SMALL WORLD CONSULTING

A Carbon Baseline for Cumbria

A report by Small World Consulting Ltd

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Contents

Document control

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1 Executive Summary

This report looks at Cumbria's greenhouse gas emissions in three ways:

Extraction-based emissions: These are the emissions that will result from the burning of any fossil fuels that are extracted from the ground in Cumbria, ***wherever this takes place***. This type of emissions reporting is important for understanding the climate change implications of decisions relating to mining and other forms of extraction in the county.

Production-based emissions: These are the ***net emissions that are physically released in Cumbria***, most notably by the burning of coal, oil and gas, plus those arising from the production of electricity used in the county (wherever that generation takes place). This is the UK government's standard emissions reporting approach, and only CO_2 emissions are reported by BEIS at the local level. However, it also excludes emissions arising from the production of goods and services that are used by residents, visitors and industry, if they are produced elsewhere; for example, emissions from lime production taking place in Cumbria, even though the lime is transported outside of the county and used elsewhere. It also includes motorway emissions from vehicles that are passing through the country without stopping. We use the term 'net emissions' because we subtract any negative emissions (taking CO_2 back out of the air) that result from Land Use, Land Use Change and Forestry (LULUCF).

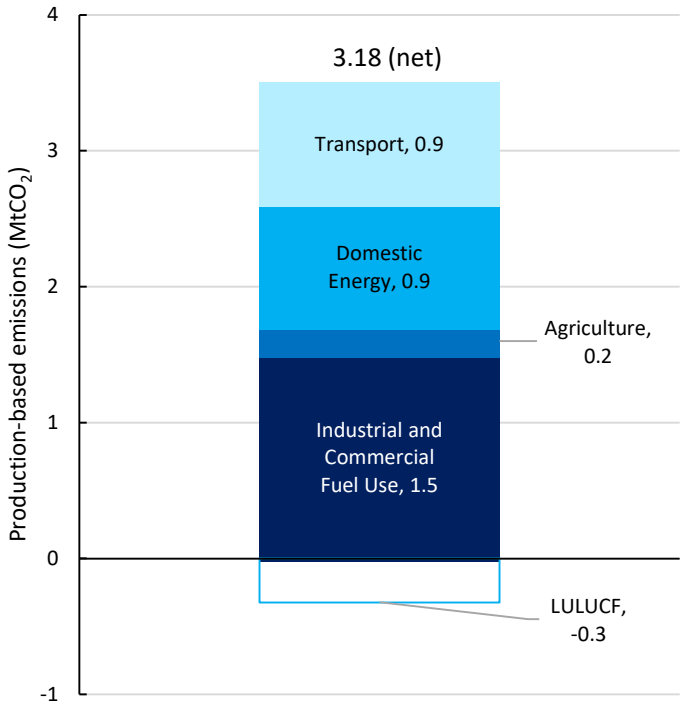


Figure 1. Cumbria's production-based CO_2 emissions in 2017 by category.

Consumption-based emissions: We assess the greenhouse gas 'footprint' of residents, visitors and industry, including the supply chains of everything that residents and visitors buy and do whilst in Cumbria. Consumption-based reporting attributes the emissions from product and service supply chains to Cumbria, ***regardless of where emissions are physically released during production***. Consumption-based reporting is important for looking at the climate change impacts that people and businesses have through their entire

lifestyles, including the food they eat and the things they buy. For example, taking a consumption-based approach, the impact of driving includes not just the exhaust pipe emissions, but also emissions resulting from the manufacture and maintenance of cars and emissions resulting from the extraction, refining and transport of fuels to the pump. For businesses, it includes the full impact of business practices, including procurement supply chains. The footprint of Cumbria's industry is reported separately as there is some unavoidable double counting with the footprint of residents and visitors, where people buy from local companies.

There is currently no fossil fuel extraction in Cumbria, although planning permission has been given for a Whitehaven coal mine with extraction-based emissions of 8.4 million tonnes (Mt) CO_2e per year for 50 years, totalling 420 MtCO_2e.

The largest part of the production-based carbon footprint comes from transport, closely followed by industrial and commercial fuel use. Emissions from vehicles on the M6 motorway have been excluded. Cumbria's production-based footprint is 3.2 Mt CO_2 (Figure 1). Note that only CO_2 data was available, and so other GHG emissions (e.g. methane from Agriculture) are not captured in this analysis. The data is also produced on a two-year lag, and so the most recent data from 2017 are presented in this report.

Cumbria's consumption-based GHG emissions by consumer type in 2018 (Figure 2) were as follows:

- Annual emissions from residents: 6,315 kilotonnes (kt) CO_2e (12.7 tCO_2e per person per year)
- Annual emissions from visitors whilst in Cumbria: 1,608 ktCO_2e (26 kgCO_2e per visitor day)
- Annual emissions from visitors travelling to/from Cumbria: 4,452 ktCO_2e (71 kgCO_2e per visitor day)
- Annual industry emissions: 13,174 tCO_2e

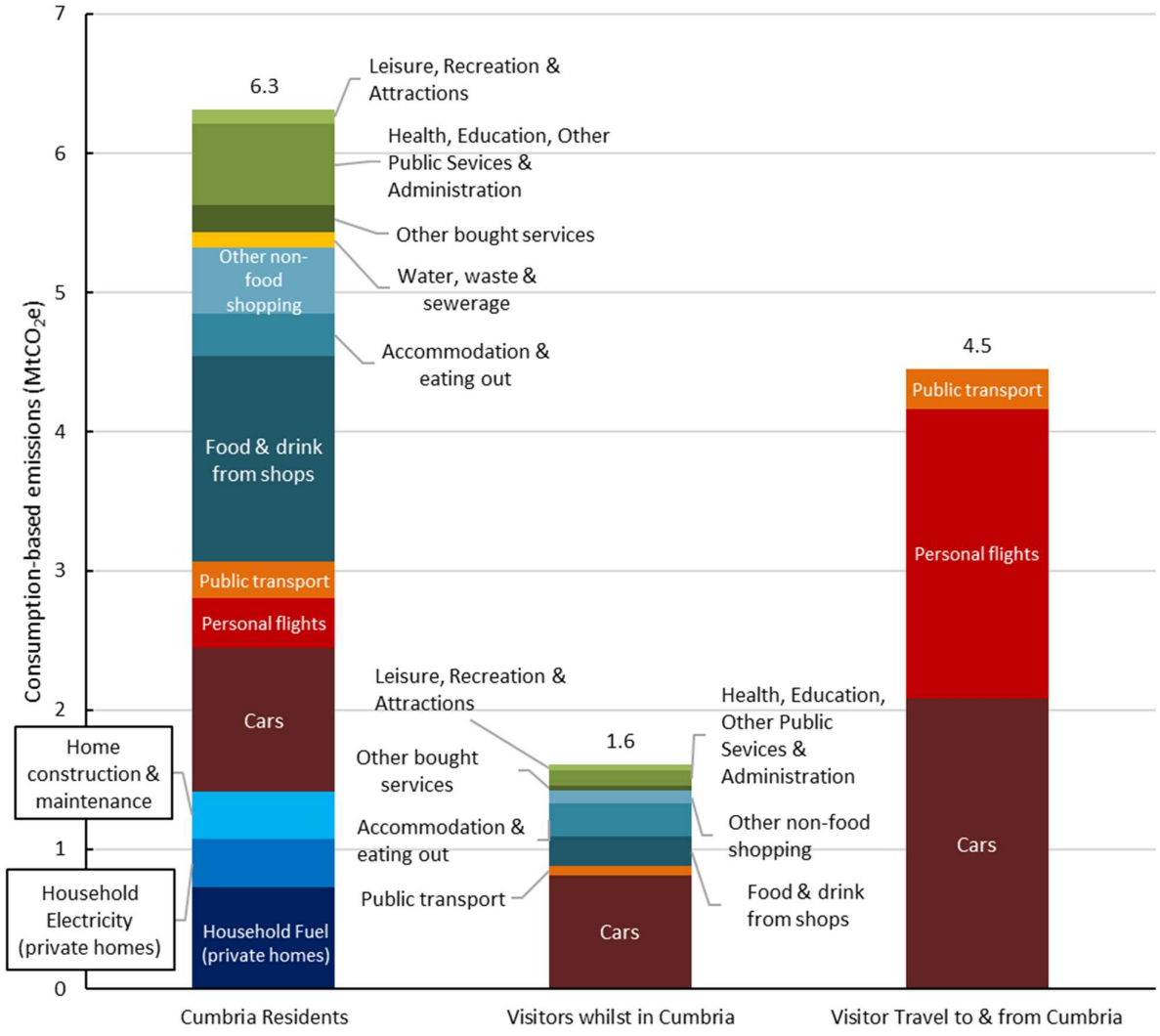


Figure 2. Cumbria's consumption-based GHG emissions in 2018 by category.

Vision

We sketch out a vision for low-carbon Cumbria which would improve quality of life for residents and promote sustainable tourism. We also outline how industry, in particular agriculture, will contribute to and thrive in low-carbon Cumbria.

Targets and Recommendations

We propose a target that includes the following components:

- Energy-only CO_2 measured on production basis, excluding the M6 (which Cumbria has little influence over);
- GHG emissions for Food consumed by residents and visitors;
- GHG emissions for Other goods purchased by residents and visitors;

- GHG emissions from Visitor travel to and from Cumbria, excluding international visitor travel; and
- Land Use, Land Use Change and Forestry (negative emissions).

We provide five possible targets and from these recommend Net Zero by 2037 (Figure 3), which is the most feasible target that can be regarded as being in line with the requirements laid down by the IPCC for "well below 2 degrees and in pursuit of 1.5 degrees."

Extraction-based emissions and renewable and nuclear energy production figures are excluded from the methodology for the net-zero trajectory for Cumbria. We suggest adopting separate targets for renewable energy produced in Cumbria that is exported to the national grid, and for extraction-based emissions reporting.

Option 3 - Net Zero by 2037: 13% annual reduction in energy only CO_2 emissions; 5% annual reduction in food and other purchased goods emissions; 10% annual reduction in visitor travel emissions per visitor day; 400% increase in annual LULUCF removals after 15 years.

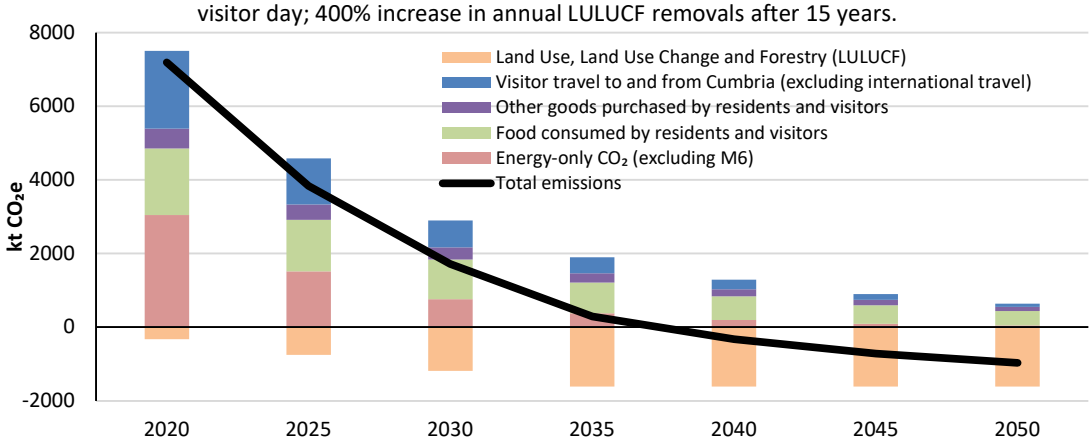


Figure 3: Recommended pathways to Net Zero for Cumbria by 2037

2 Introduction

In May 2019, the UK parliament followed Carlisle, South Lakeland district councils in declaring a climate emergency, and the government amended the 2008 Climate Change Act to strengthen its climate ambition, legislating for a target to reduce the UK's emissions to Net Zero by 2050. Subsequently, many other local authorities, including two more of the six local authorities within Cumbria, have begun to declare climate emergencies and make commitments to reduce local emissions. By mapping out Cumbria's carbon footprint, this report seeks to help the county's policymakers understand how best to respond to the climate emergency. We have taken a broad look at the emissions in Cumbria from three different perspectives: extraction-based, production-based and consumption-based emissions. This enables us to analyse the priorities for industry, individual residents and visitors, and mines and quarries respectively.

Following the limited global action on emissions reduction in the last decade, the United Nations Environment Programme (UNEP) now estimates that CO_2 cuts of 2.7% per year are required to keep within 2°C of warming

and much greater cuts of 7.6% per year would be required to limit warming to 1.5°C[1]. The UNEP sets a global requirement to limit temperature rise to "well below 2°C and in pursuit of 1.5 °C," and for rich industrialised countries such as the UK to cut further and faster than this. This report sets out a 2018 baseline of emissions against which Cumbria can measure its reductions and recommended reduction targets.

For the consumption-based emissions estimate, we are using the term 'footprint' to describe the sum of the direct and indirect greenhouse gas emissions that arise throughout supply chains of activities and products in carbon equivalents. The inclusive treatment of supply chain emissions differs from the more standard production-based emissions assessment that is also included in this report but gives a more complete and realistic view of impacts of final consumption of residents, visitors and industries.

Emissions resulting from the production of goods purchased by Cumbrian residents and visitors would not feature in a production-based emissions assessment, unless the entire supply chain was within Cumbria. For example, in the case of local beer much of the supply chain might lie within Cumbria but in the case of a smartphone it would not. To give another example, in a consumption-based assessment, the footprint of travel includes, on top of the direct vehicle emissions, those resulting from the extraction, shipping, refining and distribution of fuel, emissions resulting from the manufacture and maintenance of vehicles, and so on. Thus, in the case of car travel the final figure is typically around double that of the exhaust pipe emissions. In a third example, the consumption-based footprint of electricity consumption includes components for the emissions associated with fossil fuel extraction, shipping, refining and transport to power stations, as well as those resulting from the electricity generation process itself; whereas a production-based footprint would only include emissions arising at the point of generation.

We also include an extraction-based emissions assessment in order to properly reflect the impact of any fossil fuel mining or drilling activities that may take place in Cumbria, even if the fuel is burned elsewhere.

[1] UNEP (2019). Emissions Gap Report 2019. Executive summary. United Nations Environment Programme, Nairobi. https://www.ipcc.ch/sr15/

The figures are best estimates-based on the data made available to us, and there are caveats based on assumptions made. The intention of the carbon budget is to 'measure the unmeasurable' as far as possible and thereby:

- Create best estimates;
- Differentiate between more significant and less significant actions (at least by order of magnitude);
- Create a culture of climate action;
- Cut carbon;
- Raise awareness at a policy level and show leadership; and
- Learn about how to deal with climate change at a local area level.

New for the 2019 report, we provide extraction-based and production-based emissions in addition to the updated consumption-based emissions which we reported on in 2012.

2.1 Extraction-based GHG emissions

We provide a short analysis of emissions arising as a result of extraction activities in Cumbria. This includes any fossil fuels that are extracted within the boundaries of Cumbria regardless of where they will ultimately be burned. This type of emissions reporting is important for understanding the climate change implications of decisions relating to mining and other forms of extraction in the county.

2.2 Production-based CO_2 emissions

We provide a summary of production-based emissions for Cumbria in 2017 as estimated by Ricardo Energy for BEIS[2]. This is the UK's standard emissions reporting approach. It is useful for monitoring energy use but does not cover the impact of purchased goods and services. The production-based assessment covers the net emissions that take place in Cumbria plus those arising from the production of electricity used in the county, wherever that generation takes place. However, it excludes imported emissions from the production of goods and services that are used by residents, visitors and industry in the county, whenever their supply chains are not within Cumbria. It includes emissions from:

- Industrial and commercial energy use;
- Domestic Electricity, Gas and Other fuels;
- Transport (excluding aviation and sea shipping, but including vehicles that pass through the county on the M6 without stopping); and
- Net negative emissions resulting from land management, such as peat restoration and tree planting.

The production-based estimate covers only CO_2 and most significantly omits CH_4 and N_2O emissions from Agricultural activities.

