules are methane (molecular mass 14) and 43% of the molecules are CO_2 (molecular mass 44). To find the mass fraction, the calculation performed is:

$$\frac{\text{methane mass}}{\text{total mass}} = \frac{0.57 \times 14}{0.57 \times 14 + 0.43 \times 44} = 0.325 \Rightarrow 32.5\%$$

D.3. EFW EMISSION CALCULATIONS

When considering emissions from incineration, only CO_2 from fossil carbon (e.g oil-derived polymers) is considered as contributing to net emissions because the CO_2 formed from biogenic carbon sources was sequestered from the atmosphere during the material's formation. The waste composition was used as for LFG calculations, assuming private waste has same composition as waste landfilled by the council.

Net emissions from the EFW were calculated using information regarding waste composition[158]. With 58.7% of the carbon in the waste being of biogenic origin, the remaining 41.3% is from fossil sources and therefore contributes to net emissions when incinerated. Overall 10.6% of the waste is fossil carbon so 1 tonne of waste contains 0.106 t carbon which produces 0.389 t CO_2. A small contribution of 22 kg CO_2e from methane and N_2O results in 0.411 t CO_2e per t of waste. Multiplying this by 230,000 yields 94.5 kt CO_2e. Additional 2.3 kt CO_2e is added to account for additional fuel oil used in the auxiliary burners. The electricity generated by the EFW is estimated to be 195200 MWh per year. Using the predicted grid carbon intensity at 2050 results in an offset of 4.88 kt CO_2e (18.7 kt CO_2e in 2025). Overall this yields net annual emissions at 2050 of **89.6 kt CO_2e** which could be reduced to ~18 kt CO_2e with deployment of CCS at 80% efficiency.

Figure D.3 shows the predicted emissions should an EFW be built and start operation in 2025 yet receive no waste from the local authority, i.e local authority waste goes straight to landfill.

D.4. PETERBOROUGH ERF EMISSION CALCULATIONS

In the ERF the fossil carbon of the incinerated waste content results in 0.2375 t of CO_2e per tonne of waste[159]. The 85 kt annual incineration total therefore produces 20.2 kt CO_2e. The ERF also exports 55,000 MWh of electricity annually. This is currently offsets 7.3 kt CO_2e and by 2050 will offset 1.3 kt CO_2e. Thus the annual net emissions are currently 12.9 kt CO_2e and will rise to 18.9 kt CO_2e by 2050.

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[158] Waterbeach Energy From Waste Facility Carbon Assessment, Fitchner Consulting Engineers Ltd

