SMALL WORLD CONSULTING

A greenhouse gas emissions assessment and target scenario for the Broads

A report by Small World Consulting Ltd

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Executive summary

Background

As the world wakes up to the climate and wider environmental emergency, rapid reduction of greenhouse gas emissions and sustainable land management are becoming increasingly central to the local, national and international policy agendas.

Together, the UK's 15 National Parks (NPs), and 46 Areas of Outstanding National Beauty (AONBs) are home to over 1.5 million residents, attract approximately 250 million visitors per year, and account for around 18% of the UK's land area. If these protected landscapes can become exemplars of low-carbon transition and environment-conscious land management, their national and international profiles could give them a level of influence that far outweighs the scale of their own emissions. The exciting and creative challenge for each protected landscape is to find a way to cut emissions in line with current science, and be leaders in land stewardship and planning authority while simultaneously creating better places for people to live, work and visit.

This report

This report, for the Broads, is one of a series of methodologically compatible reports produced for each UK National Park and Welsh AONB, with the Cotswolds AONB and Cannock Chase AONB also joining. They are designed to provide a robust and consistent evidence basis for climate action, matched to the unique characteristics and circumstances of each protected landscape, as we enter an era in which climate mitigation and sustainable land management become ever more central to all our lives, our work and to all policy decisions.

This report contains a consumption-based assessment of the greenhouse gas emissions attributable to residents and visitors, including travel to and from the landscape (Figure 1), and a set of Paris-aligned target recommendations for transitioning to a low-carbon economy.

Consumption-based emissions reporting differs from more traditional production-based reporting, such as that used by the UK in setting its 2050 net zero target. A production-based assessment would cover all the emissions that are directly produced within the boundary of the landscape whether by people or businesses or from land, plus those arising from production of the electricity used within the landscape. However, the consumption-based approach adopted here covers, in addition, all indirect emissions that are embodied in the goods and services consumed by residents and visitors within the landscape. In doing so, it better reflects the full climate impact of people's lifestyles, and brings into focus for policy makers important areas of climate impact that a production-based assessment overlooks. The most important of these are the impact of food, of other purchased items (such as cars, clothes, IT equipment, household goods and furnishings), and of residents' and visitors' travel to and from the landscape, outside its boundaries.

Accounting for emissions from land use and management is also crucial for National Parks and AONBs. These landscapes are mostly rural, with comparatively small population and large parts of land under various forms of agricultural management, in addition to non-agricultural habitats such as woodlands, wildflower meadows, heathlands and peatlands. Land-based emissions originate

predominantly from ruminants (methane), synthetic fertiliser use (nitrous oxide), and degrading peatlands (mostly CO_2). These emissions are, to a degree, compensated by carbon sequestration in existing woodlands, meadows, hedgerows, and healthy peatlands, while agricultural soils could also sequester carbon under certain types of management. Reducing land-based emissions and scaling up land-based carbon sequestration efforts is going to be crucial for addressing the joint climate and ecological emergencies.

One feature of consumption-based reporting is that it does not include emissions from industry (except where an industry's goods and services are consumed by residents and visitors). Therefore, for perspective, this report also includes a simple estimate of emissions related to industries within the National Park or AONB, including their supply chains. It is important to note that there is some inevitable overlap between industry-related emissions and residents' and visitors' emissions, for example when people buy from local businesses within the area. Likewise, there is an overlap between emissions from agriculture as an industry sector and land-based emission within each landscape. Figure 1 illustrates the relationship between the main components of our central assessment and the industry emissions.

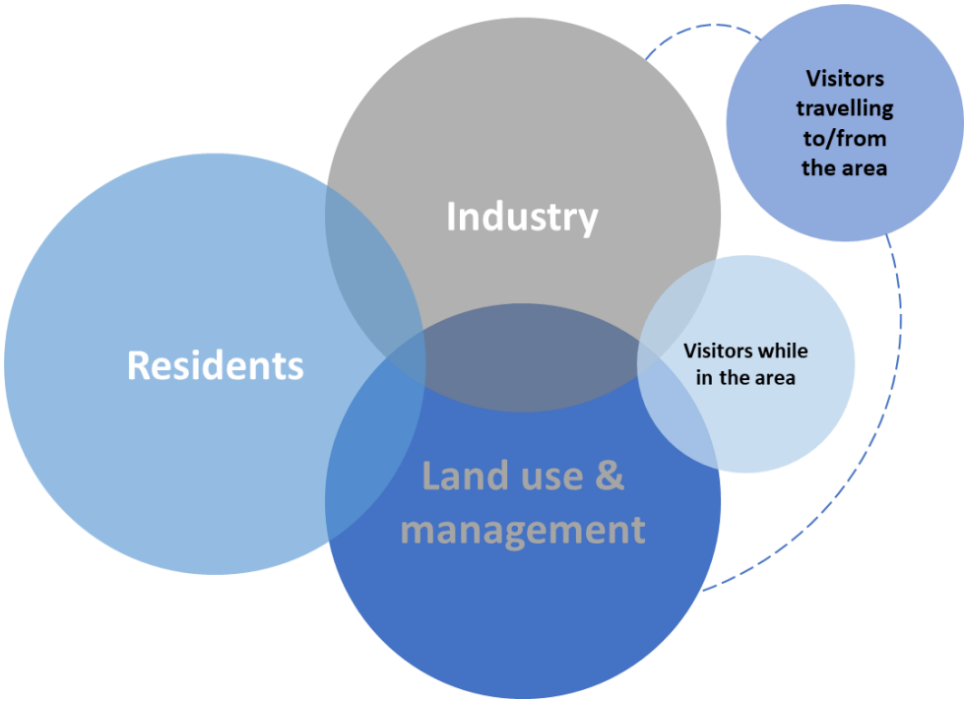


Figure 1: Boundaries of the greenhouse gas footprint assessment

This report also includes a scenario for Paris-aligned greenhouse gas emission targets across six key areas. These areas were selected for the original Lake District National Park assessment, and have been chosen in order to find a "best fit" between competing desires: to cover everything of significance within the influence of local policymakers, to keep the boundary simple to describe, to avoid double-counting, and to make use of any data readily available for tracking progress. As a result, the scope for the target areas is slightly different from that of the overall emissions assessment. The six target areas are:

- Energy-only emissions by residents, visitors and industry

- Food and drink consumed by residents and visitors
- Other goods purchased by residents and visitors
- Visitor travel to and from the National Park or AONB
- Land use non-CO_2 component (including emissions from livestock and fertilisers
- Land use CO_2 component

Area studied

For a study of this type, the shape of the Broads – consisting of tight boundaries formed around river valleys – is a challenge. A hypothetical rectangle formed by the Broads' northern, southern, western and eastern edges would have an area of 1,000 square kilometres, whereas the actual total area of the Broads is only 300 square kilometres. "Broads Settlements" tend to represent only small slivers within the Broads boundary, despite the Broads forming an essential part of these areas' character. Data has largely been gathered at postcode level, as well as from other geographies such as the Census Output Areas (COAs) and Lower Super Output Areas (LSOAs) that consist of multiple postcodes. Postcodes are not designed with the boundaries of protected landscapes in mind, which inevitably leads to overlaps with areas outside the boundary of the Broads.

To try and ensure that a complete picture is generated, as an early part of the study the Broads Authority reviewed the postcode areas in and adjacent to the Broads. This created two areas: one containing postcodes that lie at least partly in the Broads area, reported as the main part of this study and referred to as "The Broads Executive Area", and a set of "adjacent areas" consisting of settlements that are heavily influenced by the Broads, referred to as "The Broads Adjacent Gateway Settlements".

Details of this analysis are presented in Appendix 10.1

Limitations and uncertainties

Due to the complexity of supply chains and the limitations of available data, consumption-based emissions estimates always contain a considerable degree of uncertainty. However, given current constraints on data availability, these estimates are sufficiently robust to provide an evidence basis for carbon management and target setting. The estimate of industry-related emissions is particularly crude, being based on comparatively simple revenue data and generic UK-wide emission factors.

Results

The Broads Executive Area (excluding Adjacent Gateway Settlements)	
Annual emissions from residents	**251,105 tCO_2e** (14.1 tCO2e per person per year)
Annual emissions from visitors while in the area	**85,594 tCO_2e** (16.8 $kgCO_2e$ per visitor-day)
Annual emissions from visitors travelling to/from the area	**112,728 tCO2e** (35.6 $kgCO_2e$ per visit)

Annual industry emissions	**341,896 tCO_2e**
The Broads Adjacent Gateway Settlements	
Annual emissions from residents (adjacent settlements)	532,104 tCO_2e (14.0 tCO_2e per person per year)
Annual emissions from visitors while in the area (adjacent settlements)	137,554 tCO_2e
Annual emissions from visitors travelling to/from the area (adjacent settlements)	178,951 tCO_2e
Annual industry emissions (adjacent settlements)	417,975 tCO_2e

Key highlights

The Broads has a unique geography among UK's designated landscapes, being shaped by navigable waterways with multiple gateway towns on the borders. A decision was therefore made by the Broads Authority to consider the gateway settlements separately due to their economic sphere of influence through visitors.

In the Broads, 70% of fens and 80% of wet woodland eco-systems, both of which are known for having peat soils, are estimated to be in a healthy condition thanks to successful conversation efforts to date. This level is much higher than the UK average, with an estimated 80% percent of UK peatlands having been modified and damaged to varying degrees through various forms of land management.[1]

The Broads' average residents' household spending excluding public services is 12.8% above the UK average. This is very close to the estimated average household spending across all UK National Parks (12.9% above the UK average). The data indicates a demographic profile dominated by both working age and retired populations.

In a given year, the footprint of the residents in the Broads Executive Area is estimated to be nearly 14.5% higher than the UK average. Several fossil fuel-based sources of greenhouse gas emissions are particularly high: residents' emissions from flying are estimated to be nearly 40% higher than for an average UK resident, household fuel emissions (excluding driving) are around 13% higher than the UK average, and emissions from driving and other transport are around 20% and 27% above the UK average, respectively. Household electricity emissions are around 11% lower than for an average UK resident. It must be noted that our estimates for emissions from household fuel and electricity use do not include renewable energy solutions such as solar panels and heat pumps, nor do they factor in the uptake of electric vehicles. As of 2019, the share of these technologies across households was comparatively low and no suitable data with sufficient geographical detail was available. The footprint from household fuel use (excluding driving) is particularly uncertain since more properties are off the gas grid in the Broads compared to several overlapping unitary Local Authorities, and because there is insufficient data for residual fuel use (oil, coal, biomass).

[1] See IUCN National Committee United Kingdom Peatland Programme (2021), "Peatland Damage"; https://www.iucn-uk-peatlandprogramme.org/about-peatlands/peatland-damage

The Broads has a moderate share of visitors staying overnight (around 14% of all visitors), but their estimated average duration of stay of 5.3 days is one of the highest among all National Parks and AONBs on the current programme. 9% of the visitors' footprint while in the Broads Executive Area is estimated to be from accommodation (excl. food), which is third behind food (nearly 52%) and other shopping (12%). Estimated average mileage travelled on land to get to the Broads is around 100 miles and is dominated by cars, while relatively few visitors come from overseas (flights and ferries). As a result, the visitors' footprint while travelling to & from the NP is dominated by vehicle fuel (70%), followed by embedded footprint of producing and maintaining cars (18%). Overall, around 43% of the total visitors' footprint can be attributed to their activities while in the Broads Executive Area, and the remaining 57% to travelling to & from the area, together equivalent to around 79% when compared to the estimated footprint of the residents within the Broads Executive Area.

The industry footprint in the Broads Executive Area, excluding the British Sugar factory in Cantley while including all the COA regions on the Area's border, is dominated by "production" (all types of manufacturing, 43%), "agriculture and fishing" (18%), and "transport and storage" (11%). The production footprint is comparatively high given the agriculture- and tourism-dominated landscape, and despite the large emitters within and close to the Broads boundary having been excluded from the estimates. A fundamental difficulty with estimating industry footprint is that locations where companies are registered and where the required business data is available do not always match with the locations of business activities and emissions. Another challenge is the insufficient number of sectors reported in the business data that matches closely to the boundary of a protected landscape, which forces us to apply generic UK-wide emissions factors. These are likely to be the underlying causes of the relatively high production emissions in the Broads reported here.

Given its location and connectivity to sizeable population centres in East Anglia, the Broads Executive Area is estimated to have a considerable traffic footprint from the major roads (A47, A1064, A146, A143), which amounts to 55% compared to the total footprint of the residents. Through traffic is estimated to account for account for nearly 86% of the emissions from the major roads.

Targets scenario

As part of the assessment, we set minimum Paris-aligned targets for each of the six shortlisted components of the carbon baseline, as illustrated in. When combined, they result in a Paris-aligned emissions trajectory (Figure 6) that reflects the unique characteristics and circumstances of the Broads. The same approach has been used for all the National Parks and the level of ambition is set to be equal for each one and in line with sector-level targets for achieving territorial net zero emissions by 2050 for the whole of the UK, even though the resulting emissions trajectories are different for each National Park. For the Broads Executive Area, net zero emissions are not reached until the 2070s, and projected net greenhouse gas emissions in 2050 are 84,569 tCO_2e. We emphasise that this later net zero date is a reflection on the unique characteristics of the Broads, rather than a difference in ambition.

The net zero date also assumes the recommended decarbonisation and carbon sequestration efforts, including land use change, ratchet up to the required levels immediately in the base year of

the assessment. In reality, the high levels of ambition for different sectors explored in this report are likely going take several years to achieve, given that post-COVID emissions have largely rebounded, and that decarbonisation trends to date have been relatively small in magnitude compared to what we know is required for keeping global warming below the safer 1.5°C limit from the Paris Agreement. These factors are expected to push the projected net zero year back by several years. The net zero date should therefore not be taken in isolation as a level of ambition. Furthermore, in the case of the Broads, potential for land management improvements to sequester carbon and offset residual emissions is somewhat limited by the nature of the landscape and by the success of conservation work already undertaken which limits the further scope for improvements.

The dominance of healthy wetland habitats and medium-grade agricultural land on mineral soils within the Broads limit the opportunity for peatland restoration and woodland creation. However, there is likely to be more scope for this in the neighbouring unitary Local Authorities. The Broads will therefore need to work in partnerships with the Local Authorities alongside other stakeholders such as water utility companies, the National Farmers Union and local landowners, to facilitate peatland restoration, woodland creation and the uptake of more sustainable agricultural practices across the whole region. The goal of such partnerships should be to identify and scale up opportunities to reduce land-based emissions and enhance carbon sequestration in the Broads itself as well as in the nearby areas, while also promoting co-benefits such as biodiversity gains, improved water and air quality, greater flood resilience and enhanced recreational value. Among the measures feasible within the Broads borders are:

- Restoration of the remaining degraded fen and wet woodland areas;
- Adoption of innovative management practices for high-grade agricultural land on peat soils to reduce peat emissions (e.g. paludiculture);
- Adoption of regenerative agricultural practices for grassland and cropland areas on mineral soils (e.g. grazing legume species, cover crops, agroforestry and hedgerows);
- Small-scale woodland creation.

To achieve net zero aspirations for the wider region, the partnering Local Authorities will need to adopt similar agricultural and wetland management measures, while simultaneously driving large-scale forestation programmes guided by the principle of “right tree in the right place”.

Residents: 251,105 tCO_2e

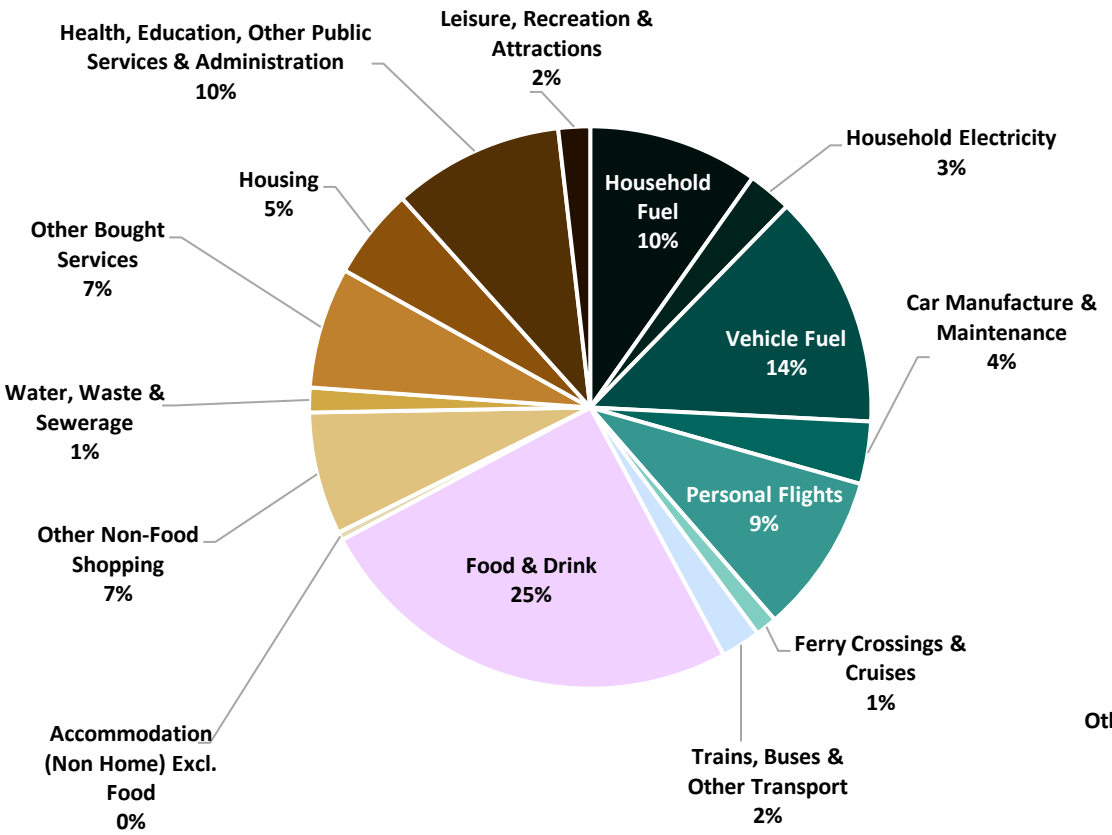


Figure 2: (left) Residents' GHG emissions in the Broads Executive Area, by percentage

Visitors travel to & from the area: 112,728 tCO_2e

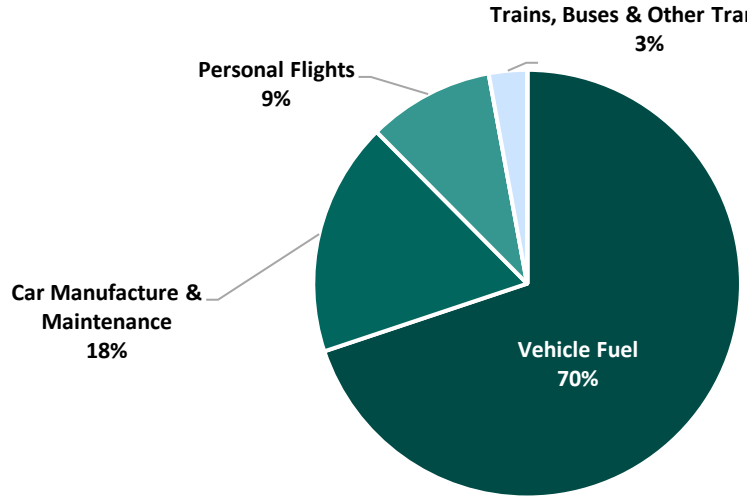


Figure 3: (top right) Visitors' GHG emissions on the way to & from the Broads Executive Area, by percentage

Visitors while in the area: 85,594 tCO_2e

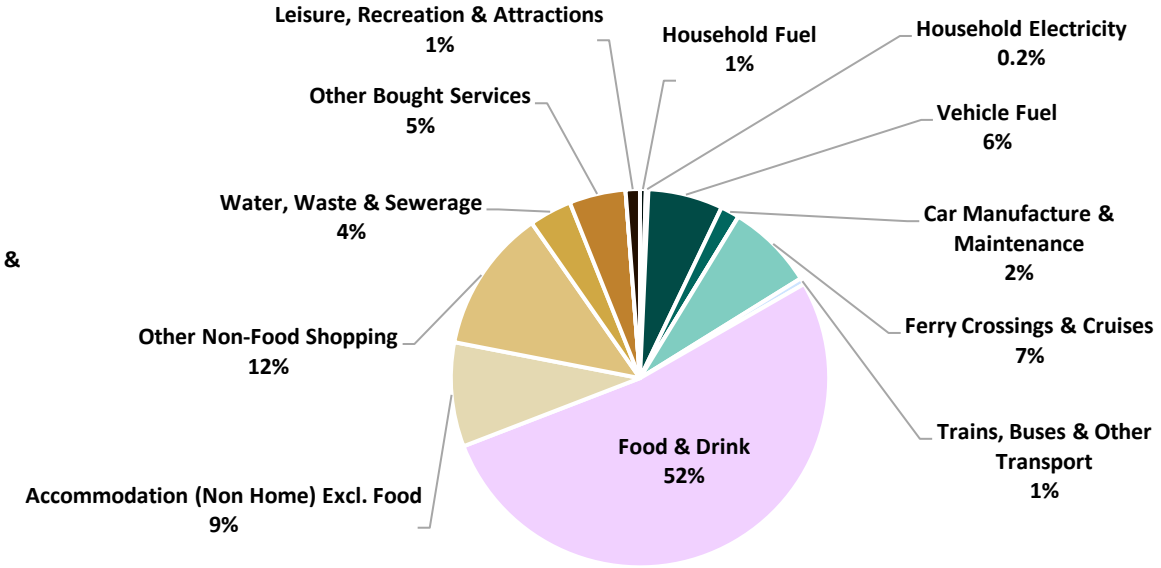


Figure 4: (bottom right) Visitors' GHG emissions while in the Broads Executive Area, by percentage

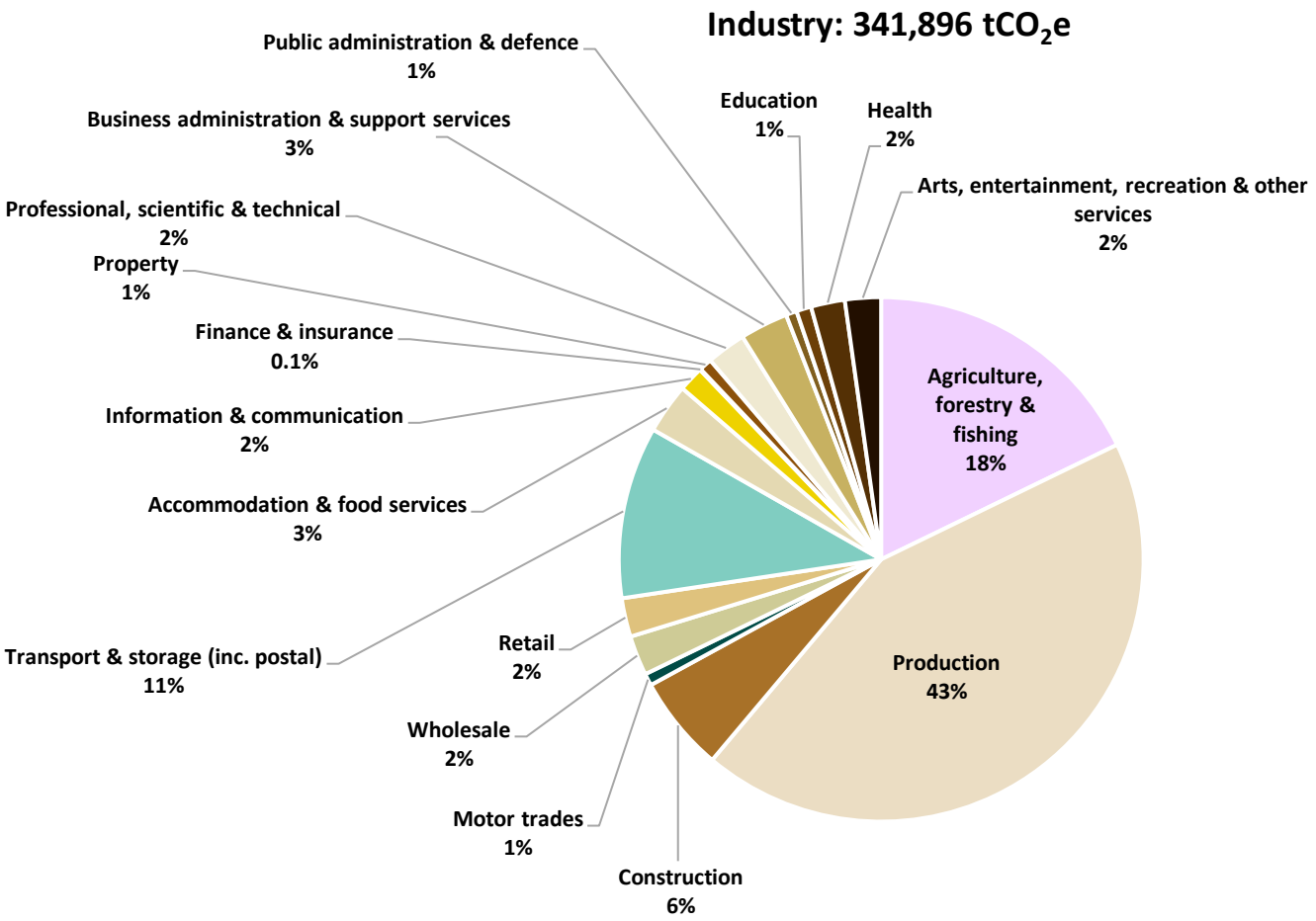


Figure 5. An estimate of emissions from industries within the Broads and their supply chains (scopes 1, 2 and upstream scope 3)

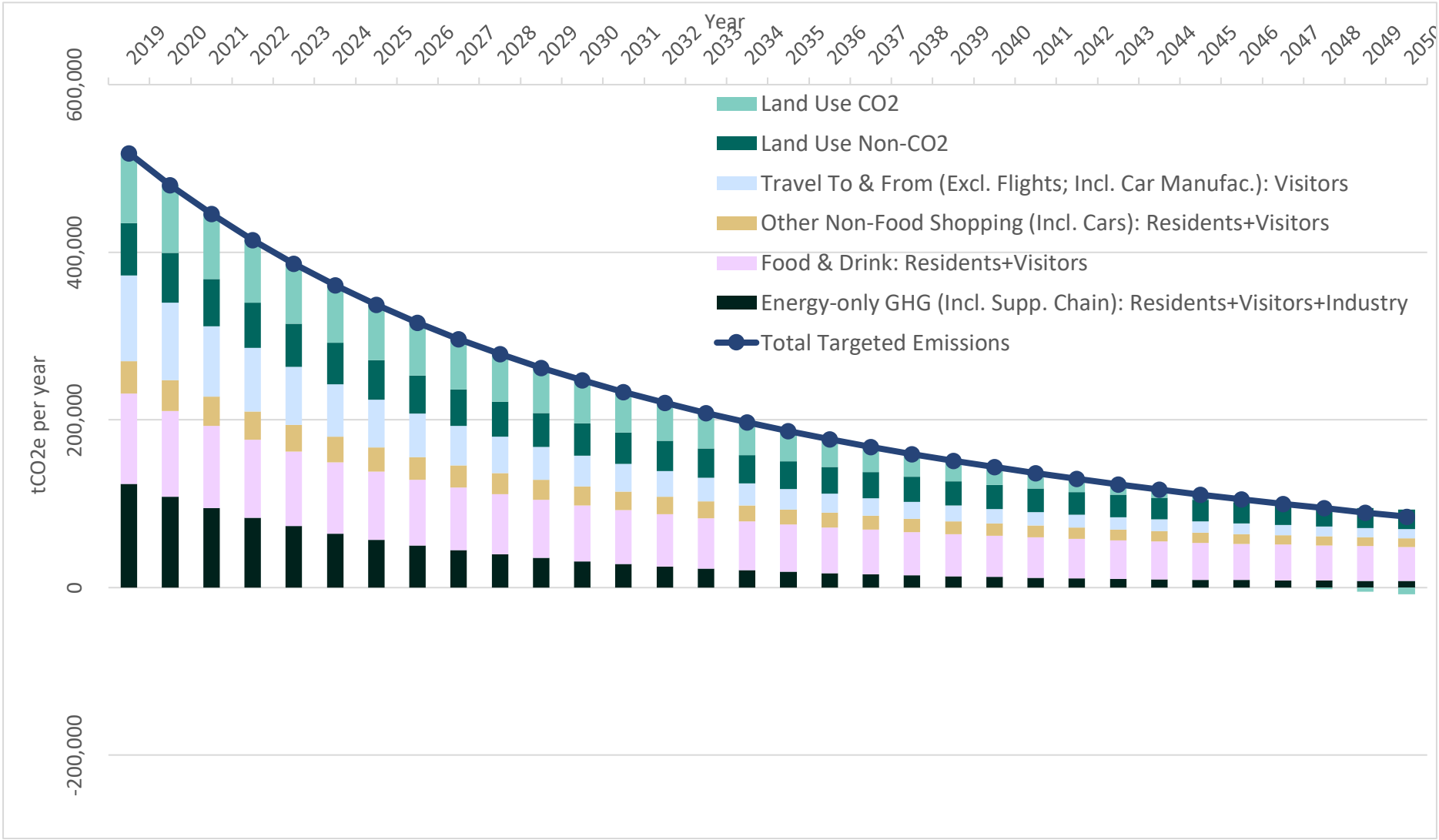


Figure 6: Recommended consumption-based target pathways for the Broads Executive Area across the six shortlisted categories of emissions between 2019 and 2050. The total emissions reach net zero in the early 2070s (not shown). The projected net zero date for the Broads Executive Area is comparatively late because the potential for land management improvements is somewhat limited by the nature of the landscape and by the success of conservation work to date.

1. Introduction

As the world wakes up to the climate and wider environmental emergency, rapid reduction of greenhouse gas (GHG) emissions and sustainable land management are becoming increasingly central to the local, national and international policy agendas. In 2019, the UK strengthened its production-based targets, setting itself a legally binding target of net zero by 2050. This prompted the family of UK National Park Authorities, the Broads Authority, and several Areas of Outstanding Natural Beauty (AONBs) to seek assessment of their greenhouse gas emissions collectively. The ambition of these protected landscapes was to go beyond the UK Government's production-based targets and identify the full consumption-based scale of the greenhouse gas emissions attributable to residents and visitors, including travel to and from the landscape.

This report, for the Broads, is one of a series of methodologically compatible reports produced for each UK National Park, each Welsh AONB, as well as the Cotswolds and Cannock Chase AONBs in England. The baseline year for the assessment is 2019, the most recent pre-COVID year. The report also includes recommendations for Paris-aligned targets on GHG emissions reduction across six key areas, as well as for carbon sequestration through land-based climate mitigation measures. Together with the estimated 2019 GHG baseline, achieving these targets would mean the Broads Executive Area reaching consumption-based net zero emissions by the early 2070s, subject to the targets being fulfilled and to the considerable uncertainties remaining in the data. A major factor behind this comparatively late projected net zero date for the Broads is its limited potential for land management improvements to sequester carbon and offset residual emissions, which stems from the unique nature of the landscape and the success of conservation work to date.

Together, the UK's 15 National Parks and 46 AONBs are home to over 1.5 million residents, attract approximately 250 million visitors per year, account for around 18% of the UK's land area, and contain significant amounts of peat. If they can become exemplars of low-carbon transition and environment-conscious land management, their national and international profiles could give them a level of influence that far outweighs the scale of their own emissions. The exciting and creative challenge for each protected landscape is to find a way to cut emissions in line with current science, and be leaders in land stewardship while simultaneously creating better places for people to live, work and visit.

Almost every action connected with people living, working and spending time in the protected landscapes gives rise to greenhouse gas emissions, which lie within the influence and therefore management responsibilities of the National Park Authorities, the Broads Authority or Local Authorities for the AONB. While the need to transition from fossil fuels to renewable energy is the single greatest challenge in responding to the climate emergency, for the protected landscapes in particular, land management is also a critical element of dealing with both the climate and biodiversity crises.

The unique characteristics of each protected landscape give rise to different priorities and opportunities for cutting greenhouse gas emissions and for sustainable land management. For example, the ratio of visitors to residents varies greatly. Some National Parks and AONBs have large industrial or military sites within their boundaries. To varying degrees, each landscape is traversed by major roads that carry considerable volumes of traffic (not necessarily stopping in the area). All these factors affect the economic makeup of each landscape's geography, and have strong

implications for the associated GHG footprint and decarbonisation efforts. In terms of land management challenges and opportunities, the protected landscapes vary greatly in their levels of peatland and woodland coverage, in their amount and types of agricultural land, and in the population densities of residents and visitors.

The main body of this report is designed for a broad audience, including some who may be less familiar with carbon analysis, but who have an active interest in the findings. This includes National Park and AONB board members, local businesses, partner organisations, and members of the general public who wish to participate in the transition to a low-carbon and sustainable economy. A technical appendix has been produced for those wishing to consult more methodological detail.

2. Policy drivers

2.1. Climate change policy

While the world has had to focus on dealing with the global pandemic since January 2020, climate change has nevertheless remained high on the international agenda. This section summarises key drivers for change which the National Park may wish to respond to in delivering its statutory duties.

Climate change driven by anthropogenic GHG emissions, plus the wider ecological crisis, are some of the biggest challenges facing humanity today, and a joined-up response to tackling them is likely to improve both situations. A 2018 report by the Intergovernmental Panel on Climate Change (IPCC) outlined the need to reduce global greenhouse gas emissions by 45% (from 2010 levels) by 2030, and achieve net zero emissions by 2050[2]. It states that these reductions are necessary in order to limit the increase in global mean temperature to 1.5°C relative to pre-industrial levels. This is the more ambitious target of the Paris Agreement by the parties to the UN Framework Convention on Climate Change (UNFCCC); it is also understood to be a "safer" warming limit both for societies and ecosystems globally. In 2019, the UK Government agreed to a legally binding target of net zero greenhouse gas emissions by 2050.

Subsequently, the IPCC published its Sixth Assessment Report (AR6) in stages, with the final volume released in March 2022. Compiled by the world's leading scientists, this report provides a comprehensive update on the latest scientific learnings about climate change, and is intended to serve as a resource for global climate negotiations, national policies and business planning.

The first part of the AR6, entitled "Climate Change 2021: The Physical Science Basis", was released ahead of the 26th UNFCCC Conference of the Parties (COP26) hosted in Glasgow in November 2021[3]. Notably, it affirms that the increase of carbon dioxide, methane, and nitrous oxide in the Earth's atmosphere through the industrial era, i.e. since the late 19th century, is the result of human activities. What is clear in the report is that our chance of limiting the increase in global mean temperature to 1.5°C above pre-industrial levels now appears small. Keeping warming below the "safer" 1.5°C limit will likely require the most ambitious actions – i.e. those at the top end of known technical feasibility – to reduce emissions and also upscale efforts on carbon sequestration.

[2] IPCC (2018) Special Report: "Global Warming of 1.5°C Summary for Policymakers." https://www.ipcc.ch/sr15/chapter/spm/.

[3] IPCC (2021) Climate Change 2021: The Physical Science Basis https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/.

The Department of Business, Energy and Industrial Strategy (BEIS) is the lead for reporting on GHG emissions in line with the UNFCCC requirements in the UK, including Scotland and Wales. An independent body, the UK Climate Change Committee, advises the whole of the UK, including devolved administrations, on emissions targets and progress. The Sixth Carbon Budget (2020) recommends that the UK set a budget to require a 78% reduction in UK greenhouse gas emissions by 2035 relative to 1990, which is a 63% reduction from 2019 levels[4]. Further detail relating to this is provided in Section 2.4 of this report, outlining associated real-world change towards decarbonisation.

Ahead of COP26, in October 2021, the UK Government published its Net Zero Strategy: Build Back Greener[5]. This outlines the Government's strategy to reduce emissions across the economy, including power, fuel supply and hydrogen, industry, heat and buildings, transport, waste, and greenhouse gas removals. It also considers supporting the wider transition across the economy.

COP26 concluded with the agreement of the Glasgow Climate Pact, with 153 countries putting forward new 2030 emissions targets ("Nationally Determined Contributions", NDCs)[6]. The NDCs pledged at COP26 are estimated to represent a trajectory towards a temperature *rise* of 2.4°C (relative to pre-industrial levels) by the end of the century, whereas the existing Net Zero pledges, if fully implemented, would limit global warming to 1.8°C.[7]

Prior to COP26 closing on the 13th of November, the UK's Environment Act 2021 received Royal Assent, becoming law on the 9th of November 2021 as an Act of Parliament. The broad aims of the UK Environment Act are to improve air and water quality, protect wildlife, increase recycling and reduce plastic waste. The Act also provides the means to set targets for particulate matter (affecting the quality of ambient air) and species abundance. More importantly, it sets environmental principles which the National Park Authorities or Local Authorities for AONBs will need to be familiar with as they fulfil their statutory planning authority obligations, namely:

- The principle that environmental protection should be integrated into policymaking,
- The principle of preventative action to avert environmental damage,
- The precautionary principle, insofar as it relates to the environment,
- The principle that environmental damage should, as a priority, be rectified at source,
- The "polluter pays" principle.

2.2. Health impacts of air pollution

In addition to the impact of climate change on the environment, greenhouse gas emissions also have an impact on human health and well-being. It is estimated that between 28,000 and 36,000 UK deaths each year are attributable to air pollution. Poor air quality can have a disproportionate impact on the health and wellbeing of children, older people and other vulnerable individuals. The

[4] Climate Change Committee (2020): "The Sixth Carbon Budget: The UK's Path to Net Zero," p. 13 https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf.
[5] HM Government (2021), "Net Zero Strategy: Build Back Greener" https://www.gov.uk/government/publications/net-zero-strategy.
[6] COP26, "The Glasgow Climate Pact," p.8 https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf.
[7] https://climateactiontracker.org/global/temperatures/.

NHS has identified that more than 2,000 GP practices and 200 hospitals are in localities affected by toxic air. In the UK, 5.4 million people are currently receiving treatment for asthma: 1.1 million children (1 in 11) and 4.3 million adults (1 in 12). Every day, three families are devastated by the death of a loved one due to an asthma attack, and tragically, two thirds of these deaths are preventable (Asthma UK, 2020).

2.3. Climate-driven impacts in the UK

The impact of climate change on our natural world is evidenced by higher temperatures, changing rainfall patterns, changes in ecosystems, sea level rise, increasing frequency and intensity of storm surges, retreating glaciers, and melting sea ice and ice sheets. In the UK we are seeing significant changes in the winter and summer rainfall patterns. The UK Met Office's latest report states that "Winters in the UK, for the most recent decade (2009-2018), have been on average 5% wetter than 1981-2010 and 12% wetter than 1961-1990", and that "Summers in the UK have also been wetter, by 11% and 13% respectively"[8]. Total rainfall from extremely wet days increased by around 17% in the decade 2008-2017 for the UK as a whole. However, the changes are most marked for Scotland, and not significant for most of southern and eastern England. In addition to increasing precipitation volumes, climate change has already made it 12-25% more likely that the UK will again experience a summer as hot as 2018, which is projected to become 50% more likely with future warming.

In terms of human responses to flooding, a recent report by Natural England also suggests that environmental inequality is greater within deprived communities, which experience the largest negative climate impacts, e.g. flood risk, air pollution, poor-quality river water and waste hazards. Research has shown that there are significant mental health impacts associated with flooding, including a 20.1% chance of probable depression within 12 months, 28.3% probable anxiety and 32.6% probable PTSD for those individuals who directly experience being flooded (based on the cost per household over a 2-year period, ranging from £3,144 to £6,980 dependent on flood depth)[9].

In addition, climate-driven changes in rainfall patterns and temperatures create significant adaptation challenges for species that depend on their local environmental conditions and habitats, posing an even greater risk to future biodiversity and food security.

2.4. Real world action and behaviour change

The Sixth Carbon budget, together with sector reports, has responded to these policy drivers with high-level proposals that necessitate real-world planning, action and behaviour change. Key highlights from the report are listed below:

- By the early 2030s, all new cars and vans, and all domestic and non-domestic replacement boilers are low-carbon – largely electric.
- By 2040 all new trucks are low-carbon.
- UK industry shifts to using renewable electricity or hydrogen instead of fossil fuels.
- UK industry captures its remaining carbon emissions and stores them safely (and permanently).