2.3 Consumption-based GHG emissions

Since the last carbon baseline for Cumbria carried out in 2012 by Small World Consulting, there have been changes in the numbers and behaviours of residents and visitors in Cumbria, changes in the data that is

[2] BEIS, June 2019, UK local authority and regional carbon dioxide emissions national statistics: 2005-2017. https://tinyurl.com/UKCO2PB

available to understand these behaviours, and changes in the carbon intensity of different activities and consumables, as well as some evolution in the details of the methodology used. For example, the carbon intensity of electricity in the UK has decreased by nearly 40% since 2012, bringing the carbon footprint of electricity down relative to 2012.

This report provides a fresh estimate of carbon emissions for Cumbria, using a similar consumption-based approach to the one used in 2012. It provides an up-to-date basis for understanding the carbon management priorities and a new baseline against which future actions can be evaluated.

Because there have been changes in the background economy as well as developments in the methodology, and the type and quality of data that is available, the results presented here cannot be used to compare against the 2012 footprint nor to assess the impact of local actions since 2012.

2.4 Scope and Limitations

We provide a broad perspective on the carbon issues and help to clarify the priorities from a carbon management perspective. The figures contained are best estimates. Even where accurate data are available, all carbon footprints that seek to include supply chain emissions almost always contain considerable uncertainty. This report also relies upon estimates of consumption-based emissions from a range of data sources, including visitor surveys, which themselves contain considerable uncertainty.

This report estimates greenhouse gas (GHG) emissions from consumption by Cumbria residents and visitors, including travel to and from Cumbria. It covers all the 'basket of six' greenhouse gases and the term 'carbon footprint' is used as a shorthand to mean the GHG emissions released both directly and indirectly within supply chains of goods and services.

The consumption-based assessment includes emissions resulting from everything residents do and buy in their personal lives and everything that visitors do and buy while in Cumbria, as well as their travel to and from the county. More specifically, the following is within the scope of this report:

- all residents' personal travel and visitor travel to, from and around Cumbria;
- fuel and electricity consumed in homes and places to stay;
- emissions from food and drink and other purchases;
- emissions resulting from the use of services, including public services; and
- the supply chains of all the above (e.g. fuel supply chains and embodied emissions).

As a separate analysis, we also include a simple assessment of industry emissions. Consistent with the consumption-based reporting approach, this includes both direct emissions and supply chain emissions.

Electricity generated and fed into the National Grid, whether from renewables, nuclear or fossil fuel, is not a carbon removal, and therefore cannot be counted as a negative emission in either production-based or consumption-based accounting. As is the convention in production-based emissions reporting, emissions from electricity production are attributed to electricity use. Therefore the direct emissions from Sellafield are excluded from the production-based accounts, which instead apply a UK grid average carbon intensity to all grid electricity use.

It is worth noting that double counting occurs when businesses within Cumbria sell either to other businesses in Cumbria or to residents or visitors (Figure 4). This is difficult to eliminate, but should be remembered. In particular, accommodation is both sold and consumed by residents and visitors, and the same is true for food and drink, except where this is exported from Cumbria.

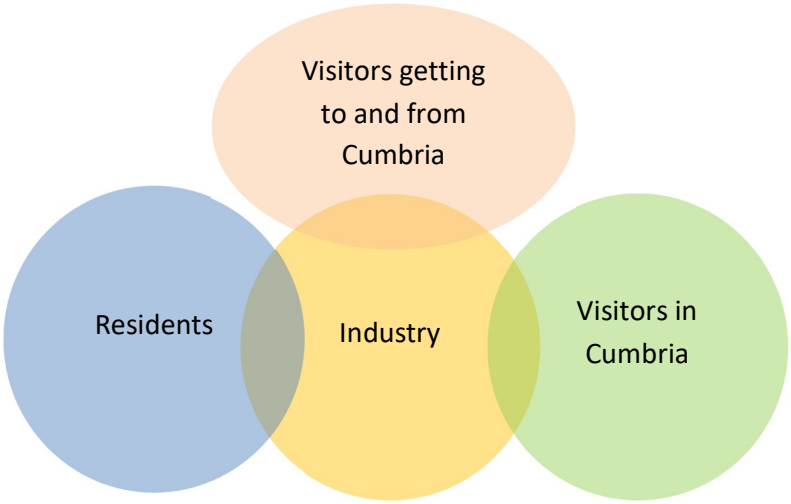


Figure 4: The consumption-based footprint of industry overlaps with that of residents and visitors where they buy locally produced goods and services.

3 Cumbria's Extraction-based GHG emissions

There are currently no active sites extracting hydrocarbons in Cumbria. However, in 2019 Cumbria County Council gave planning permission for the proposed Woodhouse Colliery near Whitehaven, to extract 2.43 million tonnes of coking and 0.35 million tonnes middling coal per year. If used, **this coal would generate around 8.4 $MtCO_2e$ per year** (calculated using emissions factors from BEIS, 2017). This is just over one and a half times the annual consumption-based greenhouse gas footprint of all Cumbria's residents. Over the course of its 50-year lifetime, the mine would be expected to extract coal with an extraction-based footprint of 419 $MtCO_2e$.

4 Cumbria's Production-based CO_2 emissions

Cumbria's total production-based emissions for 2017 were 3.18 $MtCO_2$ (Figure 5). This includes emissions railways passing through the county, and removals from land use, such as through peat restoration and tree planting. Emissions from vehicles travelling along the M6 motorway have been excluded.

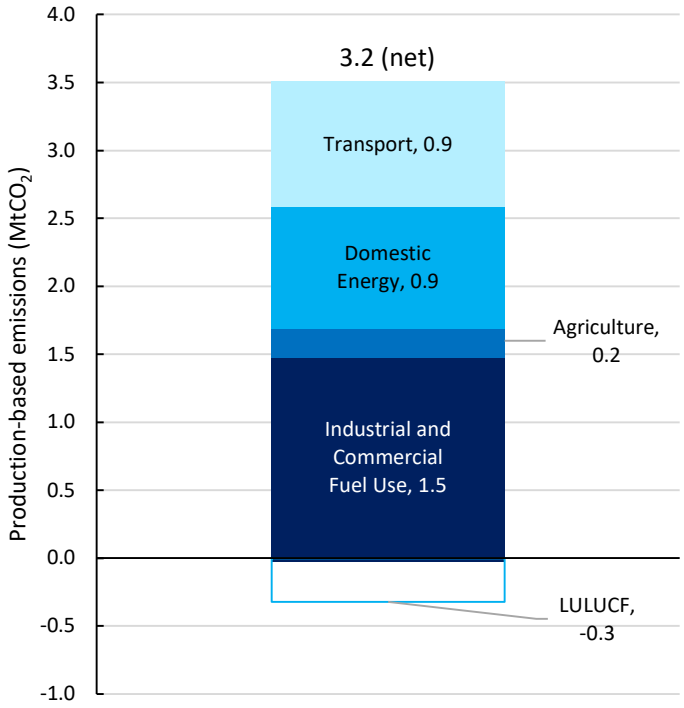


Figure 5: Production-based CO_2 emissions and removals from Cumbria in 2017

Broken down by local authority, the highest emissions (excluding removals from Land Use, Land Use Change and Forestry – LULUCF) originated in Eden and South Lakeland (both approximately 0.74 $MtCO_2$ in 2017), followed by Allerdale (0.65 $MtCO_2$, Figure 6A). Removals from LULUCF in Cumbria are estimated to be around 0-20 tonnes Carbon per km^2 from Forest Land, with minor removals from grassland and cropland management[3]. When LULUCF is included, CO_2 emissions from South Lakeland were lower than Eden in 2017.

[3] Centre for Ecology & Hydrology for BEIS (2019). Mapping Carbon Emissions & Removals for the Land Use, Land Use Change and Forestry Sector: Report based on the 1990-2017 Inventory. See: www.gov.uk/government/statistics/uk-local-and-regional-carbon-dioxide-emissions-national-statistics-2005-to-2017

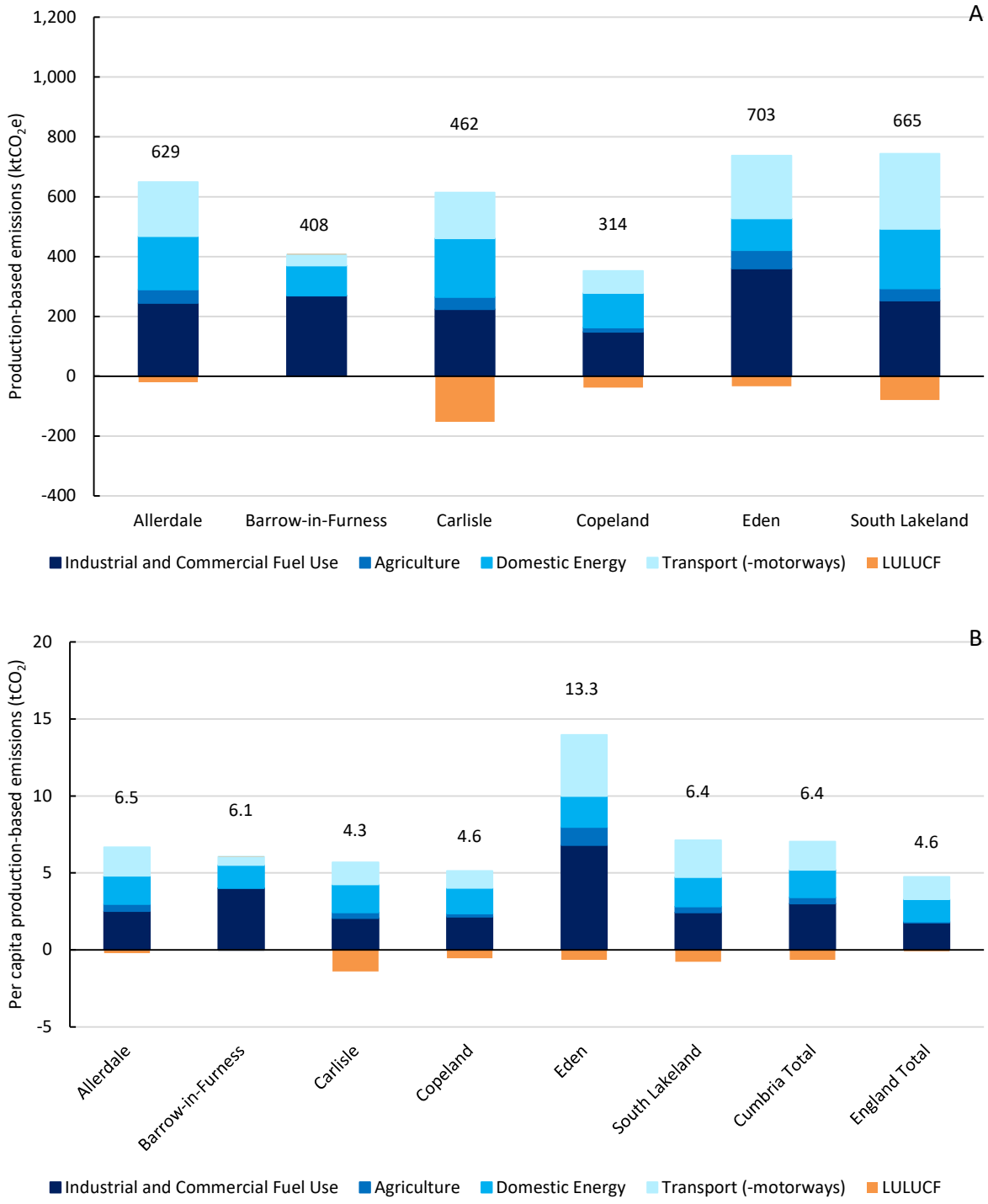


Figure 6: A) Total production-based CO_2 emissions by sector, broken down by Cumbrian local authority; B) Production-based CO_2 emissions by sector and region, per capita basis. Totals above bars include removals from LULUCF

4.1 Transport

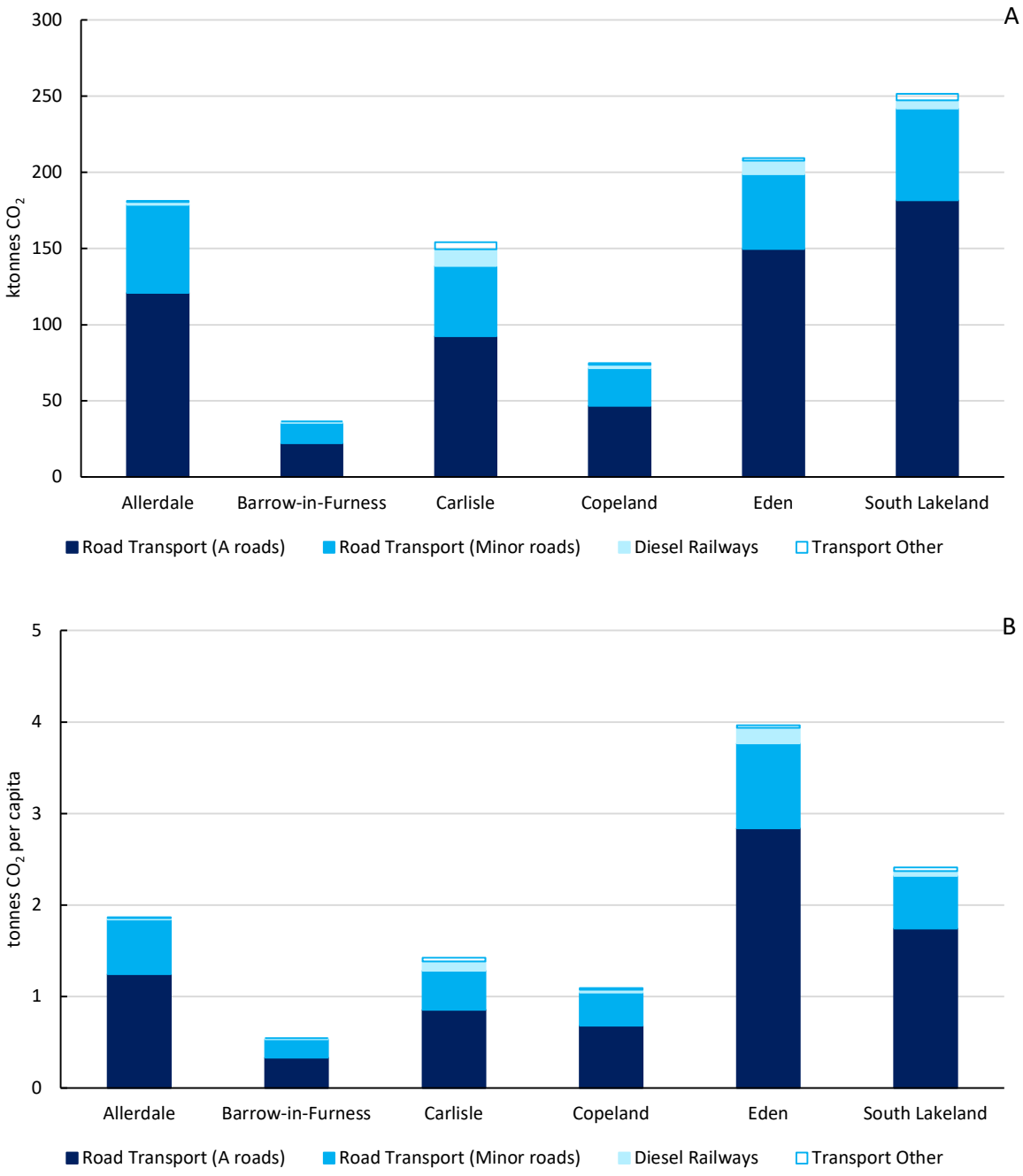


Figure 7: Production-based CO_2 emissions from Transport in Cumbria, broken down by mode and local authority. A) Total emissions by LA and sector; B) Per capita emissions by LA and sector

As the largest component of the production-based footprint (Figure 5), Cumbria's transport emissions can be broken down by transport mode, and split by local authority (Figure 7A). The M6 motorway passes through Eden, South Lakeland and Carlisle, resulting in high transport emissions from traffic, but these have been

excluded from the analysis. A roads and minor roads are significant sources of emissions across all local authority areas. On a per capita basis, Eden residents have the highest production-based transport footprint (Figure 7), likely because the popular A66 passes through the area, and the vehicle emissions are shared among a relatively low population. Per capita transport emissions from Carlisle and South Lakeland are more similar to those of Allerdale and Copeland, due to their higher populations. Cumbria's transport emissions per capita are, 22% higher than the UK national average (Figure 8).