[159] Bioma Output Report, August 2019

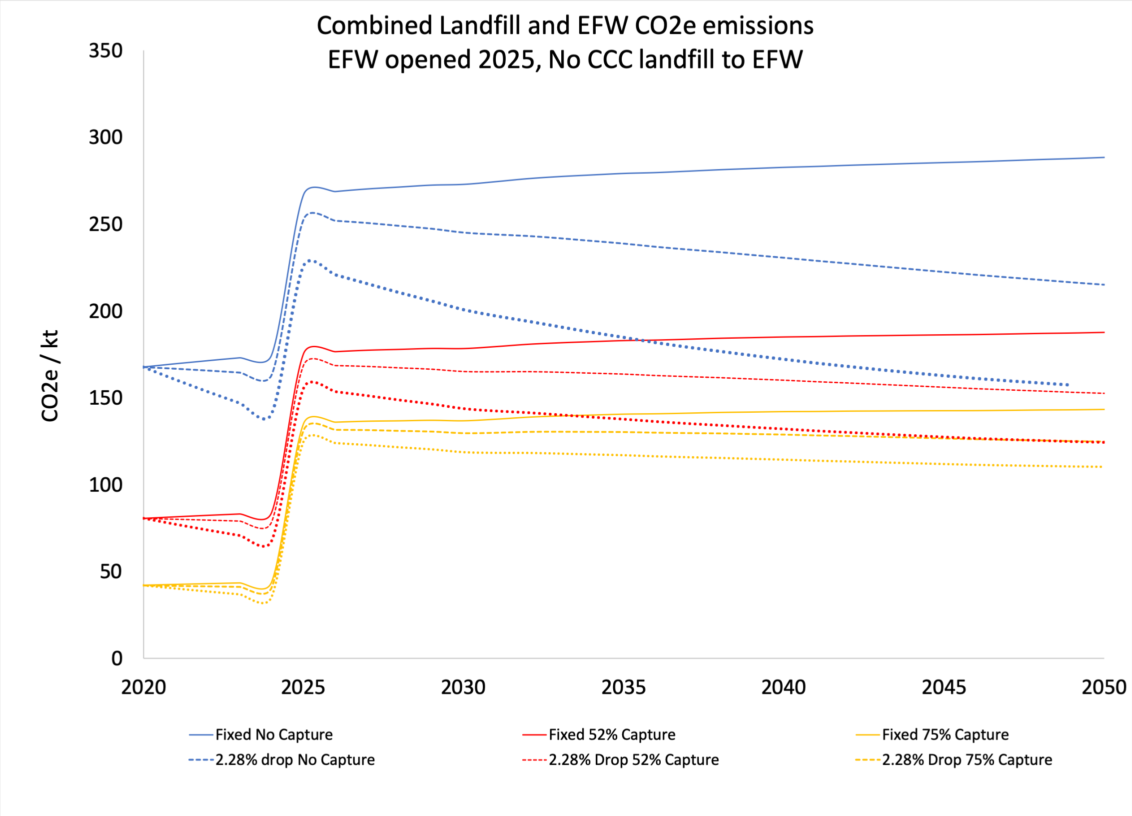

Figure D.1: Predicted emissions for EFW starting at 2025 with no diversion of CCC waste to landfill. Landfill gas capture rates are the most important factor in determining emissions.

D.5. COMPOSTING AND RECYCLING EMISSIONS

In addition to biogas combustion data (Figure D.4), the data from Amey Cespa refers to the generation of ~19,200 MWh of electricity (offsetting 5.25 kt CO_2e (2018) and 0.6 kt CO_2e (2050)) from biogas recovery and methane production[160]. However, clarification should be sought from Amey Cespa as it is unclear as to which processes and facilities the data pertains.

Regarding comparison to national perspective, non-household composting (1.1 Mt CO_2e), anaerobic digestion (0.2 Mt CO_2e) and Mechanical Biological Treatment (MBT) (0.6 Mt CO_2e) accounted for 1.9 Mt CO_2e of emissions in 2017[161]. Cambridgeshire produces 180 kt of recycling every year and Peterborough 36 kt. England as a whole in 2017/18 produced 10.86 Mt of recycled/composted waste[162]. Scaling this up to UK via population (factor of 1.2[163]) yields 13.03 Mt). Thus Cambridgeshire and Peterborough accounted for 1.66% of recycling and composting and this fraction which was applied to

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[160] Waterbeach Information Request & supporting docuements, from Amey Cespa and made available to Cambridgeshire County Council

[161] Table 14, Final UK greenhouse gas emissions national statistics 1990-2017, BEIS

[162] Local authority collected waste generation 2000 to 2017, Local Authority Collected Waste Management Statistics, DEFRA

[163] United Kingdom population mid-year estimate 2018, ONS

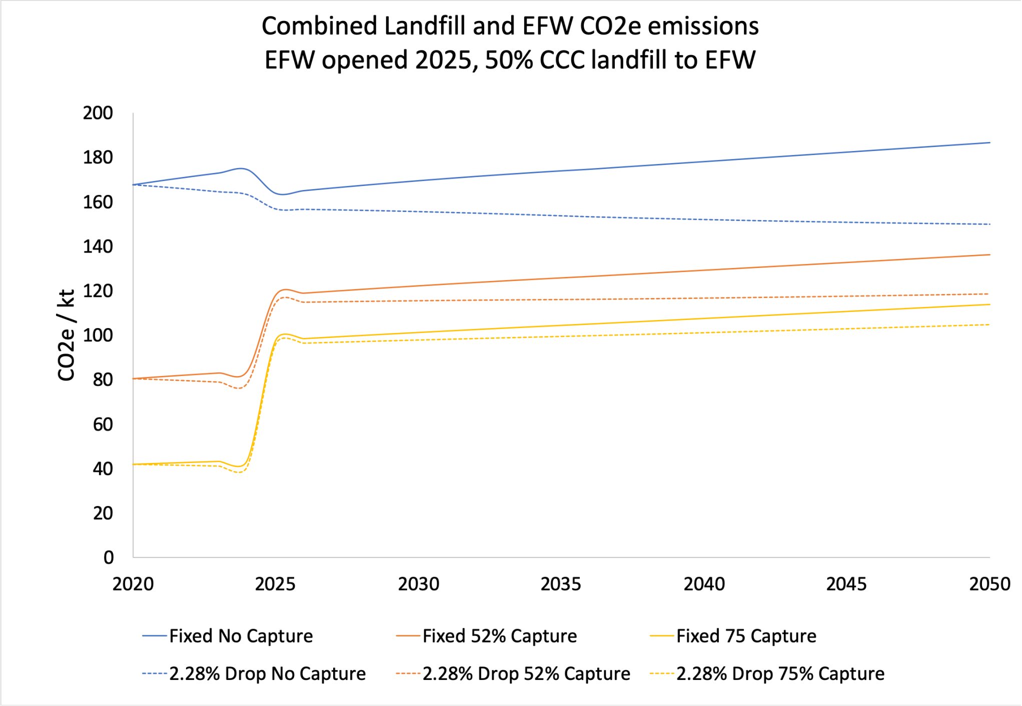


Figure D.2: Predicted emissions for EFW starting at 2025 with 50% diversion of CCC waste to landfill. The effect of landfill gas capture rate is diminished after the introduction of the EFW.