[8] Met Office (2015), "UK Climate Projections: Headline Findings", July 2021, version 3 p. 6-7 https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18_headline_findings_v3.pdf

[9] Priest, S., Viavattene, C., and Cotton, J. (2019) Environment Agency presentation: "New economic costs for the mental health impacts of flooding."

- By 2035 the UK's electricity production is zero carbon.
- Low-carbon hydrogen is scaled up as a fuel for shipping, transport and industry, and for some buildings it replaces natural gas for heating (demand for natural gas is set to double/treble by 2050).
- UK wastes fewer resources and reduces its reliance on high-carbon goods.
- UK has a national programme to improve insulation of existing buildings[10].
- Fewer miles travelled by car and air.
- Diets change, reducing consumption of high-carbon meat and dairy products[11] by 20% by 2030.
- Agriculture and the use of farmland are transformed, while maintaining the same levels of food per head produced today.
- By 2035, 460,000 hectares of new mixed woodland are planted to remove CO_2 from the atmosphere and deliver wider environmental benefits.
- By 2035, 260,000 hectares of current farmland are dedicated to producing energy crops.
- Woodland coverage of the UK's land surface rises from 13% today to 15% by 2035 and 18% by 2050.
- Peatlands are widely restored and managed sustainably.

Detailed guidance is contained within eleven sector reports, namely: 1) Aviation, 2) Buildings, 3) Fluorinated gases (F-gases), 4) Electricity generation, 5) Fuel supply, 6) Greenhouse gas removals *i.e. a) Bioenergy with carbon capture and storage (BECCS), b) Direct Air Capture with Carbon Storage (DACCS) and c) Wood in Construction*; 7) Manufacturing and construction, 8) Shipping, 9) Surface transport, 10) Waste and finally 11) Agriculture, Forestry and Other Land Use (AFOLU). In relation to agriculture and land, the report specifically comments that recommendations for policy "must be implemented in a way that is fair to farmers," and that "policy design must account for the challenges of the changing climate and reflect wider environmental priorities, including for biodiversity, to harness potential synergies and avoid unnecessary trade-offs. Policies are also needed to cut food waste and encourage a reduction in consumption of meat and dairy"[12].

The key challenge for Local Authorities, National Park Authorities and the Broads Authority will be translating the targets and initiatives to their geographical areas.

2.5. Policy implications for local planning authorities

The Broads Authority is the Local Planning Authority for the designated landscape, handling planning applications and managing development across the landscape in a similar way to the other English, Welsh and Scottish National Park Authorities. However, there is a unique difference: as well as being the local planning authority, the Broads Authority is also a harbour and navigation authority for the port of Norwich. The Authority was established under the Norfolk and Suffolk Broads Act 1988, with further provisions made through the Broads Authority Act 2009 for management of the navigation area. Notably, the last vessel entry into the Port of Norwich was in 1988, so the

[10] Building regulations for new homes have been strengthened to require high energy performance and electric vehicle charging points. See documents F, L, O and S of the Building Regulations approved documents list: https://www.gov.uk/government/collections/approved-documents>

[11] In the context of food, the term "high-carbon" means that GHG emissions from producing a unit of calories and nutrition ready for human consumption are high compared to other food types. For further details, see Poore & Nemecek (2018), "Reducing food's environmental impacts through producers and consumers," *Science*, 360(6392), 987-992.

[12] Climate Change Committee (2020), "The Sixth Carbon Budget: The UK's Path to Net Zero," p.30.

Authority's ability to influence transport in terms of shipping and storage may be limited. The Broads Authority therefore has a unique perspective in that it also needs to protect the interests of navigation as one of its three purposes[13]. As the Broads has been shaped by navigable waterways, and has multiple gateway towns on its borders, the Broads Authority is responsible for setting spatial planning policies for its area as outlined in the National Model Design Code[14]. County planning responsibilities, including minerals and waste planning, sit with Norfolk and Suffolk County Councils[15].

Planning is one tool the Authority can use to address GHG emissions, specifically through decarbonisation of the built sector. The Broads Authority may benefit from developing a Sustainable Construction Supplementary Planning Document (SPD) to push the construction sector to consider embodied GHG emissions in materials used, achieve large improvements in energy efficiency, and install low/zero-carbon energy technologies in new-builds. Planning policies can also encourage the uptake of low/zero-carbon transport in new developments. Although new-builds emit relatively small quantities of GHGs compared to existing buildings, GHG savings achieved in new-build stock will minimise the need for expensive future retrofitting. They will also demonstrate the potential of – and stimulate the market for – building techniques and products. However, the Broads Authority may be constrained in the impact it can make, as only 13-18 new-build homes are constructed within the Broads' boundary in a typical year. Production of guidance on sustainable extensions may prove the greater opportunity, since local residents more often choose to increase the floor area of an existing home rather than building a new one. The Broads Authority already benefits from a climate change checklist which could be developed further.

Planning can also inform what types of renewable energy technology that will be appropriate and where within the landscape, facilitating communities and businesses switching to non-fossil fuel sources of power and heat. There is also scope for planning to increase urban green space, through new green infrastructure, tree planting and habitat creation, especially in the adjacent areas to the Broads through collaboration with the unitary Local Authorities. Any new tree plantations should be guided by the "right tree, right place" principle, with additional sensitivities of navigating waterways and wetlands. Local Plan policies on Ecosystem Services and Biodiversity Net Gain could deliver biodiversity and climate change adaptation benefits through development. Planning for provision of non-motorised transport routes, and opportunities for active travel may be worthy of greater exploration, along with use of waterways as a means of public transport in connecting communities. These are important both for leisure and commuting within the Broads Executive Area and the Broads Adjacent Gateway Settlements, given that each of these two regions is estimated to attract around 3 million day visitors and 0.5 million overnight visitors per year.

3. The Broads: demographic profile and key statistics

In section 3.1 – 3.2 we consider the key characteristics of people and landscape which may call for further reflection later in this GHG emissions assessment, in terms of the likely impact on land

[13] Draft Broads Plan (2022), "Partnership strategy for the Norfolk and Suffolk Broads 2022-27", p.6 and 37.
[14] Ministry of Housing, Communities & Local Government (2021), "National Model Design Code".
[15] Draft Broads Plan (2022), "Partnership strategy for the Norfolk and Suffolk Broads 2022-27", p.41

management and behaviour arising from the changes needed to create a more sustainable long-term future for both people and nature. These insights may benefit the delivery of projects by the programme partners.

3.1. People and key characteristics

The Broads has one of the smallest residential populations of all UK National Parks. The draft Broads Plan (2022) suggests a population of 6,500[16]. For the purpose of this carbon footprint assessment, mid-2019 population estimates were used, including residents in all postcodes that fall at least in part within the geographical boundary of the Broads, which gives 17,747 residents. This difference is explained by the fact that some postcodes cover rural and more urban areas, and the rural part often (but not always) lies within the Broads, e.g. if a postcode includes a farm located partly in the Broads, plus a street of houses in a village adjacent to the Broads. This postcode inclusion approach defines the "Broads Executive Area", the main region for which we report the key carbon baseline and net zero results.

There are no major settlements wholly within the Broads, only hamlets and small villages. However, the National Park's boundary includes parts of many villages and some towns, including Great Yarmouth, Lowestoft, Beccles, Bungay and the city of Norwich[17]. The "Broads Adjacent Gateway Settlements" region was therefore also considered within the assessment. In drawing the boundaries of both the Broads Executive Area and the Broads Adjacent Gateway Settlements regions, the following methods were applied:

- Define the boundaries using geographical features (e.g. an A-road or a stream);
- If a settlement is partially in the Broads Executive Area and has a population of under 2,000, include all the postcodes within it;
- If a settlement has more than 2,000 people, include all its postcodes within 0.5 km of the Broads Executive Area;
- Do not split any postcodes.

Based on these criteria, the Broads Adjacent Gateway Settlements region is estimated to have a population of 38,062 residents. Both assessment regions are illustrated in Figure 7. Further details on the postcode selection are given in Appendix 10.1.

A distinctive feature of the Broads is its 125 miles of navigable waterways. There are some 11,000 licensed boats that use the waterways[18]. Many of these vessels serve as temporary homes, and some are permanent dwellings.

[16] Draft Broads Plan (2022). "Partnership strategy for the Norfolk and Suffolk Broads, 2022-27."
[17] Sustainability appraisal scoping report (2021). "Broads Plan and Local Plan for the Broads," p. 10.
[18] Draft Broads Plan (2022). "Partnership strategy for the Norfolk and Suffolk Broads 2022-27," p.34.

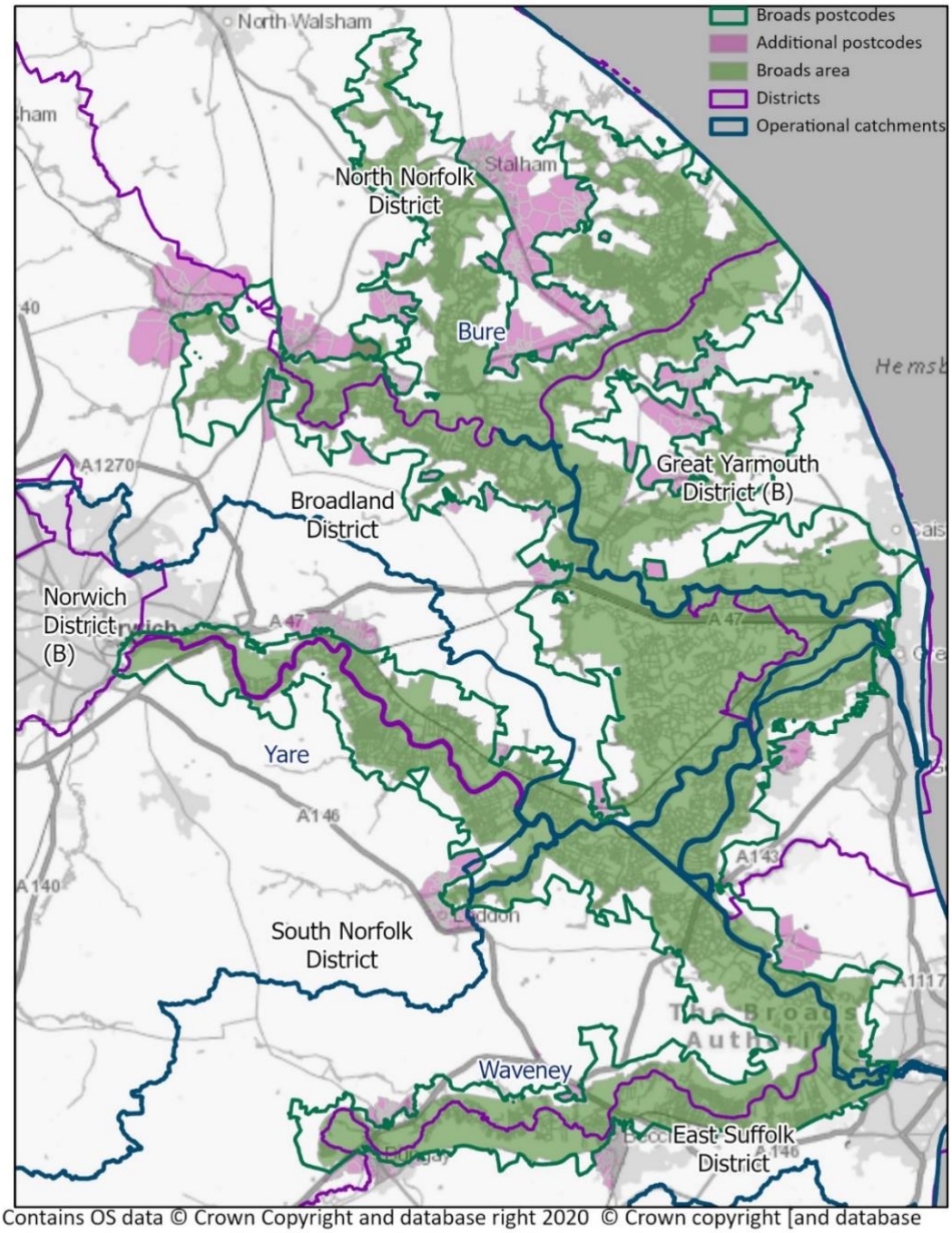


Figure 7: Boundaries of the Broads Executive Area ("Broads postcodes") and the Broads Adjacent Gateway Settlement ("Additional postcodes") regions. Reproduced with permission from the Broads Authority, under licence

When considering partnership-working on decarbonisation agendas, there are 8 local authorities represented within the National Park: Norfolk County Council, Suffolk County Council, North Norfolk District Council, East Suffolk Council, Great Yarmouth Borough Council, Norwich City Council, South Norfolk District Council and Broadland District Council. The Local Plan for the Broads (2019) suggests

that the resident population withing the landscape is growing relative to the 2011 Census, although the latest census would help to confirm whether this remains the case. The age profiles (2011 Census) for the Broads indicate numbers notably higher than the England averages for the 45-59 and 65-74 age ranges. The biggest population increases occur in the 60-74 (41.6%) and 75 and over (23.8%) age groups[19]. These increases may impact on health and social care planning by the relevant local authority and NHS partners, given that data on consumer spend within the Broads Executive Area also shows healthcare spending to be 37.4% higher than the UK average (see Section 3.3).

The Broads also has the lowest percentage of households with dependent children (16.2%) when compared to the national average (29.1%), neighbouring districts and other National Parks (21.7%). This is mirrored in the data on consumer spend within the National Park, which shows a 35.6% lower spend than the UK average on education; see Section 0. However, the percentage change in the resident population shows an increase of 6.7% for the 15-29 group. There may be planning implications for secondary and further education if this trend continues for the 2021 census, although full-time students account for only 1.7% of people who are "economically active and inactive", which is below the England average (3.4%)[20].

Economic activity data (2011 census) shows that the percentage of self-employed people resident in the National Park (16.3%) is considerably higher than the England average (9.8%). Engaging small and medium enterprises in carbon literacy will therefore be essential in any future decarbonisation strategy for the Broads. Patterns of part-time and full-time employment are on a par with National Park averages, although the data shows a significantly higher proportion of retired people (24.2%) than the England average (13.7%), reflecting the population changes previously described. This is also higher than the National Park average (20.3%). In terms of professions, the largest groups consist of managers/directors (18.1%), considerably higher than the England average (10.3%), but reflective of the higher proportion of self-employed people. The next largest groups are non-management professionals (16.4%) and skilled trades (14.4%)[21]. Although the Broads' resident population is generally more affluent than then UK average, there are some pockets of income deprivation, particularly in and near Great Yarmouth[22].

The most notable index of deprivation reveals widespread barriers to housing and services in the Broads. The percentage of caravans, or other mobile or temporary structures, is higher (3.2%) than the England and Wales average (0.4%), which may be a reflection of the wetland environment[23]. This is also evidenced by the Norfolk Caravans and Houseboats Accommodation Needs Assessment (2017), which highlighted the needs of boat dwellers, Gypsies, Travellers and Travelling Show people who have a long history of living and working in the area[24]. According to the Broads Plan (2022), "A major constraint on housing development is flood risk and the application of national planning policy in relation to this". This suggests that in order to futureproof housing and accommodation as part of climate adaptation efforts, more innovative solutions may be required, something to be

[19] Sustainability Scoping Report (2021). "Appendix 3: Baseline Data".
[20] Sustainability Scoping Report (2021). "Appendix 3: Baseline Data," p.25 and 27.
[21] Sustainability Scoping Report (2021). "Appendix 3: Baseline Data," p.28.
[22] Broads Local Plan (2021). "Deprivation Topic Paper," p. 5.
[23] Sustainability Scoping Report (2021). "Appendix 3: Baseline Data," p.32.
[24] RRT Consultancy Ltd. (2017). "Norfolk Caravans and Houseboats Accommodation Needs Assessment, including Gypsies, Travellers and Travelling Show People," p.7.

considered within local planning policy. Current plans for new residential moorings and dwellings by location are outlined within the Housing Supply Topic Paper (2018)[25].

It is important to understand and reflect upon the diverse demographic profile of the landscape when considering opportunities for potential to change behaviour in spending habits. Further detail pertaining to the key consumption and industry characteristics in the Broads, including its estimated business turnover of 1.98 billion pounds within the Broads Executive Area and 2.18 billion pounds within the adjacent gateway settlements, can be found in Appendix 10.2.

3.2. Geography and landscape

The Broads is the smallest National Park in England with an area of 303 km^2 (30,300 ha). It is renowned for its low-lying wetlands, and its importance as an inland waterway which forms part of the Broadland Rivers Catchment flowing out into the North Sea. The Broads is defined by its history, being essentially a man-made landscape, shaped over centuries. Its peatlands were excavated in Medieval times to provide a fuel source for neighbouring Norwich and Great Yarmouth, and later flooded as sea levels rose, in spite of the construction of windpumps and dykes. The boundary of the Broads follows the flood plains and lower reaches of the area's three main rivers – the Bure, Yare and Waveney – and their tributaries, the Thurne, Ant, Wensum and Chet; see Figure 8. It is estimated that around 13 million tonnes of carbon are stored in the Broads' peat soils, which will continue to capture and store existing and additional carbon in the future, under appropriate water level and land management conditions[26].

The monitoring data used in the draft Broads Plan (2021) suggests that despite significant improvements in water quality in recent decades, all the Broads' water bodies and river reaches, and more than 90% of rivers in the Broads catchment, are failing European Water Framework Directive targets. This is due to myriad factors that continue to affect water quality: pollution from wastewater, urban areas, transport and rural areas; land erosion; physical modification of water courses; changes to the flow and level of water; dissolved oxygen; salinity; demand for water use.

The Broads is now predominantly an undeveloped landscape containing a rich patchwork of interconnected habitats, including rivers, shallow lakes ("broads"), fen, reed bed, drained marshland, wet woodland, saltmarsh, intertidal mudflats and sand dunes. More than 7200 hectares within the National Park are designated national Sites of Special Scientific Interest. Many are of international importance for their habitats and wildlife, such as the Broads Special Area of Conservation and the Broadland Special Protection Area. One area of the wetland is also designated as a Wetland of International Importance under the Ramsar Convention. Local agriculture is primarily a mix of livestock grazing and some arable cropping, with grassland the dominant feature in the floodplain. Agricultural land is predominantly classed as Grade 3, with some non-agricultural pockets of Grade 4 land. Reed and sedge cutting remain a traditional and important local industry. All these landscape factors are important to consider regarding the potential for Land Use and Land Use Change in Section 5.6.

[25] Housing Supply Topic Paper (2018). "Local Plan for the Broads." Amended July 2018.
[26] Draft Broads Plan (2022). "Partnership strategy for the Norfolk and Suffolk Broads 2022-27," p. 19.

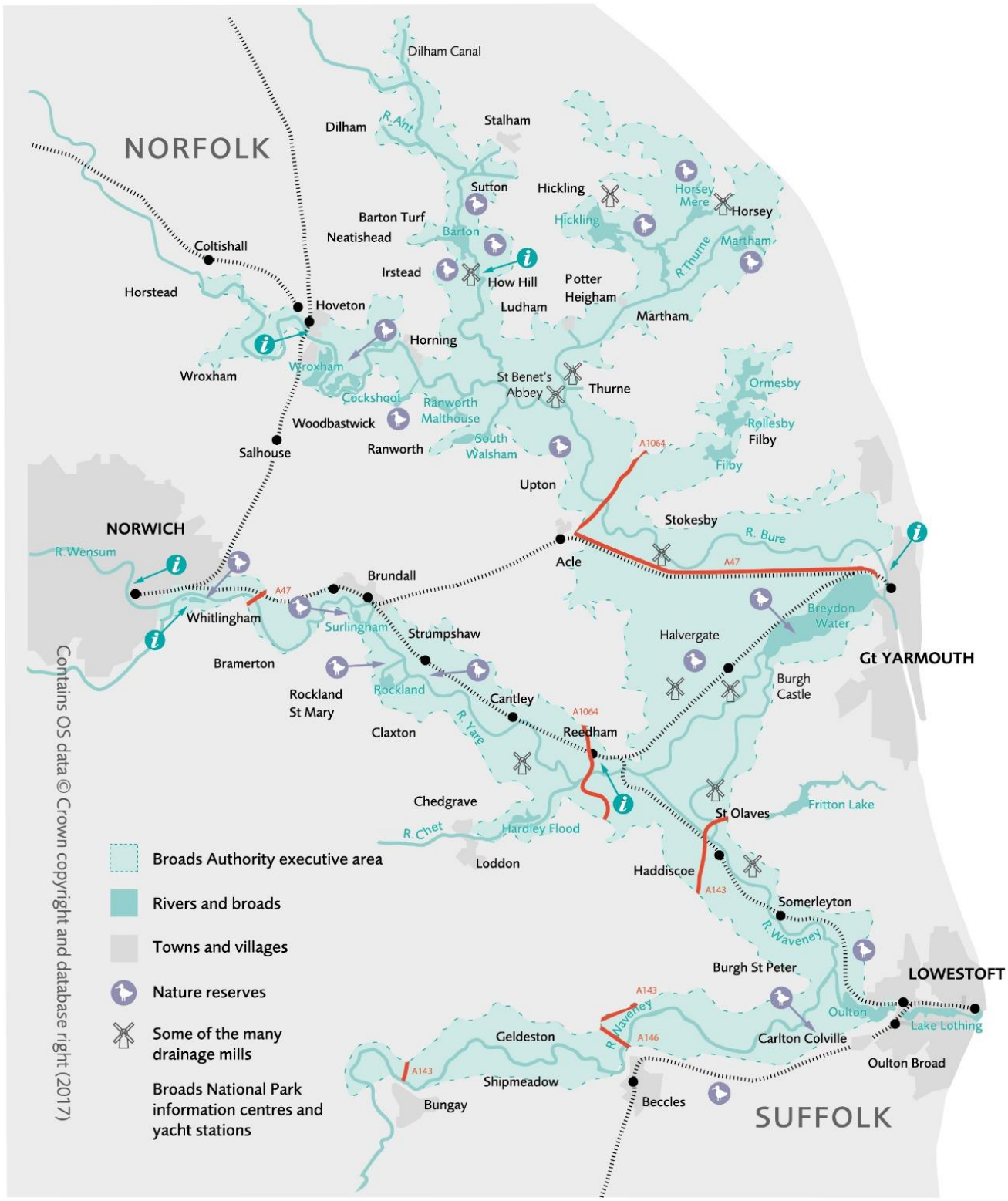


Figure 8: The Broads Executive Area showing key geographical characteristics. Reproduced with permission from the Broads Authority, under licence

3.3. Consumption and spending characteristics

When it comes to the National Park or AONB's residents, learning shared from a Catapult Energy Systems (2021) report suggests that people in vulnerable circumstances are at increased risk of experiencing barriers to adopting the behavioural changes identified as being key to achieving net zero GHG emissions[27]. The categories of vulnerability included: rural, low income, privately renting, residents with disabilities, pensionable age residents, the digitally excluded and those disproportionately affected by COVID-19.

A number of results, particularly around spending habits, may be influenced by levels of affluence and lack of means within the National Park or AONB. We therefore include a brief commentary on indices of deprivation as an indicator of economic wealth within the National Park or AONB, as this provides context for the spend-based consumption analysis and results, which may be influenced by such factors.

According to the Office for National Statistics (ONS) Household Expenditure Survey for different demographic groups, the average affluence of residents in all the National Parks and AONBs who joined this programme is higher than the UK average, even though these landscapes tend to have pockets of deprivation. On average, the Broads residents spend around 12.8% more than other UK residents (Table 1), excluding public services. This is the average across all National Parks. The consumption data supports the demographic profile of a mixture of working-age and retired populations, which is different from most other National Parks which tend to have predominantly older and, in many cases, more affluent residents.

A detailed summary of the key statistics and spending habits for the Broads residents is provided in Appendix 10.2.

Table 1 : Relative difference in consumer spending per capita (excluding public services) between the Broads Executive Area and the UK average.

Consumer Expenditure Category	**The Broads Executive Area VS UK Consumer Spending (Excl. Public Services)**	**All NPs vs. UK**
Food & non-alcoholic drinks	9.9%	10.2%
Alcoholic drinks, tobacco & narcotics	12.6%	14.6%
Clothing & footwear	9.3%	9.2%
Housing, fuel & power	-10.6%	-8.3%
Household goods & services	19.7%	16.7%
Health	37.4%	41.9%
Transport	26.7%	29.8%
Communication	4.6%	4.7%
Recreation & culture	23.2%	22.1%
Education	-35.6%	-39.8%

[27] Catapult Energy Systems (June 2021). "Net Zero Societal Change Analysis: Summary report," p. 11.

Restaurants & hotels	4.5%	3.1%
Miscellaneous goods & services	9.3%	7.8%
Other expenditure items	24.0%	23.1%
Total	**12.8%**	**12.9%**

4. GHG reporting conventions and methods

The following part of this report provides an estimate of greenhouse gas (GHG) emissions resulting from consumption by residents and visitors, including travel to and from the National Park or AONB, along with a section introducing the methodology. By taking a consumption-based approach, we include embodied, indirect emissions in everything that residents and visitors buy and do while in the area. The assessment covers all greenhouse gases in the "basket of six", and the term "carbon footprint" is used as shorthand to mean the GHG emissions released both directly and indirectly within supply chains of goods and services.

More specifically, the following are within the scope of the assessment:

- all residents' personal travel and visitor travel to, from and around the area;
- 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).

The baseline year for the assessment is 2019, the most recent pre-COVID year.

Accounting for emissions from land use and management is also crucial for National Parks and AONBs. These landscapes are mostly rural, with comparatively small population and large parts of land under various forms of agricultural management, in addition to non-agricultural habitats such as woodlands, wildflower meadows, heathlands and peatlands. Land-based emissions originate predominantly from ruminants (methane), synthetic fertiliser use (nitrous oxide), and degrading peatlands (mostly CO_2). These emissions are, to a degree, compensated by carbon sequestration in existing woodlands, meadows, hedgerows, and healthy peatlands, while agricultural soils could also sequester carbon under certain types of management.

As a separate and overlapping analysis, we also include a simple assessment of emissions from industry within each protected landscape and associated supply chains (Scopes 1, 2 and upstream Scope 3). We provide this to give some sense of the relative scale of industry emissions compared to those linked to visitors and residents. However, important caveats apply to this assessment. Firstly, it is not possible to eliminate the double counting of emissions, occurring when industries within the area sell to each other or to residents and visitors. Secondly, this crude estimate for industry has been made by applying generic, UK-wide emissions factors for each industry sector to local revenue data from businesses registered in the area. This may in some cases misrepresent actual industry-related activities within the landscape boundary.

Figure 9 illustrates the relationship between the main components of our central assessment and the industry emissions.

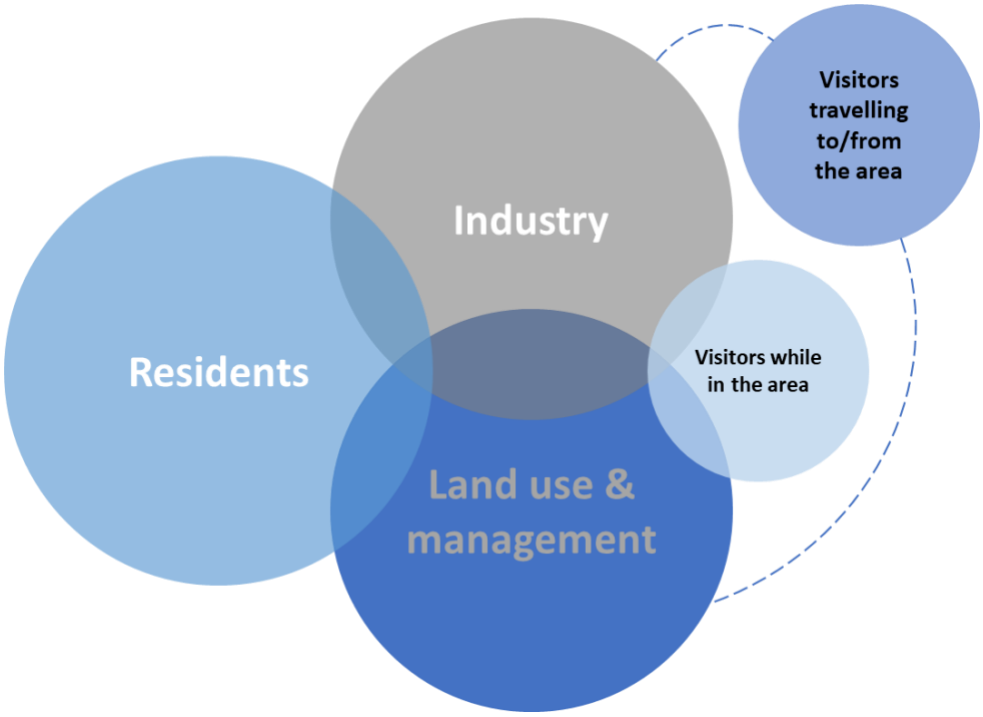


Figure 9: Boundaries of carbon footprint assessment (Repeat of Figure 1)

This report also includes a recommendation for Paris-aligned greenhouse gas targets across six key areas. These six areas have been selected in order to find a best-fit between the competing desires to cover everything of significance within the influence of policy makers, to keep the boundary simple to describe, to avoid double counting, and to make use of any data readily available for tracking progress. As a result, the scope for the target areas is slightly different from that of the overall emissions assessment. The six target areas are:

- Energy-only emissions (incl. supply chains) by residents, visitors and industry
- Food and drink consumed by residents and visitors
- Other goods purchased by residents and visitors
- Visitor travel to and from the National Park or AONB
- Land use non-CO_2 component (including emissions from livestock and fertilisers)
- Land use CO_2 component

The Greenhouse Gas Protocol considers six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur Hexafluoride (SF_4). It also categorises company emissions into three scopes: Scope 1 for direct emissions from company facilities and vehicles; Scope 2 for indirect emissions from electricity and steam consumed in company activity but generated elsewhere; and Scope 3 for indirect emissions in the value chain[28]. Scope 3 can be split into two parts: upstream and downstream. Our assessment of Industry

[28] Greenhouse Gas Protocol, "Technical Guidance for Calculating Scope 3 Emissions: Supplement to the Corporate Value Chain (Scope 3) Accounting and Reporting Standard", https://ghgprotocol.org/sites/default/files/standards/Scope3_Calculation_Guidance_0.pdf.

emissions includes scope 1, 2 and upstream scope 3 (Figure 10). This can be thought of as the full "carbon footprint" of industry up to the point of sale. Similarly, when residents and visitors buy goods and services, we include the embodied emissions of these purchases.

In the report, we measure greenhouse gas emissions in tonnes of carbon dioxide equivalent (tCO_2e)[29]. We have used 100-year global warming potential (GWP) conversion factors for all non-CO_2 gases, in line with established greenhouse gas accounting conventions. In other words, we consider the contribution that each gas makes over a one-hundred-year period. However, it should be remembered that if we are interested in climate impacts over a shorter timescale, the relative importance of some gases increases. In particular, the relative contribution of methane is roughly doubled if we are interested in climate impacts over a period of fifty years, or roughly three times as important as represented in this report if we are looking at climate impacts by 2050.

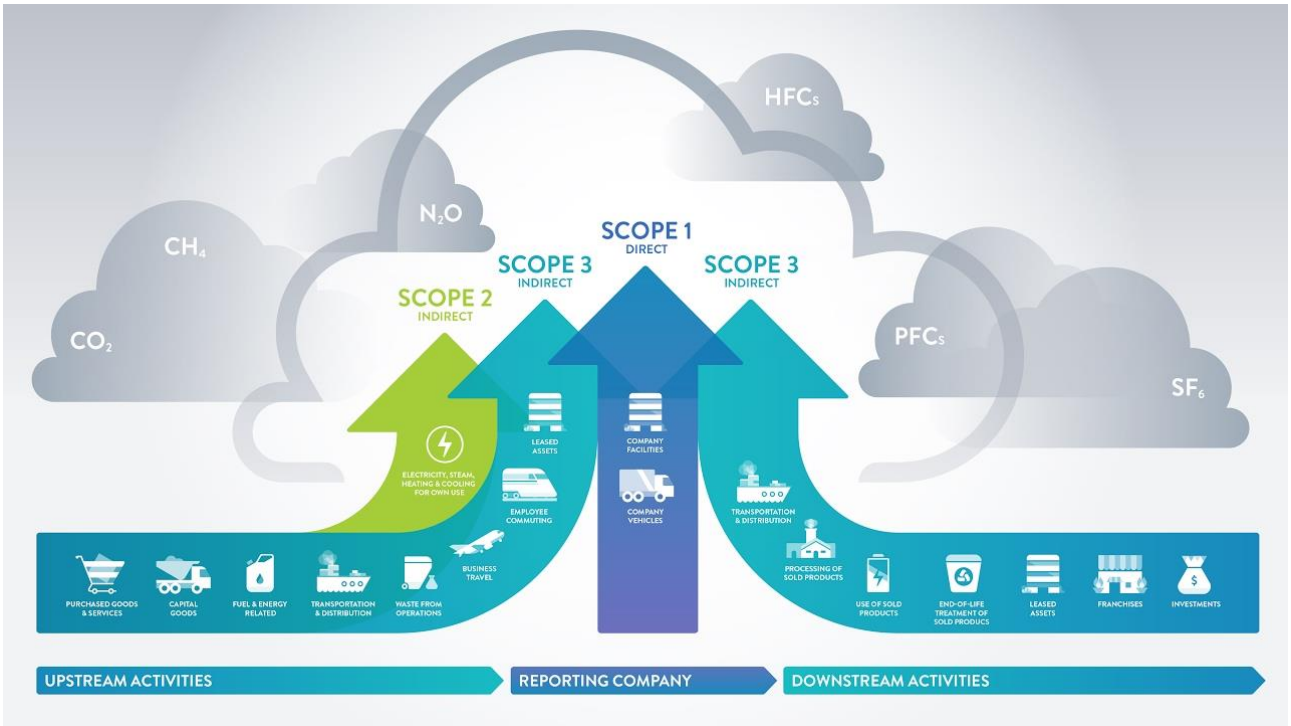


Figure 10: Types of greenhouse gas emissions used for carbon accounting. Source: Greenhouse Gas Protocol.

A National Park's or AONB's greenhouse gas emissions could be reported in three ways:

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 while in the National Park. Consumption-based reporting attributes the emissions from product and service supply chains to the National Park, ***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 and operations, including the food they eat and the products and services they buy. For example, taking a consumption-based approach, the impact of driving includes not just the exhaust pipe emissions, but also emissions

[29] DEFRA (2014) Guidance: "Calculate the carbon dioxide equivalent of an F gas"; see https://www.gov.uk/guidance/calculate-the-carbon-dioxide-equivalent-quantity-of-an-f-gas, accessed 07.12.2021.

resulting from the manufacture and maintenance of cars, and emissions resulting from the extraction and refining of fuels and their transport to the pump. For businesses, it includes the full impact of business practices, including procurement supply chains. The footprint of the National Park's industry is reported separately, as there is some unavoidable double-counting with the footprint of residents and visitors, where people in the National Park buy from local companies.

Production-based emissions: These are the net emissions that are physically released in the National Park, most notably by burning coal, oil and gas; those arising from the production of electricity used in the National Park (wherever that power is generated), and direct emissions associated with land use within the National Park or AONB (parts of agriculture, peatland degradation, etc.). This is the UK Government's standard emissions-reporting approach and only CO_2 emissions are reported by the Department for Business, Energy & Industrial Strategy (BEIS) at the local level. However, it also excludes emissions arising from production – outside the landscape – of goods and services that are used in the area by residents, visitors and industry. The approach also includes through-traffic emissions from vehicles that are passing through the National Park or AONB without stopping. We use the term "net emissions" because we subtract any negative emissions (i.e. removal of CO_2 from the air) that may result from Land Use, Land Use Change and Forestry (LULUCF).

Extraction-based emissions: These are the emissions produced by burning any fossil fuels that are extracted from the ground in the National Park, wherever they are burned. This type of emissions reporting is important for understanding the climate change implications of decisions relating to any fossil fuel extraction in the National Park.

As mentioned earlier, in this assessment we focus on a consumption-based approach and report the Scope 1, 2 and 3 GHG footprints of residents and visitors, including visitor travel to the area. Since we are including upstream scope 3 emissions, our parallel rough assessment of industry emissions can also be regarded as taking a consumption-based approach. The datasets used are outlined in Appendices 10.3 and 10.4.

5. The Broads: Consumption-based GHG emissions

5.1. Results overview

Here, we outline our analysis of the Broads Executive Area residents and visitors' GHG emissions for 2019 (Figure 11). Residents' emissions were estimated at 251 thousand tCO_2e (Figure 12) and visitors' emissions – from time spent in the area and during travel to and from – were estimated at 198 thousand tCO_2e (Figure 13 and Figure 14). The resident population stands at 17,747 people, compared to over 3.1 million visitors per year (both single-day and overnight). A full breakdown of these figures is provided in Appendix 10.5. The data shows that the typical footprint resident of the Broads Executive Area resident is 14.5% higher than that of the average UK resident. The final annual consumption per year for residents (including public services) is over 588 million pounds.

In contrast, the Broads Adjacent Gateway Settlements residents' emissions were estimated at 532 thousand tCO2e (Figure 15). The region's visitors' emissions, while travelling to and from the area and while in the area, were estimated at 317 thousand tCO2e (Figure 16 and Figure 17).

To indicate the scale of annual GHG emissions from the Broads Executive Area residents and visitors, you would need to plant over 1,214 Premier League football pitches with broadleaf trees, and let them grow for over 100 years, to mitigate the combined GHG emissions of the regions' residents and visitors for the single year of 2019. This shows the need to prioritise GHG emissions *reductions* to limit global warming, rather than just mitigating emissions through carbon removal. Emissions reductions, including decarbonisation of industry and personal consumer spending, will be challenging in our modern world, but represents the more practical option.

For simplicity in facilitating personal behaviour change, the typical UK resident's average carbon footprint can be split into four key categories: food, home and accommodation, travel, and everything else[30]. We shall use these four key categories to comment on the results, and to suggest where the local councils and partners could target initiatives aimed at behaviour change.

[30] Berners-Lee, M (2021), "How Bad Are Bananas: The Carbon Footprint of Everything", p.149

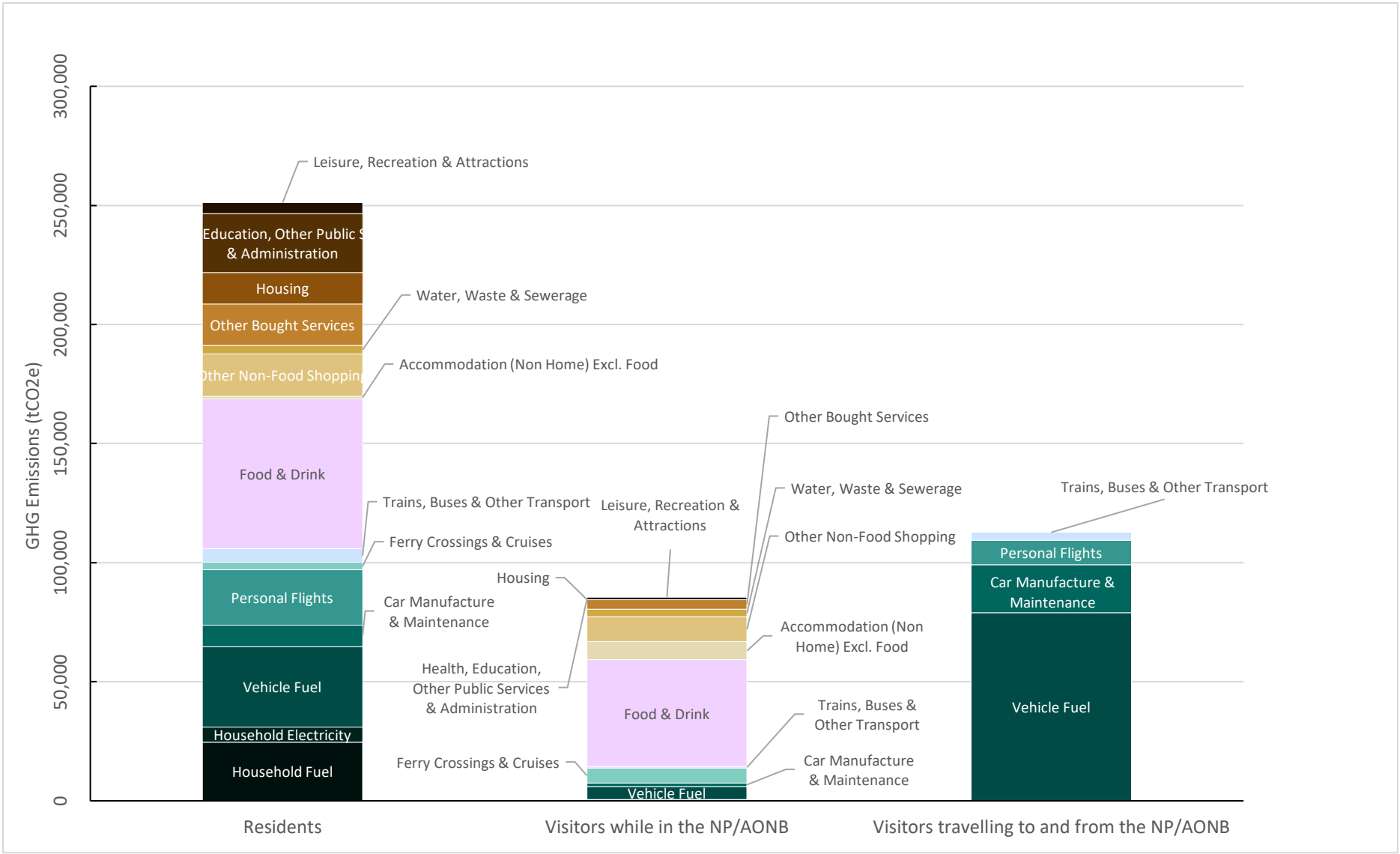


Figure 11: A consumption-based assessment of emissions relating to residents, visitors, and visitor travel to and from the Broads Executive Area.