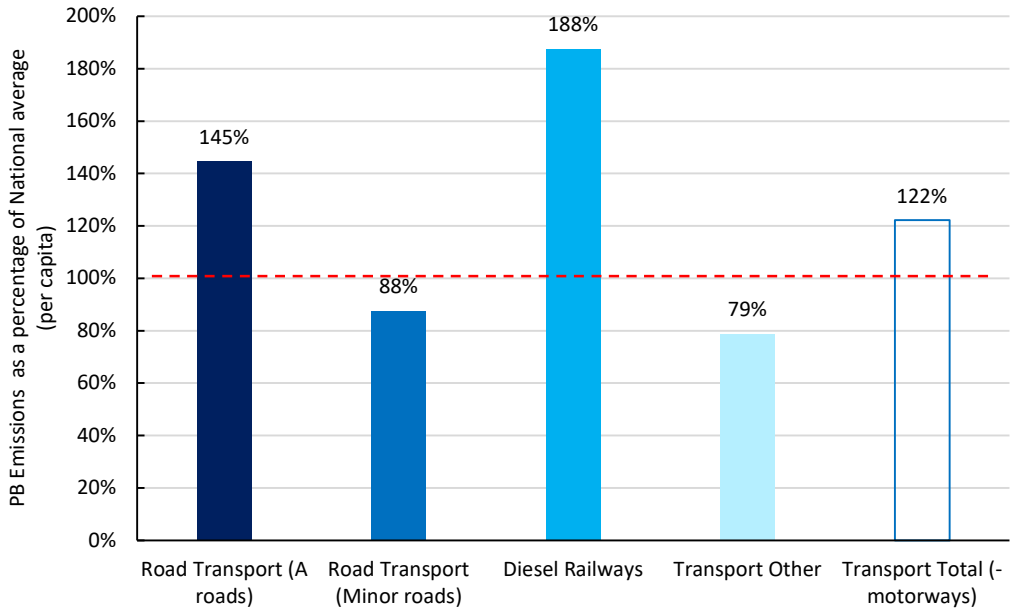


Figure 8: Per capita production-based emissions as a percentage of the national average

By excluding motorways, the production-based emissions for Eden and South Lakeland are significantly reduced although they are still the highest in Cumbria – due in part to the number of visitors to these areas. Whilst this information is useful to inform decisions about how best to reduce emissions from road travel within Cumbria, the issue of motorways must not be ignored for the following reasons:

- 40% of all production-based transport emissions in Cumbria are a result of motorway travel (Figure 9), and even if all other emissions were reduced, these emissions would still remain. This highlights the need for Cumbria to join the national call for more incentives to buy and use electric vehicles.
- The presence of motorways in Cumbria allows many of the residents to live where they do.
- Whilst many of the motorway users are travelling straight through without stopping, many also do stop in Cumbria and the Cumbria visitor economy is built on the fact that visitors can access the area easily.
- Whilst it may not be possible for Cumbria authorities to directly impact the emissions arising from motorways, they can play a part by sending important messages to make more polluting vehicles less socially acceptable.

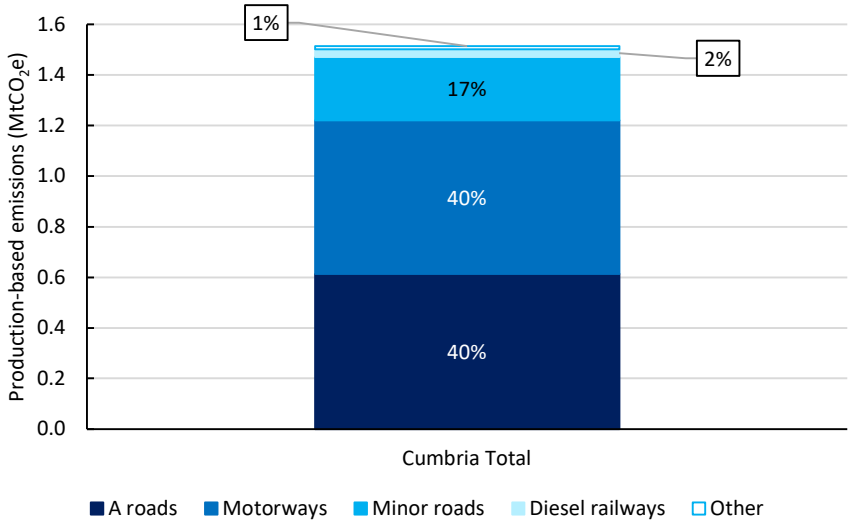


Figure 9: Total production-based emissions (2017) from Transport in Cumbria, *including* emissions from motorways

4.2 Industry and Commercial

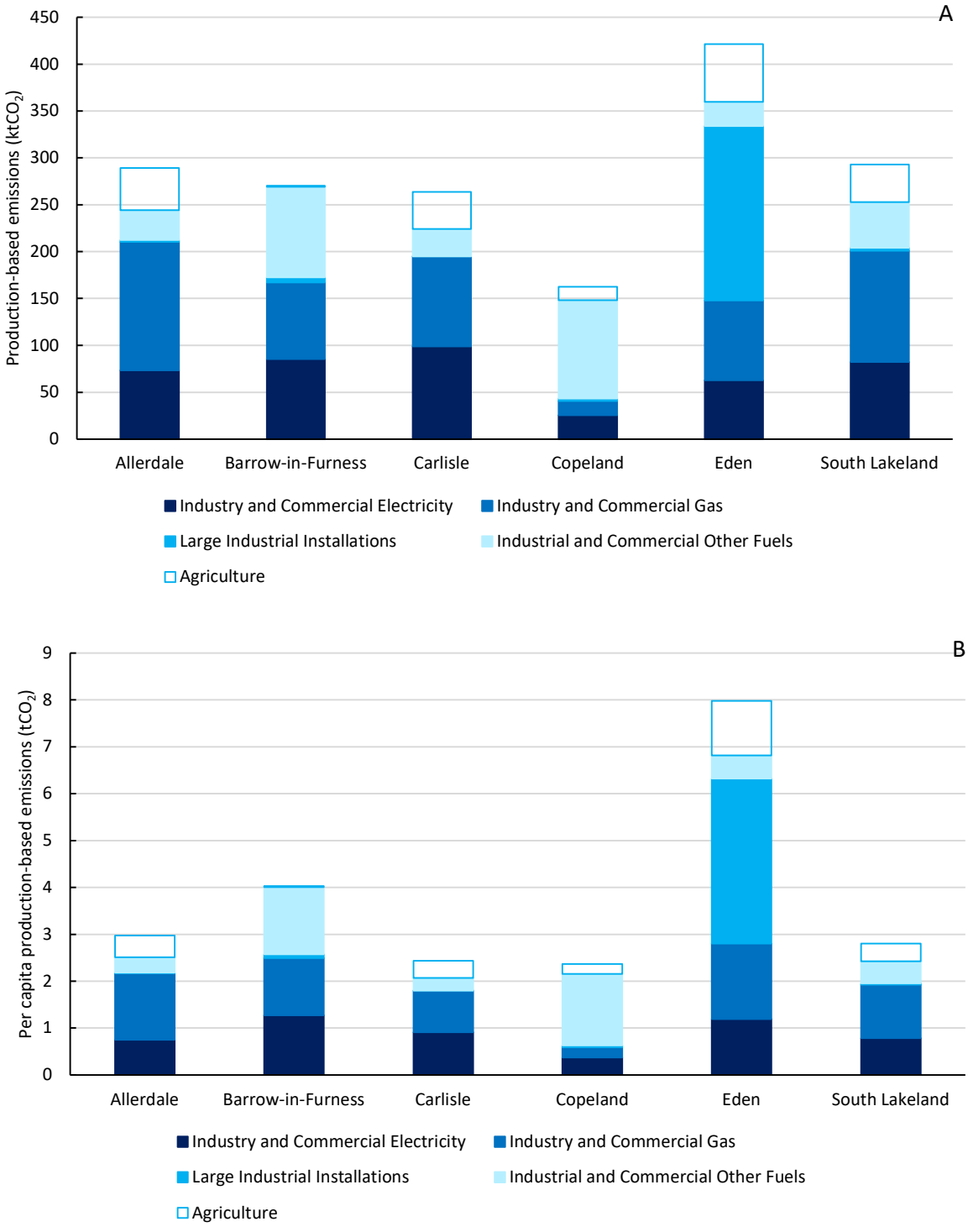


Figure 10: Production-based CO_2 emissions from the Industrial and Commercial sectors. A) Total production-based emissions by LA and sector; B) Per capita emissions by LA and sector

Cumbria's Industrial and Commercial (including Agriculture) production-based emissions was estimated as 1.7 $MtCO_2$ in 2017. This category encompasses direct CO_2 emissions from businesses in Cumbria. At the local authority level, Eden was projected to be the main source, responsible for 421.2 $ktCO_2$ (Figure 10), of which

emissions from "Large Industrial Installations" comprised 44%. Production of lime in this area is a major source of CO_2 emissions. "Large Industrial Installations" refers to point sources of CO_2 emissions from sectors including manufacturing and mining. It is estimated from fuel consumption and emissions from industrial processes.

Per capita emissions are again highest in Eden, due to high emissions (particularly from "Large Industrial Installations") spread over a low population.

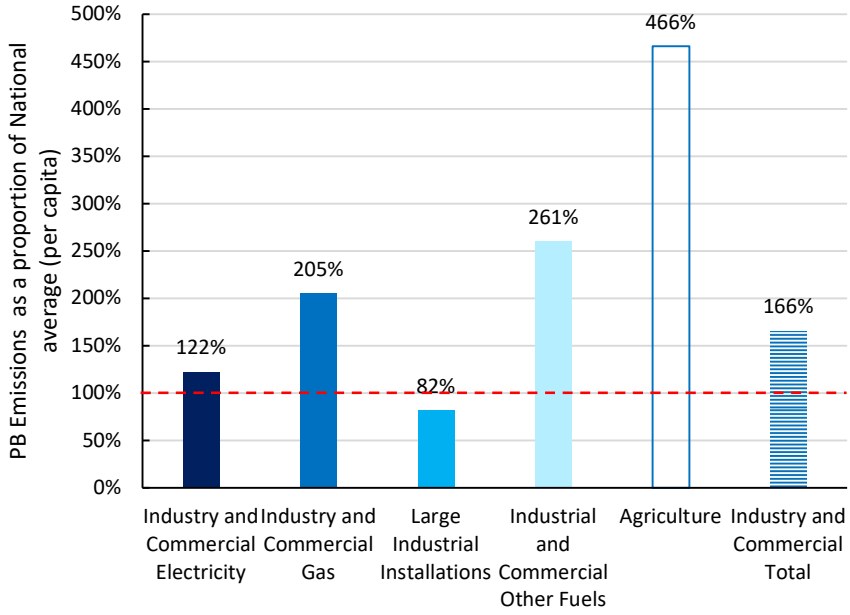


Figure 11: Industrial and Commercial production-based CO_2 emissions per capita as a proportion of the national average. The red dashed line marks the national average (100%).

Cumbria's per capita Industry and Commercial CO_2 emissions are 66% higher than the UK national average (3.41 vs. 2.06 tCO_2; Figure 11). This is primarily driven by Cumbria's Industrial and Commercial consumption of gas, electricity and other fuels. Despite being 4.6 times higher than the national average, agricultural CO_2 emissions are only a small proportion (12%) of Cumbria's overall Industry and Commercial footprint. It should be noted that non-CO_2 agricultural emissions are not captured here, and the true scale of GHG emissions from Agriculture may be much greater.

4.3 Domestic (within the home)

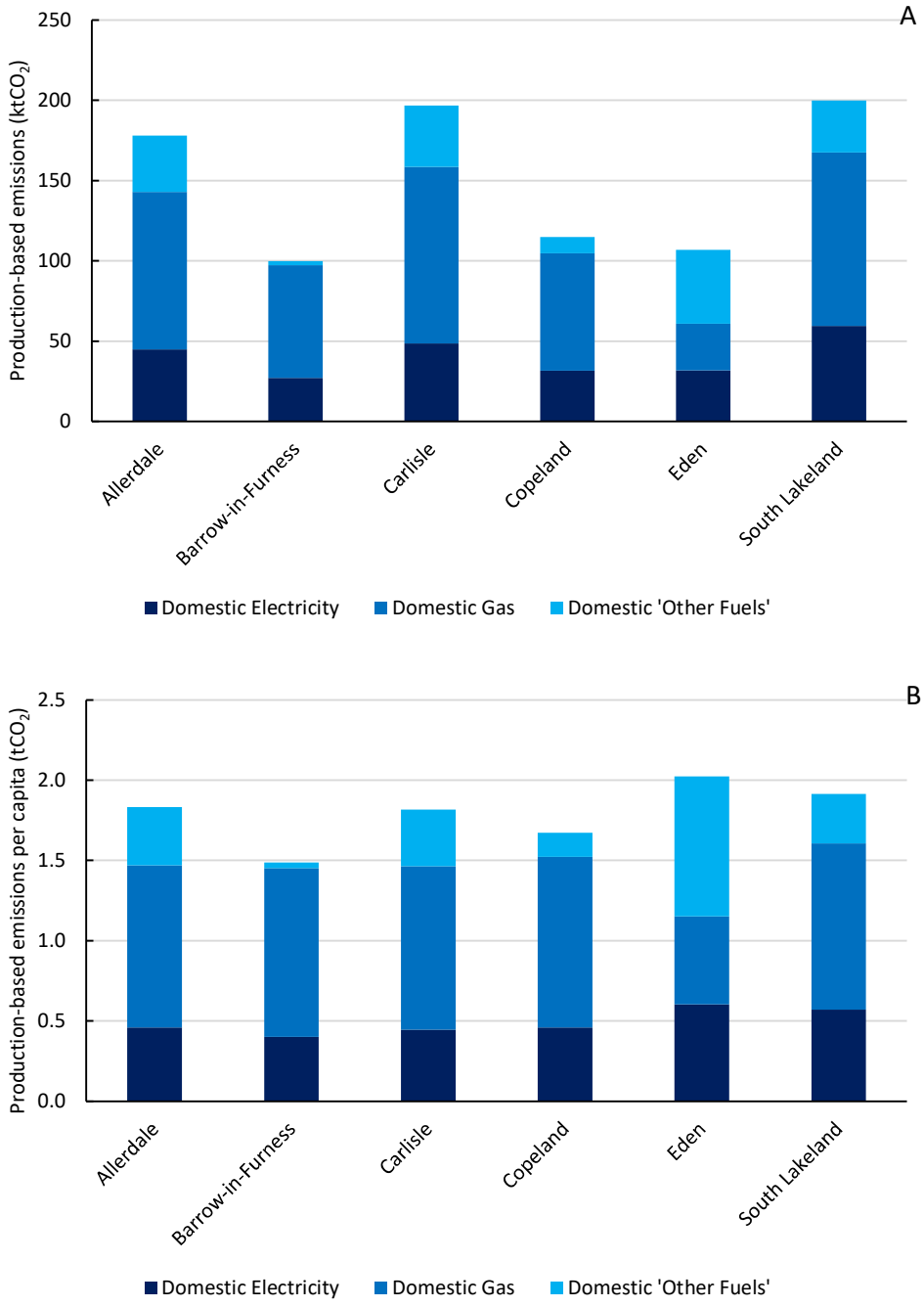


Figure 12: Production-based CO_2 emissions from Domestic sources. A) Total CO_2 emissions by LA and energy type; B) per capita production-based CO_2 emissions by LA and energy type

Total domestic production-based CO_2 emissions were highest in South Lakeland, Carlisle and Allerdale, the three most populous local authorities in Cumbria (Figure 12A). Emissions from gas consumption account for the biggest proportion of domestic emissions, at 55%. On a per capita basis, emissions from domestic energy use are similar across all local authorities, ranging from 1.49 tCO_2 in Barrow-in-Furness to 2.02 tCO_2 in Eden (Figure 12). However, the components of the footprint vary across local authorities, particularly with regards to consumption of gas or "Other Fuels". The contribution of "Other Fuels" to the per capita footprint is greatest

in Eden (43%, vs 14% Gas), where rural communities are less likely to be connected to mains gas, instead relying on heating oils or solid fuels. "Other Fuels" contribute between 16-20% of the average resident's Domestic emissions footprints in Allerdale, Carlisle and South Lakeland.