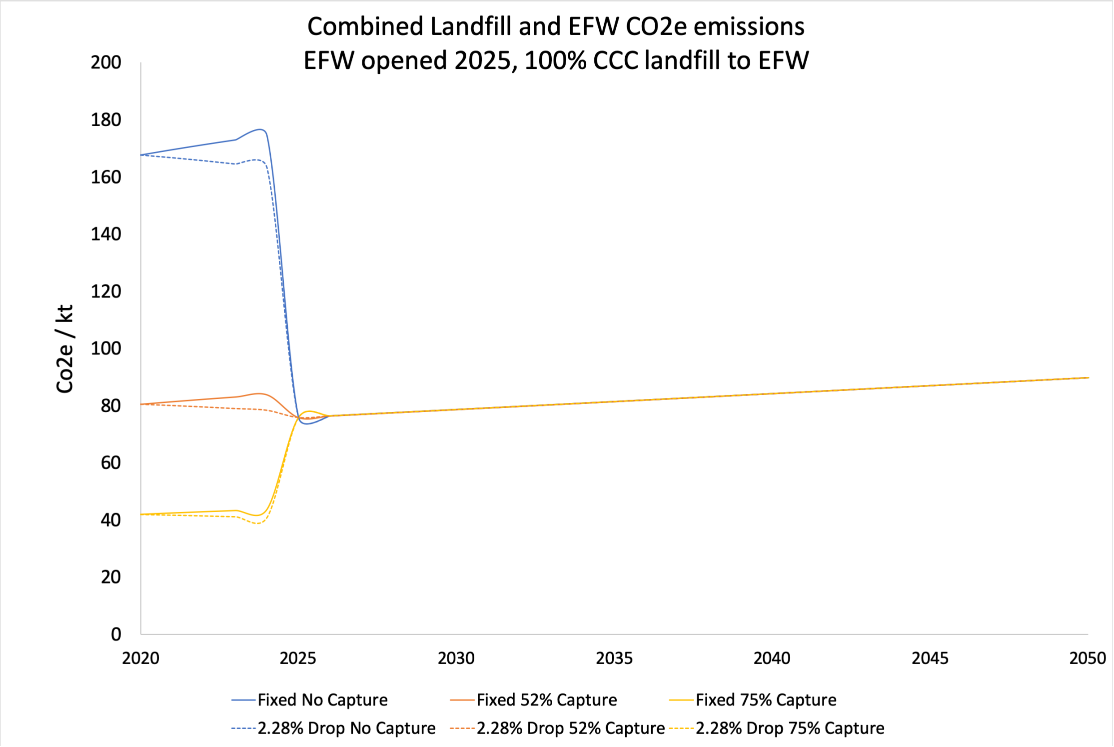
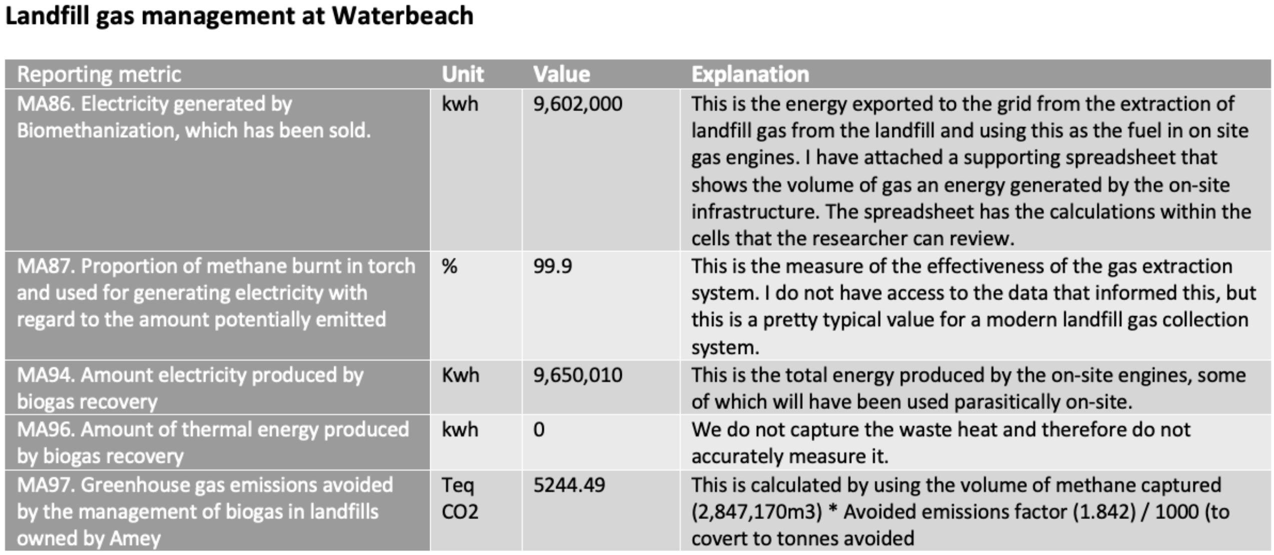