The Broads Executive Area

Residents: 251,105 tCO_2e

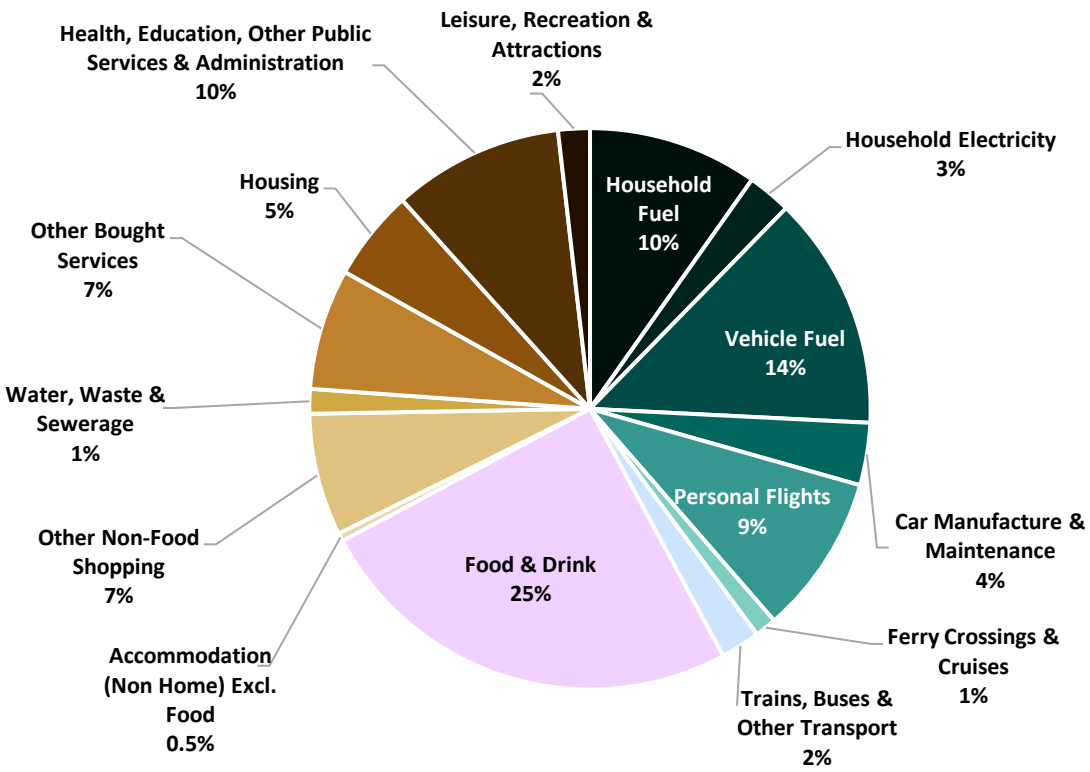


Figure 12: (left) Residents' GHG emissions in the Broads Executive Area, by percentage (Repeat of ***Error! Reference source not found.****)*

Visitors travel to & from the area: 112,728 tCO_2e

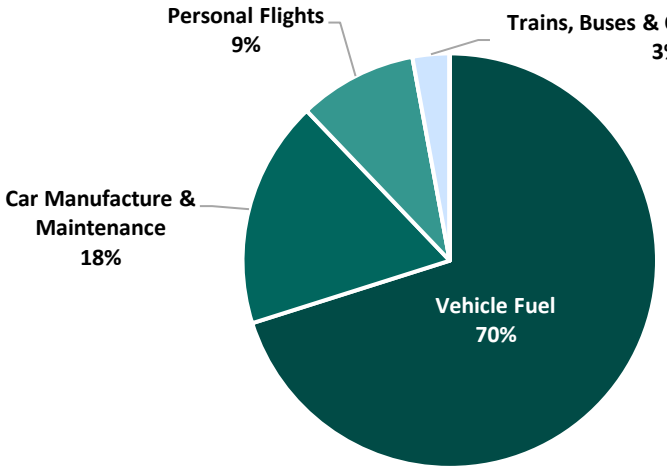


Figure 13: (top right) Visitors' GHG emissions on the way to and from the Broads Executive Area, by percentage (Repeat of ***Error! Reference source not found.****).*

Visitors while in the area: 85,594 tCO_2e

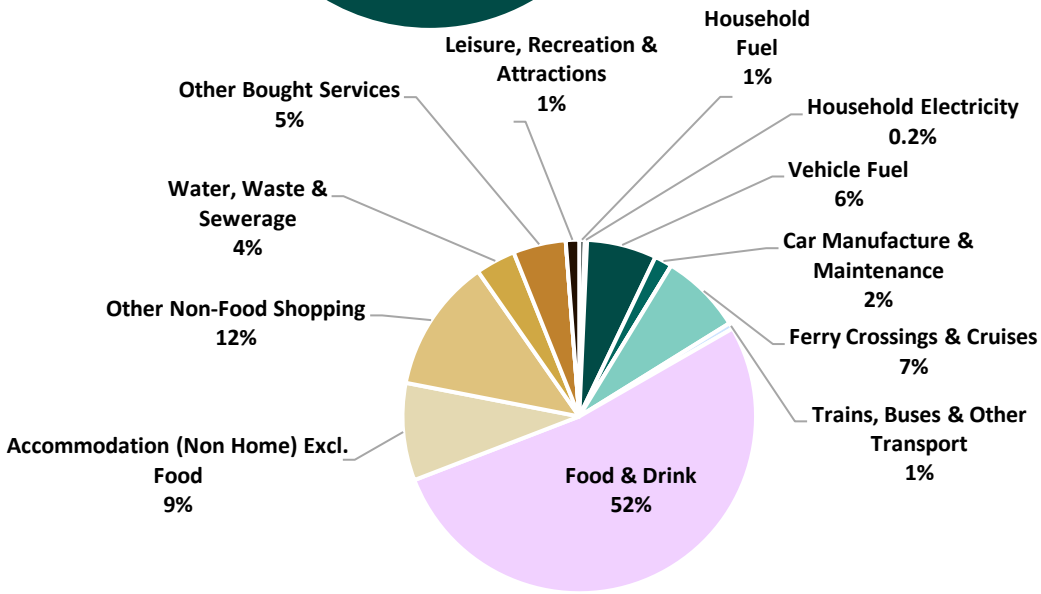


Figure 14: (bottom right) Visitors' GHG emissions while in the Broads Executive Area, by percentage (Repeat of ***Error! Reference source not found.****).*

The Broads Adjacent Gateway Settlements

Residents: 532,104 tCO_2e

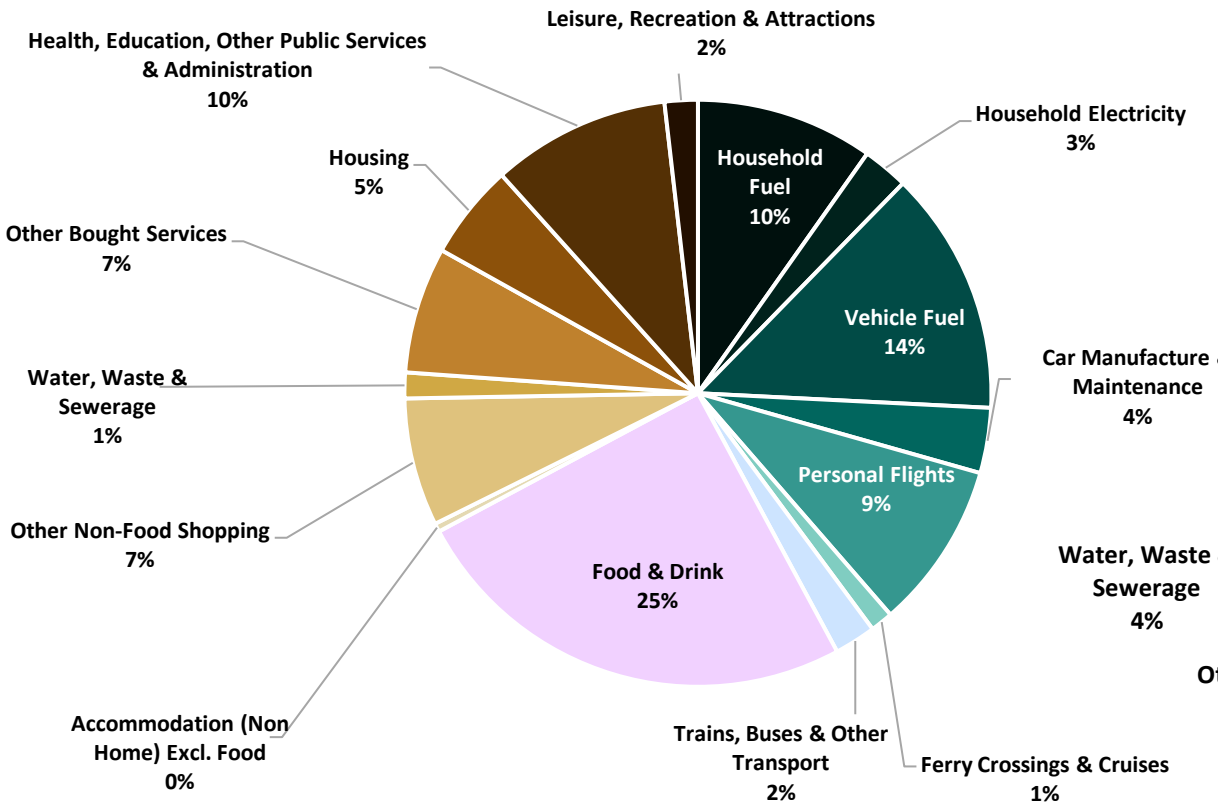


Figure 15: (left) Residents' GHG emissions in the Broads Adjacent Area, by percentage

Visitors travel to & from the area: 178,951 tCO_2e

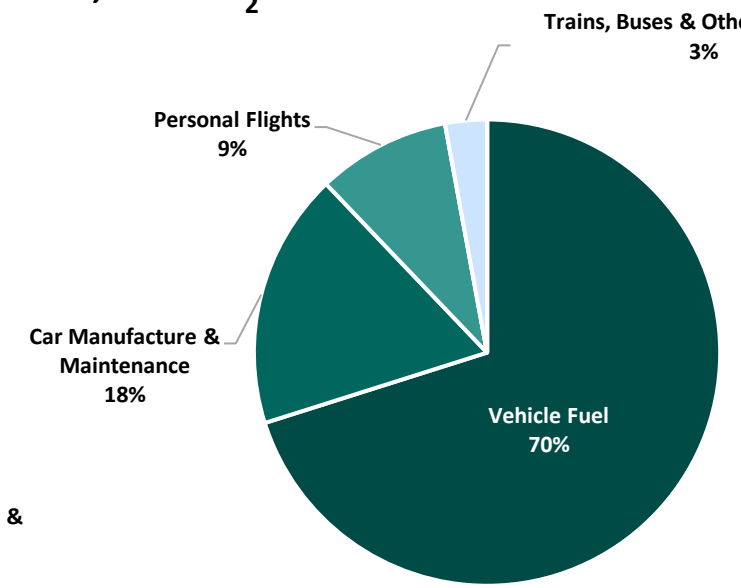


Figure 16: (top right) Visitors' GHG emissions on the way to and from the Broads Adjacent Area, by percentage

Visitors while in the area: 137,554 tCO_2e

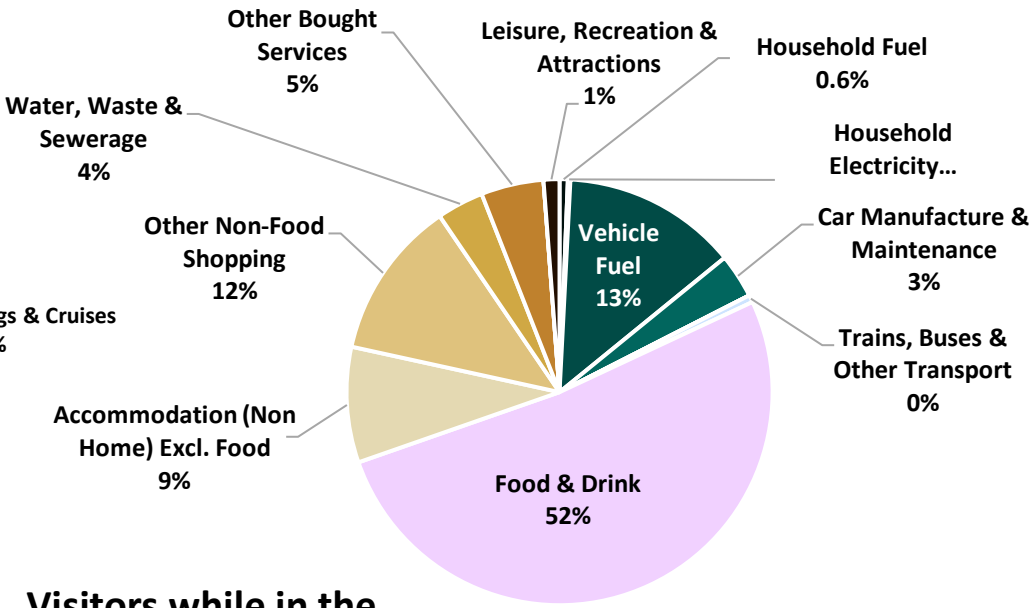


Figure 17: (bottom right) Visitors' GHG emissions while in the Broads Adjacent Area, by percentage

5.2. Residents' and visitors' GHG footprint components

The Broads Executive Area residents' emissions totalled 251 thousand tCO_2e in 2019, with the highest emissions arising from Food and Drink (25%), Vehicle Fuel (14%), Health, Education, Other Public Services and Administration (10%), and Household Fuel (10%). Personal Flights account for 9% of residents' emissions, the fourth lowest among the National Parks.

The residents' emissions within the Broads Adjacent Gateway Settlements totalled 532 thousand tCO_2e in 2019, over double the amount within the Broads Executive Area. The breakdowns of the residents' emissions by category are very similar in the two regions, reflecting on similarities in the demographics and the associated consumption patterns.

The Broads Executive Area visitors' emissions totalled 198 thousand tCO_2e in 2019, comprised of 112,728 tCO_2e from travelling to and from the National Park, and 85,594 tCO_2e produced while in the National Park. The chart presenting visitor travel to and from the National Park indicates that GHG emissions are dominated by Vehicle Fuel (70%) and the embodied emissions associated with Car Manufacture and Maintenance (18%) for the vehicles they are using, with only 3% related to the remainder of public transport (excluding flights). Of the footprint of visitors while in the National Park, 52% is linked with Food and Drink, while Other Non-Food Shopping accounts for 12%, followed by Accommodation (9%), Boating (denoted as "Ferry Crossings and Cruises" in Figure 13, 7%), and Vehicle Fuel (6%).

In comparison, visitor emissions for the Broads Adjacent Gateway Settlements totalled 317 thousand tCO_2e in 2019, comprised of 178,951 tCO_2e from travelling to and from the area, and 137,554 tCO_2e while in the area. We apportioned all the emissions from boating in the Broads to the Executive Area, which resulted in a higher relative share of driving-related emissions for the visitors while in the adjacent region.

5.2.1. Food

When considering behaviour change around food at its simplest level, we look at the sustainable choices available to us when we buy food and drink from shops, and when we "eat out". The carbon footprint from food and drink in the Broads is considerable: for residents it is 62,930 tCO_2e (25% of the residents' total), and for visitors 44,878 tCO_2e (52% of the visitors' total); see Appendix Sections 10.5 and 10.6. "Buy local, eat local" has become a common aspiration among the more environmentally aware, along with eating seasonal fruit and vegetables, and varying traditional eating patterns to include more plant-based protein and meal choices (a "flexitarian" diet). It is also possible to use carbon intensity as the basis for choosing which meat to consume, with beef having the highest intensity, then in descending order: lamb, pork and chicken. As well as alleviating the burden on the environment, these kinds of dietary choices can also help individuals live healthier lifestyles. This is because red meat (beef, lamb, pork) as a source of protein and fat is typically a moderately-to-high calorie density food, and therefore needs to be consumed in moderation for a balanced healthy diet. Lean protein sources like turkey and chicken, on the other hand, have a low-calorie density. The amount of calories people eat and drink has a direct impact on weight, with obesity being a key risk factor for long term conditions in later life; see section 5.2.4.

Eliminating food waste can reduce an individual's food footprint by a further 12%, as well as saving them money. Forgoing fruit and veg grown in hot-houses or air-freighted to the UK in favour of local, seasonal varieties could deliver a 5% reduction in the total food footprint[31]. Ship-transported and frozen produce are also good low-carbon alternatives, as the emissions per item are far lower than for air-freighted goods [32].

In farming communities particularly, food production and consumption seem to be one of the hottest and most polarising topics, particularly given the potential impact on farming livelihoods and traditional lifestyles. We suggest that these complex topics would benefit from a collaborative approach between the agricultural industry and other land managers, together with the NHS and public health bodies, to achieve a transition pathway that is acceptable to all and that acknowledges the issues pertaining to food production in the UK. Farmers are facing a difficult socio-economic context as they try to respond to climate change, achieve biodiversity net gain and produce food, while also facing the challenge of an ageing workforce and workers opting to leave the industry.

Based on the science, the "National Food Strategy for England, Independent Review of England's food chain from field to fork" outlines a number of recommendations for government, with a formal response to be released in a white paper expected imminently[33]. The recommendations are targeted on achieving shifts in the national diet by 2032 (compared to 2019) to meet commitments aimed at improving health, climate and nature, including: a 30% reduction in meat consumption; a 30% increase in the consumption of fruit and vegetables; a 50% increase in fibre intake; a 25% decrease in consumption of foods high in fat, sugar and/or salt[34].

The Sixth Carbon budget (2021) supplementary "Agriculture and land use" report references "modelling by Oxford University of Public Health's Eatwell Guide, the Government's official guide to achieving a healthy and balanced diet", which provides some even more challenging proposals. It suggests "an average reduction in the consumption of meat by around 89% for beef, 66% for pork and 63% for lamb, and a 20% reduction in dairy products"[35].

The health improvements that accompany a more sustainable diet are highly relevant when considering the public health agenda and the public purse. Diet-related health issues are long-term conditions that place a considerable load on the NHS. Being overweight is associated with many of the most common long-term health risks, i.e. coronary heart disease, hypertension (high blood pressure), liver disease, osteoarthritis, stroke, type 2 diabetes and cancer. According to data from the Department of Health: "people with long-term conditions account for about 50% of all GP appointments, 64% of all outpatient appointments and over 70% of all inpatient bed days"[36], and treatment and care for people with long-term conditions is estimated to absorb around £7 in every £10 of total health and social care expenditure (Department of Health, 2012).

These discussions present significant challenges for the agriculture industry, regarding how to transition given the implications for livestock and food production in the UK. The National Farmers'

[31] Hoolohan, C. Berners-Lee, M., McKinstry-West, J. and Hewitt, C.N. (2013), "Mitigating the greenhouse gas emissions embodied in food through realistic consumer choices.." *Energy Policy* Vol. 63, p. 1065.
[32] Berners-Lee, M. (2010) "How Bad Are Bananas – The Carbon Footprint of Everything," p. 26-29.
[33] National Food Strategy Independent Review, The Plan Chapter 16: The Recommendations.
[34] National Food Strategy Independent Review, The Plan p.147.
[35] The Sixth Carbon Budget, "Agriculture and land use, land use change and forestry" section, p.21.
[36] Department of Health (2012) Policy Paper. "Long-term conditions compendium of Information: 3rd edition."

Union (NFU) is aware of these and has set the goal of reaching net zero greenhouse gas (GHG) emissions across the whole of agriculture in England and Wales by 2040[37]. Achieving this would require considerable reductions of emissions from livestock, and reduced use of synthetic fertilisers, while actively pursuing efforts to sequester carbon by creating woodland, restoring peatland within agricultural land, and implementing regenerative farming practices[38].

5.2.2. Homes and accommodation away from home

The "Home and accommodation" category accounts for 45,254 tCO_2e (18%) of the footprint of the Broads residents, and 8,241 tCO_2e of the visitors' footprint (10% of their footprint while in the National Park). We considered the following components: household fuel (24,587 tCO_2e; 10% of residents' total footprint), housing (13,155 tCO_2e; 5%), household electricity (6,338 tCO_2e; 3%), and accommodation away from home (1,175 tCO_2e; 0.5%); see Appendix 10.5 for further details. The single biggest intervention the public can readily make is changing their energy supplier (switching to one that is divesting from fossil fuels) and actively sourcing a supply derived from genuinely renewable energy, e.g. solar, wind, tidal and/or hydro-electric power. The public generally lack knowledge about where their household energy comes from, with many consumers not being able to distinguish between:

a) "green tariffs" backed only by cheap Renewable Energy Guarantees Origin (REGO), which have little impact on encouraging further expansion of renewable electricity generation, and
b) suppliers that are more genuinely investing in renewable electricity, and offering tariffs wholly backed by Power Purchase Agreements (PPAs).

Further improvements can be made by reducing energy use within homes. Options vary from lowering the thermostat temperature, to improving home insulation, to replacing oil or gas boilers with alternatives such as an electric heat pump. Moving off-gas-grid properties from oil heating to a heat pump has the potential to reduce emissions significantly, while offering householders a more convenient system. Increased electricity demand in rural areas can be met by local renewable energy production and/or improved grid connections, which are particularly relevant if the locals will be using electric heat pumps and electric vehicles. We recognise that affordability is always a factor, and depends on individuals' financial means; however, a variety of home energy efficiency measures can be installed at different levels of cost, often met in part by access to Government grants or other funding.

5.2.3. Travel

Travel is responsible for the biggest share of the total footprint of the Broads visitors (126,417 tCO_2e; 64%), including the entire footprint of travelling to and from the National Park and 16% of the visitors' emissions while in the Park. The majority of this travel footprint comes from fuel, 84,504 burned in private vehicles, (84,504 tCO_2e; 43% of visitors' total), vehicle manufacture and maintenance (21,395 tCO_2e; 11%), personal flights (10,412 tCO_2e; 5%), as well as comparatively small amount from the use of boats on the National Park's waterways (3.2%), followed by trains, buses and other transport (2%).

[37] National Farmers Union (2021), "Achieving Net Zero, Farming's 2040 goal."
[38] The Sixth Carbon Budget, "Agriculture and land use, land use change and forestry" section.

Travel accounts for 30% of the residents' GHG footprint. In considering residents' travel we looked at personal flights (23,15 tCO_2e; 9% of residents' footprint), vehicle fuel (33,853 tCO_2e; 13%), vehicle manufacture and maintenance (9,022 tCO_2e; 4%), trains, buses and other transport (5,729 tCO_2e; 2%), and ferry crossings and cruises (3,132 tCO_2e; 1%). See Appendix 10.5 for further details.

Car travel is the single largest contributor to the overall footprint of the Broads (33% of the combined footprint of the residents and visitors).

All National Park users – whether visitors travelling to and from, or residents travelling locally – could benefit from work undertaken with local authorities to promote the use of public transport. This could explore mechanisms to help fast-track electrification of public-use vehicles such as buses, taxis and hire vehicles, and to influence Government to support the transition from diesel-powered to electric trains.

The Broads National Park offers unique opportunities to consider using the waterways as a means of public transport by exploring the potential for water bus services, if these are not already in place. A UK example of busy waterways offering a valued mode of transport – for both visitors and workers – is Transport for London's "Thames Clippers River Bus" service, which operates 7 days a week with vessel speeds exceeding 30 miles per hour. Another example is the Windermere Ferry, which is limited to 10 nautical miles per hour. However, use of the Broads' waterways is constrained by the speed limit of 3-6 mph in force; this is likely to be too slow for journeys to work, meaning that trains may be a better option for commuters.

Previous considerations by the Broads Authority have indicated that the most feasible target market for Boat Buses could be tourists; however, the final mile poses a challenge for visitors using public transport. Local knowledge suggests that one option might be the Wroxham - Horning - Ranworth - St Benets route, with a 2-hour cruise time. Another option might be to explore a) the capability of the yards at Wroxham to offer a service linking the train station to the Hoveton Great Broad Nature Trail, and b) the level of demand for such a service. Exploring opportunities to link boat and/or train services to cycleways could yield a wider range of travel options, if provision can be made to carry bicycles on public transport. Electric bicycle rental schemes might also be worth considering, and would make cycling more accessible for a broader range of age groups and capabilities.

In terms of vehicle fuel use, variations in residents' annual mileage, and in vehicle size (both residents and visitors) make a big difference to carbon footprints. If someone drives 10,000 miles in a year, the associated emissions are around 4.5 tCO_2e if their vehicle is a small petrol run-around, 5.6 tCO_2e for a medium family-size car and 8.3 tCO_2e for a large car. It is also worth noting that while car travel can have a high footprint if the driver travels alone, it becomes a far lower-carbon option per person when a car is full, e.g. transporting a family of 4 or 5.

The vehicle type also affects the GHG impact. A trip from Manchester to London in an average petrol car would produce 0.11 tCO_2e of emissions, including the embodied emissions of the vehicle and its fuel. For the same journey an ordinary hybrid vehicle produces 0.08 tCO_2e, and for a plug-in electric hybrid car the figure is 0.07 tCO_2e. The average diesel car's greenhouse gas emissions are slightly lower than for petrol, at 0.10 tCO_2e, but bear in mind that while diesel vehicles produce less CO_2e per mile and deliver better fuel economy than petrol vehicles, they may perform less well in terms of soot and nitrogen oxide production. Exhaust fumes are a key contributor to air pollution, so the

cleanest choice is an electric car, which would also produce the lowest emissions: 0.04 tCO_2e[39]. We note that the latter estimate accounts for the current average carbon intensity of the UK electricity grid and the embedded carbon footprint of manufacturing the battery (largest embedded footprint of manufacturing electric vehicles), both of which are expected to come down as electricity generation and other related industries decarbonise.

In the UK in 2019, 10% of all new cars and vans purchased were electric[40]. The Committee on Climate Change (CCC) has recommended that 60% of all new cars and vans sold should be electric by 2030, and the Government recently announced a ban on selling new petrol, diesel or hybrid cars in the UK from 2030[41]. As the Broads has a more affluent demographic profile on average, the typically cost-prohibitive entry into owning an electric car is more likely to be within reach for some residents in the area. Aside from switching to an electric car, there are other choices that everyone can make to reduce vehicle emissions:

- The average person walks 210 miles per year[42]. Walking an additional 2.5 miles per week for local journeys, e.g. visits to local shops or the school run, could save 1.3 tCO_2e in a year and bring co-benefits for health.
- Emissions would be reduced if more people travelled more often by bicycle, perhaps on an electric bike which uses just 5% of the energy per mile of an electric car.
- Driving outside the rush hour avoids prolonged time at low vehicle speeds: an average car crawling five miles each way emits 22 $kgCO_2e$ a day, which over a year would equal 4.8 tCO_2e.
- When replacing an ageing medium family-size car, downsizing to a small petrol car would save 1.1 tCO_2e a year.
- When replacing an ageing large car, downsizing to a medium family-size petrol car would save 2.7 tCO_2e a year.
- If affordable, replacing a large car with an electric hybrid car would save 4.49 tCO_2e a year. Switching to a fully electric car would provide further footprint reductions.

It is not possible to identify from this assessment whether visitors are using their own vehicles or hire cars, but where hire cars are used it may be beneficial for the National Park to work with local providers to fast-track electrification of vehicles. In either case, increasing the availability of electric car charging points could encourage visitors to travel by electric vehicle.

The other main contributor to the travel footprint is flying. One approach that could have the single biggest impact in reducing this travel footprint could be to step up messaging that encourages the public to fly less, and suggest in particular that they reduce “casual flying” for short-haul trips where other means of transport are feasible, e.g. travel by train, bus and/or boat.

[39] Like all other road vehicles, electric cars emit particulates from tyres and breaks. Compared to tailpipe exhaust, these emissions mostly impact air quality rather than on climate. A bigger average weight of electric cars relative to conventional cars, driven by the battery, leads to marginally higher emissions from tyres. On the contrary, regenerative breaking into the battery means electric cars have lower emissions from breaks compared to conventional cars.

[40] https://www.ft.com/content/d57efdf6-ffad-11e9-be59-e49b2a136b8d https://www.ft.com/content/d57efdf6-ffad-11e9-be59-e49b2a136b8d.

[41] https://www.bbc.co.uk/news/science-environment-51366123549814 25

[42] Department of Transport (2019)), “National Travel Survey (England): 2018”.

5.2.4. Everything else

The remainder of the residents' footprint consisted of: public services including health and education (24,686 tCO_2e; 10% of residents' footprint), other bought services (17,490 tCO_2e; 7%), other non-food shopping (17,712 tCO_2e; 7%), leisure, recreation and attractions (4,587 tCO_2e; 2%), and waste, water and sewage (3,570 tCO_2e; 1%). The remainder of the visitors' emissions arose from: water, waste and sewerage (3,121 tCO_2e; 4% of the footprint while in the area), other non-food shopping (10,487 tCO_2e; 12%)), other bought services (4,132 tCO_2e; 5%), and leisure, recreation and attractions (1,047 tCO_2e; 1%).

The biggest single factor in the "everything else" category is health and education. As discussed in Section 5.2.1, there can be a causal relationship between food, obesity and long-term health conditions. The public health "prevention" (of illness) agenda is therefore also important in helping National Parks and Local Authorities to decarbonise, as well as benefiting health and well-being.

We suggest that the role played by the National Parks in enabling the public to access green/blue space – known to support mental and physical well-being – should not be underestimated. Recent research by White *et al.* (2019) identified that the amount of recreational time individuals need to spend in natural environments in order to gain self-reported health and well-being benefits is at least 120 minutes per week[43]. White *et al.* (2010) also suggest that green space combined with aquatic blue space (water) offers enhanced perceived benefits, which can be incorporated into landscape design and opportunities for improving public accessibility[44].

Summary of key findings of exposure to green space to gain health and wellbeing benefits (White et al. 2010 and 2019)

Threshold ≥ 120mins green space exposure per week = health and wellbeing benefits.

Results suggest it does not matter how "threshold" achieved per week.

E.g.

4 x 30 mins = 120 mins
6 x 20 mins = 120 mins

Psycho-physiological benefits gained from sitting passively in natural settings.

Scenes with water are associated with greater positive affect and higher perceived restorativeness than those without water.

The next biggest factors to consider in the "Everything else" category are other bought services and other non-food shopping. Simply put, the choices we make around which goods and services we purchase count towards our carbon footprint, due to the amount of fossil fuels used in production, or the air/road miles associated with those products and services. Making different choices when procuring goods and services can make a notable difference in reducing the resulting carbon costs.

Encouraging a circular economy within the National Park and its neighbouring Local Authorities may help reduce the emissions associated with goods and services. A circular economy is a model of

[43] White *et. al.* (2019) "Spending at least 120 minutes a week in nature is associated with good health and well-being." *Scientific Reports*. 9:7730 https://doi.org/10.1038/s41598-019-44097-3.

[44] White, M.P., Smith, A., Humphryes, K., Pahl, S., Snelling, D. and Depledge, M. (2010) "Blue space: the importance of water for preference, affect and restorativeness ratings of natural and built scenes." *Journal of Environmental Psychology* 30, 482–493.

production and consumption that involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible, rather than throwing them away and buying new.

In terms of waste, water, and sewerage, the National Park Authority is well-placed to support partners in strategic planning to deliver multi-environmental benefits, especially given the new Environment Act (2021) and the role the National Park Authority plays in processing and scrutinising planning applications. It is important to consider opportunities for:

- Mitigating the impact of air pollution
- Supporting healthy river basin catchments
- Supporting and restoring nature
- Protecting endangered species and fragile habitats
- Highlighting and improving the relationship between people and the landscape

Another issue to bear in mind: interventions to "slow the flow" in flood risk areas. When choices are made around nature-based solutions in upstream areas (such as the Broads Catchment), or civil engineering solutions downstream which are likely to use cement in their construction, we suggest that both cost and carbon benefits are considered when undertaking option appraisals.

5.2.5. Comparison of residents' GHG emissions with UK national average by category

Figure 18 compares then average per capita footprint of the Broads residents' footprint with the UK national average.

5.3. Industry assessment

This section presents the GHG emissions from industry but first outlines the scope of the industry assessment given that two approaches were used, as explained in Section 5.3.1.

5.3.1. Scope of industry assessment

Aside from the footprint of residents and visitors, we also include, for perspective, a rough assessment of the footprint of industries and their supply chains. We use data from the Office for National Statistics' Inter-Departmental Business Register (IDBR) for business turnovers in Census Output Areas (COA). This is used rather than Local Authority Gross Value Added (GVA) data since it is more geographically specific (see Appendices 10.7.1 to 10.7.3). Please note that the reported turnover data does not necessarily reflect on the actual geographical distribution of locations where business revenue is being generated.

Because of confidentiality constraints regarding the ONS IDBR data, we also had to include all COA geographies overlapping with the landscape's boundary, leading to marginal overestimates of the total turnover and the resulting industry footprint within the landscape. The industry footprint assessment is comparatively crude since COA-level business turnover data has only fifteen broad sectors, and the footprint calculation is based on the associated industry-specific carbon intensity averages for the UK. The use of UK-average carbon intensities could have a particular effect on the footprints for agriculture and forestry, because these sectors are known to have unique features across most National Parks and AONBs.

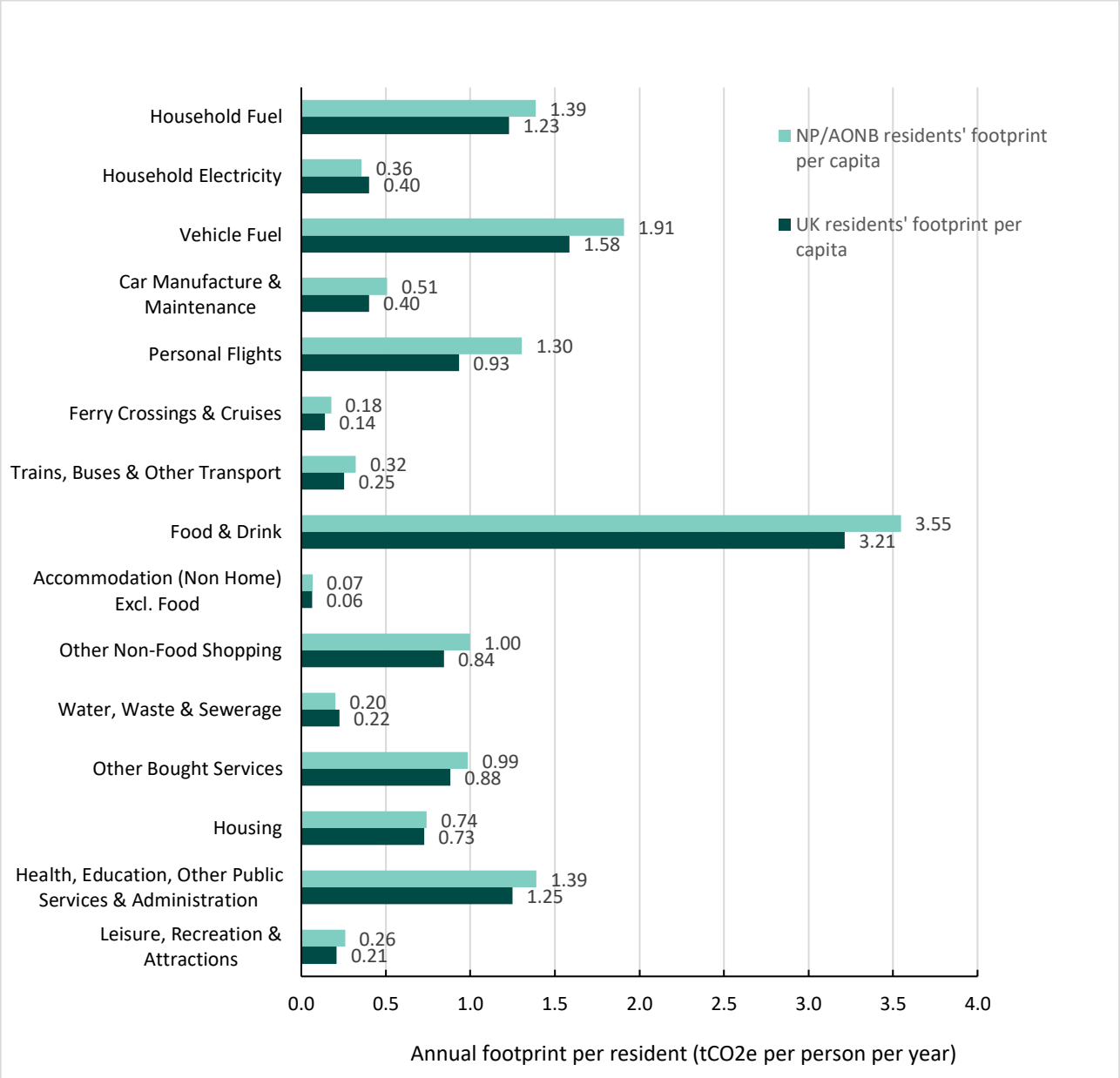


Figure 18: Residents' GHG footprints compared between the Broads average and the UK national average, by category

Please also note that this assessment overlaps with our more detailed analysis of resident and visitor emissions, since it is not feasible to eliminate double-counting arising from sales by local businesses to residents and visitors.

5.3.2. Industry sector analysis

The ONS UK Standard Industrial Classification (SIC) Hierarchy is used in formulating data analysis by the UK government to assess economic activity[45]. For transparency we include the IDBR broad industry group structure and see how this compares with the SIC (2007); see Appendix 10.7.1. When interpreting the results, please note that the IDBR production category includes mining, quarrying and utilities (Division 05/09, 35/39); added together with manufacturing (Division 10/33). Similarly,

[45] https://onsdigital.github.io/dp-classification-tools/standard-industrial-classification/ONS_SIC_hierarchy_view.html

the SIC (2007) code “arts, entertainment and recreation” is aggregated to include: “Other service activities; activities of households as employers; undifferentiated goods-and-services-producing activities for own use; and activities of extraterritorial organisations and bodies”, Division 90/99 respectively.