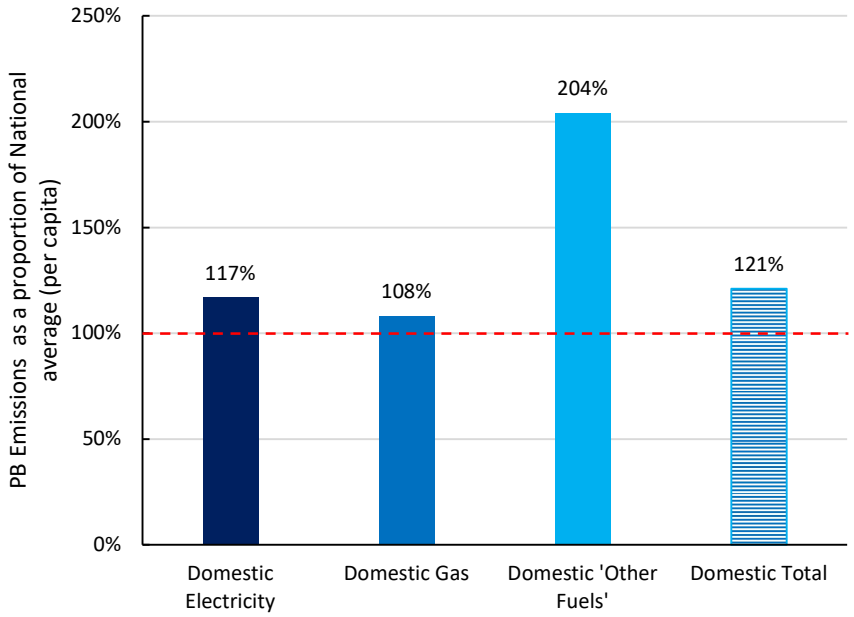


Figure 13: Domestic production-based CO_2 emissions per capita as a proportion of the national average. The red dashed line marks the national average (100%).

Cumbria's overall per capita production-based domestic emissions are 21% higher than the UK national average of 1.49 tCO_2 (Figure 13). Emissions from "Other Fuels" are over double the national average, but only form 18% of Cumbria's overall Domestic footprint.

5 Cumbria's Consumption-Based GHG Emissions

The total GHG 'footprint' of residents and visitors is estimated at 11.5 $MtCO_2e$ for 2018. This includes visitors' travel to and from Cumbria, their consumption within Cumbria, and everything residents do, whether within or outside of the boundary of Cumbria. The consumption-based assessment includes all GHG emissions associated with everything that residents and visitors buy or consume – this includes the supply chains involved in provision of goods and services.

5.1 Emissions by consumers

Emissions by consumers are broken down into two categories: Residents of Cumbria and Visitors to Cumbria. Resident emissions account for 51% of the total (Figure 14). Visitors travelling to and from Cumbria make up 36% of the total footprint, and 13% of the emissions come from visitors within Cumbria. The emissions per resident per day are 35 $kgCO_2e$ which is the same as the UK average, whereas the emissions for visitor are 26 $kgCO_2e$.

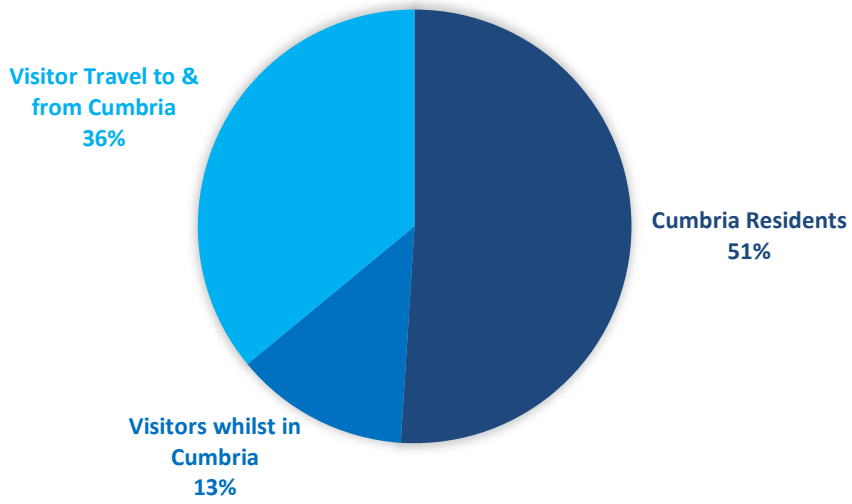


Figure 14: The GHG footprint of residents and visitors: 12.3 $MtCO_2e$.

Broken down by category, highest emissions arise from visitor air travel (2.1 $MtCO_2e$), visitor fuel consumption (1.4 $MtCO_2e$ travelling to Cumbria and 540 kilotonnes (kt) CO_2e within Cumbria) and resident food and drink (1.5 $MtCO_2e$; Figure 15).

On a per capita basis, Cumbria residents' consumption-based footprint is broadly in line with the UK average. Cumbria visitors have a greater proportion of driving emissions (both fuel and wear and tear) in their footprint whilst in Cumbria (approximately three times the UK average), and a higher proportion of emissions from eating out and recreational activities than residents. Overall, visitors' footprint is less than that of the UK average due to lower emissions from household energy and other services. These differences reflect the difference between typical activities of residents and visitors. In contrast to residents, visitors' emissions are dominated by air and road travel. Visitors emit more carbon travelling to and from Cumbria than they do during their stay.

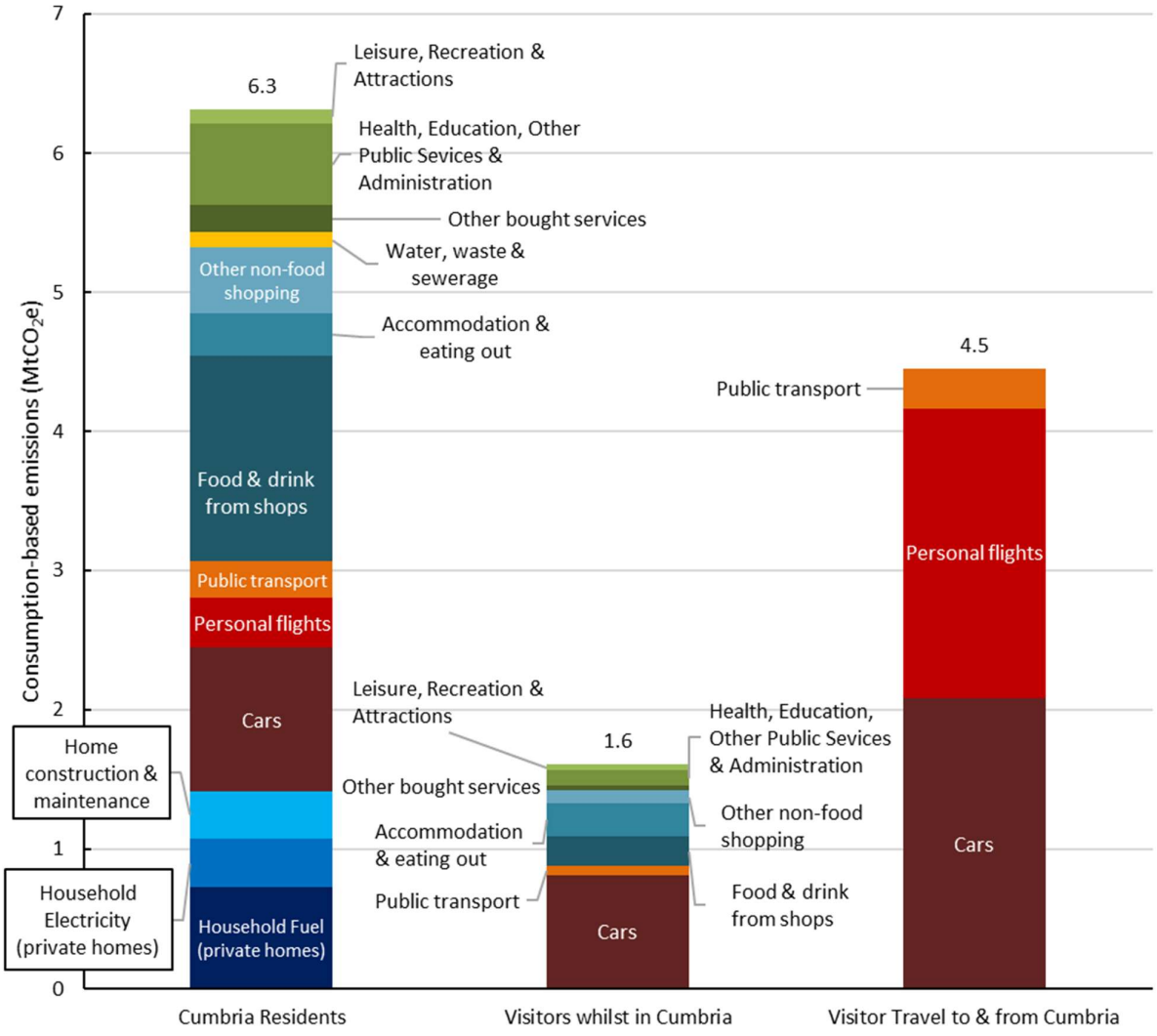


Figure 15: Total consumption-based GHG emissions broken down by category and consumer

5.1.1 Residents

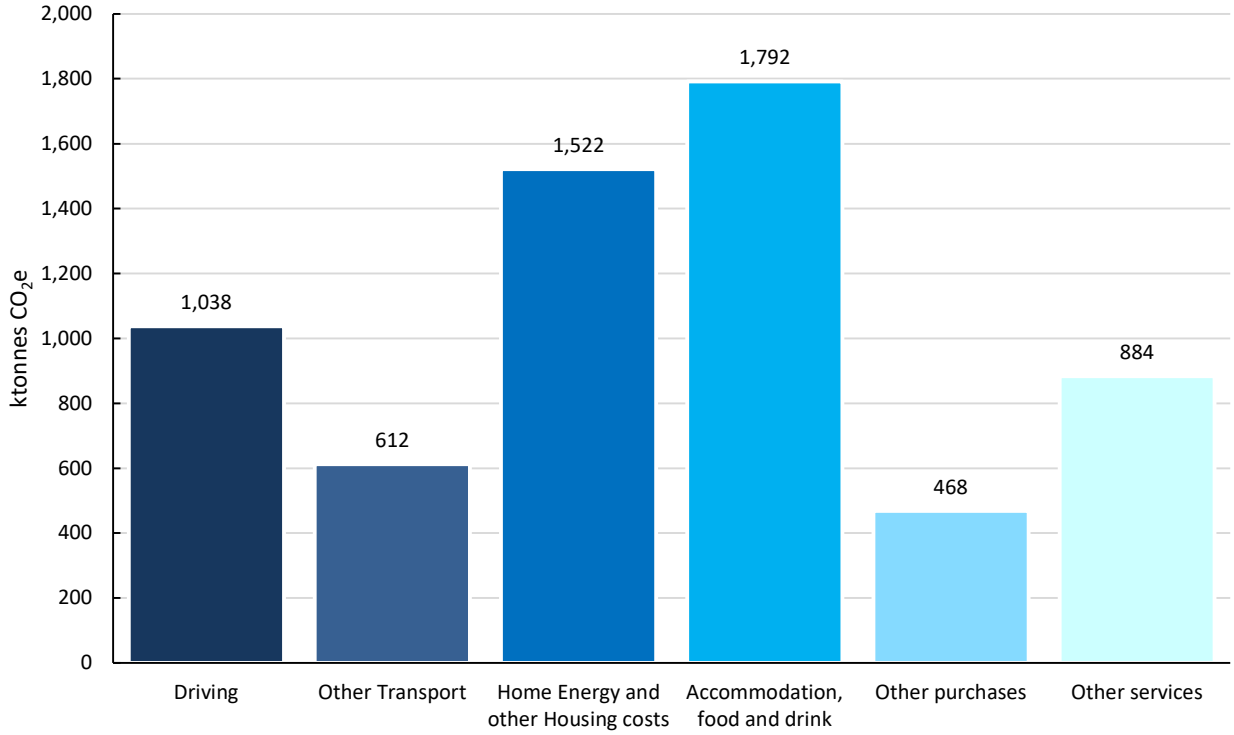


Figure 16: Cumbria residents' total emissions broken down by broad category

The biggest area of consumption is food and drink (and any accommodation whilst travelling) which contributes 28% (1.8 $MtCO_2e$) to the resident footprint (Figure 16). This is mainly derived from the production of food and drink bought in shops. Housing account for 24% (1.5 $MtCO_2e$) of residents' emissions. Emissions are predominantly from gas and electricity consumption. At 16% (1.0 $MtCO_2e$), driving is the third biggest impact of the resident footprint. This includes both fuel and vehicle wear and tear.

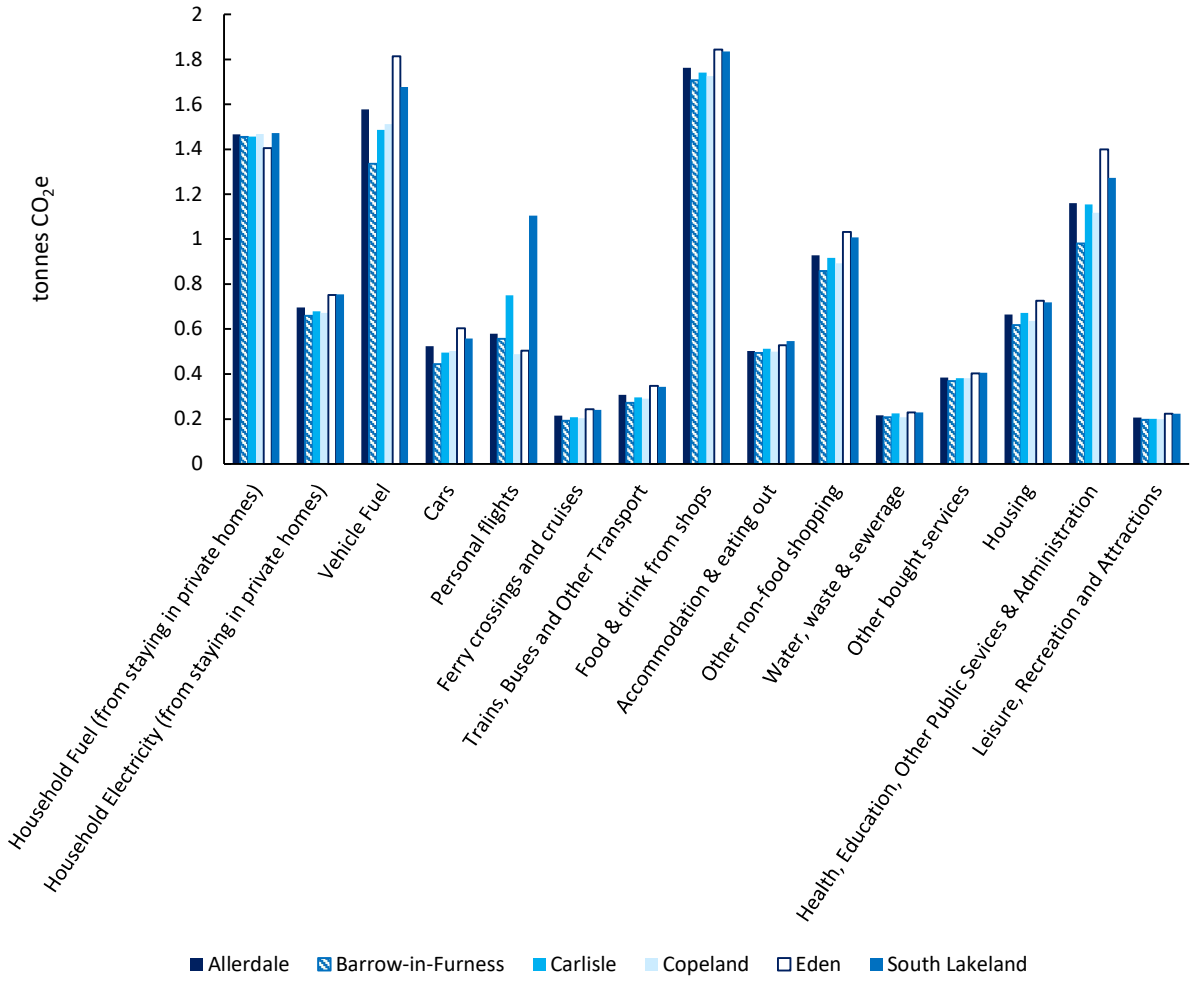


Figure 17: Per capita resident emissions broken down by category and local authority.