Figure D.3: Predicted emissions for EFW starting at 2025 with 100% diversion of CCC waste to landfill. Landfill gas capture becomes unimportant after 2025 and CCS will be the most important mitigation technology.



Landfill gas management at Waterbeach

Reporting metric	Unit	Value	Explanation
MA86. Electricity generated by Biomethanization, which has been sold.	kwh	9,602,000	This is the energy exported to the grid from the extraction of landfill gas from the landfill and using this as the fuel in on site gas engines. I have attached a supporting spreadsheet that shows the volume of gas an energy generated by the on-site infrastructure. The spreadsheet has the calculations within the cells that the researcher can review.
MA87. Proportion of methane burnt in torch and used for generating electricity with regard to the amount potentially emitted	%	99.9	This is the measure of the effectiveness of the gas extraction system. I do not have access to the data that informed this, but this is a pretty typical value for a modern landfill gas collection system.
MA94. Amount electricity produced by biogas recovery	Kwh	9,650,010	This is the total energy produced by the on-site engines, some of which will have been used parasitically on-site.
MA96. Amount of thermal energy produced by biogas recovery	kwh	0	We do not capture the waste heat and therefore do not accurately measure it.
MA97. Greenhouse gas emissions avoided by the management of biogas in landfills owned by Amey	Teq CO2	5244.49	This is calculated by using the volume of methane captured (2,847,170m3) * Avoided emissions factor (1.842) / 1000 (to covert to tonnes avoided

Figure D.4: Data received from Laurie Read, Amey Cespa 28th August 2019

the national emissions total to provide an estimate for the county's emissions.

In the baseline scenario, only emissions from electricity usage are considered to drop. The energy demand increased with population (23%) but the carbon intensity drops from 0.226 kg CO_2e / kWh to 0.025 kWh, resulting in emissions of 2.0 kt. Methane emissions rise 23% to 18.45 kt CO_2e. In the further ambition scenario, methane emissions are reduced by 95% yielding a total of 2.96 kt CO_2e.

D.6. DOUBLE-COUNTING CONCESSIONS

As discussed in Section 6, some of the sources of GHGs in the waste management sector fall into other sectors covered by this report due to the range of activities included within "waste management". These emissions were included in breakdown of emissions from waste management. However, when calculating waste management's contribution to the County's total emissions, they were not included because they would already be included in other sectors' contribution to the County total. Overall, these emissions currently total around 21.6 kt CO_2 and will total around 2.4-9.4 kt CO_2 in 2050 and are listed below:

- Emissions from waste transport (currently around 4.90 kt CO_2, estimated to be 6.02 kt CO_2 (baseline) and 0.58 kt CO_2 (ambitious) in 2050)
- CO_2-only emissions from Waterbeach landfill (16.4 kt CO_2 in 2017, estimated to reduce to 8.8 kt CO_2 (baseline) and 1.8 kt CO_2 (ambitious) in 2050)

E. AFFORESTATION SCENARIOS

Below are the important details for each afforestation scenario. All tree spacing values, were available as options on the Woodland Carbon Trust toolkit for the particular tree species and so are assumed to be acceptable. (YC = Yield Class, no thinning unless stated)

S1 Sitka Spruce, spacing 2m, YC 12
S2 Native Woodland (Oak 20% YC 8 spacing 2m, Sycamore 20% YC 10, Birch 20% YC 4, Aspen 8% YC 10, Alder 10% YC 6, Rowan 10% YC 4, Willow 12% YC 4), all other spacings 2.5m
S3 Same as S1 except with 5-yearly thinning
S4 Same as S2 except with 5-yearly thinning
S5 Corsican Pine, spacing 1.5m, YC 14
S6 Oak, spacing 3m, YC 6
S7 Sycamore, spacing 3m, YC 10

For context, a spacing of 3m results in 1,111 stems per hectare and the number of stems per hectare for a spacing, s, (in m) can be calculated from the equation:

$$\text{stems per hectare} = 1111 \times \left(\frac{3}{s}\right)^2$$