Please note also that the IDBR national dataset suppresses data under seven categories, so an incomplete picture may apply to:

023 : Gathering of wild-growing non-wood products.
071 : Mining of iron ores.
072 : Mining of non-ferrous metal ores.
531 : Postal activities under universal service obligation
642 : Activities of holding companies
653 : Pension funding
843 : Compulsory social security activities

We now consider the results for industry-related GHG emissions in the Broads Executive Area, which total 341,896 tCO_2e (Figure 19). Industry-related flights are estimated to account for 6,781 tCO_2e of the total footprint but are not separately categorised. Production is the largest source of GHG emissions (148,187 tCO_2e; 43%); followed by Agriculture, forestry & fishing (60,839 tCO_2e; 18%) and Transport & storage (36,290 tCO_2e; 11%). See Appendix 10.7.2.

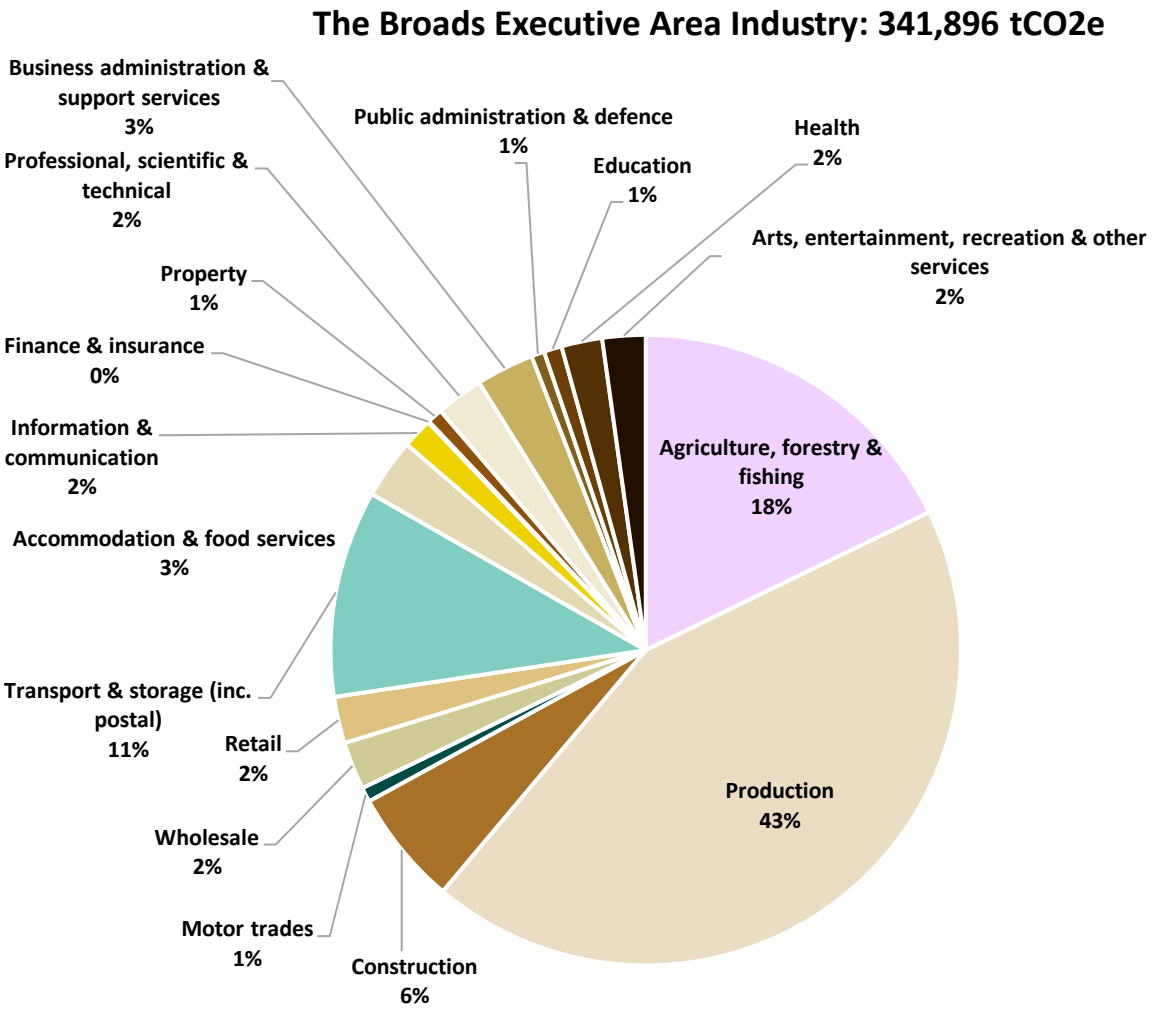


Figure 19: The Broads Executive Area consumption-based GHG emissions for Industry by percentage (Repeat of Figure 5)

We also discuss the industry footprint of the Broads Adjacent Gateway Settlements region to aid the National Park's conversations with Local Authority partners and Local Enterprise Partnerships. This footprint is estimated to be 417,975 tCO_2e (Figure 20). Production is the largest source of GHG emissions (194,102 tCO_2e; 46%), followed by Agriculture, forestry & fishing (64,840 tCO_2e; 16%), and Transport & storage (38,101 tCO_2e; 9%). See Appendix 10.7.2.

Each of the main contributing categories for both the Broads Executive Area and the Broads Adjacent Gateway Settlements regions are discussed below.

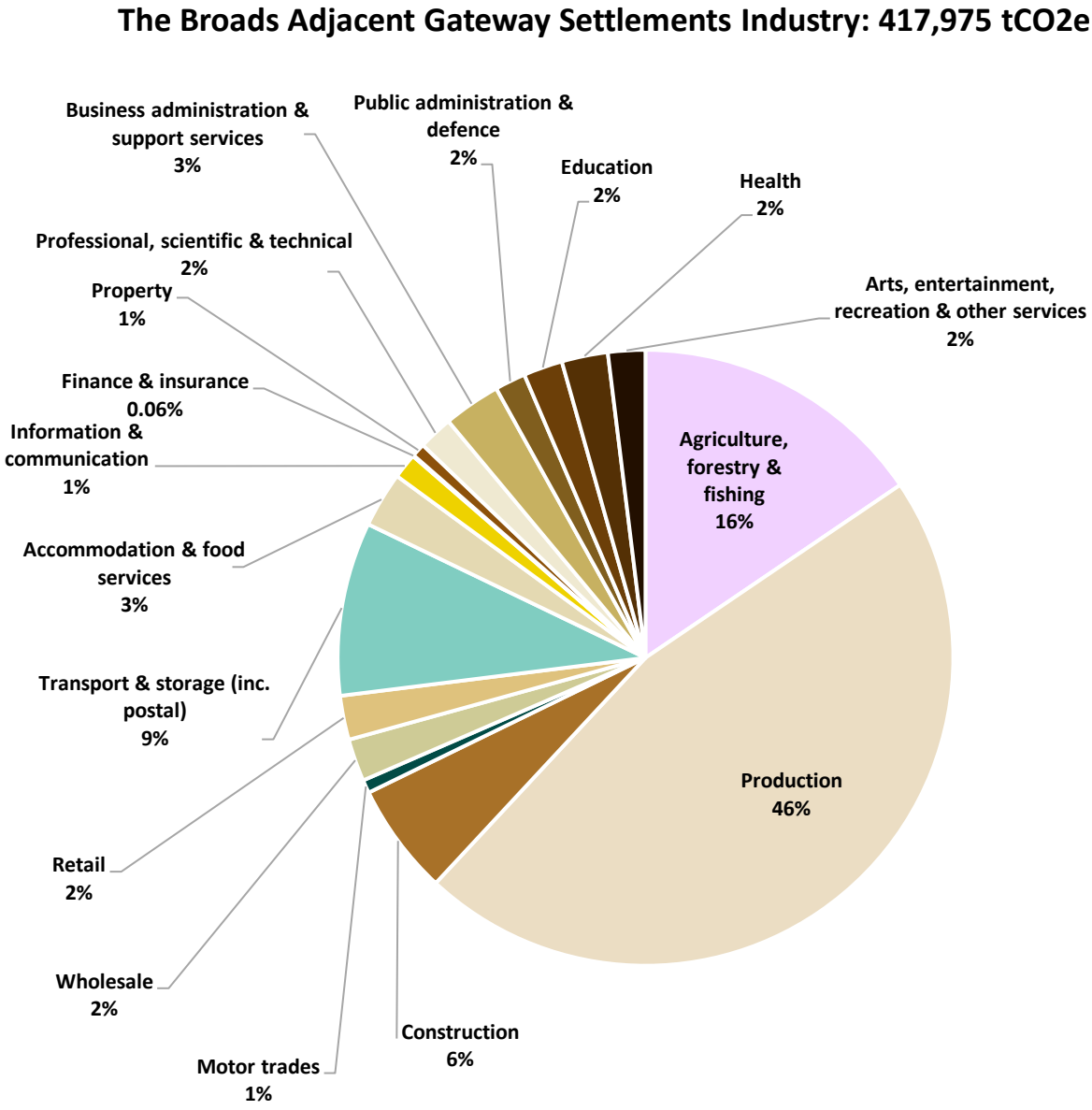


Figure 20: The Broads Adjacent Gateway Settlements consumption-based GHG emissions for Industry by percentage.

Production

Production (referring to manufacturing industries) plays an important role in the National Park (148,187 tCO_2e; 43% of the estimated total industry footprint in the Executive region), but analysis of the adjacent Broads area suggests an even greater footprint (194,025 tCO2e; (46% of the industry footprint in the Adjacent region) is generated by production on its neighbouring borders. It must be noted that there are inevitable overlaps between the two regions when it comes to industry data since it is being soused from the course COA geographies instead of the postcodes (which are distinct in each of the two regions). While the overlaps cannot be eliminated until a more spatially granular data becomes available, we suggest that manufacturing as a sector should be one of the top industries to decarbonise in the wider area. This is where Local Enterprise Partnerships may

wish to focus efforts by encouraging companies to undertake assessment of their Scope 1, 2 and 3 GHG emissions and to develop credible roadmaps to reduce them.

Agriculture

The second top industry for GHG emissions in the Broads Executive Area is agriculture, forestry and fishing (60,839 tCO_2e; 18%). This sector is also the second biggest source of emissions in the adjacent region (64,840 tCO2e; 16%). The issues pertaining to this industry are discussed in detail under 3.2 (Agricultural landscape), 5.2.1 (Food) and 5.2.4 (Everything else). However, unique to the Broads is the traditional and important local industry of reed and sedge cutting for thatching roofs that are distinctive for conservation of local heritage and buildings, which also has implications for sustainable land management[46]. More generally, the Sixth Carbon Budget (2020) "Agriculture and land use, land use change and forestry" report suggests multiple opportunities for reducing emissions, as follows.

The initial focus relates to low-carbon farming practices, including livestock measures such as selective breeding, increased milking frequency, changes to livestock diet to decrease enteric methane emissions, and improved livestock health. The second focus is on soil improvement, achieved through the use of legumes, cover crops and grass leys. The third focus is on waste and manure, including the use of anaerobic digestion and covering slurry tanks.

The Sixth Carbon Budget also discusses reducing numbers of cattle, sheep, pigs and poultry through technological and dietary changes, leading to smaller overall areas grassland and cropland, as well as shifting to new hydrogen technology. JCB, for example, have developed a prototype hydrogen tractor, so there may be benefits in the LEP collaborating with manufacturers who may be able to assist such a transition. In Norfolk the Norfolk Climate Change Partnership is carrying out a study "Sustainable Hydrogen Infrastructure For Transport (SHIFT)". This project is assessing the feasibility of opportunities for transport decarbonisation with low-carbon hydrogen in Norfolk, focusing on refuse collection vehicles in the near term.

Moving some agricultural production to greenhouses and vertical urban farms, collectively referred to as indoor horticulture, is also likely going to be required to make the UK self-sufficient in terms of food while enabling large-scale nature recovery programmes. Such technologies have been piloted successfully by other countries including the Netherlands, which has become a second largest food exporter globally despite the comparatively small land area. Changes to a more plant-based diet will go hand in hand with the recommended scaling up of indoor horticulture. In terms of innovations, options such as lab-grown meat and insects as new sources of protein should also be on the table.

Other opportunities relate to improving productivity and efficiency, with a headroom to increase average crop yields from around 8 t/ha at present to around 11 t/ha. However, climate change is likely to pose additional risks to yields. The report suggests land management measures such as increasing soil quality, smaller tillage, nutrition and pesticide management, and opportunity mapping. Innovations in breeding are also discussed along with increasing stocking density. Another key suggestion is increasing paddock grazing to 80%, which improves the quality of grass and

[46] The Broads Authority (2021), "Action Plan for the Reed and Sedge Cutting Industry."

enhances sequestration of carbon in the soil. The report suggests that only 50% of the grass produced is actually eaten.

Another clear and significant intervention that would reduce requirements from agriculture, alongside improved productivity and dietary changes, would be measures to reduce food waste, amid data showing that 3.6-13.6 million tonnes of UK food is wasted per year.

Transport and storage

The Broads' third-largest industry in GHG terms is transport and storage, which is estimated to account for 11% of emissions within the Broads Executive Area and 9% within the adjacent region. Due to the geographical area of the Broads, and the National Park's role as a Harbour and Navigation Authority, this is unsurprising. It may be worthwhile giving consideration to both surface transport and shipping.

The Sixth Carbon Budget (2020) "Surface transport" report shows that this type of transport comprised 22% of the total production-based UK GHG emissions in 2019. According to the report, "these are primarily tailpipe emissions from fossil-fuelled road vehicles, with cars (68 $MtCO_2e$), vans (20 $MtCO_2e$) and heavy-goods vehicles (HGVs) (19 $MtCO_2e$) the largest contributing types." Decarbonisation requires a sector-wide transition to vehicles that produce zero tailpipe emissions. The report suggests transitioning to battery-electric vehicles for cars and vans. For HGVs, options include battery-electric vehicles, hydrogen fuel-cells and electric road systems. Continued electrification of the rail network, together with hydrogen, battery-electric and hybrid trains, is also required to decarbonise the transport sector.

In contrast, the Sixth Carbon Budget (2020) "Shipping" report suggests that shipping emissions accounted for 3% of the total production-based UK GHG emissions in 2018. Mitigation options include improvements in vessel efficiency, and use of zero carbon fuels (principally ammonia made from low-carbon hydrogen and air separation) to displace fossil marine fuels. These typically require either engine retrofits or new propulsion and energy storage systems and have zero accounting CO_2 emissions on combustion. The report also suggests fleet efficiency improvements may be achieved via a combination of slow steaming, operational optimisation, ship hull design, engine efficiency improvements, onboard renewable power generation (e.g. solar), and wind propulsion systems. Electricity is typically employed in a limited number of niche hybrid and full electric propulsion vessels (using onboard batteries and motors), and more widely used to provide shore power, i.e. ships temporally connecting to grid electricity to power onboard systems when docked in port.

Construction

We estimate that construction is the fourth largest GHG-emitting industry in the Broads Executive Area and the adjacent region (both at 6% of the respective totals). The Sixth Carbon budget (2020) "Manufacturing and construction sector" report showed that GHG emissions from this sector contributed 12% of the total production-based UK GHG emissions in 2019. Opportunities for interventions to reduce construction-related emissions include:

- Resource efficiency: reducing the flow of materials through the economy, and using products more efficiently (and for longer), can reduce manufacturing emissions as part of a shift towards a more circular economy.

- Material substitution: manufacturing emissions can be reduced by switching from high-embodied-carbon materials to low-embodied-carbon materials. Measures include using wood in construction and using alternatives to clinker (e.g. fly ash) in cement.
- Energy efficiency*:* using energy more efficiently reduces operating costs while cutting emissions. The energy efficiency measures that we include are "low-regret" actions that often reduce fuel costs significantly. Measures include process and equipment upgrades, installing/improving heat recovery systems, and clustering/networking with other sites and businesses to efficiently utilise waste heat and other by-products.
- Fuel switching in manufacturing*:* hydrogen, electricity and bioenergy can all be used to meet demands for heat, motion and electricity, thus removing the need for fossil fuels and reducing GHG emissions.
- Carbon Capture and Storage (CCS): CCS can be used to capture CO_2 produced by larger industrial point-sources and transport it to a CO_2 storage site, thereby reducing emissions to the atmosphere[47].

IDBR and GVA based emissions comparison

We undertook a comparison between IDBR data and GVA data, as we know that economic reporting often uses GVA as the primary measure upon which many LEPs base their workforce planning; see Appendix 10.7.3. When the GVA dataset is compared to IDBR, this indicates a potential under-reporting of GVA based emissions from agriculture, production, construction, wholesale, transport and storage, accommodation and food services, information and communication, property, professional, scientific and technical business administration, and arts, entertainment and recreation (Figure 21). The Broads Authority may wish to discuss this with Local Enterprise Partnerships in the area.

[47] The Sixth Carbon Budget (2020), "Manufacturing and construction" section, p. 6-11.

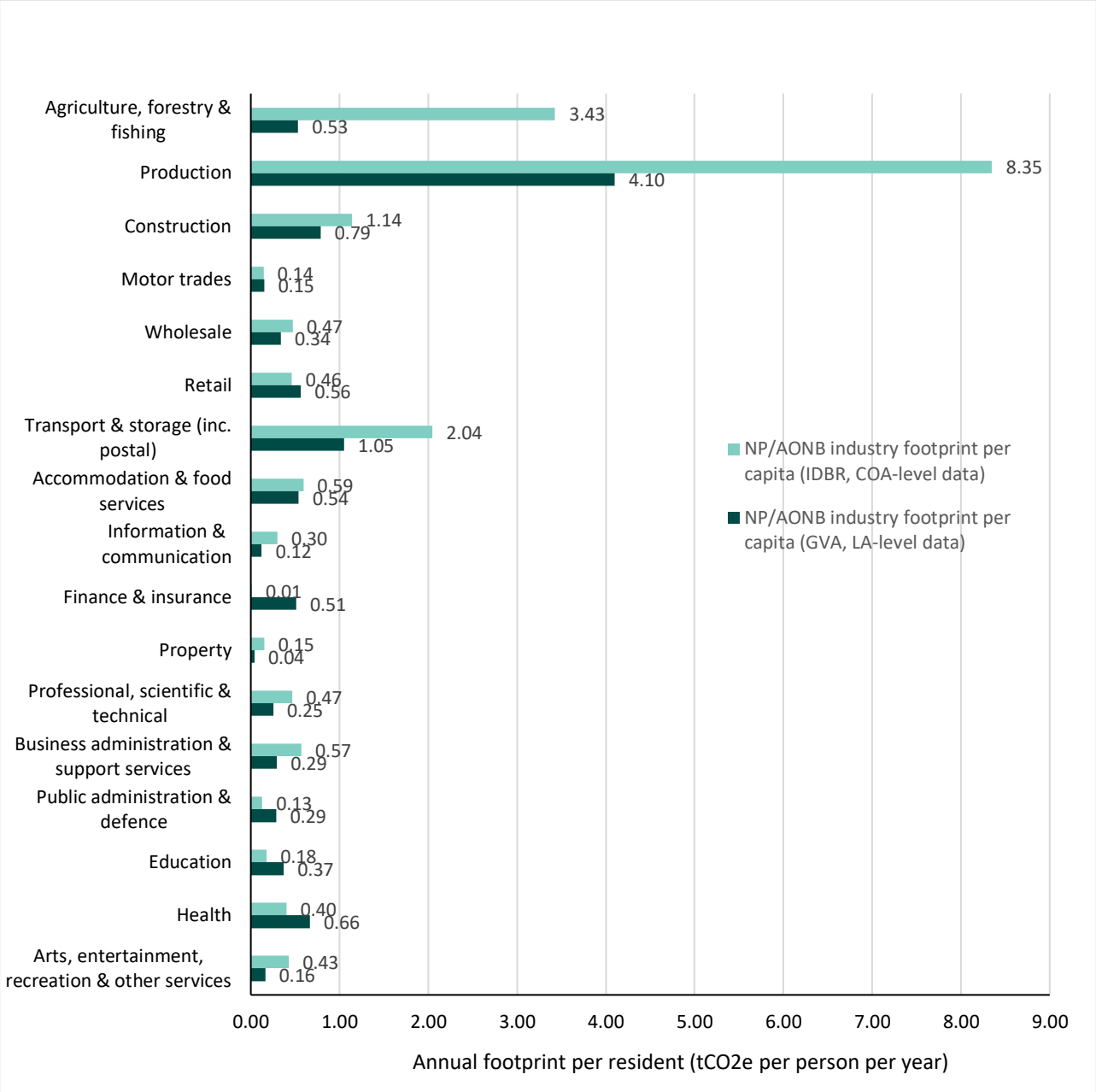


Figure 21: The Broads Executive Area industry footprint estimates: IDBR vs GVA, by sector

5.3.3. Energy-only industry analysis

This analysis is a subset of the industry carbon footprint estimate. Energy makes up 13% of emissions from industry (45,719 tCO_2e). Table 2 shows the breakdown of industry emissions from electricity and fuels in the Broads Executive Area.

Table 2: Energy-only industry (subset of industry) – The Broads Executive Area

Industry Electricity	16,079 tCO_2e
Industry Fuels Excl. Road	24,227 tCO_2e
Industry Road Fuels	5,413 tCO_2e
Total	**45,719 tCO_2e**

5.3.4. Large emitters analysis

As a further component of the industry GHG footprint analysis, the BEIS Pollution Inventory (2018) enables us to identify specific large emitters within each UK National Park (see Appendix 10.7.4). For the Broads Executive Area, the large emitter is:

- British Sugar Plc (Cantley): 120.672 $ktCO_2$ (Scope 1 only)

This amounts to around 35% compared to the estimated total industry emissions in the Broads Executive Area. We note that the estimated total IDBR-based industry footprint for the Broads Executive Area (341,896 tCO_2e) excludes the COA region hosting the Cantley factory, as well as all large emitters in the vicinity of the National Park's boundary. Furthermore, unlike the reported Cantley emissions, our total industry footprint estimate includes Scope 2 and 3 emissions. The two footprints should therefore be treated separately. The Broads Authority may choose to engage with the Cantley factory, either directly or through the relevant Local Authorities, to promote carbon assessment of Scope 1, 2, and 3 GHG emissions, as well as carbon reduction planning with a view to a net zero target[48].

We also identify where IDBR data has been suppressed the ONS's own software, which means a null value is returned for confidentiality reasons. Where this poses an issue for the reliability and validity of the results, these issues are discussed, and the missing data is approximated using LSOA-based and UK-based business turnover datasets (also made available to us by the ONS). In the case of the Broads Executive Area, none of the IDBR data was found to be suppressed.

5.3.5. Comparison of annual industry footprint with UK averages

It may be helpful for the National Park to compare itself with the UK national average for each industry category. This helps to identify patterns and pinpoint where it would be beneficial to focus partnership-working with Local Authorities. The results (Figure 22) show higher-than-national averages for: Agriculture, Forestry and Fishing, Production, Construction, Wholesale, Retail, Transport and Storage, Accommodation and Food Services, Information and Communication, Professional, Scientific and Technical, Business Administration, Health, and Arts, Entertainment and Recreation.

As background to influencing change, the UK Government enacted legislation on the 1st of October 2013 making it mandatory for the UK's largest quoted companies to report their GHG emissions (Statutory Instrument (SI) 2013/1970:5). In 2018, this SI 2013 was amended to include "emissions, energy consumption and energy efficiency action by quoted companies" (SI 2018/1155, Part 6) to reflect the true impact of their operations[49]. This was extended to all large companies, including the public sector. Due to this legislation, one should expect all large organisations to be in the process of assessing their full GHG emissions and preparing carbon reduction plans aimed at reaching net zero. However, large businesses fall under the new statutory reporting requirements and are new to carbon accounting may find the process challenging, so joined-up approaches may be helpful, particularly in the public sector.

[48] UK local authority and regional carbon dioxide emissions national statistics: 2005-2018

[49] The Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013 (SI 2013/1970) (Strategic Report Regulations 2013), enacted from 1st October 2013 to the present.

Some organisations are attempting to encourage a sector-wide approach, e.g. the National Farmers Union and water utility companies. It is recognised that there is much goodwill in industry, with many leaders and individuals in organisations concerned about the climate emergency and striving to make their business more sustainable. However, we also recognise that capacity and capability often pose challenges to medium and small enterprises that have more limited resources.

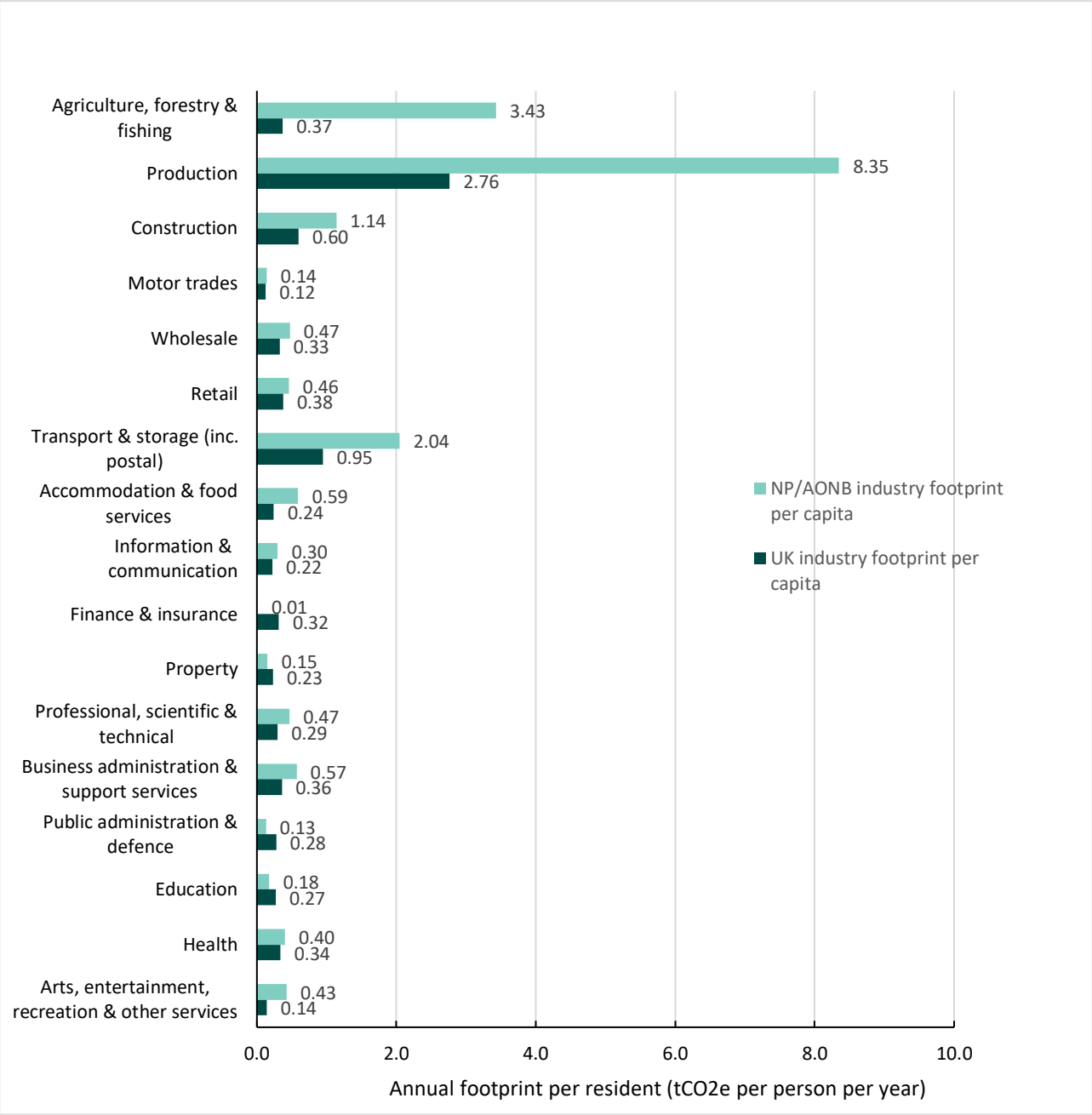


Figure 22: The Broads Executive Area industry GHG emissions compared with UK national average, by sector

5.4. Analysis of emissions from through road traffic and major roads

The analysis of the impact of through traffic has been included at the request of several National Park Authorities and Local Authorities for AONBs (see Appendix 10.8). Through traffic refers to

vehicles passing through the National Park or AONB without visiting, regardless of their origin and destination. Its footprint is estimated by comparing total traffic point counts with pump-level fuel sales within each National Park or AONB, along with assumptions about commuting in out of the area. The estimate represents the emissions from through traffic that occur within the geographical boundary of the National Park or AONB, unlike the total driving footprints of the residents and visitors that mostly occur outside of the boundary. The purpose of reporting the through traffic emissions is to show how much of the geographical footprint due to road traffic within the National Park or AONB boundary is not related to living in or visiting the area, which could be used to support new road electrification infrastructure as well as public transport.

For the Broads Executive Area, estimated total through traffic emissions from cars, buses, motorbikes, vans and lorries are **119,029 tCO_2e,.** This data is **not included** in the residents', visitors' or industry footprints.

We also report emissions from smaller and larger subsets of selected A roads, which carry elements of through traffic as well as traffic from residents, visitors and industry. The selected roads assessed for the Broads Executive Area are the A47, A1064, A146 and A143 (Figure 7). The estimated footprint of these roads within the Broads geographical boundary is 138,683 tCO_2e per year across all vehicle types. This amounts to around 55% compared to the total footprint of the residents.

5.5. Land use emissions

The land use sector differs from other sectors in the Greenhouse Gas Inventory in that it contains both sources and sinks of greenhouse gases. The sources, or emissions to the atmosphere, are given as positive values; the sinks, or removals from the atmosphere, are given as negative values (see Table 3). Our definition of the land use sector includes emissions from livestock (mostly methane), synthetic fertiliser use (mostly N_2O), degrading mineral and organic soils (peat) (mostly CO_2), and lost biomass (CO_2), as well as carbon sequestration in soils and biomass through woodland creation, peatland restoration and regenerative agriculture practices. The net land use GHG flux is therefore split into CO_2 and non-CO_2 components. Our land use sector overlaps with the "land use, land use change and forestry" (LULUCF) sector for national GHG reporting in line with the IPCC guidelines. However, LULUCF excludes emissions from livestock and fertiliser use, which are reported separately as part of the "agriculture" sector; the latter is different from our IDBR "agriculture, forestry and fishing" industry sector.

Table 3: Land use GHG emissions – The Broads Executive Area

Land use CO_2	83,880 tCO_2e per year
Land use non-CO_2	62,356 tCO_2e per year
Total: Land use	**146,236 tCO_2e per year**

Land use data is prepared by the Department for Business, Energy and Industrial Strategy (BEIS) through three subcontractors – Ricardo Energy & Environment, Centre for Ecology and Hydrology, and Forest Research – in accordance with the requirements to report UK Greenhouse Gas Emissions for the United Nations Framework Convention on Climate Change (UNFCCC). There is a risk that future improvements to the methodology for reporting land use GHG emissions might shift the

sector from a net sink to a net source of emissions, as indicated within the Sixth Carbon Budget (2020).

Although the latest (BEIS) land use emissions estimates (2019) are more accurate than in previous years, they remain subject to considerable uncertainty. This is due to an evolving methodology and a process to refine the measurement of emission factors for UK peatlands, attempting to take into account transitions from heavily modified peatlands (forested land, cropland, grassland, peat extraction, eroding bog) and semi-natural peatlands (heather-dominated and grass-dominated bogs). Peatlands in their semi-natural state may be near-natural, modified, or rewetted. The estimates for CO_2 emissions in the form of dissolved organic carbon (DOC) use Tier 1 emission factors, and therefore are the least robust of all (IPCC 2014). Tier 2 emission factors for the UK-relevant peat condition categories were subsequently developed by Evans *et al.* (2017), providing estimates for "particulate organic carbon" (POC) emissions, as well as direct CO_2 emissions. The Tier 2 estimations add more granularity and are country-specific, being tested for robustness using at least four different study locations considered reliable enough to replace Tier 1 values. The CARBINE Tier 3 carbon accounting model developed by Forest Research was employed to derive the emission factor for forested peatland between 1990 and 2019, and was tested using field data[50]. For the full set of assumptions made in order to estimate peatland emissions in the National Parks using the latest (2019) land use emissions data released by BEIS, please see Table 11 in Appendix 10.9.7 (Table A.3.4.28 in the BEIS methodology annex).

In relation to the "family" of National Parks and AONBs, it is worth noting four key reports which outline implementation of land use policy, namely:

- The 25 Year Environment Plan[51]
- Climate Change Committee (2020) – Land Use: Policies for a Net Zero UK
- Climate Change Committee (2020) – The Sixth Carbon Budget: Agriculture and land use, land use change and forestry
- England Peatland Action Plan (2021).

Given that only 13% of England's peatlands are estimated to be in a near natural state at present, the Peatland Action Plan explicitly states that: "We will support National Parks and Areas of Outstanding Natural Beauty teams to deliver significant amounts of peatland restoration over the next 10 years[52]." The next section reflects upon this guidance in terms of target setting.

5.6. Factors for consideration in LULUCF target setting

To increase reliability of the land use data, the Broads Authority has undertaken its own GIS assessment of its key habitat types by area, as described in Section 3.2, which provides baseline area data for the target setting discussed in Section 6. Reflecting upon the Sixth Carbon Budget (2021) we identify hectare per year targets for creating native broadleaf / mixed woodland, planting new productive coniferous woodland, restoring peatland, adopting agroforestry practices and increasing the extent of hedgerows (both of which improved grassland and cropland), adding legume species to improved grassland, and adopting winter cover cropping for cropland.

[50] Ricardo Energy & Environment, UK NIR 2020 (Issue 1): "UK GHG Inventory 1990-2019," Annex p. 854.
[51] HM Government (2018), "A Green Future: Our 25 Year Plan to Improve the Environment."
[52] UK Government (2021), "England Peat Action Plan", p.12.

Please note that the LULUCF GHG estimates for National Parks are published by BEIS, and given the existing levels of uncertainty they are expected to change in the future. Any changes introduced to the figures may impact on the proposed glide paths to net zero for all the UK National Parks and AONBs to varying degrees. It is expected that the BEIS LULUCF data will be refined in subsequent years, and retrospectively applied to the entire published time series. Baseline year data will therefore be impacted in future years. Sections 5.6.1 to 5.6.5 discuss the importance of woodland, peatlands, and agricultural landscapes when developing subsequent strategies to implement LULUCF targets that support climate adaptation and mitigation.

5.6.1. Trees, woodlands and forestry

The target of 55 ha of new woodland per year proposed in Section 6 is based on apportioning UK-wide woodland targets from The Sixth Carbon Budget and has been developed in discussion with the National Park officers. Our approach for apportioning the woodland target, which has been applied to all National Parks and AONBs participating in this programme, safeguards existing woodland (leaving aside the issue of replacing conifers with native broadleaf/mixed species) and protected habitats such as lowland heathland, while also reflecting on the agricultural make-up of the area. However, it is recognised that this the apportioned target does not replace discussions by the relevant Local Authorities, their members, partners and stakeholders in developing real-world operational strategies for land use change implementation, particularly in relation to developing a Tree, Forestry and Woodland Strategy. Given the constrained nature of the Broads' landscape, and the need to protect open marshes that have high biodiversity value, the Broads' focus for tree planting is likely to be outside the National Park's boundaries, and enacted jointly with the neighbouring Local Authority partners.

There are multiple issues for stakeholders to consider including the complexities associated with the "right tree, right place" principle. Key to changing hearts and minds about the volume of tree coverage is the public perception of natural beauty within protected landscapes and how much change is acceptable within historic landscapes. For instance, woodland design may benefit from emulating "natural" patterns and forms rather than linear boundaries, unless there is a historic precedent[53]. There are also practical considerations in the choice of tree species to foster long-term resilience to average the anticipated temperature increases, increased average rainfall, more frequent flood events, and more severe drought periods driven by climate change. The Met Office have recorded a 1.09°C increase in average monthly maximum temperatures over the last 60 years or so for the weather station in Lowestoft[54]. Natural England published another helpful report, worthy of review, examining the relative sensitivity of habitats to climate change[55].

Any new woodland planning requires multi-benefit opportunity mapping to identify the optimum strategic placement and economic considerations for farmers and landowners (e.g. "a wood that pays is a wood that stays"). Another key factor to consider is the UK's demand for productive woodland for construction and biomass, as well as sustainable woodland management. An example case study of where a local partnership has followed this approach to produce a woodland strategy is the Forest of Bowland Area of Outstanding Natural Beauty (2021) "Trees, Woodland and Forestry Strategy".

[53]Forestry Commission (2017), "The UK Forestry Standard: The governments approach to sustainable forestry."
[54] https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/u134xcy4j
[55] Climate Change Adaptation Manual Evidence to support nature conservation in a changing climate

5.6.2. Local authority opportunities

There are other opportunities to establish trees, some of them particularly town-friendly; for example, working with local authority partners to plant micro-forests, shrubs and hedgerows in urban settings such as parks and schools, and on public highways, e.g. roundabouts. These natural barriers can also offer some protection against air pollution if the correct species are chosen. Public highways can provide excellent spaces for pollinator patches, and the costs paid by local authorities to maintain these stretches can be reduced by changing grass-cutting regimes, as discussed in the Lancaster City Council (2021) Grassland Management Strategy[56]; see Box 1.

Box 1: Sharing the learning example case study Lancaster City Council Pollinator Patches

"Since the 1930s, England has lost 97% of its grasslands, with more than 500 species having disappeared, and more could yet follow, including hedgehogs and house sparrows. Lancaster City Council has developed several different cutting palettes specific to different grassed areas across the district, based on advice from experts in the field including Natural England, Butterfly Conservation, Lune Valley Pollinators, landscape architects and ecologists. The nine cutting palettes are public open space, managed long meadow, desirelines, meadow edges, verges, amenity prestige, informal sports, and two types of wildflower meadows (introductory mix and perennial mix)."

Source: Extracts from LCC (2021) Grassland Management Strategy

5.6.3. Peatlands and wetlands

Peatlands are globally important in tackling climate change; they cover only 3% of the global land surface, yet hold nearly 30% of the world's soil carbon[57]. In the UK, peat soils account for nearly 33% of land cover[58]. According to the UK Peatland Strategy (2018) peatlands form the UK's largest expanse of semi-natural habitat occupying 10% of the UK's land area and are extremely important habitats. They are our largest terrestrial carbon store, a haven for rare wildlife, and natural providers of water regulation, with 13% of the world's blanket bog formed in the UK.

Both the UK Peatland Strategy (2018-2040) and the Sixth Carbon Budget (2020) recommend that Peatlands are widely restored to their natural state and managed sustainably. It is estimated that eighty percent of peatlands in the UK have been modified as a result of past and present management[59].

There are three broad types of peatland in the UK:

- Blanket bog (globally rare and typically found in uplands)

[56] Lancaster City Council (2021), "Grassland Management Strategy"; https://www.lancaster.gov.uk/news/2021/feb/implementation-of-new-grassland-management-strategy.
[57] IUCN National Committee United Kingdom (2021) "About Peatlands"; https://www.iucn-uk-peatlandprogramme.org/about-peatlands.
[58] IUCN National Committee United Kingdom (2018) "UK Peatland Strategy 2018-2040", p. 25.
[59] IUCN National Committee United Kingdom Peatland Programme (2021) "Peatland Damage"; https://www.iucn-uk-peatlandprogramme.org/about-peatlands/peatland-damage.

- Raised bog (mainly found in lowlands)
- Fens (fed by both surface and groundwater)

Peatland areas in the Broads largely consist of fens; however, there are also significant areas of carr (wet woodland).

Peat restoration involves raising the water table nearer to the surface and re-establishing peat-forming fen or bog vegetation. Peatlands damaged by drainage and other human activities can rapidly lose their stored carbon, predominantly in the form of carbon dioxide (CO_2) release to the atmosphere. It's worth stating that peatlands are complex; they both emit and capture CO_2, and the balance between these processes depends on the peatland's condition. Peatlands may also be either sources or sinks of methane, and sources of nitrous oxide. However, the evidence suggests that, overall, peatland restoration delivers greenhouse gas benefits by protecting stored carbon and drastically reducing the amount of carbon dioxide emitted, even after factoring in the initial increase in methane emissions following re-wetting[60].