Figure 17 shows emissions per resident by category and local authority. Notable spikes in per capita emissions include driving in Eden and flying in South Lakeland and Carlisle.

5.1.2 Visitor travel to and from Cumbria

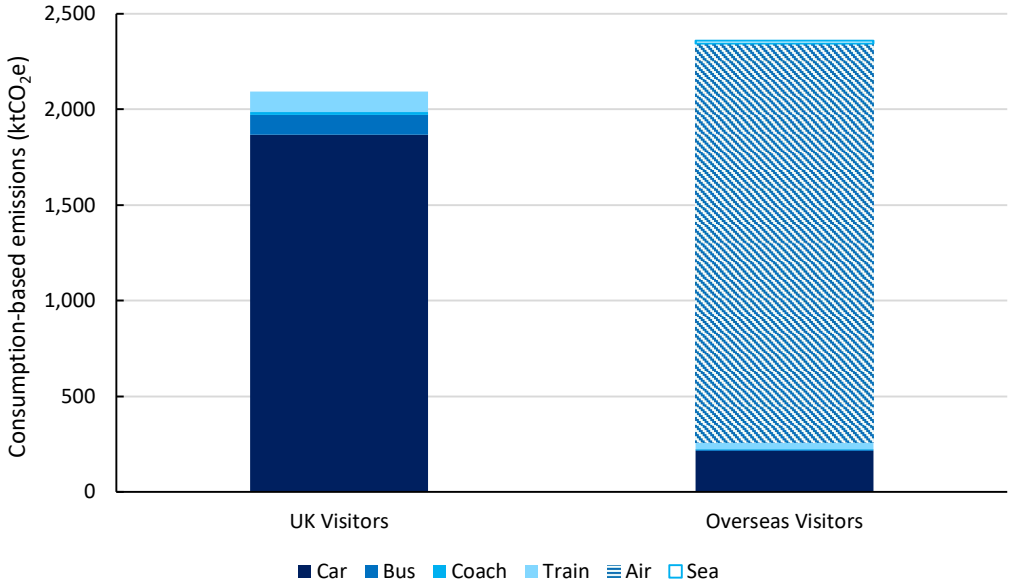


Figure 18: Emissions from visitor travel to Cumbria broken down by origin

Overseas visitor travel is dominated by air travel, whilst UK visitor travel is dominated by car transport (Figure 18). Together these constitute 36% of Cumbria's total GHG emissions.

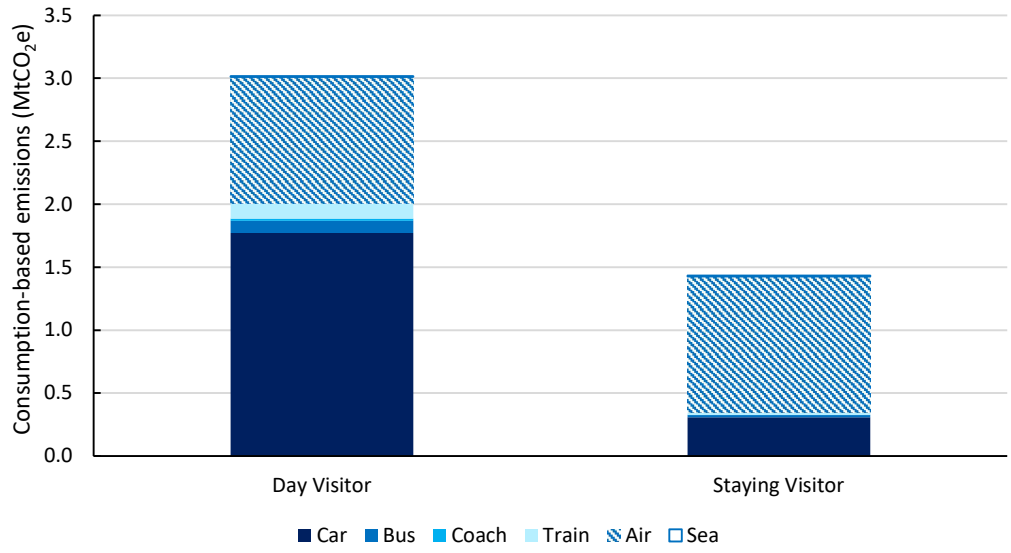


Figure 19: Emissions from visitor travel to Cumbria broken down by visitor type

The footprint of day visitors travelling to Cumbria is twice that of staying visitors. Whilst emissions from air transport are broadly similar between both groups, car transport emissions are much higher for day visitors (Figure 19).

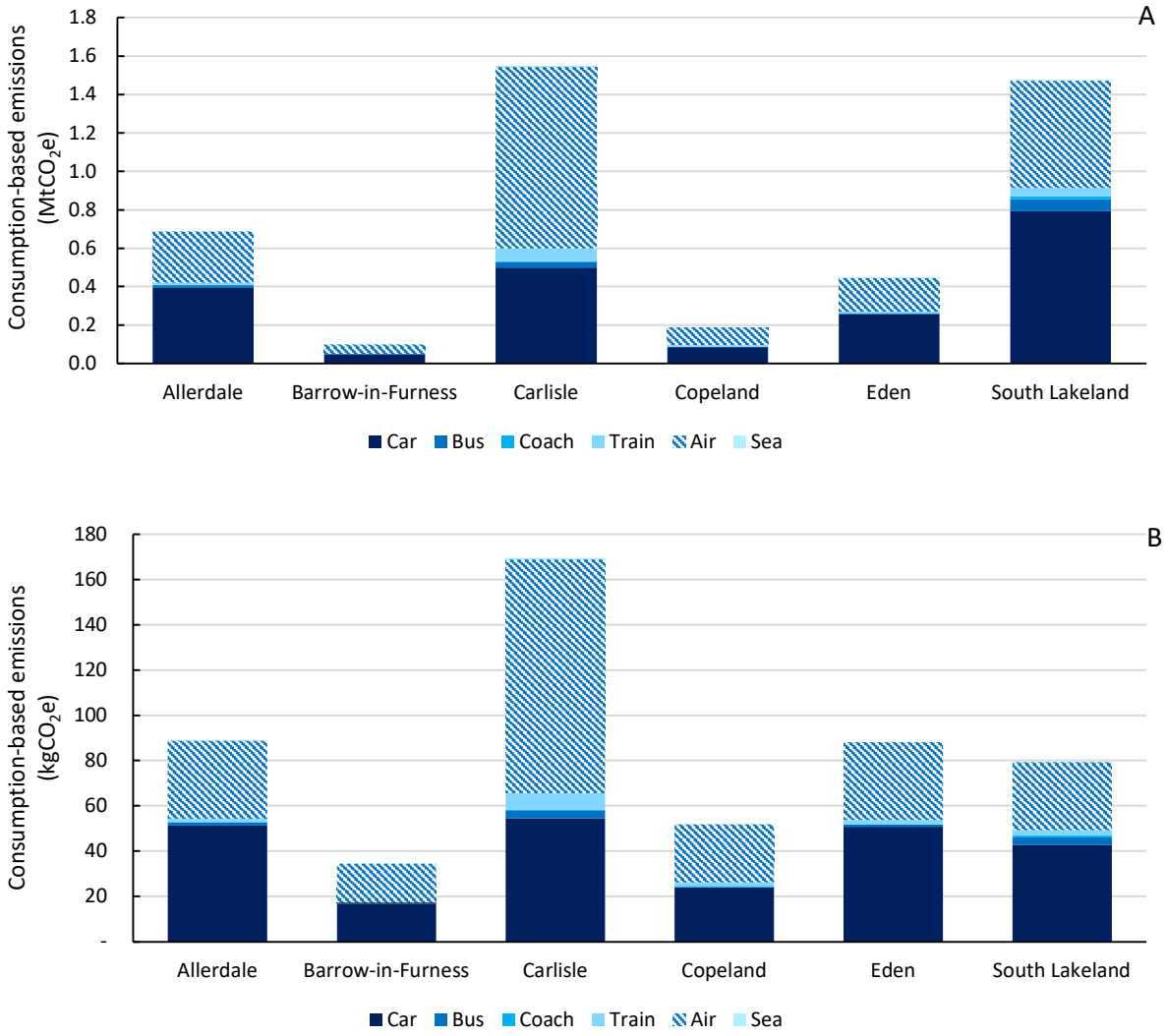


Figure 20: A) Total emissions from travelling to Cumbria broken down by area; B) Emissions per visitor travelling to Cumbria broken down by area.

Overall, Carlisle has the highest emissions from visitors travelling to Cumbria, mainly due to air travel (Figure 20A). South Lakeland has the second highest footprint due to the high number of visitors. This is evidenced by the lower emissions for South Lakeland on a per visitor basis (Figure 20B).

5.2 Emissions by activity

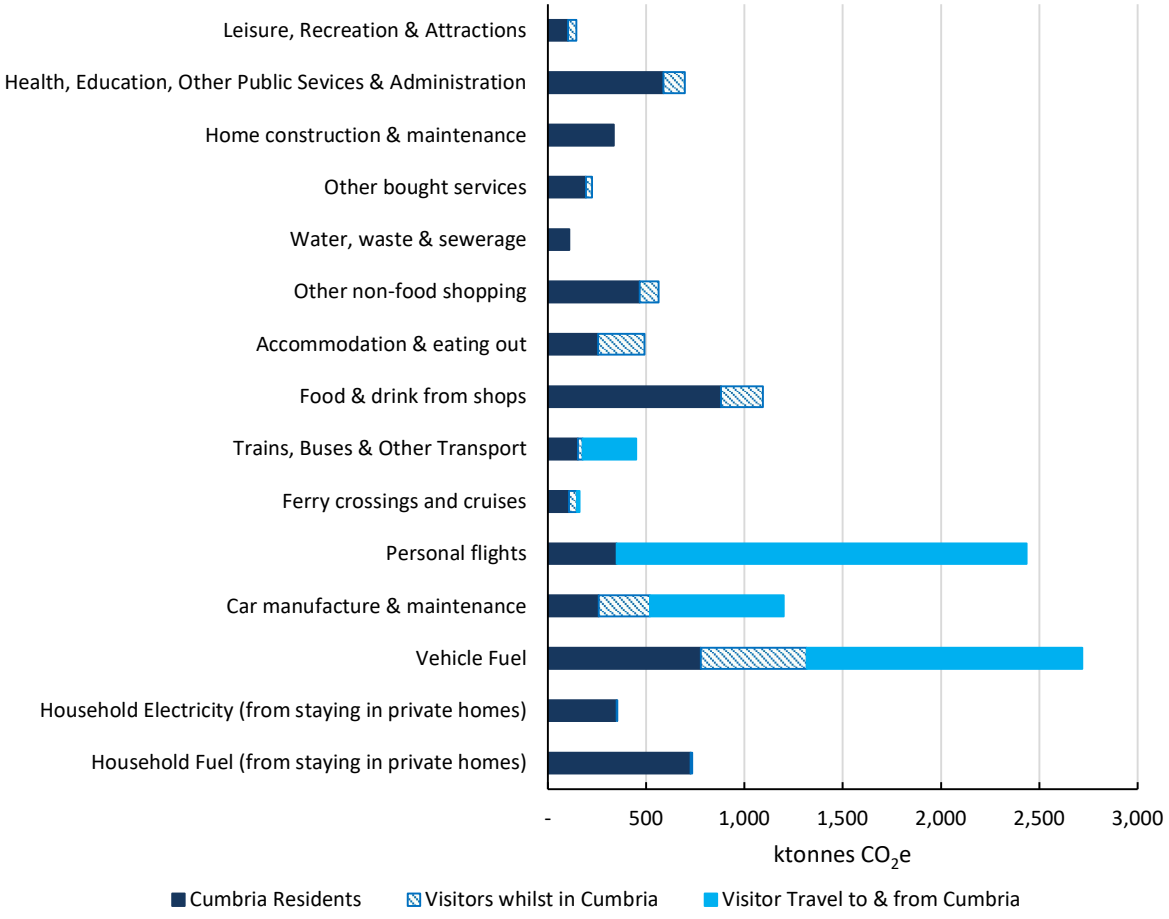


Figure 21: The GHG footprint by consumption category

Driving (including both fuel and vehicle wear and tear) and flying are the two biggest hitters, followed by accommodation, food and drink (Figure 21).

Below, we set out the main sources of emissions, starting with the largest categories.

5.2.1 Driving

Emissions attributable to driving, that is direct and supply chain emissions from vehicle fuel combustion and emissions from vehicle manufacture and maintenance, represent 32% of the total footprint of residents and visitors combined. Two thirds of this is attributable to fuel consumption, accounting for 22% of the total footprint.

Resident driving within and outside Cumbria accounts for 8% of the total footprint. The available data suggests that Cumbria residents drive around 20% more than the UK average, which is unsurprising given the geography of the County.

Visitor driving accounts for 17% of the total footprint. Of this, 72% comes from journeys to and from Cumbria, and 27% within Cumbria.

5.2.2 Flights

All flights make up 20% of the total footprint and can be broken down as follows.

Visitor flights account for 17% of the total footprint. Approximately 6% of visitors have flown to get to Cumbria. We have attributed only a proportion of the emissions from those flights to the Cumbria visit, based on the proportion of time spent in Cumbria. For example, if someone flies to the UK on holiday for ten days, and spends two days in the Lake District, then 20% of their flight is attributable to Cumbria.

Residents' flights, excluding those for business (included in industry carbon footprints), make up 3% of Cumbria's total footprint. These include all recreational flights to all destinations, made by Cumbria residents.

5.2.3 Accommodation, food and drink

Food and drink and staying in paid accommodation account for 18% of all emissions. This includes both food bought in shops and food and drink consumed in pubs, cafes, restaurants and hotels, as well as the footprint of accommodation itself.

Residents' food and drink contributes 15% to the total GHG footprint of Cumbria, of which 83% is from food purchased in shops and 17% is from eating out. This is around 28% of the total footprint of residents.

Visitor accommodation, food and drink together account for 4% of the total footprint. This includes food bought from pubs, cafes, restaurants and hotels, as well as the footprint of accommodation itself, and food from shops, which we estimate to account for around half of the 4%.

5.2.4 Household energy

Household energy (electricity and domestic fuel) makes up 9% of the total footprint and breaks down as follows.

Residents' domestic fuel comes in at 6% of the total footprint for Cumbria and 12% of the footprint of residents (3% higher than the UK average).

Residents' household electricity is 3% of the total footprint, being 6% of residents' footprint (9% higher than the UK average).

Visitor electricity and domestic fuel: a small proportion of visitor nights are spent staying with friends and relatives, giving visitors a small footprint for domestic electricity and fuel[4].

5.2.5 Non-food shopping

This category includes all inedible purchased items, apart from cars, and makes up 5% of the total footprint. Approximately 83% of non-food shopping emissions come from residents, and 17% from visitors.

[4] When staying in paid accommodation, household energy is included as part of accommodation.

5.2.6 Other Transport

This comes to 5% of the total footprint, 74% of which is from trains, buses and other land transport and 26% is from ferries and cruises. Residents account for 43% of these emissions whilst 46% arise from visitors travelling to Cumbria and only about 11% of it attributable to visitor travel during their stay. The low figures for use of public transport are probably a reflection of poor coverage in most areas of Cumbria.

5.2.7 Other

The footprint of a range of (mainly public) services has been calculated based on estimated household expenditure for residents. It has been assumed that there is no expenditure on housing and water for visitors and visitor spend on other services is estimated to be half the average of Cumbria residents. These include the following:

- **Health, education, defence and other services** (6% of the total footprint of residents and visitors combined). Several stakeholders of this report, including Cumbria County Council itself, lie within this category. Also included in this section are proportionate allocations of emissions from national infrastructure and services, such as central government and defence.
- **Housing within Cumbria** (3%). This includes both the construction and maintenance of dwellings as well as the emissions associated with renting and buying houses. In-use energy consumption, such as from heating, usually dwarfs the embodied carbon in the construction, maintenance and upgrading of the buildings themselves and should therefore be the primary consideration.
- **Water and sanitation** (1%).
- **Other expenses** (2%). This includes a range of mainly intangible services including financial and professional services.