We estimate that peatland accounts for nearly 25% of the Broads' land area. Restoring peatland is therefore a highly important consideration for the National Park, and considerable success has been achieved in recent years in restoring the wet woodland and fen habitats in the area. This has been made possible through large-scale field campaigns to ground truth and improve existing national peat datasets. A considerable amount of peat under agricultural areas (predominantly grazing) has been moved from intensive to extensive management, which has reduced the degradation levels and the associated emissions, but the agricultural peat is likely to remain a relatively large emitter until the broad "wet farming" (paludiculture) and "regenerative agriculture" practices are adopted across the region.

Building on the successes to date, it would be useful to continues assessing the soil depths throughout the landscape, which could present opportunities to employ citizen science. New hydrology assessments may also be beneficial where appropriate, i.e. where assessment identifies the need for water management, to boost the water levels in the peat soils. Work in partnership with water utility companies is therefore recommended, given their responsibility for ensuring water quality and sustainability as part of the Water Framework Directive Regulations. Water utility companies are also responsible for delivering the Water Resources East Regional Plan and Water Resources Management Plans.

Specifically in the case of the Broads, the following multiple land use options may be considered to deliver long-term climate and biodiversity objectives:

- Maintain, enhance and increase areas of priority fen, reed bed, grazing marsh and wet woodland, protecting peatland ecosystems as carbon sinks and seeking environmental net gain
- Develop areas of wet farming including extension of commercial reedbeds that has multiple ecosystem benefits
- Create new sustainably managed amenity land that has multiple ecosystem benefits

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

- Create new areas of long-term rewilding and rewetting for nature and flood management

5.6.4. Blue carbon sequestration

Marine and coastal carbon sequestration, or "blue carbon", techniques are increasingly recognised as important solutions to climate change. However, the carbon sequestration processes in these habitats are relatively understudied compared to terrestrial habitats such as woodlands and peatlands, and their carbon storage potential is less well understood as a result[61]. The practicalities of creating and maintaining these sequestering marine habitats are, in general, also less industry-ready compared to terrestrial climate solutions[62]. As such, they have not been included in the projections for future carbon sequestration provided in this report. With sufficient data in the future, blue carbon sequestration may allow the Broads to accelerate its carbon sequestration efforts and help reach an earlier Net Zero date.

A 2021 Natural England report found that most UK studies analysing blue carbon habitats only cover small geographic areas, for example the south coast of England or west coast of Scotland[63]. For some habitats, like seagrasses, carbon sequestration estimates largely come from European and global studies which have vastly different climate conditions and abundance compared to the UK. Because of this lack of the local UK evidence, the available estimates of carbon storage rates for various distinct blue carbon habitats may not accurately represent different areas of the UK. However, restored saltmarshes in Eastern England are estimated to have initial sequestration rates of 3.9 tCO_2e/ha/year (declining to 2.4 tCO_2e/ha/year after 20 years), while kelp forests in Scotland are estimated to sequester 1.47 tCO_2e/ha/year. Studies of seagrasses in temperate waters are estimated to sequester between 0.42 to 1.36 tCO_2e/ha/year[64]. It may therefore be a worthwhile endeavour for the Broads to create or restore blue carbon habitats along its coastline[65].

5.6.5. Agricultural landscape and food production

In considering land use and land use change potential, it is also important to understand the nature of the land in the protected landscape and how it contributes to UK food security. The UK is a net importer of food (Figure 23). Only 55% of food consumed in the UK (by economic value) is of UK origin, with 26% imported from Europe[66].

[61] https://www.frontiersin.org/articles/10.3389/fmars.2022.851448/full.
[62] https://www.frontiersin.org/articles/10.3389/fclim.2020.575716/full.
[63] Natural England (2021). "Carbon storage and sequestration by habitat: a review of the evidence (second edition; October 2021), Chapter 6 – Marine and coastal habitats", p. 149-171.
[64] PostNote Blue Carbon (September 2021).
[65] Pembrokeshire Coast National Park Management Plan (2014-2019), "Local Development Plan 2 (2015-2031)", p.6.
[66] GOV. UK (2021) "National statistics: Food Statistics in your pocket: Global and UK supply"; https://www.gov.uk/government/statistics/food-statistics-pocketbook/food-statistics-in-your-pocket-global-and-uk-supply.

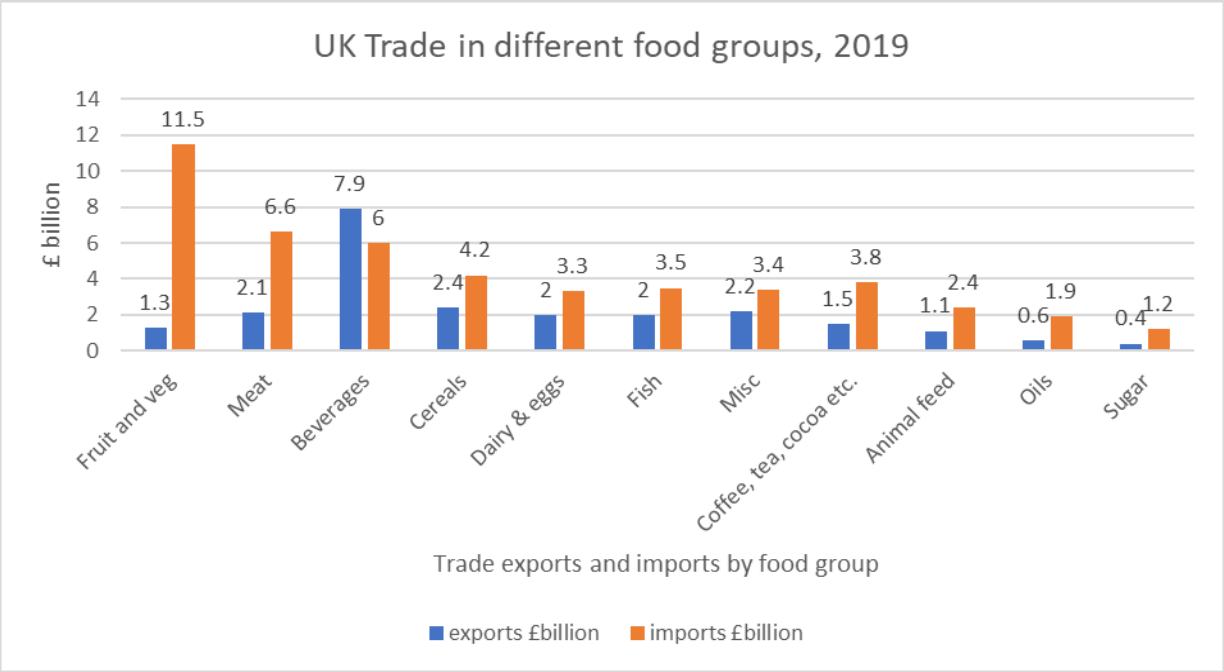


Figure 23: UK trade in different food groups, 2019

The Agricultural Land Classification System (England and Wales) identifies six grades of land. Grades 1, 2 and subgrade 3a are considered the "best and most versatile" land category in the current planning system. This land is deemed to be the most flexible and productive, and the best to deliver future crops for food and non-food uses (such as biomass, fibres and pharmaceuticals). Subgrade 3b is deemed only moderate-quality agricultural land, with substantial limitations that affect the choice of crop, level of yield, and/or timing and type of cultivation/harvesting. Grades 4 and 5 both designate poor-quality agricultural lands. Along with level 3b they offer, in general terms, the greatest opportunities for land use change. Such change could be marginal or could raise possibilities for larger projects such as woodland creation, peatland restoration and grassland improvement. However, we suggest reviewing all opportunity mapping in the context of regional food production and security, given that the UK is a net importer of food; see Figure 23.

In the case of the Broads, the agricultural landscape is based on a long history of drainage to allow livestock grazing interspersed with arable cropping, mainly for cereals, which is supported by the moderately fertile river valley and flood plain soils[67]. There is therefore a dynamic tension between agriculture and maintaining the optimum hydrology, water quality and nutrient conditions for wetland habitats and biodiversity to thrive which also support the storage of carbon. The landscape is low-lying with some areas below sea level. A key challenge for the easterly, low-lying wetland landscape of the Broads will therefore be adapting to the impacts of sea level rise and the projected changes in rainfall patterns impacting water management[68].

[67] Natural England (National Character Area Profile 80). The Broads.
[68] Draft Broads Plan (2022), "Partnership strategy for the Norfolk and Suffolk Broads," 2022-27, p. 6.

Unlike the Lincolnshire/Cambridgeshire fens which have large swathes of highly productive Grade 1 agricultural land, DEFRA's MAGIC site shows that the Broads agricultural land is predominantly classed as Grade 3, with some non-agriculture pockets of Grade 4 land[69]. The National Farmers Union recognises the importance farmers play in managing, protecting and enhancing these unique and fragile fenland habitats alongside food and horticultural production. It may be helpful for the National Park to engage with the National Farmers Union as key stakeholders in land management strategies for improving water quality[70].

In addition, reed and sedge cutting remains a traditional and important local industry. Fen management in the Broads has changed considerably since the early 1900s, when local labour and products dominated markets; now, only areas of high-quality thatching reed and sedge are managed commercially by a small group of experienced producers. In a 2012 assessment, it was identified that a significant factor for the lower overall reed production is the loss of traditional wetland management to conservation management (longer rotational cutting and burning), which has resulted in a decrease in the amount of good thatching-quality reed[71].

With more than 7200 hectares of land designated as Sites of Special Scientific Interest in the Broads, and the pressing need to restore wetland habitats to mitigate and adapt to climate change while enhancing biodiversity, there clearly are constraints for agriculture as an industry in the region. Multiple ecological and economic factors unique to the geographical area therefore need consideration. While the Broads Authority produced individual action plans addressing specific issues in recent years by, it may benefit from producing a holistic strategy for land management, including agriculture, water management, biodiversity, and climate change adaptation and mitigation. Such a multi-stakeholder strategy needs to consider multiple benefits of managing land differently, and support living communities as stewards of the land.

5.6.6. UK Timber production context

The UK is heavily reliant on imported timber; timber products worth £7.5 billion entered the UK in 2020, compared to exports of £1.5 billion. The UK mostly uses timber in sawmills, for making wood-based panels, and increasingly for wood fuels (although this remains a small proportion of the total). In 2020 the UK softwood industry harvested around 10 million green tonnes, and the hardwood industry 0.8 million green tonnes[72]. This only satisfies around a fifth of current UK demand; the rest is met by imports from Sweden, Norway, the USA and other countries. This makes the UK the world's second-largest importer of wood, which poses a risk to the security of supply for construction and manufacturing[73].

[69] https://magic.defra.gov.uk/.
[70] NFU (2019), "Delivering for Britain: Food and farmers in the Fens."
[71] Broads Authority (2012), "Action Plan for the Reed and Sedge Cutting Industry."
[72] Forest Research (2021) "UK Wood Production and Trade: 2020 Provisional Figures."
[73] Tilhill (2022) "Confederation of Forest Industries Warns More Tree Planting is Urgently Needed to Avoid UK Facing Crisis in Wood Supply", https://www.tilhill.com/resource-hub/our-news/confederation-of-forest-industries-warns-more-tree-planting-is-urgently-needed-to-avoid-uk-facing-crisis-in-wood-supply/.

Figure 24 illustrates timber production and trade in the UK, as reported by Forest Research.

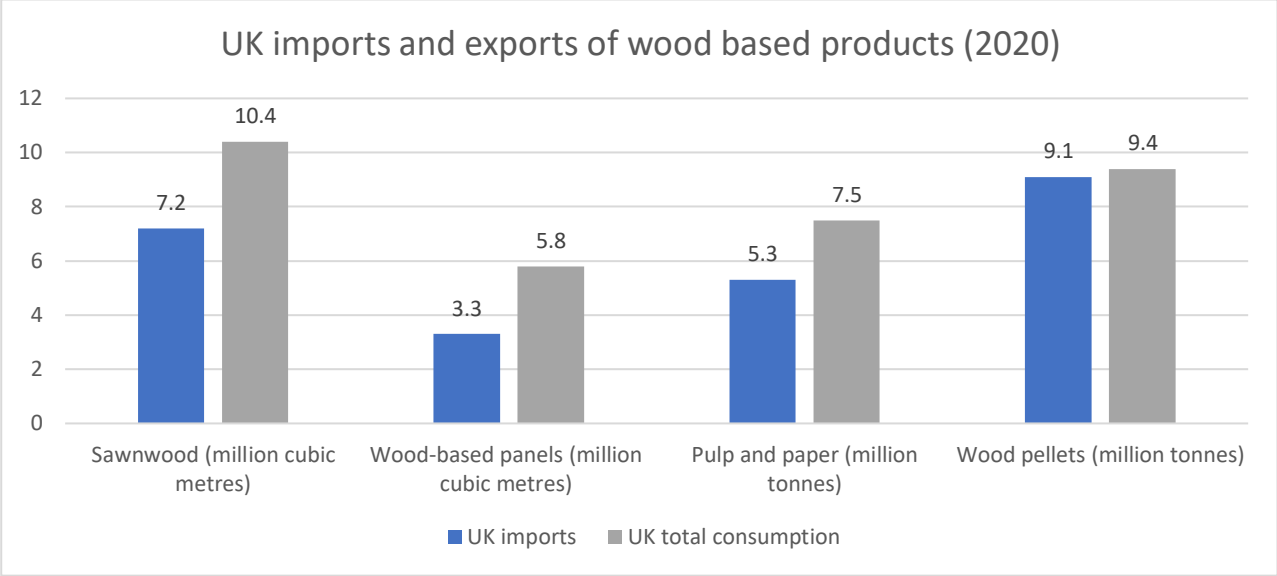


Figure 24: Self-generated from Forest Research (2021) UK Wood Production and Trade: provisional figures 2020 release

Demand for wood from UK forests continues at unprecedented levels, but the market remains constrained by a lack of supply. There is rising demand for wood, but limited availability due to long rotation periods, diversification into tangible assets, and increasing recognition of the environmental benefits of woodlands. There may also be new opportunities for monetisation, such as woodland carbon code credits. Capital values are therefore rising, although there is concern within the industry as to whether this trend is sustainable. The value of growth for the UK forestry market in 2018 showed a 19% drop in supply; however, the overall market value went up by nearly 6%, meaning a 30% increase in the average value per gross hectare, although this value varies according to region. In contrast, Savills (2019) states that in the north of Scotland prices are relatively low and static, indicative of "the geography and productive capacity of the woodland resource, with large areas of low-quality softwood, remote from timber markets and often challenging to harvest"[74]. In terms of the timber marketplace, the best softwood parcels traded at higher prices of £79 per cubic metre in 2021 (Softwood Sawlog) compared to small roundwood sales of almost £38 per cubic metre[75]. This is in contrast to carbon credits (for carbon sequestration) sold on the UK open market at £10-25 per tCO2e[76] (Forest Research states 1.25 to 1.43 cubic metres per tonne for roundwood).

[74] Savills (2019) "The Forestry Market: UK Rural – March 2019," p.3.
[75] Forest Research (2021) Timber Price Indices https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/timber-statistics/timber-price-indices/.
[76] Strutt & Parker (2021) Rural Hub: "5 ways to generate income from carbon farming."

6. A vision for a low-carbon National Park: GHG targets

This section outlines the aspiration for the Broads Executive Area to set a challenging glide path to reach a consumption-based Net Zero target by the early 2070s, and beyond this date, to become a carbon sink as one of the "lungs" of the East of England region, contributing to the UK's Net Zero target. It also outlines the planning assumptions used. We note that the later net zero date is a reflection on the unique characteristics of the Broads, coupled with the consumption-based assessment boundary adopted for all the National Parks and AONBs on the programme, which brings the footprints of sectors such as travel, food and drink, and other goods and services into the scope. The level of ambition is set to be equal across all the National Parks and AONBs on the programme, and is in line with sector-level targets for achieving territorial net zero emissions by 2050 for the whole of the UK.

To deal with certain targets such as energy, we have taken a pro-rata approach for all National Parks based on a percentage of GHG emissions. However, the land use sector requires a bespoke approach of setting UK targets in proportion to known key habitats within the Broads, and uses area assumptions.

Six categories of emissions were selected for the original Lake District National Park assessment and have been chosen in order to find a best fit between the competing desires to:

(i) Cover everything of significance within the influence of policy-makers;
(ii) Keep the target simple enough to describe;
(iii) Avoid double-counting;
(iv) Make use of any readily available data for tracking progress.

As a result, the scope for the target categories is slightly different from that of the overall emissions assessment in Section 5. The six target categories are summarised below, with further supporting data in Appendix 10.9.4.

- **Target Category 1: Energy-only greenhouse gas emissions.** This includes emissions relating to energy use within the National Park by residents, visitors and industry. It includes emissions from roads, except those from (estimated) through-traffic that does not stop in the National Park. This target has been chosen because relatively high-quality data is regularly published by BEIS, and because it covers a significant proportion of the total emissions. Furthermore, its selection allows us to draw on a robust tool developed by the Tyndall Centre for Climate Change to help local authorities establish Paris-aligned trajectories for energy-only emissions reduction in local areas.
- **Target Category 2: Food and drink consumed by residents and visitors.** This includes food and drink at the point of purchase in shops as well as from hospitality businesses. A food and drink target is important because when measured on a consumption basis, this category represents roughly a quarter of UK residents' emissions.
- **Target Category 3: Other goods purchased by residents and visitors while in the area.** This includes all purchases of tangible non-food and drink items such as clothing, electronic equipment, furniture, soft furnishings and cars. This target is important because it brings two particular elements into the landscape's carbon management agenda: sustainable

consumption of non-edible products, and circular economy principles into the Broads carbon management agenda.

- **Target Category 4: Visitor travel to and from the area.** We include here only travel within the UK, not visitor travel to the UK. International travel is omitted purely due to the practical difficulty of tracking change (as described in Appendix 10.9); visitor aviation emissions are still an important consideration for policymakers.
- **Target Category 5: Land use non-CO_2 component.** This includes all net non-CO_2 emissions from land within the National Park or AONB, and most notably includes enteric emissions from ruminants, and emissions from manure and fertilizer use. A comparatively small contribution to the non-CO_2 land use emissions comes from a range of ecosystems, in both near-natural and modified states, for example from peatlands releasing methane.
- **Target Category 6: Land use CO_2 component.** This most notably includes emissions from degrading peat and carbon sequestration by woodland, farm trees, hedges and soils (including healthy peat) in the National Park or AONB. It is the only emissions category that stands to become negative, relative to present-day values, through land use and management targets. This involves reducing peatland emissions through restoration projects, and also sequestering carbon by creating new woodlands, switching to agroforestry systems, extending hedgerows and adopting better practices for managing agricultural soils. Therefore, the CO_2 land use component could well enable "net zero" and "net negative" emissions in any of the National Parks.

Across these six categories, the 2019 carbon baseline for the Broads Executive Area is estimated at **518,377** tCO_2e per year.

Following the principles outlined above, some components of the wider carbon footprint of The Broads presented in the previous sections have been excluded from the 2019 carbon baseline and the associated emissions reduction targets. These excluded components are:

- Residents' travel by air, ferries, trains, buses and other transport (excl. cars). Local public transport will be counted through the energy GHG emissions linked to local industry (Target Category 1 above), and travel outside of The Broads is beyond the scope of influence by local authorities
- Residents' holiday accommodation outside the National Park
- Residents' housing (construction and maintenance)
- Residents' health, education and other public services
- Residents' and visitors' other bought services (e.g. financial, telecoms, travel agents, hairdressers)
- Residents' and visitors' art, sport and other leisure activities
- Residents' and visitors' water, waste and sewerage
- Industries' supply chains (both within and outside the National Park)

Our expectation is that these footprint components will be tackled, where appropriate, by the other local authorities, the UK Government, international climate agreements, and the local, national and international industries responsible for the respective types of emissions.

Our recommended target trajectories are summarised in Table 4, and represent the minimum that can be considered to be Paris-aligned. For some of the target areas where primary data is lacking, an element of expert judgement has been applied to determine what is required. The targets have been set to fit with the best available science and the latest policy recommendation. Some or all will require appropriate support from government in order to be feasible, and part of the role of each Local Authority may be to push for the necessary support.

Table 4. Decarbonisation targets for the selected components of carbon footprint. For further details, see Appendix 0

Category	New Model for All National Parks and AONBs (2021) – used in this report	Achievable ceiling
1. Energy only GHG emissions (incl. supply chains) by residents, visitors and industry	**13.3%** (specific to the Broads) reduction per year	**5%** of present-day emissions
2. Food consumed by residents and visitors	**5%** reduction per year	**30%** of present-day emissions
3. Other goods purchased by residents and visitors	**5%** reduction per year	**10%** of present-day emissions
4. Visitor travel to and from the National Park or AONB	**10%** reduction per year	**7.5%** of present-day emissions
5 & 6. Land use (non-CO_2 and CO_2)	We have split land use emissions and targets into non-CO_2 and CO_2 components. See Appendix 10.9.8 for further details	**30%** of present-day emissions for the non-CO_2 component only; Achievable ceiling is not applicable for the CO_2 component in the current assessment

The six elements outlined above can be combined into an overall decarbonisation pathway, which in the case of the Broads Executive Area results in a net zero date by the early 2070s. Note that targets 1 to 4 should be adjusted in proportion to any significant changes in resident and visitor numbers in the National Park.

Each trajectory, apart from that for the land use CO_2 component, has been based on exponential decay (emissions decreasing by the same proportion each year) towards residual unavoidable emissions in the long run. The proposed reductions are broadly aligned with the Paris Agreement and with the UK's 2050 net zero policy.

The LULUCF CO_2 component has been assumed to change linearly with time, which is characteristic of gradual uptake of a number of measures to manage land sustainably, increase its carbon uptake (and/or reduce CO_2 emissions through restoring peatland), and enhance biodiversity. The rate of change has been drawn from the Sixth Carbon Budget and apportioned to the Broads according to its land characteristics (see Appendix Section 10.9.8).

When the Sixth Carbon Budget's apportionment methodology is applied to the Broads, it produces the annual target for land use change summarised in Table 5, plus the associated annual increases in carbon sequestration flux. When measured in hectares per year converted, the "legumes (improved grassland)" target comes on top at around 250 ha/yr., followed by "restored peatland" at 97.5 ha/yr. and "cover cropping (arable land)" at 97.4 ha/yr. Other measures are comparatively

small, and we assume no new productive conifer plantations in the Broads in order to prioritise native broadleaf and/or mixed species. When converted to changes in carbon sequestration fluxes, the "restored peatland" (-1,197 tCO_2e per year added each year) provides the largest amount of sequestration, followed closely be "new native broadleaf / mixed woodland" (-1,015 tCO_2e per year added each year). The third largest carbon sequestration flux is from "legumes (improved grassland)" (-514 tCO_2e per year added each year), while the other measures have a much smaller effect (Table 5). This clearly illustrates the priorities for land use measures in order to achieve Net Zero.

We emphasise that priority must be given to managing agricultural land sustainably, both to enhance soil carbon sequestration, and to achieve co-benefits such as biodiversity gains and flood risk mitigation[77]. However, global evidence shows that soil carbon sequestration is a slow process, and requires the necessary management practices to be maintained indefinitely. Also, despite one's best efforts, carbon sequestration in soils tends to reach saturation over time (years/decades), and it is vulnerable to climate change as predicted increases in flood events are likely to increase soil erosion[78]. Typical sequestration values associated with regenerative agricultural practices (such as agroforestry, hedging, and growing legume-rich grasses and cover crops) are estimated to be between 1 and 3 tCO_2e per year per hectare in the first couple of decades. This is only a small fraction (a fifth to a tenth) of the carbon sequestration benefits typically achieved by creating new woodland on similar timescales, which – due to its natural simplicity and its age-old familiarity – is always going to be the main source of carbon sequestration, and delivers wider co-benefits such as biodiversity gains. Healthy soils alone cannot reverse the negative effects associated with centuries-long conversion of natural landscapes to pasture and cropland, nor can they offset the broad-ranging emissions associated with our economic activities. It is therefore imperative that regenerative agricultural practices aimed at enhancing soil carbon stocks go hand in hand with ambitious woodland creation (and where applicable, peatland restoration) programmes.

Table 5: The Broads: Apportioned Sixth Carbon Budget targets for land use change and the associated additions to annual carbon sequestration fluxes. These targets need to be maintained until 2070 under the proposed pathway

Proposed Land Use Targets	**Value**	**Units**
New Native Broadleaf / Mixed Woodland	55.0	ha per year
New Productive Coniferous Woodland	0.0	
Restored Peatland	97.5	
Agroforestry (improved grassland & cropland)	44.7	
New Hedgerows (improved grassland & cropland)	2.6	
Legumes (improved grassland)	250.2	
Cover Cropping (cropland)	97.4	
Associated Carbon Sequestration	**Value**	**Units**
New Native Broadleaf / Mixed Woodland	-1,015	tCO_2e per year capacity added each year
New Productive Coniferous Woodland	0	
Restored Peatland	-1,197	

[77] Bossio, D. A., *et al.* (2020). "The role of soil carbon in natural climate solutions." *Nature Sustainability*, 3(5), 391-398.

[78] Frank, D., *et al.* (2015). "Effects of climate extremes on the terrestrial carbon cycle: concepts, processes and potential future impacts." *Global Change Biology*, 21(8), 2861-2880.

Agroforestry (improved grassland & cropland)	-105	
New Hedgerows (improved grassland & cropland)	-27.2	
Legumes (improved grassland)	-514	
Cover Cropping (cropland)	-114	

Based on the target-setting assumptions outlined in Table 5 and in Appendix 10.9.8, the Broads Executive Area will achieve a total cumulative reduction in the net annual GHG emissions of 433,808 tCO_2e per year between the base year (2019) and 2050. The net estimate includes both reductions in emissions and carbon sequestration, depending on the contributing footprint category. Percentage breakdown of the projected total cumulative reduction in the net annual GHG emissions by individual footprint categories and land-based measures is provided in Figure 25.

The assumptions above imply that the Broads Executive Area would reduce net GHG emissions from 518,377 tCO_2e per year in 2019 to 84,569 tCO_2e per year in 2050 (Figure 26), eventually achieving Net Zero emissions by early 2070s (not shown). As mentioned above, the later net zero date is a reflection on the unique characteristics of the Broads, rather than a lack of ambition compared to other UK National Parks or the UK as a whole[79].

The proposed net zero pathway assumes the recommended decarbonisation and carbon sequestration efforts, including land use change, ratchet up to the required levels immediately in the base year of the assessment. In reality, the high levels of ambition for different sectors explored in this report are likely going take several years to achieve, given that post-COVID emissions have largely rebounded, and that decarbonisation trends to date have been relatively small in magnitude compared to what we know is required for keeping global warming below the safer 1.5°C limit from the Paris Agreement. These factors are expected to push the projected net zero year back by several years. The stated net zero date on its own should therefore not be taken as the main level of ambition to decarbonise for a given landscape.

An alternative target trajectory for the Broads Executive Area using all consumption and landscape-based emissions as the baseline if given in Figure 27. The resulting 2019 baseline is marginally higher for the Broads, but the corresponding pathway to net zero is quite similar to the default one (Figure 26).

[79] An alternative emissions target could adopt different boundaries, focusing only on emissions from fossil fuels, electricity and land use within the region, but still including their associated supply chains. This would result in a net zero date in the mid-2050 for the Broads Executive Area. This approach would be more aligned with national UK reporting, but would not take account of the key sources of footprint such as food and drink, travel and other goods and services. Regardless of the assessment boundary, achieving net zero emissions presents a major challenge for any landscape, and this challenge is more significant for the areas like the Broads because of its unique wetland as well as agricultural habitats. Given the scale of the challenges we face to limit the extent of climate change, we recommend that the default consumption-based approach reflecting on the full carbon footprint of our lifestyles, which has been adopted for all the National Parks and AONBs participating in this programme, is used as the main guidance for actions to reduce emissions, even though the resulting later net zero date may require careful explanation.

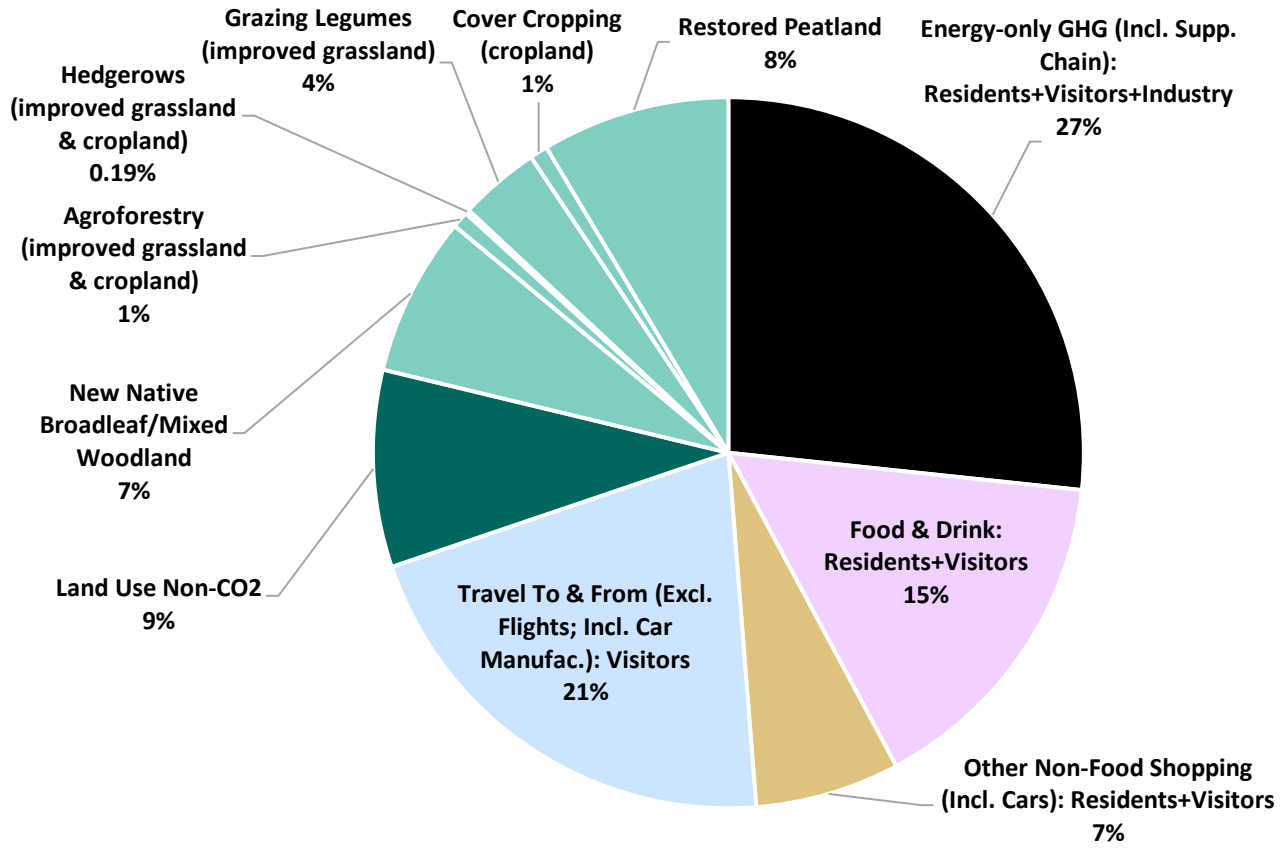


Figure 25. Percentage breakdown of the projected cumulative reduction in net annual GHG emissions for the Broads Executive Area between the base year (2019) and 2050 according to the individual emitting categories and carbon sequestration measures considered in this assessment

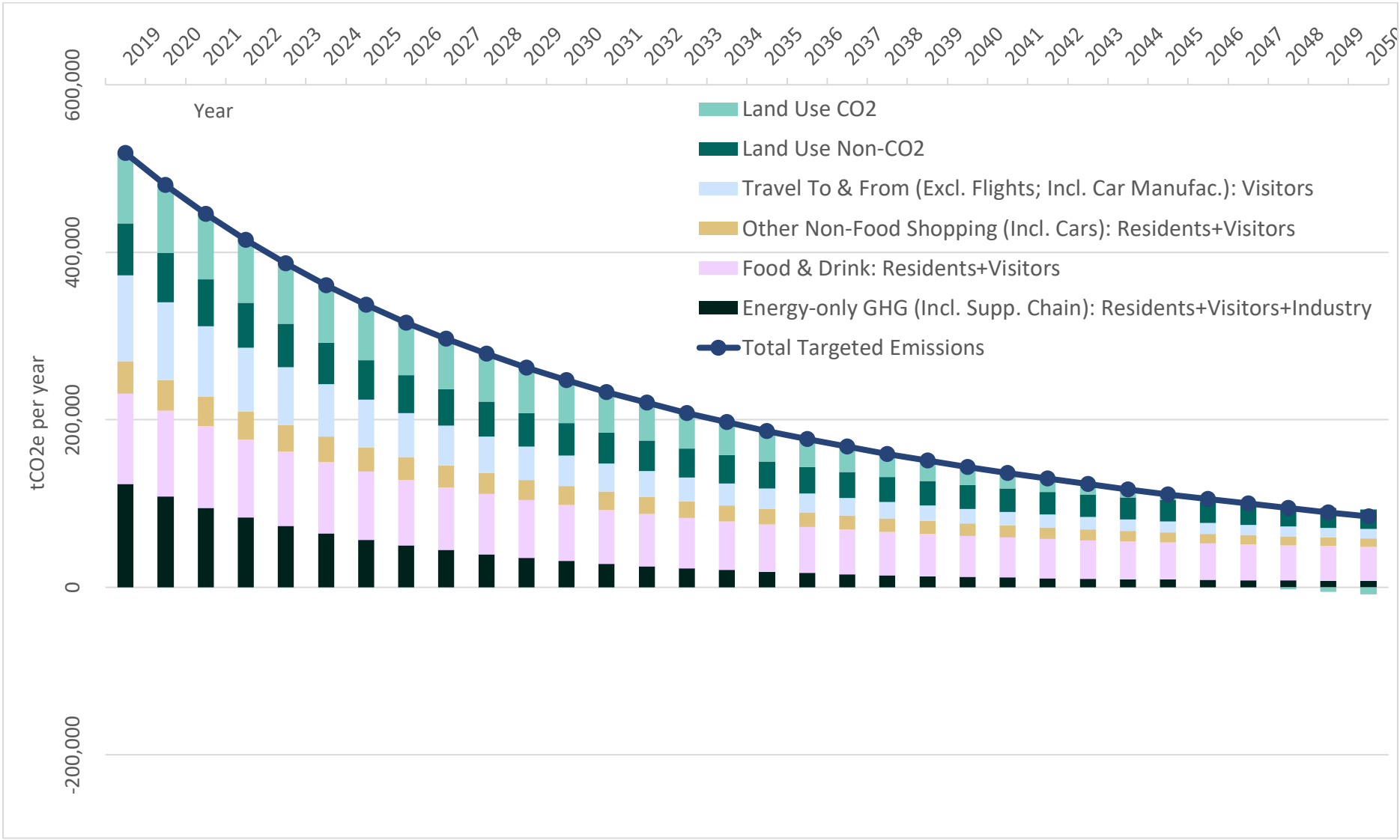


Figure 26. Recommended target pathways for the Broads Executive Area across the six shortlisted categories of emissions between 2019 and 2050. The total emissions reach net zero in early 2070s (not shown). The projected consumption-based net zero date for the Broads is comparatively late because the potential for land management improvements is somewhat limited by the nature of the landscape and by the success of conservation work to date. (Repeat of Figure 6)

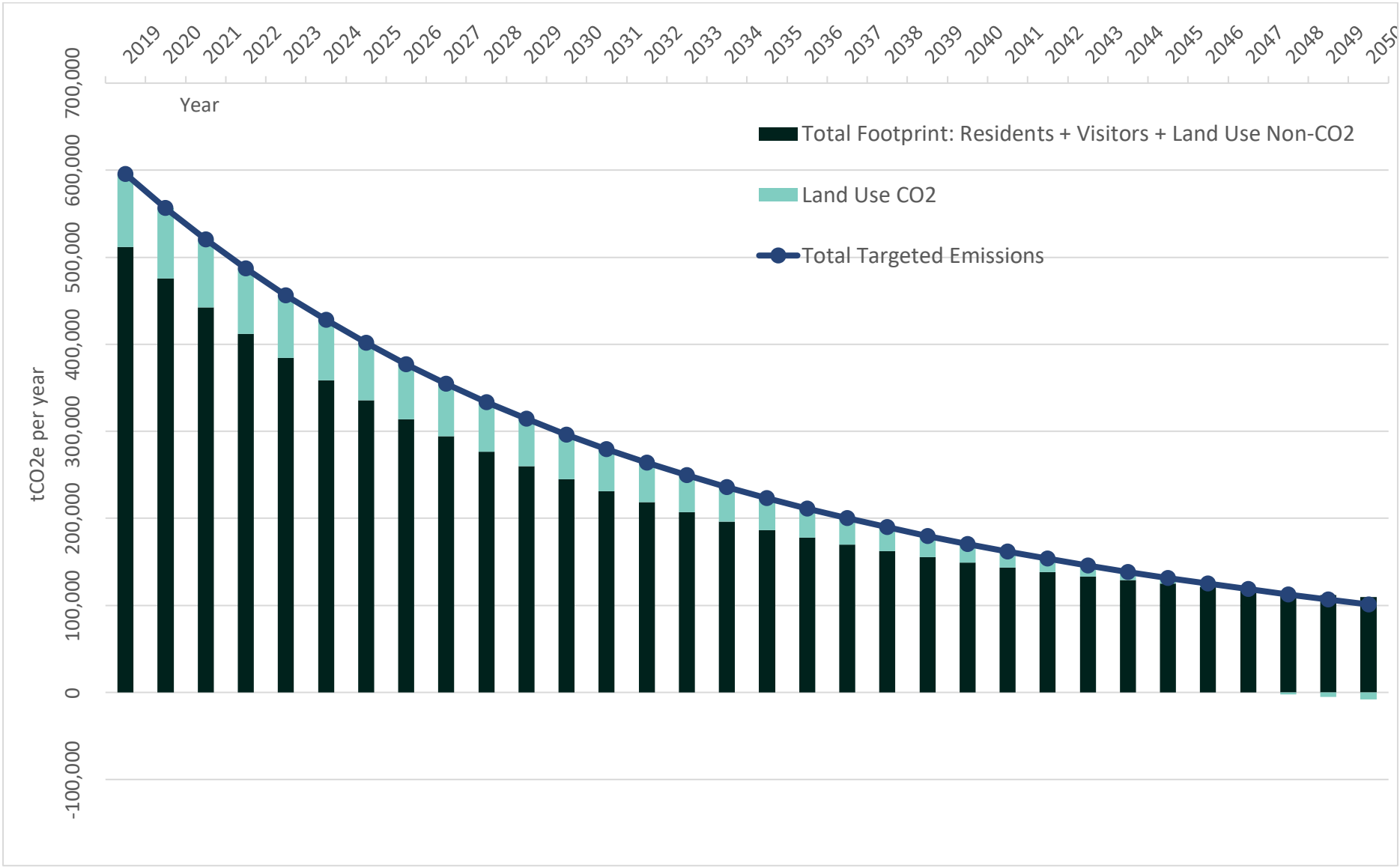


Figure 27. The Broads Executive Area: Alternative pathway to Net Zero (based on full consumption and land use footprint in the area)

7. Conclusions and recommendations

The emissions assessment in this report is designed to bring every relevant area of carbon management into perspective for policy makers. A transition to a low-carbon future for the Broads entails strong action in many areas: construction, home energy, food production and diets, travel and transport, business energy use, the nature of tourism and the visitor experience, the circularisation of the material economy (including repair, maintenance, renting and reselling of consumer goods), and significant changes in land management.

The challenge is to find a coherent way of bringing these policy areas together, one that adds up to more than the sum of its parts and delivers an enhanced experience of living, working and spending time in the National Park.

The Local Authorities' planning powers are a tool that can provide substantial leverage in:

- Preparing the construction sector for zero-carbon building (embodied GHG emissions),
- Ensuring that new buildings are energy-efficient and supplied with low/zero-carbon energy (operational energy / GHG emissions),
- Encouraging low/zero-carbon transport in new developments (cycling, electric vehicles, etc.),
- Implementing Ecosystems Services-oriented policies and Biodiversity Net Gain initiatives in new-builds.