5.3 The carbon footprint of industry

This simple analysis of industries gives a broad perspective on emissions from businesses in Cumbria (Table 1 & Figure 22). It should not form part of the baseline figure because there is double counting between this and the footprint of residents and visitors and also because this simple analysis is drawn only from gross value added (GVA) data and generic macro-economic modelling of the carbon intensity of different industries in the UK. It is not based on local information about the characteristics of each industry in Cumbria. It does not, for example, take account of any of the specific characteristics of farming in Cumbria, compared to farming in the UK as a whole. However, the analysis does suggest the following:

- The overall scale of industry's footprint is larger than that of all residents and visitors together;
- Emissions from manufacturing of basic materials (a wide-ranging category covering the discovery and processing of raw materials, including minerals, metals, forestry and chemical products) are estimated at 37% of the total from all industry (Table 1);
- Transport is the next most important sector; and

For most industrial sectors, supply chain emissions (scope 3) are much higher than those emitted directly by businesses themselves (scope 1) or from their electricity consumption (scope 2). However, in the case of agriculture, emissions from fertilizer and livestock mean that direct emissions dominate. It should be noted that the data covers all businesses that are registered in Cumbria. Also, in line with Office of National Statistics conventions on the treatment of distribution sectors, the footprint of retail and wholesale businesses does not include the emissions embodied in the goods that are sold but not produced by those businesses. Figure 23 presents a breakdown of consumption-based industry emissions by district council area.

Table 1: Annual GHG footprint of industry by sector and scope

	ktCO$_2$e				
Sector	Direct	Electricity	Supply Chain	Total	% of Grand Total
Agriculture, forestry and fishing	619	9	338	**967**	**7.3%**
Mining and quarrying	65	1	29	**95**	**0.7%**
Manufacturing of food and drink	65	16	756	**837**	**6.4%**
Manufacturing of basic materials	1,719	154	2,971	**4,844**	**36.8%**
Manufacturing of equipment and machinery	87	38	906	**1,031**	**7.8%**
Electricity, gas, steam and air-conditioning supply	352	153	344	**849**	**6.4%**
Water supply; sewerage, waste management	164	5	125	**294**	**2.2%**
Construction	82	8	674	**764**	**5.8%**
Wholesale and retail trade, repair of motor vehicles	107	21	421	**549**	**4.2%**
Transportation and storage	891	9	413	**1,313**	**10.0%**
Accommodation and food service activities	41	11	413	**465**	**3.5%**
Other Services	123	48	995	**1,166**	**8.9%**
Grand Total	**4,315**	**473**	**8,386**	**13,174**	**100%**

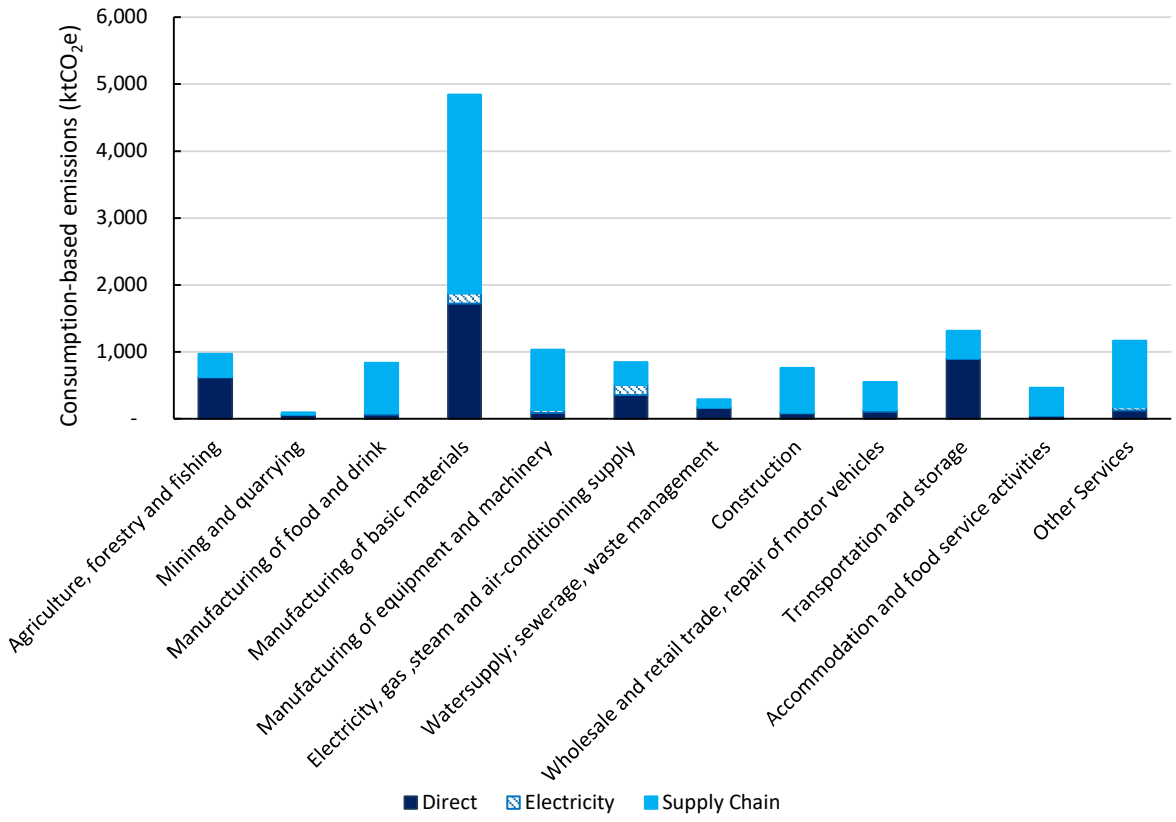


Figure 22: An estimate of the carbon footprint of industry

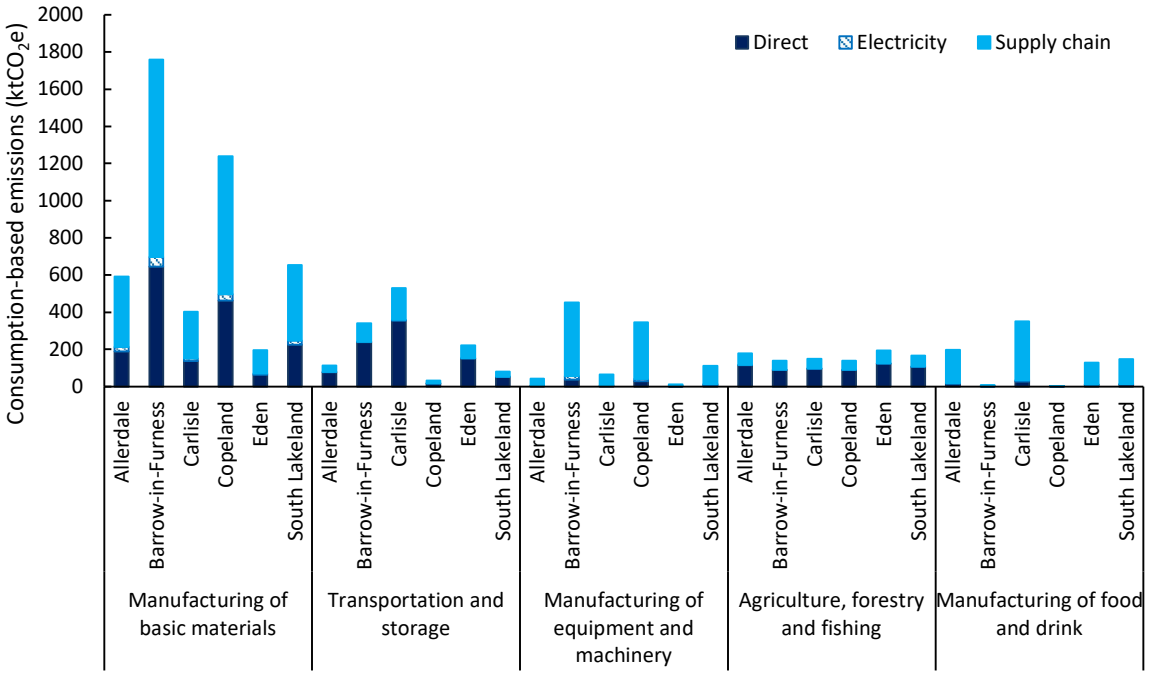


Figure 23: Top five industries broken down by scope and district council

6 A vision for low-carbon Cumbria

The targets and recommendations that follow are intended as part of wider roadmap to a better future for Cumbria. We imagine them to be implemented in ways that maximise co-benefits, especially in terms of health, community and economy. We now sketch out that vision from the perspective of residents, visitors and businesses.

6.1.1 For residents

Although there are more visitors, it feels less crowded. People are spending less time on the roads and have more freedom to take more exercise. The diets are improved, nutritionally balanced and sustainably sourced. Homes are more comfortable to live in; warmer, safer, and cheaper to run and more resilient to the climate crisis. Residents stay for longer, as there is no need to move on for better pastures. Communities are more integrated thanks to greater co-operation between residents, businesses and local government to improve peoples' lives.

6.1.2 For visitors

Cumbria is more beautiful, quieter and cleaner. It's exciting to visit because you can feel the sustainability transition taking place here. It is easier than ever to leave the car behind. Bikes (electric and conventional) are everywhere. There are fewer cars, and all are electric. The roads in towns and countryside are cleaner, quieter and calmer. You can get any and every kind of food you desire, but delicious, healthy, plant-based options are everywhere. People come to Cumbria for a glimpse of a better future; tourism is thriving.

The stunning landscape looks all the more beautiful with more wildlife, more trees, less erosion and no pollution in our lakes and rivers.

6.1.3 For businesses

The economy thrives with more jobs, especially in tourism, land management, and green energy. Emphasis on the green economy sectors shows that Cumbria is leading the way toward Net Zero, and this is a major attraction for young, educated workers to take up the job opportunities the county has to offer in both new and traditional industries. The quality of the environment is recognised as the best in England. Plenty of leisure time provides opportunities for employees to live active healthy outdoor lives, and this is a major draw for inward investment.

Farming thrives, maintains a strong links with our cultural heritage whilst taking a leading role in its response to the emerging science on sustainable agriculture. Farming still produces some high-quality meat as well as grazing for improved biodiversity, as well as an increase in crop production where appropriate. Cumbria has an even stronger reputation for high quality agricultural produce that commands a high price and is increasingly exported.

7 Targets

7.1 Guiding principles

In creating target options, we have tried to work from the following principles, as far as is practical, recognising trade-off between these attributes:

- everything that is important and within Cumbria's strong influence should be included;
- the headline target should be easy to describe;

- there should be a Net Zero year and a trajectory to meet it;
- the overall target should be made up of sub- targets covering different elements of Cumbria's carbon; and
- the target should be achievable, as part of a wider pathway to improving the quality of life for residents and visitors, and the health of the economy.

7.2 Scope

The target includes the following:

- Energy-only CO_2 measured on a production basis, excluding the M6 (over which Cumbria has little influence);
- GHG emissions from Food consumed by residents and visitors;
- GHG emissions from Other goods purchased by residents and visitors;
- GHG emissions from Visitor travel to and from Cumbria, excluding international visitor travel; and
- Land Use, Land Use Change and Forestry (LULUCF) – these are net negative emissions.

Since both resident and visitor numbers are likely to increase, the target will be normalised to reflect changes in resident and visitor populations as a proportion of the UK population.

After careful consideration, we have excluded the international component of visitor travel from this target. This is not because flights are unimportant, but rather because we do not have the metrics to estimate the proportion of each flight that should be attributed to Cumbria and how this might change over time.

The energy-only component is CO_2 rather than GHGs as this is how BEIS reports production-based emissions; the data for other GHGs is not available.

Business supply chains are included where businesses supply the local and visitor economy. To include all business supply chains would require more detailed assessment that the rough first estimate provided in this report. However, businesses should still be encouraged to manage their own supply chain carbon.

7.3 Target Options

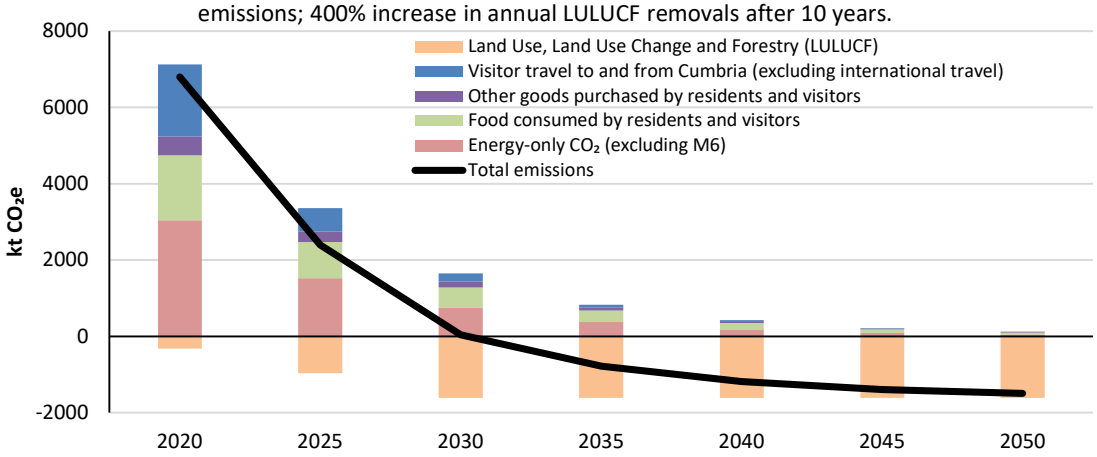
Five target options are offered with varying levels of ambition. Each has a different Net Zero date and a different trajectory for each component within the scope. We provide a rough guide to what meeting each target might require in terms of actions on each component.

For example, Option 3 comprises a 13% per year reduction in energy-related CO_2 (as prescribed by the Tyndall Carbon Budget Tool[5]), 5% per year reductions in the footprint of food and purchased goods, and a 10% per year reduction in the carbon footprint per visitor day of visitors travelling to and from Cumbria. As for all options, negative emissions from land use change rise by a factor of 5 over either a 10- or 15-year period (and this figure has been chosen as a feasible target after discussion with Lake District National Park Authority).

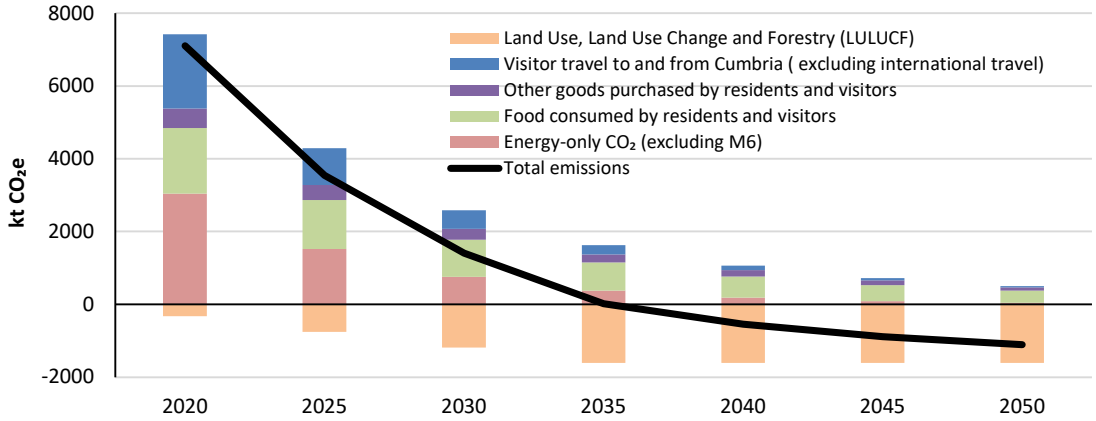
[5] A budget tool for energy only CO_2 for local authorities, based on IPCC recommendations for 'well below 2 degrees and in pursuit of 1.5 degrees,' developed by the Tyndall Centre and available at https://carbonbudget.manchester.ac.uk/reports/

The five options and their trajectories are summarised in Figure 24 and Table 2.