Although it is accepted that new-builds present limited opportunities to reduce GHG emissions compared to tackling emissions from residents and existing buildings, these opportunities are still important, as they:

- Aggregate to the existing stock every year,
- Reduce the need for future expensive retrofitting before 2040, even though it is crucial to pursue retrofitting to improve insulation and switch to renewable heating for existing housing stock,
- Demonstrate (more easily) that zero-carbon construction and operation of buildings is technically possible,
- Help stimulate and grow the market for building techniques and products that are more sustainable (also relevant for retrofitting existing buildings), bringing their cost down,
- Encourage existing building owners and occupants to upgrade their properties.

If all the targets proposed in this report were met, the Broads Executive Area would reach emissions of approximately 84,569 tCO2e per year by 2050, with annual carbon sequestration in the region scaling up to around -8,246 tCO2e per year, and residual emissions dropping roughly to 92,815 tCO2e across the shortlisted policy priority areas (18% of the present-day carbon footprint baseline). The Broads would subsequently achieve net zero GHG emissions in the early 2070s. The later net zero date is a reflection on the unique characteristics of the Broads.

Although designed as the minimum to attain Paris-aligned targets, the trajectories for each of the six components of the target are steep and challenging. This reflects the severity of the climate emergency in which the world now finds itself. The Broads' consumption-based net zero date in the early 2070s should not be interpreted as a lower level of ambition compared to the rest of the UK since all geographical areas vary in their potential for negative emissions, and in the case of the Broads, potential for land management improvements is somewhat limited by the nature of the landscape and by the success of conservation work to date.

The dominance of healthy wetland habitats and medium-grade agricultural land on mineral soils within the Broads limit the opportunity for peatland restoration and woodland creation. However, there is likely to be more scope for this in neighbouring local authorities. Within the Broads border, the priority should be given to restoration of the remaining degraded fen and wet woodland areas, implementation of innovative management practices for productive agricultural land on peat soils to reduce peat emissions (e.g. paludiculture), and adoption of regenerative agricultural practices for grassland and cropland areas on mineral soils.

Some emissions included in the targets fall directly under the statutory powers of the Broads Authority, for example those associated with the use of boats on the area's waterways or with new housing and business developments. These emissions need be targeted through the Management Plan developed and implemented by the Authority in conjunction with the relevant stakeholders.

In meeting the targets, some help from outside the Broads can be expected, thanks to anticipated changes in the UK and global economy. For example, the electricity grid is endeavouring to decarbonise, and the use of electric vehicles will be more widespread, meaning less fossil fuel powering all forms of road transport. On top of this, the public may become increasingly carbon-conscious and choose more sustainable options, for example insulating their homes, installing renewable heating systems and solar panels, and opting for less carbon-intensive diets. Last but not least, businesses would also want to play an active role in the transition to low carbon by cutting their direct emissions, while simultaneously opting for suppliers that provide products and services with lower embedded carbon, thus accelerating the transition across the whole value chain.

A degree of help can also be expected to come from government policies, and where this is not sufficient, part of the role of the Broads will be to push for the support needed to ensure that the National Park attains the recommended targets. This will require active engagement with all stakeholders, drawing on existing relationships and nurturing future ones, including partnership programmes with local organisations, with neighbouring Unitary Authorities, with the UK Government, and with the general public. It is through collaborative creative thinking, taken forward in sustained joint efforts by all stakeholders, that the exciting and realistic vision outlined in this report – of how a low-carbon future could work for everyone in the Broads – will become a reality.

Land management is central to all National Parks and deserves a separate discussion. The wide-ranging land use measures proposed for the Broads, dominated by restored peatland (which includes both fen, wet woodland and agricultural land on peat soils) and new native broadleaf / mixed woodland (both within the Broads and in the adjacent catchment areas), must be ambitious enough and sustained for long enough, for the sequestration flux to scale up sufficiently year on year, in line with the suggested land use CO_2 pathway. Establishing irreversible carbon sinks (with

biodiversity co-benefits) relies on the availability of suitable incentives enabling land managers to implement land use changes such as woodland creation, peatland restoration and regenerative farming, in line with current recommendations by the UK Government.[80]

Furthermore, public perceptions of how a protected natural landscape should look may also need to evolve, in order for people to continue visiting the National Park and finding it beautiful after changes in land use. Most UK National Parks and AONBs have considerable areas of low-grade grassland and moorland, which create the landscapes familiar to many in the UK and abroad. However, centuries ago the majority of the UK was covered in woodland, compared to just 12% today, and relatively large swathes of land may need to be returned to this forested state in the coming years and decades, in line with climate goals. Visitors and residents' perception of natural beauty in these protected landscapes may therefore need to shift towards greater appreciation of more widespread woodland coverage, alongside protected and restored peatland areas, applying the "right tree, right place" principle.

To assist with the transition towards the required land use and management options, there are a range of new funding opportunities which may be available to landowners, tenant farmers or public sector partners, depending on each set of grant conditions. These options are listed below.

Environmental Land Management Schemes (ELMS)

Three new schemes were piloted during 2021, and launched in 2022, to reward environmental land management: the Sustainable Farming Incentive, Local Nature Recovery, and Landscape Recovery[81]. Through these schemes, according to current public communications, farmers and other land managers may enter into agreements to be paid for delivering the following: clean and plentiful water, clean air, thriving plants and wildlife, protection from environmental hazards, mitigation of and adaptation to climate change, beauty, heritage, and engagement with environmental law.

Woodland grants and incentives[82]

- Forestry Commission Local Authority Treescapes Fund
- Forestry Commission Urban Tree Challenge Fund
- Woodland Creation Planning Grant
- HS2 Woodland Fund (land must be within a 25-mile zone of phase one of the HS2 route from London to the West Midlands)
- England Woodland Creation Offer (new grant scheme for farmers and landowners to encourage investment in woodland creation)
- Woodland Carbon Code or Scottish Forestry Grant Scheme
- Woodland Carbon Guarantee
- Countryside Stewardship grants
- Woodland Creation and Maintenance part of Countryside Stewardship
- Woodland Tree Health part of Countryside Stewardship

[80] UK Sixth Carbon Budget: "Agriculture, Forestry and Other Land Use" section.
[81] https://www.gov.uk/government/publications/environmental-land-management-schemes-overview/environmental-land-management-scheme-overview.
[82] https://www.gov.uk/government/publications/woodland-grants-and-incentives-overview-table/woodland-grants-and-incentives-overview-table.

- Woodland Improvement (WD2 and capital items) part of Countryside Stewardship

Peatland restoration

- Peatland Code
- Nature for Climate Peatland Grant Scheme

As a response to the climate and ecological emergency, we hope that the Broads Authority members and partners welcome this greenhouse gas emissions assessment, its findings and recommendations to help the partnership support decarbonisation and plan actions for change.

8. Acronyms

AFOLU	Agriculture, Forestry, and Other Land Use
BEIS	UK Government Department for Business, Energy and Industrial Strategy
CH_4	Methane
CO_2	Carbon Dioxide
COA	Census Output Areas
DACCS	Direct Air Capture with Carbon Storage
DEFRA	Department for Environment, Food and Rural Affairs
DOC	Dissolved organic carbon
EV	Electric vehicle
GIS	Geographic Information System
GDPR	General Data Protection Regulations
GWP	Global warming potential
GVA	Gross Value Added
Ha	Hectares
HFCs	Hydrofluorocarbons
IDBR	Office for National Statistics' Inter-Departmental Business Register
LEP	Local Enterprise Partnership
LULUCF	Land Use, Land Use Change and Forestry
NAEI	National Atmospheric Emissions inventory
NFU	National Farmers' Union
N_2O	Nitrous Oxide
ONS IDBR	Office of National Statistics' Inter-Departmental Business Register
PFCs	Perfluorocarbons
POC	Particulate organic carbon
SPD	Sustainable Construction Supplementary Planning Document
SF_4	Sulphur Hexafluoride

9. Glossary

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate change and its effects (IPCC AR5 Glossary Annex 11)

Air pollution: Degradation of air quality with negative effects on human health or the natural or built environment due to the introduction, by natural processes or human activity, into the atmosphere of substances (gases, aerosols) which have a direct (primary pollutants) or indirect (secondary pollutants) harmful effect (IPCC, 2018: Annex 1: Glossary [Matthews, J.B.R. (ed)]).

Anaerobic digestion: Anaerobic digestion (AD) is a natural process in which plant and animal materials are converted into useful products by micro-organisms in the absence of air. The process releases biogas (mainly a mixture of around 60% methane and 40% carbon dioxide), which can be used directly to provide heat, power or transport fuel. Biogas can also be purified by removal of the carbon dioxide to produce biomethane, which can be fed directly into the public natural gas grid in the same way as natural gas or used as a vehicle fuel. The types of materials suitable for AD include food waste, slurry and manure, crops and crop residues (DEFRA, GOV.UK, published 9th December 2021).

Anthropogenic emissions: Emissions of greenhouse gases, greenhouse gas precursors and aerosols caused by human activities. These activities include the burning of fossil fuels, deforestation, land use changes, livestock production, fertilization, waste management, and industrial processes (IPCC AR5 Glossary Annex 11).

Anxiety: A feeling of stress, panic or fear that can affect your everyday life physically and psychologically (NHS, 2021).

Asthma: A common lung condition that causes occasional breathing difficulties. It affects people of all ages and often starts in childhood, although it can also develop for the first time in adults.
There's currently no cure, but there are simple treatments that can help keep the symptoms under control (NHS, 2021).

BEIS pollution inventory: The UK Government (department for Business, Energy and Industrial Strategy (BEIS)) produces an annual greenhouse gas inventory for local authorities and large industrial sites that act as point-sources of emissions, which forms a consistent time series of UK greenhouse gas emissions from 1990 onwards (www.gov.uk, 2021).

Biodiversity: Biological diversity means the variability among living organisms from all sources, including *inter alia*: terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems (UN, 1992).

Biodiversity net gain: Biodiversity net gain (BNG) is an approach to development, and/or land management, that aims to leave the natural environment in a measurably better state than it was beforehand (Local Government Association, 2022).

Carbon capture and storage: The process of capturing and storing carbon dioxide (CO_2) before it is released into the atmosphere (Grantham Research Institute on Climate Change and the Environment, 2018).

Carbon intensity: The amount of emissions of carbon dioxide (CO_2) released per unit of another variable such as gross domestic product (GDP), output energy use or transport (IPCC, 2018: Annex 1: Glossary [Matthews, J.B.R. (ed)]).

Carbon flux: A carbon flux is the amount of carbon exchanged between Earth's carbon pools, i.e. the oceans, atmosphere, land and living things, during a specified time period (e.g. a day or a year).

CARBINE model: A modelling tool used to estimate the carbon stocks of stands and forests (in living and dead biomass and soil), and any associated harvested wood products. It is also used to estimate the greenhouse gas emissions avoided through the use of wood products that displace fossil fuels and fossil-fuel intensive materials (Forest Research, 2021).

Catapult (energy systems): Energy Systems Catapult was set up to accelerate the transformation of the UK's energy system and ensure that UK businesses and consumers capture the opportunities of clean growth. The Catapult is an independent, not-for-profit centre of excellence that bridges the gap between industry, government, academia and research. The Catapult takes a whole-systems view of the energy sector, helping it identify and address innovation priorities and market barriers in order to decarbonise the energy system at the lowest cost (Catapult Energy Systems, 2021).

Consumption-based footprint assessment: This means assessing the greenhouse gas "footprint" of residents, visitors and industry in a given landscape, including the entire lifestyles of residents, visitors' travel to and from the area, and supply chains of industry. Put differently, consumption-based footprint assessment includes everything that residents and visitors buy and do while in the landscape, as well and their travel to and from the area. Consumption-based reporting attributes the emissions from product and service supply chains to the landscape, regardless of where emissions are physically released during production (Small World Consulting, 2022).

Coronary heart disease (CHD): A major cause of death in the UK and worldwide. CHD is sometimes called ischaemic heart disease or coronary artery disease, and describes what happens when blood supply to the heart is blocked or interrupted by a build-up of fatty substances in the coronary arteries.

Census output areas (COAs): The 2001 Census Output Areas are designed specifically for statistical purposes. They are based on data from the 2001 Census and were built from postcode units. Output Areas are used not only for Census output but also as the basis of Super Output Areas, which have been introduced as stable and consistently sized areas for Neighbourhood Statistics. (ONS, 2022).

Climate action: Actions taken to pursue the goal of positive change for the climate.

Cumbria's Zero Carbon Programme: The Zero Carbon Cumbria Partnership is working towards the shared aim of making Cumbria the first carbon-neutral county in the UK, by 2037. It is funded by a £2.5 million grant from the National Lottery Climate Action Fund (Cumbria Action for Sustainability, 2022).

Decarbonisation: The process by which countries or other entities aim to achieve a low-carbon economy, or by which individuals aim to reduce their consumption of carbon (IPCC AR5 Glossary Annex 11).

Direct emissions: Scope 1 (direct emissions from owned or controlled sources) includes company facilities and vehicles (Greenhouse Gas Protocol (2013), Technical Guidance for Calculating Scope 3 Emissions, Version 1.0).

Ecosystem services: Ecological processes or functions that have monetary or non-monetary value to individuals or wider society. These are frequently classified as (1) supporting services such as biological productivity or *biodiversity* maintenance, (2) provisioning services such as food or fibre, (3) regulating services such as climate regulation or *carbon sequestration*, and (4) cultural services such as tourism or spiritual and aesthetic appreciation (IPCC, 2018: Annex 1: Glossary [Matthews, J.B.R. (ed)]).

Electric vehicle: A car, a van, a bus or a lorry that uses electric motor and battery storage as sole means of propulsion and energy. Electric vehicles do not generate direct emissions apart from those associated with tyres and break pads.

Electric heat pump: An air-, ground-, or water-source heat pump is an electric heating system that absorbs internal heat energy from the air, earth or water outside, to provide domestic space heating and hot water. To transfer the heat energy from the colder outdoors to the warmer indoors, a heat pump uses a relatively small amount of electricity (around 30% of the total heat transferred). The heat pump works in reverse of an air conditioning system and is sometimes combined with the latter.

Embodied emissions: This term (also referred to as "embedded carbon") describes the set of greenhouse gas emissions attributed to the whole production process of a product, up to the point of usage.

Environmental land management: An approach providing the means to store carbon, reduce the risks from a changing climate such as more frequent and severe flooding or crop failures, and restore wildlife and habitats, while maintaining a thriving agricultural and forestry sector, growing high-quality food and timber, and supporting human health and well-being.

Extraction-based emissions: These are the emissions produced by burning any fossil fuels that are extracted from the ground within a given landscape, wherever they are burned. This type of emissions reporting is important for understanding the climate change implications of decisions relating to any fossil fuel extraction in the landscape (Small World Consulting, 2021).

Flexitarian diet: A flexitarian or semi-vegetarian diet (SVD) is one that is primarily vegetarian with the occasional inclusion of meat or fish (Derbyshire E.J., "Flexitarian Diets and Health: A Review of the Evidence-Based Literature." *Front Nutr.* 2017; 3:55. Published 6th Jan, 2017. Doi:10.3389/ fnut.2016.00055)

Fossil fuels: A fossil fuel is a hydrocarbon-containing material formed underground over tens of millions of years from the remains of dead plants and animals that humans extract and burn to release energy for use. The main fossil fuels are coal, petroleum and natural gas, which humans extract through mining and drilling.

Greenhouse gas (GHG): Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself, and clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O, and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs) (IPCC AR5 Glossary Annex 11).

Greenhouse gas protocol: The GHG Protocol establishes comprehensive global standardised frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions. The standards are designed to provide a framework for businesses, governments, and other entities to measure and report their greenhouse gas emissions in ways that support their missions and goals (ghgprotocol.org, 2022).

GHG reporting: The quality of greenhouse gas (GHG) inventories relies on the integrity of the methodologies used, the completeness of reporting, and the procedures for compilation of data. To this end, the Conference of the Parties (COP) has developed standardised requirements for reporting national inventories. The UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (Annex I Parties) require each Annex I Party, by 15th April each year, to provide its annual GHG inventory covering emissions and removals of direct GHGs (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3)) from five sectors (energy; industrial processes and product use; agriculture; land use, land-use change and forestry (LULUCF); and waste), and for all years from the base year (or period) to two years before the inventory is due (United Nations Framework Convention on Climate Change, 2022).

Hybrid car: A car that combines a conventional combustion engine with an electric motor and battery storage.

Hypertension: High blood pressure.

Indirect emissions: Indirect emissions may be classified as Scope 2 and 3 emissions. Scope 2 are indirect emissions from the generation of purchased electricity, steam, heating and cooling consumed by the reporting company. Scope 3 includes all other indirect emissions that occur in a

company's value chain. The 15 categories in scope 3 are intended to provide companies with a systematic framework to measure, manage and reduce emissions across a corporate value chain. The categories are designed to be mutually exclusive, to avoid a company double-counting emissions among categories (Greenhouse Gas Protocol (2013), Technical Guidance for Calculating Scope 3 Emissions, Version 1.0 p.6).

Land cover map: The UK Centre for Ecology and Hydrology (UKCEH) uses satellite imagery and machine learning algorithms to classify land cover according to one of 21 distinct habitats. The first national Land Cover Map of Great Britain was produced in 1990. Since 2016, Land Cover Maps and land cover change data have been produced on yearly basis. The UKCEH land cover (habitat) classes are based on the UK Biodiversity Action Plan (BAP) Broad Habitats (Jackson, 2000). They describe the physical material occupying the surface of the United Kingdom, providing an uninterrupted national dataset of land cover classes from grassland, woodland and fresh water to urban and suburban built-up areas (CEH, 2022).

Natural capital: That part of nature which directly or indirectly provides value to people, including ecosystems, species, freshwater, soils, minerals, the air and oceans, as well as natural processes and functions (Natural Capital Committee, 2019).

Net Zero: Net zero emissions are achieved when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic greenhouse gas removals over a specified period. Where multiple greenhouse gases are involved, the quantification of net zero emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential and others, as well as the chosen time horizon). See also "Net zero CO_2 emissions", "Negative emissions" and "Net negative emissions" (IPCC, 2018: Annex 1: Glossary [Matthews, J.B.R. (ed)]).

Osteoarthritis: A condition that causes joints to become painful and stiff, and may impact movement. Almost any joint can be affected by osteoarthritis, but the condition most often causes problems in the knees, hips and small joints of the hands (NHS, 2021).

Point sources: Point source pollution comes mostly from spills, leaks and discharges at a single point or over a small area. It's often easy to identify because it results from mainly isolated events or activities with a clear link to a polluter (Environment Agency, 2022).

Partnership management plan: Every National Park and AONB has a Partnership Management Plan, which is among its most important documents. This Plan sets out how a range of organisations will work together to achieve shared objectives for the future management of the National Park or AONB. Each Management Plan will look 5-10 years ahead (National Parks England, 2022; https://landscapesforlife.org.uk).

Pollinator patches: A pollinator patch is a bed of annual flowers which may be native, non-native or a mixture of both. To be a successful pollinator patch, the ground needs to be meticulously prepared, which involves digging the site over and removing all existing vegetation, especially grasses, docks and nettles. Seed is sown in the spring (Lune Valley Beekeepers, 2022).

Production-based emissions: These are the net emissions that are physically released in a given

landscape (most notably by burning coal, oil and gas), those arising from the production of electricity used in the area (wherever that power is generated), and direct emissions associated with land use within the landscape (parts of agriculture excluding fuel use and supply chains, peatland degradation, etc.) (Small World Consulting, 2022).

Paris Agreement: The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted in December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC. The agreement, adopted by 196 Parties to the UNFCCC, entered into force on 4th November 2016, and as of May 2018 had 195 Signatories and was ratified by 177 Parties. One of the goals of the Paris Agreement is "Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels", recognising that this would significantly reduce the risks and impacts of climate change. The temperature targets require reducing net anthropogenic greenhouse gas emissions through a range of measures collectively referred to as climate mitigation. Additionally, the Agreement aims to strengthen the ability of countries to deal with the impacts of climate change through climate adaptation measures. The Paris Agreement became fully effective in 2020. See also United Nations Framework Convention on Climate Change (UNFCCC), Kyoto Protocol and Nationally Determined Contributions (NDCs). (IPCC, 2018: Annex 1: Glossary [Matthews, J.B.R. (ed)]).

Paris-aligned greenhouse gas targets: Greenhouse gas emission reduction targets (and/or carbon sequestration targets) that are aligned with the Paris Agreement targets on warming.

Post-traumatic stress disorder (PTSD): Post-traumatic stress disorder (PTSD) is an anxiety disorder caused by very stressful, frightening or distressing events. People experiencing PTSD often relive the traumatic event through nightmares and flashbacks, and may experience feelings of isolation, irritability and guilt. Problems sleeping, insomnia, and concentration difficulties are often associated with PTSD. These symptoms are often severe and persistent enough to have a significant impact on the person's day-to-day life (NHS, 2022).

Precautionary principle: As referred to within the Environment Bill 2021, the precautionary principle states that where there are threats of serious or irreversible environmental damage, a lack of scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation (GOV.UK, 2021). This appears to have been adopted from the United Nations General Assembly (1992) definition.

Public health prevention: This is split into three categories:

Primary prevention: Taking action to reduce the incidence of disease and health problems within the population, either through universal measures that reduce lifestyle risks and their causes or by targeting high-risk groups.

Secondary prevention: Systematically detecting the early stages of disease and intervening before full symptoms develop – for example, prescribing statins to reduce cholesterol, and taking measures to reduce high blood pressure.

Tertiary prevention: Softening the impact of an ongoing illness or injury that has lasting effects. This is done by helping people manage long-term, often complex health problems and injuries (e.g. chronic diseases, permanent impairments) in order to improve as much as possible their ability to function, their quality of life and their life expectancy (Local Government Association, 2022).

Quoted (listed) company: Under the Companies Act 2006, a "quoted company" means a company whose equity share capital:

(a) has been included in the official list in accordance with the provisions of Part 6 of the Financial Services and Markets Act 2000 (c. 8), or
(b) is officially listed in a European Economic Area (EEA) State, or
(c) is admitted to dealing on either the New York Stock Exchange or the exchange known as Nasdaq.

In paragraph (a) "the official list" has the meaning given by section 103(1) of the Financial Services and Markets Act 2000 (Legislation.gov.uk, 2006).

Railway electrification: The process of transition from diesel-powered locomotives (trains) to electric railways using either electric locomotives (hauling passengers or freight in separate cars), electric multiple units (passenger cars with their own motors) or both. Electricity is typically generated in large and relatively efficient generating stations, transmitted to the railway network, and distributed to the trains via overhead power lines.

Resilience: The capacity of social, economic and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure while also maintaining the capacity for adaptation, learning and transformation. This definition builds on the definition used by the Arctic Council (2013) (IPCC, 2018: Annex 1: Glossary [Matthews, J.B.R. (ed)]).

Revenue: In accounting, revenue is the total amount of income generated by the sale of goods and services related to the primary operations of the business. Commercial revenue may also be referred to as sales or as turnover.

Rewilding (landscape recovery): There are varying definitions for rewilding, from popularised terms to more science-based definitions. In the public perception the practice of "rewilding" has emerged as a method for returning native flora and fauna to landscapes humans have altered. However, due to differing definitions and interpretations, the practice of rewilding has been both promoted and criticised in recent years. Benefits of rewilding include flexibility to react to environmental change and the promotion of opportunities for society to reconnect with nature. Criticisms include the lack of a clear conceptualization of rewilding, insufficient knowledge about possible outcomes, and the perception that rewilding excludes people and agriculture from landscapes. This particularly relates to the re-introduction of natural predators such as wolves and lynx where there may be human-wildlife conflicts, specifically where communities' livelihoods and food production are impacted.

(Summarised from Alice Di Sacco, Kate A. Hardwick, *et al.* "Ten golden rules for reforestation to optimize carbon sequestration, biodiversity recovery and livelihood benefits," *Global Change Biology*, 27, 7, (1328-1348), (2021). https://doi.org/10.1111/gcb.15498)

Riparian woodland: Woodlands on the banks of natural bodies of water, such as lakes and rivers.

SIC codes (industry sectors): Information about activities of businesses and industry in the UK – including data on the production and trade of goods and services, sales by retailers, characteristics of businesses, the construction and manufacturing sectors, and international trade – is collected by the Office of National Statistics. "Standard industrial classification of economic activities" (SIC) codes are used to classify and report industrial activity in specific sectors (ONS, 2022).

Supply chain: The suppliers used by a company or organisation to produce and distribute products, goods and services.

Sustainable land management: A knowledge-based procedure that helps integrate land, water, biodiversity, and environmental management (including input and output externalities) to meet rising demands for food and fibre while sustaining ecosystem services and livelihoods. Sustainable land management is necessary in order to satisfy the requirements of a growing population while avoiding irreversible damage to ecosystems that support our livelihoods. Improper land management can lead to land degradation and a significant reduction in the productive and service functions (biodiversity niches, hydrology, carbon sequestration) of watersheds and landscapes (The World Bank).

Slurry: Manure is organic matter that is used as organic fertilizer in agriculture. Most animal manure consists of faeces. Common forms of animal manure include farmyard manure or farm slurry (liquid manure).

Statutory instrument: Statutory instruments are the most common form of secondary (or delegated) legislation in the UK. The power to make a statutory instrument is set out in an Act of Parliament and nearly always conferred on a Minister of the Crown. The Minister is then able to make law on the matters identified in the Act, using the parliamentary procedure set out in the Act. Statutory instruments may follow affirmative or negative procedure, or have no procedure at all; the decision on which to use is fixed by the Act (UK Parliament, 2022).

Toxic air: This refers to pollutants in the air at high enough concentrations to cause or contribute to an increase in mortality or an increase in serious illness, or pose a present or potential future hazard to human health.

Turnover: A synonym to business revenue.

Zero-carbon energy supply: Zero carbon means that no carbon emissions are being produced from a product or service (for example, a wind farm generating electricity, or a battery deploying electricity) (National Grid, 2022).

10. Appendices

10.1. Appendix: Selection of Postcodes for "The Broads Executive Area" and "The Broads Adjacent Gateway Settlements Area"

Appendix 10.1 was kindly produced by Harry Mach, Project Manager, The Broads Authority.

One of the challenges of mapping any form of activity in the Broads is that the geographical coverage of the Broads Executive Area maps closely to the flood plain, and tends to take small chunks out of larger settlements. A resident who lives in the Broads will do most of their shopping, driving and working outside the National Park.

The data sources that form the basis of the Small World model are often only published at postcode level. Therefore, by including postcodes that are within the Broads, the study area will inevitably expand somewhat outside the Broads boundary. However, it will do so in an inconsistent manner.

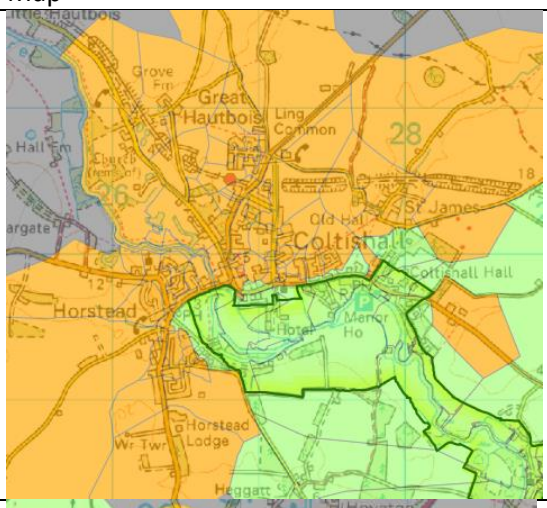
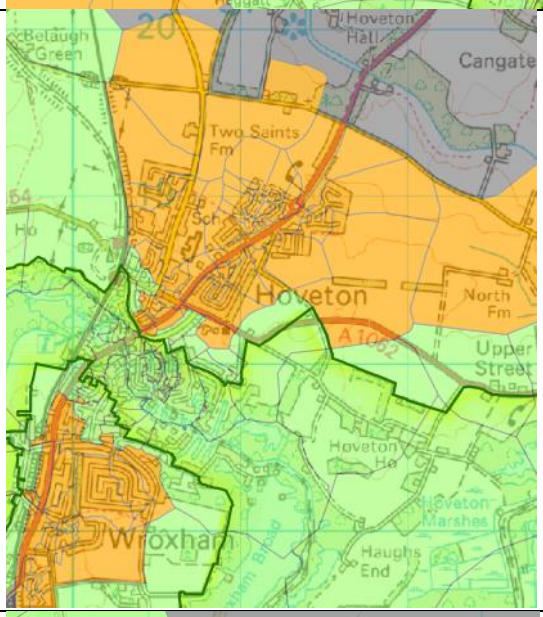
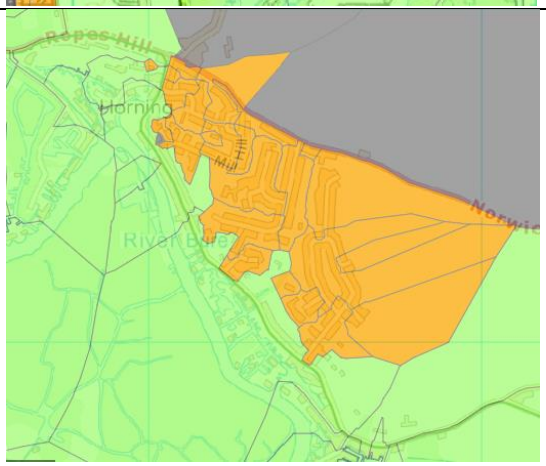
To allow for a more complete understanding of the area, the Broads Authority carried out an analysis of the areas that should be considered as "adjacent areas", i.e. places where decisions made relative to the Broads are relevant to the footprint of residents and visitors. For example, tourism travel and spend in Wroxham & Hoveton is heavily influenced by the Broads, despite only a small part of the settlement falling within the Broads Executive Area.

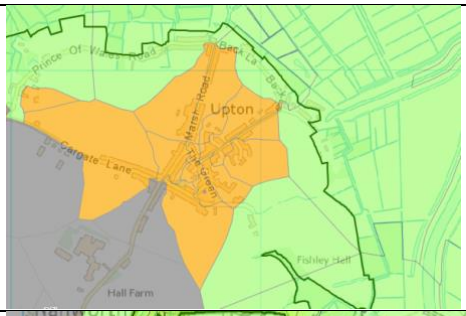
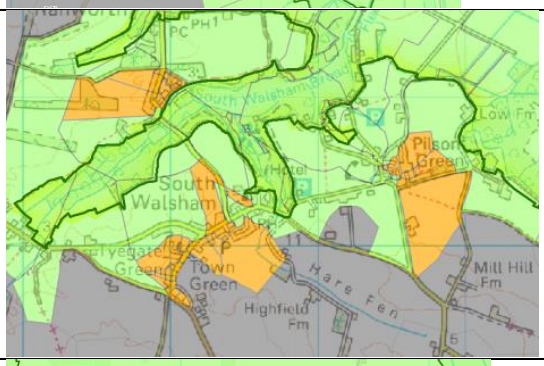
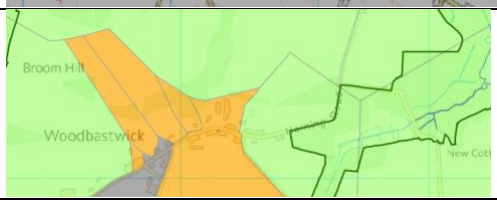
Principles

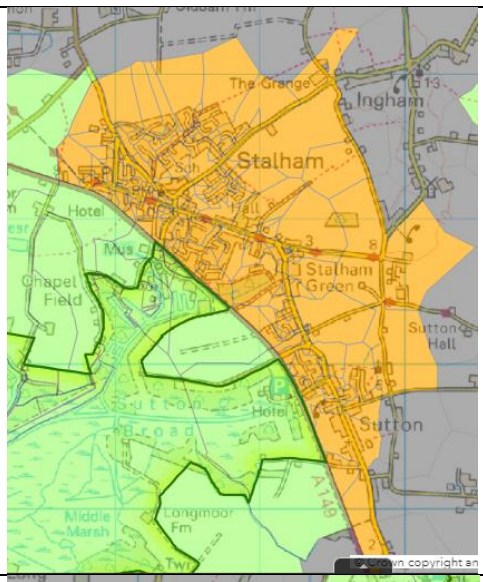
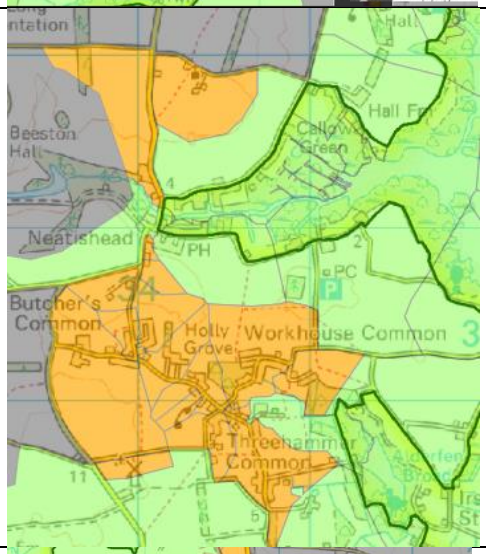
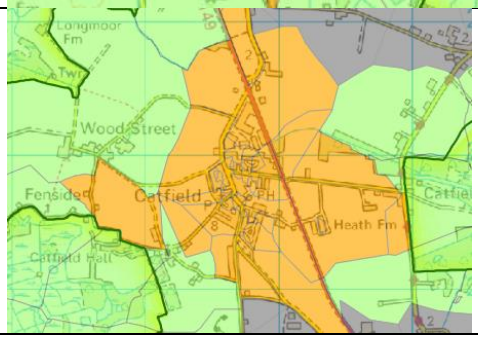
- Prefer to include rather than exclude.
- Decisions need to be consistent and clear.
- This is a decision-making tool, so as far as possible we need to measure aspects that The Broads Authority can influence.
- Businesses that primarily serve the Broads Tourism trade (i.e. a pub near the waterways) should be included.

In drawing the boundaries for the adjacent area, the following methods have been applied:

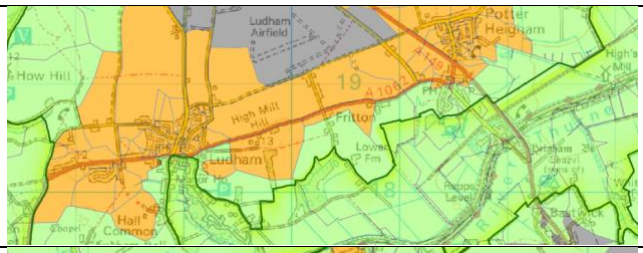
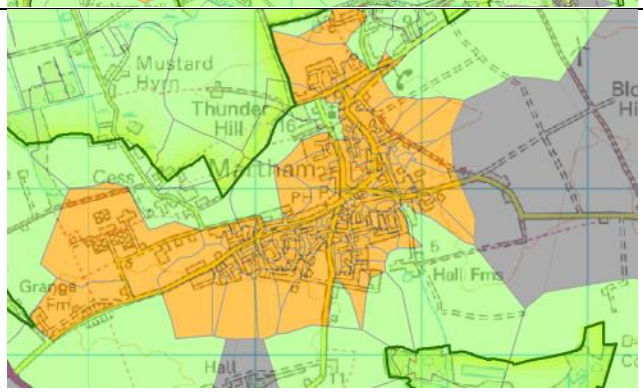
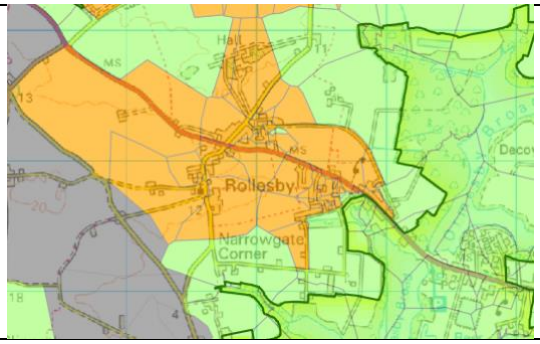
- Aim to have boundaries defined by geographical features (A-road or stream) when adding new postcodes.
- If a settlement is partially in the executive area and has a population of fewer than 2,000, include it.
- For areas where a settlement has more than 2,000 people, include areas of the settlement falling within 0.5 km of the Broads Executive Area.

Location	Map	Suggested Action
Coltishall		As Coltishall has a population of under 2,000 and is a gateway to the Broads (particularly around Horstead Mill) it is included in the area. The postcodes extend into neighbouring farmland.
Hoveton & Wroxham		Wroxham and Hoveton are the "gateway to the Broads" but also two small settlements. To the North a sensible boundary is St Peters Lane, and a sensible Southern boundary is the housing estate between Salhouse Road and Norwich Road.
Horning		A comparison on Google Maps appears to show that most of the businesses relevant to the broads are on Lower Street, which is included in these polygons. However, there is a range of accommodation options in the rest of Horning, so it may be valid to expand the selection here to include the entire town. Transport is also relevant here, with the "Three Rivers Way" running alongside the Norwich Road (shown here in red).

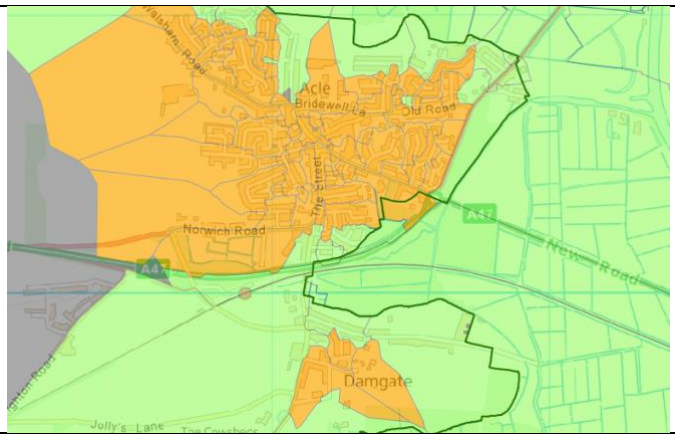
		Expand to include area between Broads and Norwich Road.
Upton		Upton is a small village bordering the Broads. Cargate lane appears a reasonable geographic boundary.
Ranworth, South Walsham & Pilson Green		These settlements are all on the edge of the Broads, with their own staithes and navigation channels to the main river.
Woodbastwick		This settlement is on the edge of the Broads, with its own staithes and navigation channels to the main river.

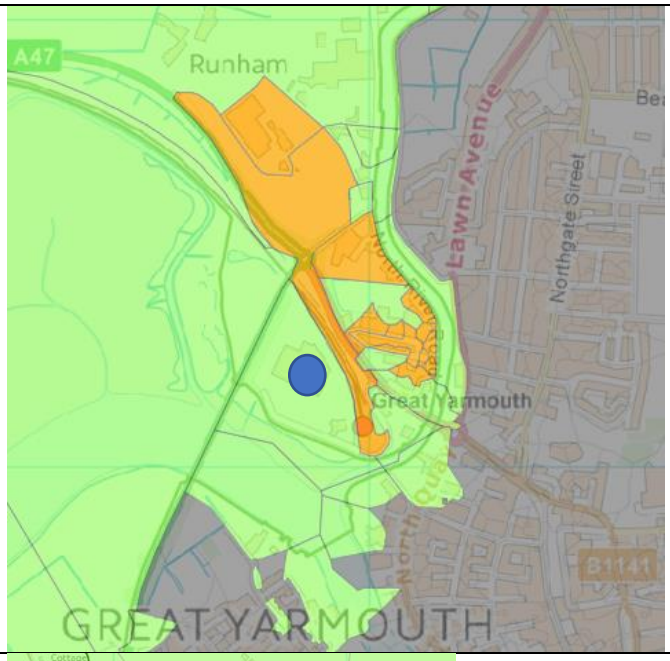
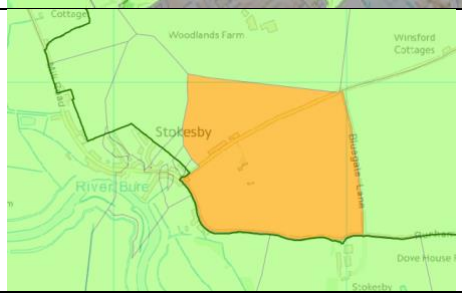
Stalham & Sutton		Stalham is another gateway settlement, influenced as a major base for Richardsons. Brick Lane appears to be a reasonable boundary.
Neatishead and Irstead		These are both very small settlements partially within the Broads boundary. Consequently, they are both fully included.
Catfield		Catfield is a small village located between two Broads valleys, and should be defined as within the Broads Influence.