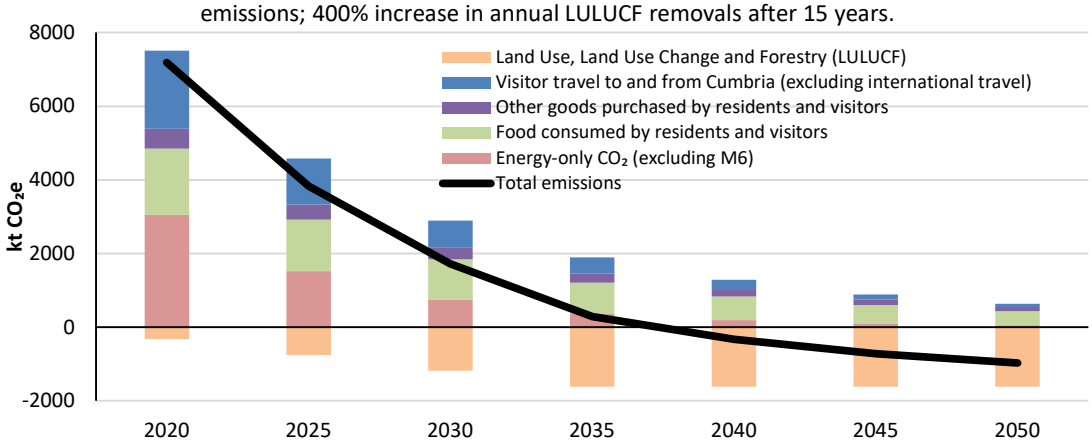
Option 1 - Net Zero by 2030: 13% annual reduction in energy-only CO_2 emissions; 11% annual reduction in food and other purchased goods emissions; 20% annual reduction in visitor travel per visitor day emissions; 400% increase in annual LULUCF removals after 10 years.



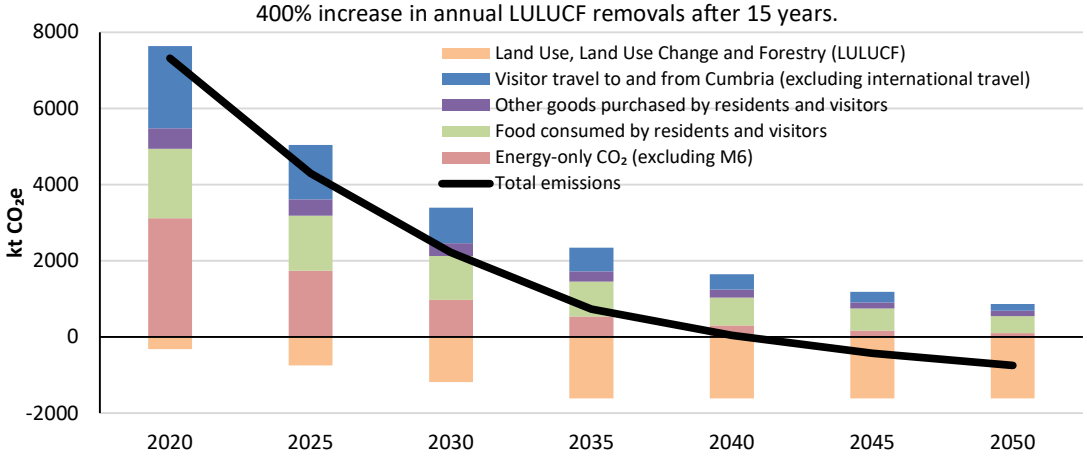
Option 2 - Net Zero by 2035: 13% per year in energy-only CO_2 emissions; 5.5% per year cuts in cut GHG from food and other purchased goods; 13% per year cut in visitor travel GHG per visitor day; 400% increase in LULUCF.



Option 3 - Net Zero by 2037: 13% annual reduction in energy-only CO_2 emissions; 5% annual reduction in food and other purchased goods emissions; 10% annual reduction in visitor travel per visitor day emissions; 400% increase in annual LULUCF removals after 15 years.



Option 4 - Net Zero by 2040: 11% annual reduction energy-only CO_2 emissions; 4.5% annual reduction in food other purchased goods emissions; 8% annual reduction in visitor travel per visitor day emissions; 400% increase in annual LULUCF removals after 15 years.



Option 5 - Net Zero by 2045: 9% annual reduction in energy-only CO_2 emissions; 4% annual reduction in food and other purchased goods emissions; 6% annual reduction in visitor travel per visitor day emissions; 400% increase in annual LULUCF removals after 15 years.

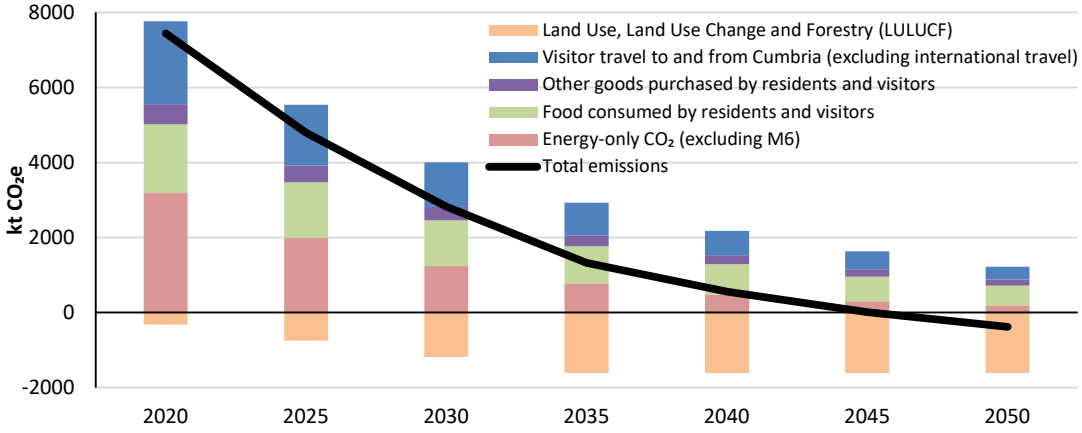


Figure 24:Five pathways to Net Zero for Cumbria

Table 2: Summary of annual reduction and total annual LULUCF removals for each target option

Target options		1	2	3	4	5
Net Zero Date		*2030*	*2035*	*2037*	*2040*	*2045*
Annual changes starting from 2019 baseline	Energy only CO_2 (annual reduction)	13%	13%	13%	11%	9%
	Food footprint (annual reduction)	11%	5.5%	5%	4.5%	4%
	Footprint of purchased goods (annual reduction)	11%	5.5%	5%	4.5%	4%
	Footprint of visitor travel to and from per visitor day, excluding overseas travel (annual reduction)	20%	13%	10%	8%	6%
	Removals from Land Use, Land Use Change and Forestry (LULUCF), (Total increase compared to baseline year)	400%	400%	400%	400%	400%

In order to help understand the realism of the options, for each one we have roughly modelled a scenario which could deliver the target (Table 3). These cover energy use (including changes in household fuel use, decarbonisation of grid electricity), transport (including the carbon intensity of driving, and the amounts of driving), food consumption (including waste levels, meat and dairy consumption, and air freight), and visitor travel (covering average length of stay, carbon intensity of driving and visitor modal shift from driving). We emphasise that our scenarios may not be the optimal pathways but are designed to give some sense of the scale of the challenge.

Table 3: An indication of how each target might be met in terms of energy, food and visitor travel

Net Zero Date		*2030*	*2035*	*2037*	*2040*	*2045*
Emissions reductions at net zero compared to 2019 baseline	**Reduction in energy only CO_2 emissions**	**78%**	**89%**	**92%**	**91%**	**91%**
	Reduction in household fuel use	60%	80%	90%	90%	90%
	Electricity decarbonisation	90%	90%	90%	90%	95%
	Reduction in carbon intensity of driving	65%	60%	50%	57%	65%
	Reduction in residents driving	65%	85%	79%	74%	68%
	Reduction in food emissions	**72%**	**60%**	**60%**	**62%**	**65%**
	Cut in waste	83%	70%	73%	75%	80%
	Cut in meat and dairy	83%	64%	65%	67%	72%
	Cut in air freight	85%	80%	80%	80%	80%
	Reduction in emissions from visitors travelling to and from	**91%**	**89%**	**85%**	**83%**	**80%**
	Increase in average stay length	100%	100%	100%	80%	50%
	Reduction in carbon intensity of driving	65%	60%	50%	57%	65%
	Reduction in visitors driving	50%	45%	40%	27%	15%

8 Discussion and Recommendations

Cumbria's target should reflect what the science tells us needs to be done in response to climate change.

It is important to be clear that the headline Net Zero date is not on its own a good indication of the level of ambition of any carbon target. Cumbria has chosen a particularly challenging scope to bring to Net Zero. This is because it has chosen to include the elements of its footprint that matter most, even though some of these they are difficult or impossible to bring to zero. For example, even with the most sustainable practices, GHGs from food cannot reach zero. Also, the inclusion of visitor travel within the UK to and from Cumbria is also relatively difficult to decarbonise to zero. On the other hand, compared to many other local areas, Cumbria has relatively high potential for negative emissions from LULUCF.

The feasibility of each target option is to a large degree dependent on emerging national policies to support the low carbon transition, as well as actions at the local level. They are also influenced to some degree by the global response to the climate change.

Option 3, Net Zero by 2037, is the most feasible target that can be regarded as being in line with the requirements laid down by the IPCC for "well below 2 degrees and in pursuit of 1.5 degrees."

We therefore recommend as follows:

- The adoption of Option 3: Net Zero by 2037.
- As well as doing what it can to meet that target, we recommend that Cumbria Net Zero Partnership identifies the support it requires from central government to make this possible.
- A further simple target on extraction-based emissions: these should remain at zero.
- Whilst visitor flying is not included within the target option, its impact on climate change should be considered as a factor in tourism strategy.
- An additional target is developed for total renewable energy exported to the grid from sources within Cumbria.

The challenge for Cumbria will be to deliver these recommendations in ways that work for everyone: residents, visitors, and industries. It will be essential to deliver the Food and LULUCF components in ways that create opportunities for farmers. This will require thoughtful conversations that combine the best science with the interests of rural communities. The climate strategy will also need to be joined up with an industrial strategy that can deliver high quality employment throughout the county.

With enough creativity, Cumbria's response to climate change can be an opportunity to enhance quality of life throughout the county. Cumbria can be a role model for local areas around the world.

9 Methodology for Extraction-based emissions

Data for the annual coal output from the West Cumbria Mine was obtained from the agenda of the 19th March 2019 meeting of Cumbria County Council's Development Control and Regulation Committee[6]. The proposal projected annual output for the mine at 2.4 Mt coking coal and 0.35 Mt middlings coal when the mine reached full operational capacity (approximately five years into operations). We based our calculations on a lifetime of 50 years at full capacity and multiplied this output volume by the emissions factors (BEIS, 2017) for combustion of coking coal and electricity generation (middlings) coal.

10 Methodology for Production-based emissions

The data behind these emissions estimates is from the Office of National Statistics Local Authority CO_2 Emissions Estimates 2005-2017, calculated by Ricardo Energy and Environment[7].

11 Methodology for Consumption-based emissions

Whilst the term 'footprint' is used in various ways, we are using it to mean the sum of the direct and indirect emissions that arise throughout supply chains of activities and products. The inclusive treatment of supply chain emissions, as presented here, differs from more standard 'production-based' emissions assessments, but gives a more complete and realistic view of impacts of final consumption.

As an example, emissions resulting from the purchase of goods by residents and visitors would not feature in a production-based emissions assessment, since all the emissions take place in the supply chains of the products rather than at the point of purchase. To give another example, in a consumption-based assessment, the footprint of travel includes, on top of the direct vehicle emissions, those resulting from the extraction, shipping, refining and distribution of fuel, emissions resulting from the manufacture and maintenance of vehicles, and so on. Thus, in the case of car travel the final figure is typically around double that of the exhaust pipe emissions. In a third example, the footprint of electricity consumption includes components for the emissions associated with fossil fuel extraction, shipping, refining and transport to power stations, as well as those resulting from the electricity generation process itself.

11.1 Boundaries of the study

The following is within the scope of this study:

- all residents personal travel and visitor travel to, from and around Cumbria;
- fuel and electricity consumed in homes and places to stay;
- emissions from food and drink and other purchased items;
- the supply chains of all the above (e.g. fuel supply chains and embodied emissions); and
- business emissions for businesses operating within Cumbria.

The following is specifically excluded:

- Bespoke treatment of impacts of land-use in the specific circumstances of Cumbria.

[6] Available here: https://tinyurl.com/vey2x5p

[7] BEIS, June 2019, UK local authority and regional carbon dioxide emissions national statistics: 2005-2017. https://tinyurl.com/UKCO2PB

11.2 Inclusion of the Kyoto Greenhouse Gases

This assessment considers the basket of Greenhouse Gases (GHG) that is covered in the Kyoto Protocol, expressed in terms of carbon dioxide equivalent (CO_2e), the sum of the weights of each gas emitted multiplied by their global warming potential (GWP) relative to carbon dioxide over a 100 year period.

11.3 GHG Protocol guidelines

We have followed the reporting principles of the *'GHG Protocol, a Corporate Accounting and Reporting Standard – Revised Edition'* (GGP) published by the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) (Ranganathan *et al,* 2015).

The GGP defines 3 scopes for emissions reporting. Scope 1 covers direct emissions from company-owned vehicles and facilities. Scope 2 includes net emissions from energy imports and exports, such as electricity. Scope 3 includes other indirect emissions resulting from company activities, as detailed by the boundaries of the study. This report includes all Scope 1 and 2 emissions and comprehensive treatment of Scope 3 emissions throughout supply chains of activities and purchases within the boundaries laid out above.

11.4 Treatment of high-altitude emissions

High-altitude emissions from aircraft are known to have a higher global warming impact than would be caused by burning the equivalent fuel at ground level. Although the science of this is still poorly understood, this study has applied an emissions weighting factor of 1.9 to aircraft emissions, to take this into account. This is in agreement with the figure suggested in Defra (2009) *'Guidelines for Company Reporting on GHG Emissions'*. The figure can also be inferred from the Intergovernmental Panel on Climate Change's Fourth Assessment Review (IPCC 2007).

11.5 Reporting approach

The start point for this work is a model of GHG emissions per capita from UK consumption. For this we used an environmental input–output model (EIO) based on 2018 ONS combined use tables and UK environmental accounts. The specific model used was developed by Small World Consulting with Lancaster University (see below). The categorisation of emissions into 105 consumption categories was simplified into a 14 category model.

An estimate of the average visitor population was derived from the Cumbria Tourism (2018) 'Visitor Survey' figures for UK and overseas visitor numbers and visitor days and from the Scarborough Tourism Economic Activity Measure (STEAM) report.

In the first instance the GHG footprint of consumption by residents and visitors whilst in Cumbria was obtained simply by multiplying average populations of each district by the UK per capita consumption footprint estimates.

11.6 Environmental Input–Output analysis (EIO)

EIO combines economic information about the trade between industrial sectors with environmental information about the emissions arising directly from those sectors to produce estimates of the emissions per unit of output from each sector. The central technique is well established and documented (for example: Leontief, 1986; Miller & Blair 1985, 2009; Berners-Lee *et al.* 2010). In the UK, the main data sources are the *'Supply and Use Tables 1997 - 2016'* and the *'Greenhouse gas emissions in the UK, 1990 to 2016'* (ONS, 2018a; ONS, 2018b), both provided by the Office of National Statistics (ONS).

The specific model used for this project was developed by Small World Consulting with Lancaster University. This model takes account of such factors as the impact of high altitude emissions that are not factored into the environmental accounts and the effect of imports. We have also used price indices to take account of changes in the economy between the production of the supply and use tables for 2016 and the baseline year of 2019.

Three main advantages of EIO over more traditional process-based life-cycle analysis (LCA) approaches to GHG footprinting are worth noting:

1) EIO attributes all the emissions in the economy to final consumption. Although, as with process-based LCA, there may be inaccuracies in the ways in which it does this, it does not suffer from the systematic underestimation (truncation error) that process-based LCAs incur through their inability to trace every pathway in the supply chains (Lenzen, 2001; Nässén *et al,* 2007).
2) EIO is an analytical and therefore impartial process for the calculation of emissions factors per unit of expenditure, whereas process-based LCA approaches entail subjective judgements over the setting of boundaries and the selection of secondary conversion factors.
3) Through EIO, it is possible to make estimates of the footprints resulting from complex activities such as the purchase of intangible services that LCAs struggle to take into account.

One of the limitations of EIO in its most basic form is that it assumes that the demands placed upon (and therefore the direct emissions from) other sectors by a unit of output within one sector are homogeneous. As an example, a basic EIO model does not take account of the carbon efficiencies that may arise from switching the expenditure on paper from a virgin source to a renewable source without reducing the actual spend. In this report, the carbon intensity per unit turnover of, for example, the hotels, pubs and catering establishments of Cumbria are assumed to be 'UK typical'. It is possible, with additional resource, to make bespoke adjustments to these generalities given relevant local data and a defendable basis for relating that data to emissions. A further assumption in the model used here is that goods from overseas are produced with the same carbon efficiency as they would have been in the UK. Overall, this assumption usually results in an underestimation of the footprint of purchased goods. A further omission for this and all EIO models that we are aware of is that the impact of land-use change around the world has not been taken into account. This would be likely to result in an increased assessment of the footprint of foods, especially animal products[8].

11.7 Adjustments based on bespoke national and local data

The result based on EIO and UK averages was adjusted to take account of key differences in consumption patterns for both visitors and residents from the UK average, wherever available data provided a reasonable basis for doing so. Estimates were also added for visitor travel to and from Cumbria. Specifically, the following adjustments were made.

11.7.1 Visitors

Travel to and from Cumbria was estimated using data from Cumbria Tourism's 2018 *'Visitor Survey'*. It gave the following data:

- Travel modes to and from Cumbria by overseas visitors, day visitors and UK staying visitors;

[8] 'How Low Can We Go?' WWF(2010) estimates that emissions from red meat production outside Europe rises by a factor around five when land-use change is taken into account.

- Ports of entry to the UK for overseas visitors from which we deduced the different modes of travel to the UK for overseas visitors;
- Proportions of overseas visitors from different countries which combined with the above gave us a tolerable estimation of the all overseas visitor miles by different modes to and from Cumbria (distances from each country from Webflyer.com); and
- Proportions of UK visitors from each UK region (allowing journey miles to be plotted using data from AA journey planner website).

In the case of overseas visitors, estimates of time spent in Cumbria were divided by estimates of the length of overseas visitor trips to give the proportion of each journey to the UK that should be allocated to Cumbria visit. ONS Travel and Tourism data (ONS 2018b) gave information leading to estimates of the average length of stay in the UK by visitors from each of the countries and regions being analysed and estimates of the lengths of stay in Cumbria came from the Cumbria Tourism visitor surveys.

Travel around Cumbria was estimated by combining data on visitor spend on transport from the STEAM report (Cumbria, 2018) and primary modes of transport used (*'Cumbria Tourism Visitor Survey,'* 2018) along with a weighting of the cost of different transport methods from primary research to achieve an estimate of the spend on different transport modes. This combined with data on visitor numbers enabled the calculation of adjustment factors for the EIO model. Assuming UK typical car efficiency and an average fuel price of £1.28 per litre in 2018 a bespoke calculation was made for car use based on Small World Consulting's hybrid "Defra plus EIO methodology" and this was used in place of adjusting the existing EIO estimate. This directly calculated the emissions based on the expected number of litres consumed based on the expenditure and then factors in the additional emissions from supply chains. The embodied emissions of car use are then added into this based on a typical ratio of embodied emissions to fuel consumption.

Other expenditure areas were adjusted using STEAM (Cumbria, 2018) data on total spend to estimate the average spend per capita based on visitor full time equivalents. These were compared to the UK typical spend per capita to obtain an adjustment factor. Where no data was available on visitor spend it was assumed to be the same as UK typical.

Visitors were not buying certain items. Some types of goods were assumed not to be bought or directly depreciated by Cumbria visitors. These included, for example, domestic appliances and power tools.

11.7.2 Residents

The basis for adjustment of resident data was taken mainly from information from the 2011 UK Census (ONS, 2011). The data from the census is described in geographical areas known as output areas (OAs). Each OA is given a specific code and describes a specific part of the country. We identified those which fell within the boundary of Cumbria to allow us to analyse the census and other data to establish facts about the resident population of Cumbria.

Electricity and domestic fuel consumption data were obtained from the ONS broken down by Local Authority (ONS, 2018). This was then used to estimate gas and electricity consumption within Cumbria. This was then compared to the UK gas and electricity consumption per capita, to obtain an adjustment factor for the EIO model.

Car fuel use and embodied emissions of driving were calculated based on ONS transport energy statistics (ONS, 2017). These were also available at local authority level. They were then compared to the UK emissions

per capita to arrive at an adjustment factor for the EIO model. The same adjustment factor was used for embodied emissions of driving.

Food consumption is not well dealt with by input output analysis due to the fact that a significant amount of food is imported to the UK. EEIO does not reflect the different practices in farming and land use in other countries or the emissions associated with importing the food. Therefore, we have used a lifecycle analysis estimate of the impact of food (Hoolohan et. al., 2013) and replaced the EEIO estimate for emissions per capita with this figure.

Other expenditure. Based on 2011 census data, similar OAs across the country have been grouped together and described by their shared social and physical demographics in a so called "output area classification" (OAC) (Gale *et al*, 2016). Thus, each OA within Cumbria is nominated an OAC name (ONS, 2011a). The family spending survey publishes estimates of typical spending profiles of each OAC group (ONS, 2018d). By combining these datasets, we estimated the typical spending profiles of the OAs within Cumbria and thus the typical spending of Cumbria. This was then compared to the typical UK spending to establish adjustment factors for typical household goods such as, clothing, transport, accommodation, which was then mapped onto the EIO model to adjust the UK model to reflect the typical spending of households within Cumbria. In areas of the economy not covered by the family spending survey it was assumed that Cumbria did not differ from typical UK spending.

11.7.3 Industry

Average emissions intensities for 105 UK industries, broken down by direct emissions (scope 1) emissions from power generation (scope 2) and supply chain (upstream scope 3) were taken from the EEIO model. These were multiplied by GVA within Cumbria from ONS GVA estimates (ONS, 2017) to arrive at an estimate of the overall consumption-based industry emissions.

11.8 Other Emissions Factors.

Where consumption estimates were based upon expenditure, the carbon intensity of activities and purchases have been taken from the EEIO model.

Where emissions estimates have been based upon physical consumption, the direct components associated with fuel combustion, from electricity generation and from most transport have been calculated using conversion factors provided by department for Business, Energy and Industrial Strategy (BEIS) in their *'Greenhouse gas reporting: conversion factors 2018'* (BEIS, 2018). However, the BEIS figures do not take account of supply chain emissions other than those produced at the point of electricity generation, and these need to be considered separately and we have referred, again to the EIO model.

11.9 Data Sources

The main sources are listed in Appendix A.

11.10 Uncertainties

The complexity of supply chains and the difficulties in obtaining accurate data dictate that footprinting can only offer an estimate rather than an exact measure, and the figures in this report should be viewed in that context. We have operated from the principle that it is more informative to make best estimates of even the most poorly understood components of the footprint, and to discuss the uncertainty openly, than to omit them from the analysis.

Overall, the results in this report should be viewed as offering a broad guide to the size and relative significance of different components.

11.10.1 Uncertainties over data

Sources of error were numerous, but the largest are thought to be as follows. Much of the data was drawn from visitor surveys, in which responses may have been systematically inaccurate, the sample group not fully representative and sample sizes were not always ideal.

11.10.2 Uncertainties over conversion factors

The areas in which the relationship between consumption and footprints is best understood are gas and electricity consumption. There is relatively good consensus over conversion factors to within around 5% in these areas. The next most certain group of conversion factors are those for travel and transport. In this category, there is uncertainty over the impact of high altitude emissions and the embodied emissions in the manufacture and maintenance of vehicles, roads and other infrastructure.

Supplies and services are the areas of greatest uncertainty. As an example, credible process based life cycle analyses of a particular specification of paper typically differ by factors of around 50% depending on the specific practices employed in the particular mill in which it was manufactured. It would also be possible for two detailed studies of exactly the same process to arrive at significantly different estimates, depending on the precise assumptions made. The EIO approach that we have adopted overcomes the truncation error that process-based approaches incur, but does suffers its own series of problems, most notably errors of aggregation – the failure to look at the particular circumstances of a supply chain by using an industry average.

12 Appendices

12.1 Appendix A: Main data sources and references

Berners-Lee, M., Howard, D.C., Moss, J., Kaivanto, K., Scott, W.A. (2011) Greenhouse gas footprinting for small businesses — The use of input–output data. *Science of the Total Environment*, **409,** pp 883-891

Cumbria Tourism (2018). Visitor Survey. Visitor expenditure breakdowns, travel modes, regions of origin, lengths of stay and proportion from overseas. URL: http://www.cumbriatourism.org/research/

Cumbria Tourism, 'STEAM Final Trend Report For 2009-2018', (Produced by 'STEAM' 2018). Overseas visitor countries of origins and lengths of stay, daily expenditure breakdowns and travel modes. URL: www.globaltourismsolutions.co.uk

Department for Business, Energy and Industrial Strategy (BEIS) (2017). Greenhouse gas reporting: conversion factors 2017 for transport and energy. URL: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting#conversion-factors-2017

Department for Business, Energy and Industrial Strategy (BEIS) (2018). Greenhouse gas reporting: conversion factors 2018 for transport and energy. URL: https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting#conversion-factors-2018

Defra (2009a). 'Guidelines for Company Reporting on GHG Emissions.' Estimate of impact of high altitude emissions.

Gale, C.G., Singleton, A.D., Bates, A.G., Longley, P.A. (2016). Creating the 2011 area classification for output areas (2011 OAC). *Journal of Spatial Information Science.* **12** (2016): 1-27

Lenzen, M. (2001) Errors in Conventional and Input-Output-based Life-Cycle Inventories. *Journal of Industrial Ecology,* **4**(4):127-148

Leontief, W. (1986) Input-Output Economics (2nd ed). New York: Oxford University Press

Miller, R.E. and Blair, P.D. (1985) Input-Output Analysis: Foundations and Extensions. Englewood Cliffs, NJ: Prentice Hall.

Miller, R.E. and Blair, P.D. (2009). Input-Output Analysis: Foundations and Extensions. Englewood Cliffs, NJ: Prentice Hall.

Northwest Development Agency Cumbria Market and Destination Profile. Tourism revenue figures for Cumbria and LDNP.

Population of Cumbria. ONS 2018 Population estimates.

Office of National Statistics (2019). Sub National energy consumption statistics for 2018. Used for comparing Cumbria consumption per capita with national average. URL: http://www.decc.gov.uk/en/content/cms/statistics/regional/regional.aspx

Office of National Statistics (2011). UK Census. URL: https://www.ons.gov.uk/census/2011census/2011censusdata

Office of National Statistics (2011a). 2011 Area Classification for Output Areas, Clusters and Names. URL: https://www.ons.gov.uk/methodology/geography/geographicalproducts/areaclassifications/2011areaclassifications/datasets

Office of National Statistics (2011a). 2011 Area Classification for Output Areas, Clusters and Names. Link: https://www.ons.gov.uk/methodology/geography/geographicalproducts/areaclassifications/2011areaclassifications/datasets

Office of National Statistics (2018). Sub-national total final energy consumption statistics 2005-2016

Office of National Statistics (2018a). Input Output Supply and Use tables, 1997 - 2014. UK supply and use tables. Link: https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/inputoutputsupplyandusetables

Office of National Statistics (2018b). Leisure and Tourism 2018 Overseas Residents visits to the UK, Section 4. Table 4.Lengths of stay in the UK of visitors from different countries of origin. Used to determine proportion of international travel attributable to the Park visit. URL:

https://www.ons.gov.uk/peoplepopulationandcommunity/leisureandtourism/datasets/overseasresidentsvisitstotheuk

Office of National Statistics (2018c). Atmospheric Emissions: Greenhouse Gas Emissions: By Economic Sector and Gas, United Kingdom*:* UK emissions of greenhouse gases by sector and gas. URL: https://www.ons.gov.uk/economy/environmentalaccounts/datasets/ukenvironmentalaccountsatmosphericemissionsgreenhousegasemissionsbyeconomicsectorandgasunitedkingdom

Office of National Statistics (2018d). Average weekly household expenditure by Output Area Classification (OAC) group, UK: Table A52. URL: https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/expenditure/datasets/averageweeklyhouseholdexpenditurebyoutputareaclassificationoacgroupuktablea52

Office of National Statistics (2017). Road transport energy consumption at regional and local authority level. Consumption statistics for fuels used in road transport at regional and local levels. URL: https://www.gov.uk/government/statistical-data-sets/road-transport-energy-consumption-at-regional-and-local-authority-level

Ranganathan, J., Corbier, L., Bhatia, P., Schmitz, S., Gage, P. and Oren, K. (2015). The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (revised edition). Washington, USA: World Business Council for Sustainable Development and World Resources Institute. Guidance on reporting organisational greenhouse gas emissions. URL: http://www.ghgprotocol.org/sites/default/files/ghgp/standards/ghg-protocol-revised.pdf

UNFCCC (1998). Kyoto Protocol to the United Nations Framework Convention on Climate Change. Kyoto: United Nations

12.2 Appendix B: Supplementary data for Error! Reference source not found.

Breakdown of emissions (kg CO_2e)	Option 1: Net zero by 2030						
	2020	2025	2030	2035	2040	2045	2050
Energy-only CO_2 (excluding M6)	3048	1519	757	377	188	94	47
Food consumed by residents and visitors	1693	945	528	295	165	92	51
Other goods purchased by residents and visitors	501	280	156	87	49	27	15
Visitor travel to and from Cumbria (excluding international travel)	1882	617	202	66	22	7	2
Land Use, Land Use Change and Forestry (LULUCF)	-322	-967	-1611	-1611	-1611	-1611	-1611
Total emissions	6802	2394	32	-786	-1188	-1391	-1496

Table 4: Raw data for 'Option 1: Net Zero by 2030'

Breakdown of emissions (kg CO_2e)	Option 2: Net zero by 2035						
	2020	2025	2030	2035	2040	2045	2050
Energy-only CO_2 (excluding M6)	3048	1519	757	377	188	94	47
Food consumed by residents and visitors	1797	1354	1021	769	580	437	329
Other goods purchased by residents and visitors	532	401	302	228	172	129	98
Visitor travel to and from Cumbria (excluding international travel)	2047	1020	508	253	126	63	31
Land Use, Land Use Change and Forestry (LULUCF)	-322	-752	-1182	-1611	-1611	-1611	-1611
Total emissions	7102	3543	1407	17	-545	-888	-1106

Table 5: Raw data for 'Option 2: Net Zero by 2035'

Breakdown of emissions (kg CO_2e)	Option 3: Net zero by 2037						
	2020	2025	2030	2035	2040	2045	2050
Energy-only CO_2 (excluding M6)	3048	1519	757	377	188	94	47
Food consumed by residents and visitors	1807	1398	1082	837	648	501	388
Other goods purchased by residents and visitors	535	414	320	248	192	148	115
Visitor travel to and from Cumbria (excluding international travel)	2117	1250	738	436	257	152	90
Land Use, Land Use Change and Forestry (LULUCF)	-322	-752	-1182	-1611	-1611	-1611	-1611
Total emissions	7185	3830	1716	287	-326	-716	-972

Table 6: Raw data for 'Option 3: Net Zero by 2037'

Breakdown of emissions (kg CO_2e)	Option 4: Net zero by 2040						
	2020	2025	2030	2035	2040	2045	2050
Energy-only CO_2 (excluding M6)	3118	1741	972	543	303	169	95
Food consumed by residents and visitors	1816	1443	1146	910	723	574	456
Other goods purchased by residents and visitors	538	427	339	270	214	170	135
Visitor travel to and from Cumbria (excluding international travel)	2164	1426	940	620	408	269	177
Land Use, Land Use Change and Forestry (LULUCF)	-322	-752	-1182	-1611	-1611	-1611	-1611
Total emissions	7314	4286	2216	731	38	-428	-748

Table 7: Raw data for 'Option 4: Net Zero by 2040'

Breakdown of emissions (kg CO_2e)	Option 5: Net zero by 2045						
	2020	2025	2030	2035	2040	2045	2050
Energy-only CO_2 (excluding M6)	3188	1990	1242	775	484	302	188
Food consumed by residents and visitors	1826	1489	1214	990	807	658	537
Other goods purchased by residents and visitors	541	441	359	293	239	195	159
Visitor travel to and from Cumbria (excluding international travel)	2211	1623	1191	874	642	471	346
Land Use, Land Use Change and Forestry (LULUCF)	-322	-752	-1182	-1611	-1611	-1611	-1611
Total emissions	7444	4790	2824	1320	560	14	-382

Table 8: Raw data for 'Option 5: Net Zero by 2045'