Thurne Valley

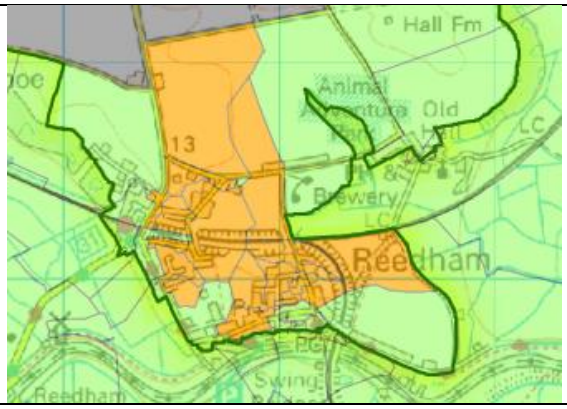
Hickling		
Potter Heigham & Ludham		These two settlements are both small and effectively surrounded by the Broads; therefore, it is sensible to include them both.
Martham & West Somerton		Martham has a population of over 2,000 so does not merit automatic inclusion. However, large parts of the village are within half a km of the Broads. As there is no sensible way to split the village, it should all be included.
Rollesby		Rollesby has a population of under 2,000 and borders the Executive Area, so it should be included. Repps Road appears to be a sensible boundary.

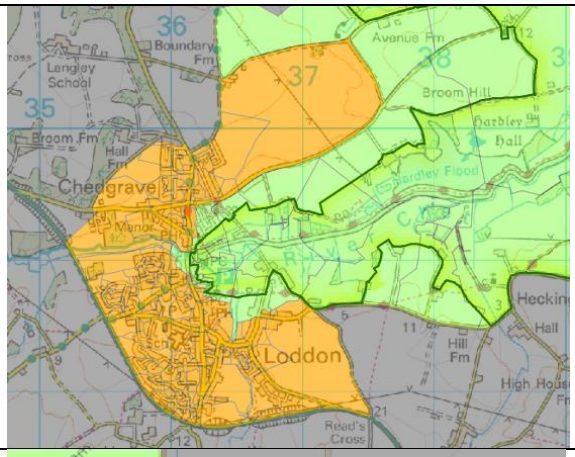
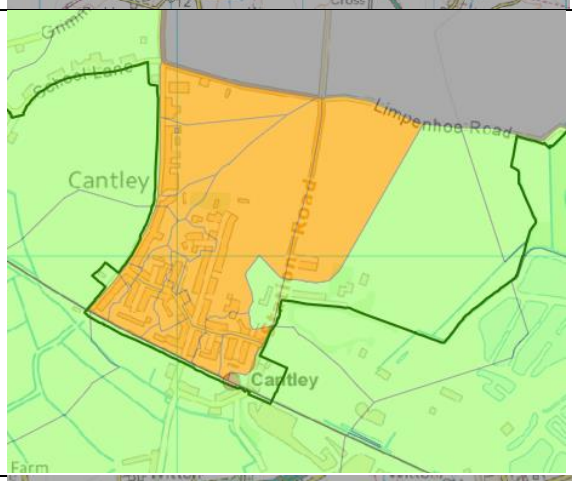
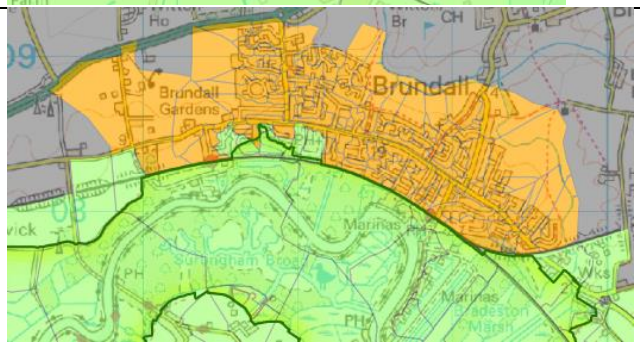
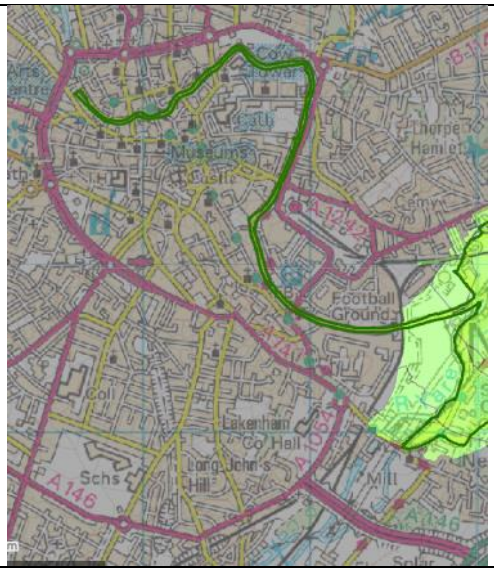
Lower Bure

Acle		Acle is another "gateway" town to the Broads. Business in the town is heavily influenced by day visitors, and there is a stopping-off point for cruisers at the Bridge.

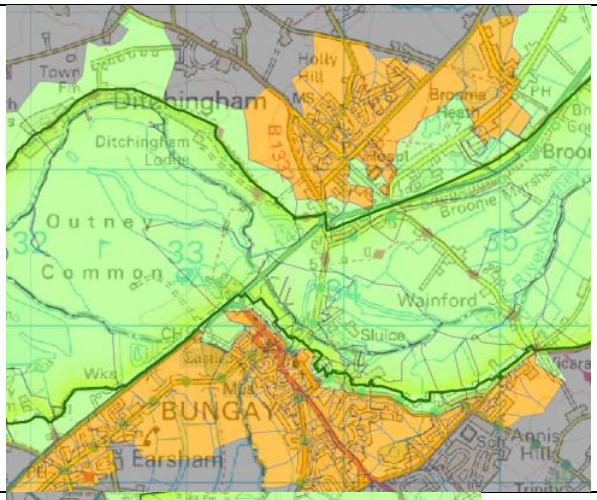
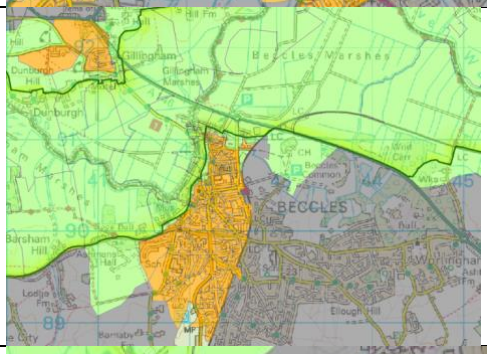
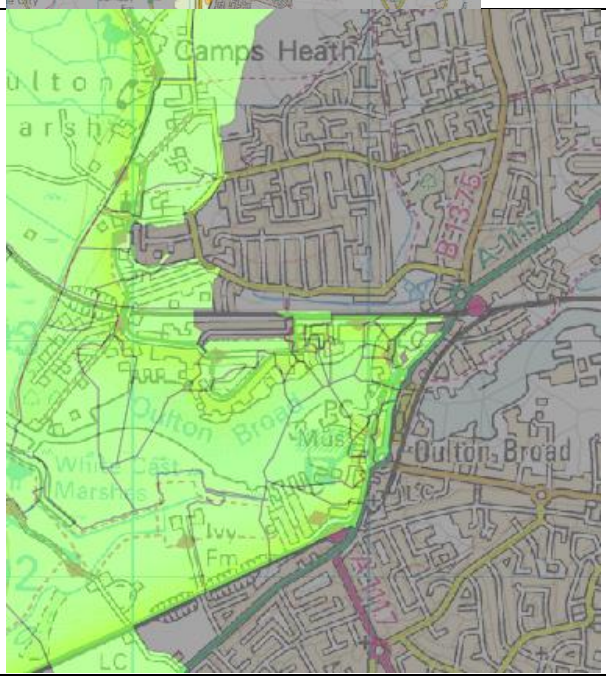
Great Yarmouth		Yarmouth as a whole should be excluded, as it would skew the survey. However, certain areas within it, such as the Vauxhall Holiday Park, should be included. N.B. This currently includes the ASDA supermarket, which is likely to represent a large amount of non-Broads emissions.
Stokesby		One extra postcode has been included at Stokesby to ensure a consistent boundary.

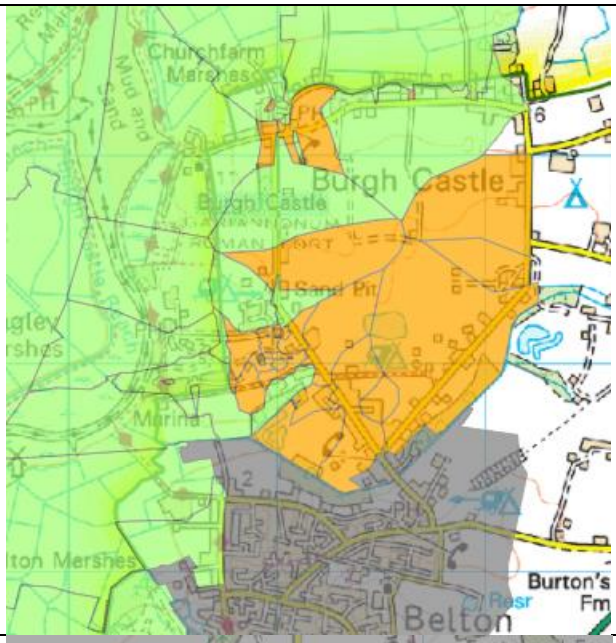
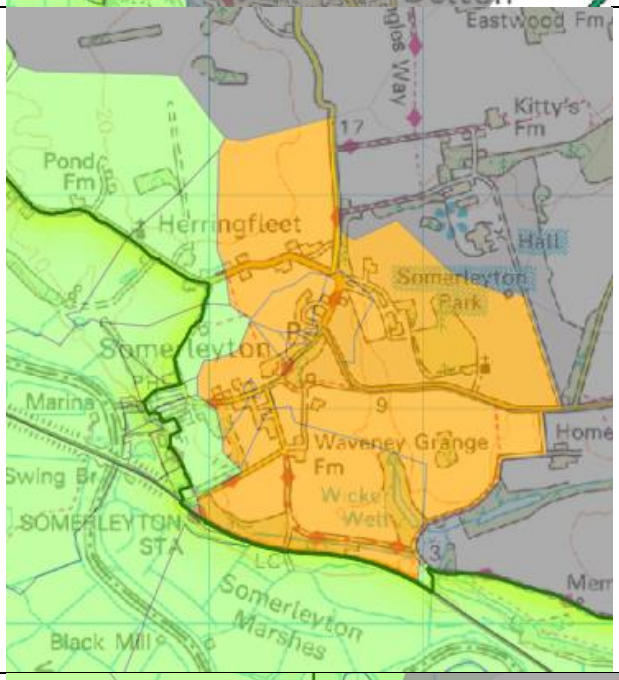
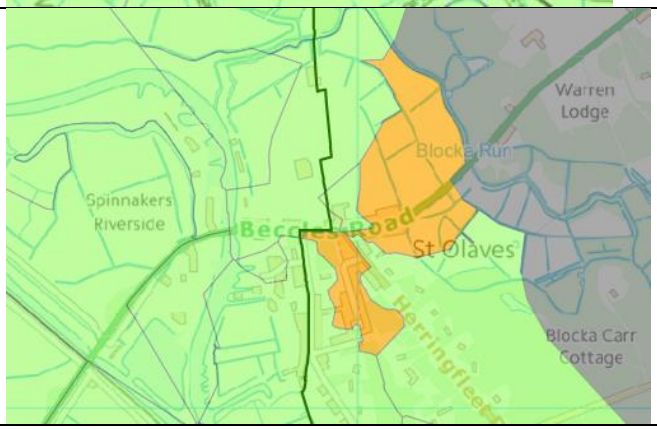
Rivers Yare, Chet & Wensum

Reedham		Reedham is a small town almost surrounded by the Broads area, so should be included. Hall Road appears to provide a reasonable boundary.

Loddon & Chedgrave		Loddon & Chedgrave combined have a population similar to Loddon. As a gateway town on the Chet, the pair play a similar role to Coltishall, and should therefore be included.
Cantley		Like Reedham, Cantley is a small town almost surrounded by the Broads area, so should be included. Limpenhoe Road seems a reasonable boundary.
Brundall		The riverside areas of Brundall fall within the Broads Executive Area. The town has several large marinas and will be the starting point for many cruises and day trips. After discussion, it was decided to include Brundall.
Norwich		After discussion, it was decided to remove the areas upstream of Trowse Bridge, as the data is unlikely to be useful. These areas are better addressed by policy from Norwich City Council.

Waveney

Bungay		Bungay is a large population centre, and therefore will not be entirely within the Broads' influence. It also does not have a waterway suitable for cruisers, so will be more influenced by kayaking and paddleboards.
Beccles		Beccles is a complex proposition. Following the principles, and including areas within half a kilometre of the Broads, means including the areas to the west of the railway as a starting point.
Oulton		The boundary at Oulton appears to map fairly well to the parts impacted directly by the Broads. The remaining areas, as part of Lowestoft, should be excluded from the footprint.

Belton, Burgh & Bradwell.		The area north of Belton contains a number of holiday parks that should be included in the analysis. Belton itself exists largely as a suburb of Lowestoft, so should be excluded.
Somerleyton		Somerleyton is a small village attached to the Broads, so should be included.
St Olaves		St Olaves is a small village attached to the Broads, so should be included.

10.2. Appendix: National Park key statistics

Table 6a: Key statistics for the Broads Executive Area

Output Variable	Value	Unit	Source		Output Variable	Value	Unit	Source
Land Area	**30,300**	ha	Official Figures / CEH LCM					
Resident Population	**17,747**	persons	ONS Mid-2019 LSOA Population; ONSPD 2019; BEIS 2019 Postcode Electricity Meters; Custom Postcodes		Average Visitors Per Day	**13,963**	persons	STEAM 2019
Resident Population Density	**0.59**	persons per ha	Based on the Above		Visitor Population Density	**0.46**	persons per ha	Based on the Above
Annual Final Consumption (Households + Public Services)	**33,163**	£ per person per year	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes		Annual Visitors Spend	**158,461,903**	£ per year	STEAM 2019
Annual Household Fuel per Resident	**6,347**	kWh per person per year	BEIS 2019 Postcode Gas; BEIS 2018 Residual Fuels; ONSPD 2019; Custom Postcodes		Annual Visitors All Types	**3,169,767**	persons per year	STEAM 2019
Annual Household Electricity per Resident	**1,054**	kWh per person per year	BEIS 2019 Postcode Electricity; ONSPD 2019; Custom Postcodes		Percentage of Visitors Staying Overnight	**14.1%**	percentage	STEAM 2019
Annual Vehicle Fuel per Resident	**3,851**	kWh per person per year	BEIS 2018 Road Fuels; ONSPD 2019; Custom Postcodes		Average Duration of Stay for Overnight Visitors	**5.3**	days	STEAM 2019
Annual Personal Flights per Resident, Economy Class	**0.89**	fraction	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes; SWC Population Estimate		Average Visitor Party Size	**3.0**	persons	Visitor Survey
Annual Personal Flights per Resident, Business Class	**0.004**	fraction	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes; SWC Population Estimate		Average Visitor One-Way Road/Train/Boat Mileage Travelled	**104**	miles	Visitor Survey
Average Resident One-Way Mileage per Flight, Economy Class	**2,132**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes		Estimated Fraction of Trips by Car	**84.5%**	percentage	Visitor Survey
Average Resident One-Way Mileage per Flight, Business Class	**3,125**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes		Estimated Fraction of Trips Involving Flights	**2.0%**	percentage	Visitor Survey
Annual Business Turnover, COA-based	**1,977,298,000**	£ per year	IDBR 2019; ONSPD 2019; Custom Postcodes		Average Visitor One-Way Mileage per Flight, Economy Class	**2,451**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes
Percentage of Suppressed Turnover Output, COA-based	**0.00%**	percentage	IDBR 2019; ONSPD 2019; Custom Postcodes		Average Visitor One-Way Mileage per Flight, Business Class	**0**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes
GVA Reconstructed from IDBR Turnover, COA-based	**806,901,897**	£ per year	UK IDBR 2019; SWC EEIO 2019		Through Traffic Share of the Major Roads' Footprint	**85.8%**	percentage	BEIS 2018 Road Fuels; DfT AADF 2019 Traffic Counts; ONSPD 2019; Custom Postcodes; STEAM 2019

Table 6b: Key statistics for The Broads Adjacent Gateway Settlements

Output Variable	Value	Unit	Source		Output Variable	Value	Unit	Source
Land Area	**NA**	ha	Official Figures / CEH LCM					
Resident Population	**38,062**	persons	ONS Mid-2019 LSOA Population; ONSPD 2019; BEIS 2019 Postcode Electricity Meters; Custom Postcodes		Average Visitors Per Day	**22,089**	persons	STEAM 2019
Resident Population Density		persons per ha	Based on the Above		Visitor Population Density		persons per ha	Based on the Above
Annual Final Consumption (Households + Public Services)	**32,661**	£ per person per year	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes		Annual Visitors Spend	**250,675,275**	£ per year	STEAM 2019
Annual Household Fuel per Resident	**6,251**	kWh per person per year	BEIS 2019 Postcode Gas; BEIS 2018 Residual Fuels; ONSPD 2019; Custom Postcodes		Annual Visitors All Types	**5,014,342**	persons per year	STEAM 2019
Annual Household Electricity per Resident	**949**	kWh per person per year	BEIS 2019 Postcode Electricity; ONSPD 2019; Custom Postcodes		Percentage of Visitors Staying Overnight	**14.1%**	percentage	STEAM 2019
Annual Vehicle Fuel per Resident	**4,252**	kWh per person per year	BEIS 2018 Road Fuels; ONSPD 2019; Custom Postcodes		Average Duration of Stay for Overnight Visitors	**5.3**	days	STEAM 2019
Annual Personal Flights per Resident, Economy Class	**0.94**	fraction	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes; SWC Population Estimate		Average Visitor Party Size	**3.0**	persons	Visitor Survey
Annual Personal Flights per Resident, Business Class	**0.006**	fraction	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes; SWC Population Estimate		Average Visitor One-Way Road/Train/Boat Mileage Travelled	**104**	miles	Visitor Survey
Average Resident One-Way Mileage per Flight, Economy Class	**2,132**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes		Estimated Fraction of Trips by Car	**84.5%**	percentage	Visitor Survey
Average Resident One-Way Mileage per Flight, Business Class	**3,064**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes		Estimated Fraction of Trips Involving Flights	**2.0%**	percentage	Visitor Survey
Annual Business Turnover, COA-based	**2,351,443,000**	£ per year	IDBR 2019; ONSPD 2019; Custom Postcodes		Average Visitor One-Way Mileage per Flight, Economy Class	**2,544**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes
Percentage of Suppressed Turnover Output, COA-based	**6.85%**	percentage	IDBR 2019; ONSPD 2019; Custom Postcodes		Average Visitor One-Way Mileage per Flight, Business Class	**0**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes
GVA Reconstructed from IDBR Turnover, COA-based	**997,840,947**	£ per year	UK IDBR 2019; SWC EEIO 2019		Through Traffic Share of the Major Roads' Footprint	**91.6%**	percentage	BEIS 2018 Road Fuels; DfT AADF 2019 Traffic Counts; ONSPD 2019; Custom Postcodes; STEAM 2019

10.3. Appendix: Summary datasets used for carbon footprint and confidence levels

Summary of Datasets					Level of granularity of data								Confidence Levels: High/Medium/Low	
Dataset	Data Year	Industry sector base	Fuel type base	Land Use base	Demographic base	Geographical pinpoints	Postcodes	COA	LSOA	MSOA	LA (Local Authority District)	NP / AONB	Original Dataset	Implement. in SWC Tool
SWC EEIO Emissions Factors for Industries	2019	■											High	Medium
SWC-BEIS Emissions Factors for Fuels	2019		■										High	High
ONS Postcode Directory	2019				■	■	■	■	■	■	■	■	High	High
Custom Postcode Boundary	2019 or later						■					▒	High	High
BEIS Domestic Electricity	2019		■				■						High	High
BEIS Domestic Gas	2019		■				■						High	High
ONS Population Demographics (2011 Census)	2011				■		■						High	High
ONS Population Numbers (mid-year)	2019								■				High	High
BEIS Non-Domestic Electricity	2019		■							■			High	Medium
BEIS Non-Domestic Gas	2019		■							■			High	Medium
BEIS Residual Fuels	2018		■								■		Medium	Medium
BEIS Road Fuels	2018		■								■		Medium	Medium
Custom DfT Traffic Points	2019					■					■	▒	Medium	High
ONS Gross Value Added (GVA)	2019	■									■		Medium	Low
IDBR Data for Business Turnover	2019	■						■	■				High	Medium
NAEI Data for Large Emitters	2018						■						High	High
BEIS CO2 Emissions	2018										■		High	Medium
BEIS Non-CO2 Emissions	2018										■		High	Medium
BEIS-DEFRA Land Use GHG Emissions for NPs (CO2 & Non-CO2)	2019 & 2017											■	Medium	High
ONS Atmospheric Emissions Inventory	2019	■											High	High
STEAM Tourism Dataset	2019	■										▒	Medium	Medium
Civil Aviation Authority	2019										■		Medium	Medium
Custom Visitor Surveys (where available)	2019 or earlier	■										▒	Medium	Medium
ONS Household Expenditure A52 (by demographics)	2018				■								Low	Medium
Custom Habitat and Peatland Maps	2019 or earlier			▒								▒	High TBC	Medium
6th Carbon Budget, Tyndall Carbon Budget Tool, National Food Strategy, etc	2019-2021	■	■	■									Medium	Medium

10.4. Appendix: Carbon footprint definitions and data sources

Consumption-based Footprint Category	Contributing Factors	Source
Household Fuel	Gas and other fuels consumed in homes	BEIS 2019 Postcode Gas; BEIS 2018 Residual Fuels; ONSPD 2019; Custom Postcodes; SWC 2019 Emission Factors. In addition for Visitors: STEAM 2019
Household Electricity	Electricity consumed in homes	BEIS 2019 Postcode Electricity; ONSPD 2019; Custom Postcodes; SWC 2019 Emission Factors. In addition for Visitors: STEAM 2019
Vehicle Fuel	Petrol and diesel use by private cars, taxis, motorhomes/campervans and motorbikes	BEIS 2018 Road Fuels; ONSPD 2019; Custom Postcodes; SWC 2019 Emission Factors;. In addition for Visitors: Visitors Survey, STEAM 2019
Car Manufacture & Maintenance	Footprint associated with making & maintaining private vehicles	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO* UK Consumption; SWC 2019 EEIO Emissions Factors
Personal Flights	Flights for purposes other than business	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes. In addition for Visitors: Visitors Survey, STEAM 2019
Ferry Crossings & Cruises	Residents: ferries, boats and cruises; Visitors (where applicable): boats (in NP) and ferries (to & from NP)	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: Visitors Survey, STEAM 2019; Custom Datasets (where applicable)
Trains, Buses & Other Transport	Trains (excl. freight), buses, coaches, etc.	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: Visitors Survey, STEAM 2019
Food & Drink	Entire food & drink consumption, including from shops, restaurants, take-aways, pubs, hotels and B&Bs	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: STEAM 2019
Accommodation (Non Home) Excl. Food	Includes accommodation energy use and supply chains (excl. food) Residents: holiday accommodation; Visitors: accommod. while in NP	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: STEAM 2019
Other Non-Food Shopping	All other shopping	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: STEAM 2019
Water, Waste & Sewerage	Water, waste and sewerage	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: STEAM 2019
Other Bought Services	Includes financial services, telecoms, letting agents (for residents only), travel agents, etc.	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: STEAM 2019
Housing	Everything connected with building, buying and maintaining private properties (for residents only)	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: STEAM 2019
Health, Education, Other Public Services & Administration	Includes hospitals, schools, police, firefighting, bin collection, etc.	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: STEAM 2019
Leisure, Recreation & Attractions	Arts & entertainment, sports facilities, libraries, museums, etc.	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes; SWC 2019 EEIO UK Consumption; SWC 2019 EEIO Emissions Factors. In addition for Visitors: STEAM 2019

10.5.1 Residents GHG emissions: the Broads Executive Area

Consumer Expenditure Categories Summary	ALL Scopes	Units
Household Fuel	24,587	tCO2e per year
Household Electricity	6,338	tCO2e per year
Vehicle Fuel	33,853	tCO2e per year
Car Manufacture & Maintenance	9,022	tCO2e per year
Personal Flights	23,152	tCO2e per year
Ferry Crossings & Cruises	3,123	tCO2e per year
Trains, Buses & Other Transport	5,729	tCO2e per year
Food & Drink	62,930	tCO2e per year
Accommodation (Non Home) Excl. Food	1,175	tCO2e per year
Other Non-Food Shopping	17,712	tCO2e per year
Water, Waste & Sewerage	3,570	tCO2e per year
Other Bought Services	17,490	tCO2e per year
Housing	13,155	tCO2e per year
Health, Education, Other Public Services & Administration	24,686	tCO2e per year
Leisure, Recreation & Attractions	4,587	tCO2e per year
Total	**251,105**	**tCO2e per year**

NOTE: The total could be marginally different to the sum of individual components due to rounding

10.5.2 Residents GHG emissions: the Broads Adjacent Gateway Settlements

Consumer Expenditure Categories Summary	ALL Scopes	Units
Household Fuel	51,938	tCO2e per year
Household Electricity	12,237	tCO2e per year
Vehicle Fuel	70,713	tCO2e per year
Car Manufacture & Maintenance	18,845	tCO2e per year
Personal Flights	52,736	tCO2e per year
Ferry Crossings & Cruises	6,529	tCO2e per year
Trains, Buses & Other Transport	11,967	tCO2e per year
Food & Drink	134,123	tCO2e per year
Accommodation (Non Home) Excl. Food	2,508	tCO2e per year
Other Non-Food Shopping	37,202	tCO2e per year
Water, Waste & Sewerage	7,584	tCO2e per year
Other Bought Services	37,252	tCO2e per year
Housing	27,868	tCO2e per year
Leisure, Recreation & Attractions	9,714	tCO2e per year
Total	**532,104**	**tCO2e per year**

NOTE: The total could be marginally different to the sum of individual components due to rounding

10.6.1 Visitors GHG emissions: the Broads Executive Area

Consumer Expenditure Categories Summary	In NP	To & From NP	Units
Household Fuel	426	0	tCO2e per year
Household Electricity	186	0	tCO2e per year
Vehicle Fuel	5,461	79,043	tCO2e per year
Car Manufacture & Maintenance	1,383	20,012	tCO2e per year
Personal Flights	0	10,412	tCO2e per year
Ferry Crossings & Cruises	6,374	0	tCO2e per year
Trains, Buses & Other Transport	472	3,262	tCO2e per year
Food & Drink	44,878	0	tCO2e per year
Accommodation (Non Home) Excl. Food	7,629	0	tCO2e per year
Other Non-Food Shopping	10,487	0	tCO2e per year
Water, Waste & Sewerage	3,121	0	tCO2e per year
Other Bought Services	4,132	0	tCO2e per year
Housing	0	0	tCO2e per year
Health, Education, Other Public Services & Administration	0	0	tCO2e per year
Leisure, Recreation & Attractions	1,047	0	tCO2e per year
Total	**85,594**	**112,728**	**tCO2e per year**

NOTE: The total could be marginally different to the sum of individual components due to rounding

10.6.2 Visitors GHG emissions: the Broads Adjacent Gateway Settlements

Consumer Expenditure Categories Summary	In NP	To & From NP	Units
Household Fuel	860	0	tCO2e per year
Household Electricity	263	0	tCO2e per year
Vehicle Fuel	18,306	125,040	tCO2e per year
Car Manufacture & Maintenance	4,635	31,658	tCO2e per year
Personal Flights	0	17,093	tCO2e per year
Ferry Crossings & Cruises	0	0	tCO2e per year
Trains, Buses & Other Transport	755	5,159	tCO2e per year
Food & Drink	70,993	0	tCO2e per year
Accommodation (Non Home) Excl. Food	12,068	0	tCO2e per year
Other Non-Food Shopping	16,589	0	tCO2e per year
Water, Waste & Sewerage	4,890	0	tCO2e per year
Other Bought Services	6,537	0	tCO2e per year
Housing	0	0	tCO2e per year
Health, Education, Other Public Services & Administration	0	0	tCO2e per year
Leisure, Recreation & Attractions	1,657	0	tCO2e per year
Total	**137,554**	**178,951**	**tCO2e per year**

NOTE: The total could be marginally different to the sum of individual components due to rounding

10.7. Appendix. Industry footprint estimates

10.7.1. Appendix: SIC Codes (2007) summary and IDBR description

SIC (2007)	The SIC hierarchy High-Level Summary
Section A	Agriculture, Forestry and fishing
Section B	Mining and quarrying
Section C	Manufacturing
Section D	Electricity, gas, steam and air condition supply
Section E	Water supply; sewerage, waste management and remediation activities
Section F	Construction
Section G	Wholesale and retail trade, repair of motor vehicles
Section H	Transportation and storage
Section I	Accommodation and food services
Section J	Information and communication
Section K	Financial and insurance activities
Section L	Real estate activities
Section M	Professional, scientific and technical activities
Section N	Administrative and support service activities
Section O	Public administration and defence; compulsory social security
Section P	Education
Section Q	Human health and social work activities
Section R	Arts, entertainment, and recreation
Section S	Other service activities
Section T	Activities of households as employers; undifferentiated goods-and services-producing activities for own use
Section U	Activities of extraterritorial organisations and bodies

IDBR

This dataset uses the 2007 revision to the Standard Industrial Classification (UK SIC 2007) in place of the 2003 revision Standard Industrial Classification (UK SIC 2003). The UK SIC 2007 is a major revision of UK SIC 2003 with changes at all levels of the SIC. Further details on Standard Industrial Classification can be found on the ONS website:

http://www.ons.gov.uk/ons/guide-method/classifications/current-standard-classifications/index.html

The broad industry group structure has been defined under UK SIC 2007 and is listed below:

Description	UK SIC 2007 Section	Division
Agriculture, forestry & fishing	A	01/03
Production	B, C, D and E	05/39
Mining, quarrying & utilities	*B, D and E*	*05/09, 35/39*
Manufacturing	*C*	*10/33*
Construction	F	41/43
Wholesale and retail; repair of motor vehicles	G	45/47
Motor trades	*G*	*45*
Wholesale	*G*	*46*
Retail	*G*	*47*
Transport & storage (inc postal)	H	49/53
Accommodation & food services	I	55/56
Information & communication	J	58/63
Finance & insurance	K	64/66
Property	L	68
Professional, scientific & technical	M	69/75
Business administration and support services	N	77/82
Public administration & defence	O	84
Education	P	85
Health	Q	86/88
Arts, entertainment, recreation and other services	R, S, T and U	90/99

Source: IDBR Meta Data

Source: SIC (2007) https://onsdigital.github.io/dp-classification-tools/standard-industrial-classification/ONS_SIC_hierarchy_view.html

10.7.2.1 Industry GHG emissions (IDBR-based): the Broads Executive Area

Industry Categories Summary (IDBR sectors)	ALL Scopes	Units
Agriculture, forestry & fishing	60,839	tCO2e per year
Production	148,187	tCO2e per year
Construction	20,205	tCO2e per year
Motor trades	2,539	tCO2e per year
Wholesale	8,380	tCO2e per year
Retail	8,155	tCO2e per year
Transport & storage (inc. postal)	36,290	tCO2e per year
Accommodation & food services	10,510	tCO2e per year
Information & communication	5,305	tCO2e per year
Finance & insurance	214	tCO2e per year
Property	2,695	tCO2e per year
Professional, scientific & technical	8,284	tCO2e per year
Business administration & support services	10,129	tCO2e per year
Public administration & defence	2,294	tCO2e per year
Education	3,143	tCO2e per year
Health	7,149	tCO2e per year
Arts, entertainment, recreation & other services	7,579	tCO2e per year
Total	**341,896**	**tCO2e per year**
ENERGY-ONLY INDUSTRY (subset of INDUSTRY) -- The Broads		
Industry Road Fuels	16,079	tCO2e per year
Industry Fuels Excl. Road	24,227	tCO2e per year
Industry Electricity	5,413	tCO2e per year
Total	**45,719**	**tCO2e per year**
LARGE EMITTERS (Scope 1) -- The Broads		
Large Emitters	**120,672**	**tCO2e per year**
INDUSTRY-RELATED FLIGHTS (subset of INDUSTRY) -- The Broads		
Industry-related flights	**6,781**	**tCO2e per year**
Land Use -- The Broads		
Land Use **CO_2**	**83,880**	**tCO2e per year**
Land Use **Non-CO_2**	**62,356**	**tCO2e per year**
Total	146,236	tCO2e per year

NOTE: The total could be marginally different to the sum of individual components due to rounding

10.7.2.2 Industry GHG emissions (IDBR-based): the Broads Adjacent Gateway Settlements

Industry Categories Summary (IDBR sectors)	ALL Scopes	Units
Agriculture, forestry & fishing	64,840	tCO2e per year
Production	194,025	tCO2e per year
Construction	24,474	tCO2e per year
Motor trades	2,898	tCO2e per year
Wholesale	9,320	tCO2e per year
Retail	9,673	tCO2e per year
Transport & storage (inc. postal)	38,101	tCO2e per year
Accommodation & food services	12,144	tCO2e per year
Information & communication	5,526	tCO2e per year
Finance & insurance	241	tCO2e per year
Property	2,959	tCO2e per year
Professional, scientific & technical	7,560	tCO2e per year
Business administration & support services	12,549	tCO2e per year
Public administration & defence	6,762	tCO2e per year
Education	8,590	tCO2e per year
Health	10,137	tCO2e per year
Arts, entertainment, recreation & other services	8,177	tCO2e per year
Total	**417,975**	**tCO2e per year**
ENERGY-ONLY INDUSTRY (subset of INDUSTRY) -- The Broads - Adjacent Area		
Industry Road Fuels	16,889	tCO2e per year
Industry Fuels Excl. Road	25,448	tCO2e per year
Industry Electricity	5,651	tCO2e per year
Total	**47,988**	**tCO2e per year**
LARGE EMITTERS (Scope 1) -- The Broads - Adjacent Area		
Large Emitters	**-**	**tCO2e per year**
INDUSTRY-RELATED FLIGHTS (subset of INDUSTRY) -- The Broads - Adjacent Area		
Industry-related flights	**6,152**	**tCO2e per year**

NOTE: The total could be marginally different to the sum of individual components due to rounding

10.7.3.1 IDBR vs GVA Industry Footprint Estimates: the Broads Executive Area

Industry Categories Summary (IDBR sectors)	NP/AONB industry footprint per capita (IDBR, COA-level data)	NP/AONB industry footprint per capita (GVA, LA-level data)	Units
Agriculture, forestry & fishing	3.43	0.53	tCO2e/person/year
Production	8.35	4.10	tCO2e/person/year
Construction	1.14	0.79	tCO2e/person/year
Motor trades	0.14	0.15	tCO2e/person/year
Wholesale	0.47	0.34	tCO2e/person/year
Retail	0.46	0.56	tCO2e/person/year
Transport & storage (inc. postal)	2.04	1.05	tCO2e/person/year
Accommodation & food services	0.59	0.54	tCO2e/person/year
Information & communication	0.30	0.12	tCO2e/person/year
Finance & insurance	0.01	0.51	tCO2e/person/year
Property	0.15	0.04	tCO2e/person/year
Professional, scientific & technical	0.47	0.25	tCO2e/person/year
Business administration & support services	0.57	0.29	tCO2e/person/year
Public administration & defence	0.13	0.29	tCO2e/person/year
Education	0.18	0.37	tCO2e/person/year
Health	0.40	0.66	tCO2e/person/year
Arts, entertainment, recreation & other services	0.43	0.16	tCO2e/person/year
Total	**19.26**	**10.77**	**tCO2e/person/year**

NOTE: The total could be marginally different to the sum of individual components due to rounding

10.7.3.2 IDBR vs GVA Industry Footprint Estimates: the Broads Adjacent Gateway Settlements

Industry Categories Summary (IDBR sectors)	NP/AONB industry footprint per capita (IDBR, COA-level data)	NP/AONB industry footprint per capita (GVA, LA-level data)	Units
Agriculture, forestry & fishing	1.70	0.24	tCO2e/person/year
Production	5.10	1.88	tCO2e/person/year
Construction	0.64	0.33	tCO2e/person/year
Motor trades	0.08	0.06	tCO2e/person/year
Wholesale	0.24	0.14	tCO2e/person/year
Retail	0.25	0.25	tCO2e/person/year
Transport & storage (inc. postal)	1.00	0.60	tCO2e/person/year
Accommodation & food services	0.32	0.24	tCO2e/person/year
Information & communication	0.15	0.07	tCO2e/person/year
Finance & insurance	0.01	0.26	tCO2e/person/year
Property	0.08	0.02	tCO2e/person/year
Professional, scientific & technical	0.20	0.09	tCO2e/person/year
Business administration & support services	0.33	0.12	tCO2e/person/year
Public administration & defence	0.18	0.12	tCO2e/person/year
Education	0.23	0.16	tCO2e/person/year
Health	0.27	0.22	tCO2e/person/year
Arts, entertainment, recreation & other services	0.21	0.07	tCO2e/person/year
Total	**10.98**	**4.88**	**tCO2e/person/year**

NOTE: The total could be marginally different to the sum of individual components due to rounding

10.7.4. Appendix: Pollution inventory for large emitters

Pollution Inventory: Large Emitters (2018 data) Within Adopted Postcode Boundaries for National Parks (2018 data)					
National Park	**LAD14NM**	**Operator**	**Site**	**Postcode**	**CO_2 emissions (kt)**
Broads	Broadland	British Sugar Plc	Cantley	NR133ST	120.672408
Peak District National Park	Derbyshire Dales	HJ Enthoven & Sons Ltd	Darley Dale	DE42LP	25.8
Peak District National Park	Derbyshire Dales	Tarmac Ltd	Ballidon Quarry	DE61QX	0.002702
Peak District National Park	High Peak	Hope Construction Materials Ltd	Hope Works	S336RP	1048.8045
South Downs National Park	Horsham	Viridor Waste Management Ltd	Horton Landfill	BN59XH	16.9
South Downs National Park	Lewes	Veolia ES South Downs Ltd	Newhaven EfW Plant	BN90HE	201.611
North York Moors National Park	Redcar and Cleveland	Cleveland Potash Ltd	Saltburn-By-The-Sea	TS134UZ	13.73193
New Forest National Park	Wiltshire	Renewable Power Systems Ltd	Poundbottom Landfill Site	SP52PU	3.82

10.8.1 Emissions from major roads: the Broads Executive Area

SELECTED A ROADS - SMALLER SUBSET -- Broads		
Road Names, Smaller Subset	A47 A1064	
Cars, Buses & Motorbikes	54,729	tCO2e per year
Vans & Lorries	23,448	tCO2e per year
Total	**78,177**	**tCO2e per year**
SELECTED A ROADS - LARGER SUBSET -- Broads		
Road Names, Larger Subset	Smaller Set + A146 A143	
Cars, Buses & Motorbikes	95,882	tCO2e per year
Vans & Lorries	42,801	tCO2e per year
Total	**138,683**	**tCO2e per year**
THROUGH TRAFFIC -- Broads		
Cars, Buses & Motorbikes	75,306	tCO2e per year
Vans & Lorries	43,723	tCO2e per year
Total	**119,029**	**tCO2e per year**

NOTE: The total could be marginally different to the sum of individual components due to rounding

SMALL WORLD CONSULTING

10.8.2 Emissions from major roads: the Broads Adjacent Gateway Settlements

SELECTED A ROADS - SMALLER SUBSET -- Broads - Adjacent Area		
Road Names, Smaller Subset	A47 A1064	
Cars, Buses & Motorbikes	57,078	tCO2e per year
Vans & Lorries	20,406	tCO2e per year
SELECTED A ROADS - LARGER SUBSET -- Broads - Adjacent Area		
Road Names, Larger Subset	Smaller Set + A146 A143	
Cars, Buses & Motorbikes	57,078	tCO2e per year
Vans & Lorries	20,406	tCO2e per year
THROUGH TRAFFIC -- Broads - Adjacent Area		
Cars, Buses & Motorbikes	50,606	tCO2e per year
Vans & Lorries	20,406	tCO2e per year
Total	**71,012**	**tCO2e per year**

NOTE: The total could be marginally different to the sum of individual components due to rounding

10.9. Appendix: Methodology

10.9.1. Appendix: History of model development

In 2010, Small World Consulting (SWC) carried out a first consumption-based greenhouse gas assessment for the Lake District National Park (LDNP). This project adopted a consumption-based assessment approach alongside more traditional production-based metrics.

This opened up policy areas such as food, shopping, business supply chains, and travel by both residents and visitors to and from the Park. The study led to a carbon budget being set each year, with a target to reduce annual emissions by 1% per year compared to business as usual (therefore 6% by 2016). Each year actions taken to cut emissions were collated from members of the Park's strategic partnership, and assessed in terms of their contribution to the target. Overall, after seven years, these emission reduction actions are thought to have accumulated to around 3% reduction in annual emissions, compared to business as usual.

Seven years after the baseline study for the LDNP, a lot had changed, including: reporting methods, underlying model data, the numbers and behaviours of residents and visitors, and the climate change agenda. SWC therefore refreshed the LDNP carbon assessment in 2017 and again in 2020, extending the latter to the whole of Cumbria. Through this work, a Zero Carbon Cumbria Partnership was formed in 2021, financed by a successful bid for National Lottery funding. Subsequently, SWC was commissioned in 2021 to undertake a similar consumption-based carbon footprint assessment for all the UK National Parks, plus several AONBs.

10.9.2. Appendix: Model development for the National Park and AONB family

Our development of a carbon footprint model for the National Parks and AONBs has been and remains an iterative process, with insights obtained from each tranche to date (namely 1, 2, 3 and 4) serving to improve various parts of the model.

Tranche 5 (April-July 2022) is considered the point by which all major updates of the model were completed. Subsequent updates, which will be applied to all National Parks and AONBs on the current programme, are possible but less likely at this stage.

The datasets and methodologies used in the May 2022 version of the footprint model are considerably more complex than in the LDNP and Cumbria assessments, but the model is robust and could easily be updated when new post-COVID data becomes available.

The main methodological challenge arises from the need to map data between various geographies: postcode, COA, LSOA, MSOA, LA, and National Park boundaries. This has been dealt with by constructing appropriate masks with mapping weights, as well as performing custom GIS analysis.

Another key addition is that of the traffic points data, which can be used to assess through-traffic in each National Park or AONB and estimate footprints linked to the motorways, the main A-roads and the largest B-roads within its boundaries.

Another noticeable change in methodology concerns industry footprint estimates. An initial analysis was conducted using GVA datasets from Local Authorities; however, when this was applied across the National Parks and AONBs, it became apparent that a better geographical representation of industry sectors within each landscape was required.

As a result, additional licences were purchased for ONS IDBR datasets, for COA-level industry turnover, in order to estimate the relevant footprint. By necessity, the turnover estimates include all COA geographies overlapping with the National Park or AONB boundary, leading to marginal overestimates. The COAs within and on the boundary that are known to contain large point-source emitters were excluded from the turnover figures.

The emissions estimates for the agriculture and forestry sector, derived using IDBR data, reflect local enterprise turnovers; however, they rely on the UK-average carbon intensities of these sectors, which may not reflect the unique farming and forestry characteristics within each landscape.

Another key footprint category updated recently is land use emissions based on the latest version of the Department of Business, Energy and Industrial Strategy (BEIS) land use CO_2 data for National Parks for 2019. The 2019 BEIS land use CO_2 dataset includes, for the first time, emissions from different types of peatland and varying levels of peat degradation. We also employ peat emission factors from this dataset, alongside afforestation and peatland restoration targets from the Sixth Carbon Budget, as part of our net zero pathway recommendations for each National Park and AONB.

A summary of the datasets used in the carbon footprint model is provided in Appendix 10.3.

10.9.3. Appendix: Outline of emissions estimation methodology

This section provides a brief outline. A more detailed methodology document will be produced separately by the end of 2022.

- Household energy-related emissions were derived from consumption data available at postcode and local authority levels. The energy-related emissions factors used included supply chain components.

- Local authority level fuel use data was employed as the starting point for estimating residents' road fuel emissions. Road traffic counts data was used to estimate emissions from through traffic and emissions from selected major roads. The emissions factors used for all transport take account of direct vehicle emissions, energy supply chain emissions and the emissions embodied in the production and maintenance of vehicles and transport infrastructure.

- Emissions from UK residents, other than those relating to household energy and vehicle use, were derived using a well-established environmentally extended input output model (EEIO) developed by Small World Consulting. Residents' emissions per capita were adjusted from the UK averages provided by the EEIO model, using demographic data for the National Park or AONB at the postcode level, together with survey data on national household expenditure.

- For visitors, the same EEIO model was used to estimate emissions from consumption other than road fuel. We used data from multiple visitor surveys and tourism modelling to derive

estimates of visitor numbers and visitor spending, which we combined with emission factors from the EEIO model.

- Emissions relating to land-based visitor travel to and from the National Park and within the National Park were derived using visitor surveys, and comparisons with resident road travel emissions.

- Emissions related to through traffic, which by definition occur within the boundary of the National Park or AONB, are estimated by comparing total traffic point counts with pump-level fuel sales within the National Park or AONB, along with assumptions about commuting in out of the area.

- Civil Aviation Authority survey data was used to estimate the emissions associated with flights taken by residents and visitors. The emission factors used take account of flight distances and flight class, and include a markup factor for high-altitude climate effects.

- A very rough estimate of industry emissions (including their supply chains), which overlaps with resident and visitor emissions, was included for added perspective. The estimate was derived from Inter-Departmental Business Registry (IDBR) turnover data for businesses registered in an area that was mapped as closely as possible to the National Park, combined with industry-specific emission factors that were drawn from the EEIO model. Separately, energy-related emissions from industry were calculated from consumption data and energy-related emission factors that included supply chain components.

- We adopted land use emissions estimates published by BEIS for all National Parks (both for the CO_2 and non-CO_2 components). For AONBs, the CO_2 component of land-based emissions and carbon sequestration was estimated separately using bespoke land use datasets provided by the AONBs following a common methodology developed as part of this programme, together with the BEIS and Natural England habitat-specific emission factors. The Non-CO_2 component of land-based emissions for AONBs (including emissions from livestock and fertiliser use) was approximated using footprint estimates for the industry sector “agriculture, forestry and fishing” derived from the IDBR data.

The data sources used are listed in Appendix 10.3.

10.9.4. Appendix: Target setting rationale

Each component of the overall emissions reduction target has been judged to be the minimum required in order to align with the IPCC’s recommendations for limiting global temperature change to 1.5°C compared to pre-industrial conditions. The components’ feasibility may depend on appropriate government and private sector support, for which the Park should advocate as part of its climate response. The steepness of the proposed emissions reduction trajectories reflects decades of global inaction, and illustrates the scale and urgency of the challenge we now face.

For energy-related emissions we drew on modelling by the Tyndall Centre for Energy and Climate Change Research for setting local authority targets. For food-related emissions we examined recommendations from the National Food Strategy and other sources. For goods other than food, the target reflects the relative difficulty of reducing emissions from global supply chains, compared

to UK energy-related emissions. For visitor travel the target reflects both possible changes in future travel habits and the likely decarbonisation of land transport. The LULUCF targets reflect the feasibility assessment in line with the Sixth Carbon Budget's 2050 net zero pathway for the UK.

Table 7 outlines the methodology used in this report (New Model for All National Parks 2022) and how it compares with an earlier iteration (Cumbria 2020). Methodological differences arose from new learning and knowledge transfer incorporated in the planning assumptions for National Park target-setting. In setting targets, we have made a pragmatic assumption that we may reach percentage ceilings in the emissions reductions that can be achieved for some sectors, as it may not be entirely possible to achieve real zero emissions in these sectors given that there will always be residual emissions.

Table 7: High-level comparison between target-setting methodology and assumptions used for Cumbria (old) and National Parks / AONBs (new)

Category	Previous model for Cumbria (2020)	New model for all National Parks (2022) – used in this report	Achievable ceiling
Energy-only emissions by residents, visitors and industry	13% per year reduction in energy-related CO_2 (as prescribed by the Tyndall Carbon Budget Tool[83]). Includes Scope 1 and 2 carbon dioxide emissions only (excl. motorways).	**13.3**% (specific to the Broads) per year reduction in energy-related CO_2 as prescribed by the Tyndall Carbon Budget Tool, and extended to other GHGs. Includes Scope 1, 2 and 3 energy-related GHG emissions expressed as tCO_2e for residents, visitors and industry.	**5%** of present-day emissions. This is our expert judgement for embedded emissions across various forms of renewable energy, for example assuming little or no CCS.
Food consumed by residents and visitors	5% reduction per year	**5%** reduction per year. This assumes 3% of emissions reduction per year from dietary changes (National Food Strategy: 30% in 10 years), 1% per year from waste reduction and 1% per year from other changes incl. technology.	**30%** of present-day emissions. This is based on the Sixth Carbon Budget (AFOLU section), which states that UK agriculture emissions are set to halve from 54 $MtCO_2e$ today to 27 $MtCO_2e$ in 2050 under the Net Zero pathway. Some further savings may come from widespread adoption of vertical farming, which is why we opted for the more ambitious 30% ceiling.
Other goods purchased by residents and visitors	5% reduction per year	**5%** reduction per year, including purchases of cars. This assumes that sectors such as cement and steel, which feed into complex supply chains (incl. making cars), will take time to decarbonise	**10%** of present-day emissions. The is our expert judgement for residual emissions from sectors such as cement and steel that will take time to decarbonise

[83] A budget tool to calculate 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/.

		globally and won't reach zero emissions in large exporters like China by 2050.	globally and won't reach zero emissions in large exporters like China by 2050.
Visitor travel to and from the National Park	Visitor travel to and from Cumbria (excluding international travel)	**10%** reduction per year. Excludes flights but includes car manufacturing. This assumes a 4% per year increase in duration of stay (roughly doubling after 20 years), a 4% per year reduction in the footprint of transport (roughly halving emissions from cars in 20 years, leaving predominantly the embedded car manufacturing footprint), and a 2% per year shift in the mode of transport from cars.	**7.5%** of present-day emissions. This is our expert judgement for embedded emissions across various forms of renewable energy, and from sectors (via supply chains) such as cement and steel that will take time to decarbonise globally (affecting car manufacturing, buildings, etc.).
Land Use	Expert judgement based on discussions with the stakeholders involved.	We have split land use into Land Use Non-CO_2 and Land Use CO_2. See Table 8 for further details.	**30%** of present-day emissions for Land Use Non-CO_2 only, which follows the arguments for the Food & Drink category. Land Use CO_2: Achievable ceiling is not applicable in this assessment due to 2050 being a comparatively short horizon in terms of land-based carbon sequestration measures

A detailed breakdown of how LULUCF targets are derived, and the relevant planning assumptions, can be found in 10.9.8. Table 8 below provides a brief overview.

Table 8. Land Use target assumptions for National Parks.

Land Use Non-CO_2	The Non-CO_2 component includes methane and N_2O emissions from livestock and fertilizer use within the National Park, which must be reduced in line with broader targets for the Food & Drink category. We therefore assume a 5% per year reduction for this component. Inevitably, there will be a small amount of double-counting, linked to residents and visitors consuming locally produced food in the area.
Land Use CO_2	The CO_2 component includes emissions from degraded peatland and other types of soil, as well as carbon sequestration through woodland creation, peatland restoration and regenerative agricultural practices. This component changes linearly with time as the land use change measures are extended to bigger land areas, and becomes negative when the carbon sink quantities exceed carbon emissions from land.

	The assumed year-on-year changes to land use are based on apportionment of the Sixth Carbon Budget targets according to present-day land use in each National Park; see Table 13. The resulting rates of land conversion (e.g. afforestation or peatland restoration) and/or application of new management practices (e.g. cover cropping or grazing legumes) are then combined with the per-hectare carbon sequestration fluxes associated with these land use changes (established from field studies and desk-based research). In the Broads, the proposed land use measures are estimated to add -2,972 tCO_2e/year to the total carbon sequestration flux in the landscape each year (i.e. an extra 2,972 tCO_2e removed per year in each of the subsequent years).

10.9.5. Appendix: Assumptions for Land Use sector

The Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories (IPCC 2006, IPCC 2014) describes a uniform structure for reporting emissions and removals of greenhouse gases. The Department for Business, Energy and Industrial Strategy (BEIS) contracts a company, Ricardo Energy & Environment, to compile an annual Inventory of UK Greenhouse Gas Emissions for the United Nations Framework Convention on Climate Change (UNFCCC). Ricardo subcontracts two further entities – the UK Centre for Ecology and Hydrology, and Forest Research – to prepare the data relating to Land Use, Land-Use Change and Forestry (LULUCF) in the UK.

The LULUCF sector differs from other sectors in the Greenhouse Gas Inventory in that it contains both sources and sinks of greenhouse gases[84]. The sources, or emissions to the atmosphere, are given as positive values; the sinks, or removals from the atmosphere, are given as negative values.

To provide context, an analysis was undertaken to understand and extract the key facts, logic and rationale applied to changes in either reporting or target-setting, as outlined in the Sixth Carbon Budget report on agriculture, forestry and other land use (AFOLU); see Table 9 and Table 10. The report states that emissions from the AFOLU sector "have declined by 16% since 1990. This is mainly due to successive reform of the Common Agricultural Policy (CAP) in the 1990s and early 2000s, which reduced livestock numbers, coupled with changes in farming practices due to EU environmental legislation to address non-GHG pollutants (e.g., Nitrates Directives). There has been little change in emissions since 2008".

Table 9: UK baseline for Agriculture emissions (2018), by GHG. Global warming potential for methane and nitrous oxide: IPCC AR5

	Percentage of UK emissions	**Quantity of CO_2 equiv.t**
Summary for Agriculture	**10%**	**54.6 $MtCO_2e$**
Breakdown		*SWC planning assumptions*
Methane (CH_4) from livestock	63%	34.4 $MtCO_2e$
Nitrous oxide (N_2O) mostly from soil	26%	14.2 $MtCO_2e$

[84] DEFRA (2021), "UK Local and Regional Carbon Dioxide Emissions Estimates for 2005-2019," Technical Report p.62.

Carbon dioxide (CO2) from fossil fuel use	11%	6.0 $MtCO_2$
Total	**100%**	**54.6 $MtCO_2e$**
Data Source: The Sixth Carbon Budget: Agriculture and land use, land use change and forestry, p.6		

Table 10: UK baseline for Agriculture emissions (2018), by source. Global warming potential for methane and nitrous oxide: IPCC AR5

	Percentage of UK emissions	**Quantity of CO_2 equiv.t**
Agriculture Breakdown		*SWC planning assumptions*
Methane from livestock (Enteric fermentation digestion process of ruminant livestock)	53%	28.9 $MtCO_2e$
Agricultural soils	21%	11.5 $MtCO_2e$
Waste and manure management	16%	8.7 $MtCO_2e$
Stationary machinery	8%	4.4 $MtCO_2e$
Other	2%	1.1 $MtCO_2e$
Total	**100%**	**54.6 $MtCO_2e$**
Data Source: The Sixth Carbon Budget Agriculture and land use, land use change and forestry p.6 Figure M.7.1		

10.9.6. Appendix: Land class categories for reporting nationally

For reporting purposes all land in the country must be identified as having remained in one of six classes since a previous survey, or as having changed to a different (identified) class in that period[85]. The six land classes are:

Land use category	Sub-category
4A: Forest Land	• Forest land remaining forest land • Biomass burning • Land converted to forest land • Drainage of organic soils • Direct N_2O emissions from N mineralisation/mobilisation
4B: Cropland	• Biomass burning • Cropland remaining cropland • Land converted to cropland • Direct N_2O emissions from N mineralisation/mobilisation
4C: Grassland	• Biomass burning • Grassland remaining grassland • Land converted to grassland • Drainage of organic soils • Direct N_2O emissions from N mineralisation/mobilisation
4D: Wetlands	• Wetlands remaining • Drainage of organic soils • Land converted to wetland
4E: Settlements	• Settlements remaining settlements • Biomass burning • Land converted to settlements • Drainage of organic soils • Direct N_2O emissions from N mineralisation/mobilisation
4F: Other land	• Harvest wood • Indirect N_2O emissions

There is a seventh category (4G) for the pool of harvested wood products.

[85] BEIS, CEH, Forest Research (2020): "National Atmospheric Emissions Inventory: Projections of Emissions and Removals from LULUCF Sector to 2050," p. 3.

10.9.7. Appendix: Changes in methodology for quantifying peatland GHG emissions

In 2017 the Centre for Ecology and Hydrology proposed changes to the methodology for reporting emissions from peatlands[86]. Emissions from the drainage and rewetting of peatlands were included for the first time in the 1990-2019 LULUCF inventory (Brown *et al.* 2021). These emissions are reported under all LULUCF land use categories and are **not** specifically identified separately. In summary, the following principles are applied:

- Emissions from drained and rewetted organic soils are allocated to UK local authorities using peat condition mapping outputs from Evans *et al.* (2017).
- The majority of the peatland area, reported in the Grassland category, includes semi-natural bog categories, extensive and intensive grassland, and rewetted bog or fen from semi-natural bog and intensive and extensive grassland.
- Emissions from active extraction of peat (on site, and off-site for horticultural peat), as well as from organic soils affected by historical peat extraction, are reported under Wetlands.
- Naturally occurring GHG emissions and/or removals from pristine areas of bog and fen, rewetted bog or fen, and from peat extraction, are now included in LULUCF reporting under Wetlands.
- Emissions of CO_2 from drained organic soils in Forest, Cropland and Settlement areas are reported in those respective categories.
- The "Other land" category predominantly comprises bare rock and scree, with no emissions or removals reported.

These recommendations were further refined for the current UK GHG Inventory 1990-2019[87].

Although the latest (BEIS) LULUCF estimations (2019) are more accurate than previous years, they remain subject to considerable uncertainty. This is due to an evolving methodology and a process to refine the measurement of emission factors for UK peatlands, attempting to take into account transitions from heavily modified peatlands (forested land, cropland, grassland, peat extraction, eroding bog) and semi-natural peatlands (heather-dominated and grass-dominated bogs). Peatlands in their semi-natural state may be near-natural, modified, or rewetted (Table 11). The estimates for CO_2 emissions in the form of dissolved organic carbon (DOC) use Tier 1 emission factors, and therefore are the least robust of all (IPCC 2014). Tier 2 emission factors for the UK-relevant peat condition categories were subsequently developed by Evans *et al.* (2017), providing estimates for "particulate organic carbon" (POC) emissions, as well as direct CO_2 emissions. The Tier 2 estimations add more granularity and are country-specific, being tested for robustness using at least four different study locations considered reliable enough to replace Tier 1 values. The CARBINE Tier 3 carbon accounting model developed by Forest Research was employed to derive the emission factor for forested peatland between 1990 and 2019, and was tested using field data.

[86] Centre for Ecology and Hydrology (2017) "Implementation of an Emissions Inventory for UK Peatlands: A report to the Department for Business, Energy, and Industrial Strategy," Issue Number 1.
[87] Ricardo Energy & Environment UK NIR 2020 (Issue 1), "UK GHG Inventory 1990-2019," Annex p. 854.

Table 11. Extract from Ricardo Energy & Environment UK NIR 2020 (Issue 1) UK GHG Inventory 1990-2019 Annex p. 858

Table A 3.4.28 Emission factors for peat condition types updated from Evans et al (2017). All fluxes are shown in $tCO_2e\ ha^{-1}\ yr^{-1}$. Note that a positive EF indicates net GHG emission, and a negative EF indicates net GHG removal.

Peat Condition	Drainage status	Direct CO_2	CO_2 from DOC	CO_2 from POC	Direct CH_4	CH_4 from Ditches	Direct N_2O	Total
Forest	Drained	2.52 to -1.79[c]	1.14[a]	0.3[b]	0.06[a]	0.14[a]	1.31[a]	**5.46 to 1.15**
Cropland	Drained	28.60[b]	1.14[a]	0.3[b]	0.02[b]	1.46[a]	6.09[a]	**37.61**
Eroding Modified Bog (bare peat)	Drained	6.18[b]	1.14[a]	5.0[b]	0.14[a]	0.68[a]	0.14[a]	**13.28**
	Undrained	6.18[b]	0.69[a]	5.0[b]	0.15[a]	0[a]	0.14[a]	**12.17**
Modified Bog (semi-natural Heather + Grass dominated)	Drained	0.13[b]	1.14[a]	0.3[b]	1.26[b]	0.66[a]	0.06[b]	**3.54**
	Undrained	0.13[b]	0.69[a]	0.1[b]	1.33[b]	0[a]	0.06[b]	**2.31**
Extensive Grassland (combined bog/fen)	Drained	6.96[b]	1.14[a]	0.3[b]	1.96[b]	0.66[a]	2.01[a]	**13.03**
Intensive Grassland	Drained	21.31[b]	1.14[a]	0.3[b]	0.68[b]	1.46[a]	2.67[b]	**27.54**
Rewetted Bog	Rewetted	-0.69[b]	0.88[a]	0.1[b]	3.59[b]	0.0[a]	0.04[b]	**3.91**
Rewetted Fen	Rewetted	4.27[b]	0.88[a]	0.1[b]	2.81[b]	0.0[a]	0[a]	**8.05**
Rewetted Modified (Semi-natural) Bog	Rewetted	-3.54[b]	0.69[a]	0[b]	2.83[b]	0[a]	0[a]	**-0.02**
Near Natural Bog	Undrained	-3.54[b]	0.69[a]	0[b]	2.83[b]	0[a]	0[a]	**-0.02**
Near Natural Fen	Undrained	-5.41[b]	0.69[a]	0[b]	3.79[b]	0[a]	0[a]	**-0.93**
Extracted Domestic	Drained	10.27[a]	1.14[a]	1.01[b]	0.14[a]	0.68[a]	0.14[a]	**13.37**
Extracted Industrial	Drained	6.18[b]	1.14[a]	5.0[b]	0.14[a]	0.68[a]	0.14[a]	**13.28**
Settlement	Drained	0.07[b]	0.57[a]	0.15[b]	0.63[b]	0.16[a]	0.03[b]	**1.61**

[a] Tier 1 default EF (IPCC 2014)
[b] Tier 2 EF (updated literature analysis in 2019 incorporating data from Evans et al. 2017)
[c] Tier 3 Forest Research CARBINE model implied EF for 1990 to 2019. The decreasing trend is due to an increase in age of forests on organic soils due to decreasing afforestation on organic soils.

10.9.8. Appendix: Target setting methodology for land use change

The land use change and management targets in each National Park or AONB, which include woodland creation, peatland restoration and several regenerative agriculture measures, are derived by apportioning land-based carbon sequestration measures from the UK's Sixth Carbon Budget (2020)[88] according to present-day land use distribution in each National Park or AONB. It is worth noting that all land use datasets have considerable uncertainties. We adopted the CEH Land Cover Map classification for land use assessments across all National Parks and AONBs on the current programme.

In the case of woodland creation, a more ambitious target has been introduced for each protected landscape through a high-level opportunity mapping and conversations with the National Park and AONB teams on the ground, with a preference (in most cases) for native broadleaf or mixed species in order to achieve broader environmental benefits across protected landscapes, such as those in National Parks and AONBs.

Our land use change and management options focus on either creating, enhancing or restoring (as applicable) four common land use types (habitats) on mineral soils, and eight types of degrading peatland habitats:

- Broadleaf woodland on mineral soil
- Coniferous woodland on mineral soil
- Improved grassland on mineral soil
- Cropland on mineral soil
- Eroding modified bog (bare peat), drained
- Eroding modified bog (bare peat), undrained
- Modified bog (heather/grass-dominated), drained
- Modified bog (heather/grass-dominated), undrained
- Cropland on peat soil, drained
- Intensive grassland on peat soil, drained
- Extensive grassland (on bog/fen), drained
- Forest on peat soil, drained.

The degraded peatland classification follows the methodology adopted by BEIS for annual LULUCF GHG inventories[89], which is based on the assessment by Evans *et al.* (2017)[90].

For the Broads, the current land use distribution is illustrated in Table 12. It is based on the 2019 CEH Land Cover Map and in-house peatland data, including ecological assessment of the condition of peatland in each habitat. The UK-wide areas of the selected land cover types and the corresponding percentages accounted for by the Broads shown for context in Table 13.

[88] UK's Sixth Carbon Budget: "Agriculture and land use, land use change and forestry" (AFOLU) report. Climate Change Committee, 2020.
[89] Ricardo Energy & Environment, UK NIR 2020 (Issue 1) "UK GHG Inventory 1990-2019," Annex p. 854
[90] Centre for Ecology and Hydrology (2017) "Implementation of an Emissions Inventory for UK Peatlands: A report to the Department for Business, Energy, and Industrial Strategy," Issue 1

At roughly 30,300 ha, the Broads accounts for around 0.125% of the UK's total land area, while the National Parks' current share of tree cover is 75% lower than its land share, with most of the existing tree cover classified as a native wet woodland habitat on organic soils. The prevalence of waterways, fen and medium-grade agricultural land alongside wet woodland means the park has limited opportunities to expand the existing woodland line with UK-wide targets from the Sixth Carbon Budget. New woodland may need to be created in the catchment areas adjacent to the Broads, which could be enabled through partnerships with the neighbouring Local Authorities, landowners and other stakeholder involved. The proposed comparatively modest target of 55 ha per year of new woodland reflects on this additional complexity. We propose all tree planting to be native broadleaf trees, recognising that a native permanent woodland also has multiple co-benefits carbon sequestration, that cannot be matched by productive coniferous forestry.

The Broads' share of improved grassland is considerably higher than the UK averages, with good potential to apply restorative agricultural practices as part of proposed UK-wide measures to manage land more sustainably, which are outlined in the Sixth Carbon Budget. However, a considerable amount of the improved grassland in the Broads (8.6% of National Park's area) is located on moderately degraded peat soils, and these areas would need to be managed differently in order to reduce peatland emissions, for example by adopting paludiculture practices.

Table 12. The Broads: Key land use types by area (present-day), including underlying peat areas and the estimated percentage of peat in a healthy condition (by area)

Land Cover (Habitat) Type	**Habitat Area (ha)**	**Peat Area (ha)**	**Estimated % of Peat Area in Healthy Condition**
Broadleaved woodland	3,164.5	2,203.2	80%
Coniferous woodland	35.3	0.7	0%
Arable and horticulture	5,103.0	139.5	0%
Improved grassland	15,371.2	2,620.7	0%
Neutral grassland	2.7	0.0	NA
Calcareous grassland	0.0	0.0	NA
Acid grassland	0.0	0.0	NA
Fen, marsh, swamp	4,101.4	2,298.8	70%
Heather	10.6	1.9	0%
Heather grassland	0.0	0.0	NA
Bog	0.0	0.0	NA
Saltmarsh	79.5	7.8	100%
Urban	209.1	90.1	0%
Suburban	493.6	81.3	0%
Total	**28,570.9**	**7,444.0**	**NA**

Table 13. The Broads: Areas of the main land cover types compared with the relevant UK totals

Land Cover Type	**Current UK Area (ha)**	**Current NP Area (ha)**	**NP Area as % of UK Area**
Broadleaf Woodland	**1,572,900**	**961**	**0.061%**

Coniferous Woodland	**1,637,100**	**35**	**0.002%**
Improved Grassland (mineral soils only)	**6,161,798**	**12,751**	**0.207%**
Cropland (mineral soils only)	**5,788,356**	**4,963**	**0.086%**
Degraded Peatland (all types)	**2,182,455**	**4,064**	**0.186%**
Total Woodland Area (Broadleaf + Coniferous)	**3,210,000**	**996**	**0.031%**
Total Agricultural Area (Improv. Grassland + Cropland)	**11,950,154**	**17,714**	**0.148%**
Total Area of Selected Land Cover Types (above)	**17,342,609**	**22,774**	**0.131%**
Total Area (incl. urban, rough grassland, water, rock, etc)	**24,249,500**	**30,300**	**0.125%**

We consider the following seven options for land use change and management that will enable carbon sequestration (or emissions reduction in the case of degraded peatland) and create wider environmental benefits (biodiversity gains, flood mitigation, air quality improvements, gains in recreational value, etc.), in alignment with the Sixth Carbon Budget:

- New native broadleaf/mixed woodland
- New productive coniferous woodland
- Peatland restoration (across all degraded types)
- Agroforestry (for improved grassland and cropland)
- Hedgerows (for improved grassland and cropland)
- Introducing legume grass species (for improved grassland)
- Introducing cover crops (for cropland)

Each of these measures is described in the subsections below.

Woodland creation

Our chosen UK-wide woodland creation target form the Sixth Carbon Budget is 50,000 ha per yr, representing medium to high levels of ambition as part of the proposed Net Zero scenario for 2050.

As a starting point, we apportion UK-wide woodland creation target based on the current woodland coverage in each National Park and AONB as a percentage of the UK coverage (see Table 13 above), which simply mirrors the approach for apportioning other land use and management options considered here (e.g. peatland restoration and a better agricultural management). However, the fact that creating new woodland requires a fundamental change to land use rather than management changes on existing land, the woodland target has to be set differently, by considering total areas of suitable habitats within each landscape. We refer to this assessment as a high-level woodland opportunity mapping, which is a first step in setting a practical woodland target, to be followed by a field-level multi-benefit opportunity mapping.

As a default rule, we safeguard habitats such as existing woodland, calcareous grassland, lowland heathland, fen and bog from the opportunity mapping for new woodland. On the other hand, habitats such as neutral grassland, acid grassland and upland heathland, part of which are commonly referred to as "moorland", are prime candidates for woodland opportunity mapping, subject to field-level ecological and economic considerations. We note that large areas of the acid grassland and upland heathland habitats contain both deep and shallow peat, typically classified as modified bog dominated by heather/grass, either drained or undrained. We exclude these areas from woodland opportunity mapping, and apply restoration targets to these types of peatland, in addition to degraded areas of peatland classified as blanket bog, peat under agricultural soils or forested peat. For arable land and improved grassland, only a relatively small fraction of the area (25%) is considered for woodland opportunity mapping, for example by creating mosaic habitats with new woodland on field margins freed by reducing livestock numbers and adopting higher-yielding crop varieties.

Our approach for apportioning the UK woodland target to each protected landscape through a high-level opportunity mapping procedure has been applied to all National Parks and AONBs participating in this programme. As a default for this assessment, we assign a custom woodland creation target that exceeds the area-based target described above, which is illustrated for the Broads in Table 14. For most protected landscapes, the ambition is around two times the minimum target based on suitable areas. This reflects on unique opportunities that Protected Landscapes have in terms of attracting both public and private grants to expand the woodland cover, and the central role they ought to play for meeting ambitious nature recovery goals across the UK. The proposed higher ambition approach is supported by field-level woodland opportunity mapping performed by several landscapes (e.g. Cotswolds, Northumberland). However, following a consultation with The Broads team, it was agreed to limit the custom woodland target to 55 ha/yr, with a caveat that a significant part of this woodland may need to be planted in the adjacent catchment areas in partnership with the neighbouring local authorities and other stakeholders involved.

Table 14. Three ways of setting new woodland targets in the Broads.

Woodland target apportioned by woodland land cover area in the National Park or AONB	15.5	ha/yr
Minimum woodland target apportioned by suitable habitat areas in the National Park or AONB	37	ha/yr
Custom woodland target in the National Park or AONB	55	ha/yr

The combined woodland target is then divided between native broadleaf/mixed woodland and productive coniferous woodland. As a default position, we opted to use a 100%-0% split in favour of native broadleaf/mixed woodland for lowland landscapes and/or those landscapes that advocate for forestry areas to be predominantly outside of their borders, for example in the sphere of influence of the neighbouring Local Authority Districts. For some upland landscapes, 80%-20% or 70%-30% in favour of the native woodland could be considered. A 50%-50% split may be applicable in exceptional circumstances such as strategic importance of forestry in certain protected areas.

In this assessment, we propose to use the 100%-0% woodland cover split in favour of native woodland for the Broads, to benefit from the broader environmental and social benefits of native woodland.

Our estimates regarding carbon sequestration in woodland biomass employ yield class (YC) 8 for native broadleaf/mixed woodland and YC 18 for productive conifer trees, as per the Sixth Carbon Budget's recommendations[91]. We use 30-year average sequestration fluxes for trees from these yield classes (inferred from the Woodland Carbon Code, WCC), to match the timescales of the Net Zero target of 2050. Different trees planted in the years ahead will be between 0 and 30 years old by 2050, which is why we adopt the 30-year average sequestration flux value in our calculations. Another simplification is that no time lag in carbon sequestration in trees is considered, with the S-shaped curve representing the actual cumulative carbon uptake in trees replaced by a linear function from the moment of planting. We also add to the biomass carbon sequestration (inferred from the WCC) representative estimates of soil carbon sequestration for woodland, from a recent literature review by Bossio *et al.* (2020)[92].

Peatland restoration

Our adopted UK-wide peatland restoration target follows the recommendation in the Sixth Carbon Budget that 79% of UK's peatland areas will need to be restored by 2050, which would be a big improvement on the current estimate that only 25% of UK's peatlands are in a healthy condition. This results in a combined annual target of just under 52,400 ha/year of peatland to restore across the UK between now and 2050.

The UK-wide peatland restoration target is apportioned to each National Park or AONB according to its total estimated area of peatland. Each National Park's and AONB's target is further broken down into sub-targets for individual peatland areas with distinct types of modification and/or degradation, following the peatland conventions adopted in the BEIS LULUCF GHG inventory (Section 10.9.7). The sub-targets are based on the estimated current surface areas of the relevant types of degraded peatland (Table 12).

Unless bespoke information on peatland degradation levels has been provided by an individual National Park or AONB, we assume that the UK-average estimate of 25% of peatland being in a near-natural or restored condition applies to all peatland areas in each landscape. The remaining peatland areas in each landscape (75%) are assumed to be in various states of degradation. For blanket bog habitats, the most common modification is peat dominated by heather/grass and drained, alongside comparatively small areas of eroding bare peat. For heathland habitats, the peat is commonly dominated by heather/grass and may be either drained or undrained. In some National Parks and AONBs, there are also organic soils under agricultural and forested areas, which have their unique types of peatland degradation and associated carbon fluxes.

As with the peatland classification, our peatland emissions factors follow the BEIS methodology (Section 10.9.7). Restoring a certain amount of peatland means reducing emissions relative to the present-day baseline in line with the adopted peat classifications and emission factors. Because of the considerable uncertainties associated with reversing degradation of peatland so that it becomes a net carbon sink, our analysis focuses on reducing emissions from degraded peat through

[91] UK's Sixth Carbon Budget, AFOLU report, page 27.
[92] Bossio, D. A., et al. (2020). "The role of soil carbon in natural climate solutions.." Nature Sustainability, 3(5), 391-398.

restoration and excludes subsequent sequestration benefits associated with a healthy restored peatland.

Agroforestry uptake

According to the Sixth Carbon Budget, 10% of UK farmland area may need to be converted to agroforestry systems by 2050 in line with the recommended Net Zero pathway. We apply this target to improved grassland and cropland systems only. Agroforestry is assumed to be current practice on 1% of UK farmland; we do not have definitive figures at this stage. Agroforestry is different from present-day farm woodland, which is estimated to cover 5% of the total farmland area in the UK.

Based on the assumptions above, the recommended increase in land managed along agroforestry principles across the UK is just over 30,000 ha/year between now and 2050, which applies to improved grassland and cropland areas. This target is apportioned to each National Park or AONB according to the size of existing areas of improved grassland and cropland within the landscape.

When recommending conversion of land to agroforestry for each National Park of AONB, we take an average of the UK agricultural land area at present and that projected for 2050, in line with the Net Zero pathway from the Sixth Carbon Budget. Under this pathway, the UK's total agricultural land area will be reduced by 3.8 million ha in favour of new woodland, restored peatland and other land uses. The reduction will be compensated by agricultural productivity increases, dietary shifts, and possibly also by moves to alternative production systems such as vertical farming.

Our agroforestry-related carbon sequestration estimates are based on the figures from Bossio *et al.* (2020) for the two most common agroforestry types – alleys and windbreaks – and account for the low tree-planting densities associated with these farming systems. The estimates include both biomass gains and soil carbon sequestration.

Hedgerows expansion

The Sixth Carbon Budget assumes a 40% increase in the area covered by hedgerows across the UK by 2050, amounting to 1,725 ha/year of new hedgerows planted across the UK between now and 2050 (based on estimated present-day coverage). This target is apportioned to each National Park or AONB according to its share of improved grassland and cropland, and is adjusted according to the projected decrease in the total area of the UK's agricultural land by 2050 (the same as for agroforestry). New hedgerows could be created by dividing larger fields, and on field margins, as part of a transition to smaller-scale and less intensive farming systems.

Our estimates of hedgerow carbon sequestration are based on trees with yield class (YC) 4. As is the case for new woodland creation, we use a 30-year average carbon sequestration flux for trees from this yield class (inferred from the Woodland Carbon Code, WCC) to match the timescales of the Net Zero target of 2050. We do not add soil carbon sequestration to hedgerow carbon flux estimates.

Grazing legumes for improved grassland

According to the Sixth Carbon Budget, 75% of UK grazed grassland area may need to be converted to less intensive systems by 2050, with legume species replacing synthetic fertilisers as natural

nitrogen fixers. We apply the grazing legumes target to improved grassland only. Grassland with legume species is assumed to account for 5% of the current improved grassland area; we do not have definitive figures at this stage.

Based on the assumptions above, the recommended increase in land dedicated to UK-wide grazing legumes is just over 120,000 ha/year between now and 2050, which applies to improved grassland areas only. This target is apportioned to each National Park or AONB according to the size of existing areas of improved grassland in the landscape, and is adjusted according to the projected decrease in the total area of UK agricultural land by 2050 (the same as for agroforestry and hedgerows).

The carbon sequestration benefit of introducing grazing legume grassland species follows the figures from Bossio *et al.* (2020).

Cover cropping for cropland

According to the Sixth Carbon Budget, it may be necessary to adopt winter cover cropping on 75% of the UK's cropland area by 2050, with cover crops preventing soil erosion, improving landscapes' flood resilience and enhancing carbon sequestration. Winter cover crops are assumed to account for 5% of the current cropland area; we do not have definitive figures at this stage.

Based on the assumptions above, the recommended increase in land dedicated to cover crops across the UK is just under 114,000 ha/year between now and 2050, which applies to cropland areas only. This target is apportioned to each National Park or AONB according to the size of existing areas of cropland in the landscape, and adjusted in line with the projected decrease in the UK's total agricultural land area by 2050 (the same as for agroforestry, hedgerows and grazing legumes).

The carbon sequestration benefit of introducing cover crops follows the figures from Bossio *et al.* (2020).

Summary: Land use targets and carbon sequestration fluxes for the Broads

Table 15 summarises the proposed land use change and management targets for the Broads, which follow the principles outlined above.

Table 15. Land use targets and the associated additional carbon sequestration fluxes per year (emissions reduction for peat) for the Broads.

Land Use / Management Category	**Land Use Change Target (ha/yr)**	**Change in Carbon Flux (tCO_2e/yr/yr)**
New Native Broadleaf/Mixed Woodland	55	-1,015
New Productive Coniferous Woodland	0	0
Agroforestry (improved grassland & cropland)	45	-105
Hedgerows (improved grassland & cropland)	3	-27
Grazing Legumes (improved grassland)	250	-514
Cover Cropping (cropland)	97	-114
Restored Eroding Modified Bog (bare peat), Drained	0	0

Restored Eroding Modified Bog (bare peat), Undrained	17	-201
Restored Modified Bog (heather/grass dominated), Drained	4	-15
Restored Modified Bog (heather/grass dominated), Undrained	0	0
Restored Cropland Peat, Drained	3	-126
Restored Intensive Grassland Peat, Drained	0	0
Restored Extensive Grassland Peat, Drained	63	-820
Restored Forested Peat, Drained	11	-35
Total	**547**	**-2,972**