SMALL WORLD CONSULTING

A greenhouse gas emissions assessment and target scenario for the Cotswolds National Landscape

A report by Small World Consulting Ltd

March 2023

Small World Consulting Ltd
Lancaster Environment Centre
Gordon Manley Building
Lancaster University, Lancaster LA1 4YQ
info@ sw-consulting.co.uk
01524 510272
www.sw-consulting.co.uk

SMALL WORLD CONSULTING

Contents

SMALL WORLD CONSULTING

Document control

National Park Carbon Footprint Model Development by: Dr Dmitry Yumashev, Mike Berners-Lee, Lorraine Ritchen-Stones, supported by representatives from UK National Parks and AONBs.

Technical Support*:* Dr Hannah Wright, Matthew Bond MRes, Dr Tom Davies, Dr Tom Higgs

Model results exported from*:* Version 10 on the 25th May 2022

Report prepared by: Lorraine Ritchen-Stones MBA, MSc, Dr Dmitry Yumashev, Mike Berners-Lee, Dr Hannah Wright, Matthew Bond MRes, Dr Tom Davies, Dr Tom Higgs

Small World Consulting Ltd, +44 (0) 1524 510272, www.sw-consulting.co.uk

Additional report contributions: Mike Elliott, Climate Action Lead, Cotswolds National Landscape

Proofreading: Jennifer Lyon, Lioness Translation

Results quality checked by: Mike Berners-Lee

Title: A greenhouse gas emissions assessment and target scenarios for the Cotswolds National Landscape

Report Version*:* 5

Status: Approved by Mike Elliott, Climate Action Lead, Cotswolds National Landscape

Dated: 22nd March 2023

Approved by: Approved by Mike Berners-Lee

Expected Changes: Client comments incorporated

Document Details

Reference: Cotswolds NL GHG Assessment Report v5 FINAL 230322

Template: National Park Carbon Baseline Report Template Version 17.doc

No. of pages: 103

Acknowledgements

With thanks to the Cotswolds National Landscape team for their input and support

SMALL WORLD CONSULTING

Executive summary

Background

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

Together, the UK's 15 National Parks 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 assessment

This report for the Cotswolds National Landscape describes one of a series of methodologically compatible assessments produced for the UK National Parks, the Welsh AONBs, and Cannock Chase AONB. As we enter an era in which climate mitigation and sustainable land management become ever more central to all our lives, work, and policy decisions, these assessments are designed to provide a robust and consistent evidence basis for climate action, matched to the unique characteristics and circumstances of each protected landscape.

The report contains a consumption-based assessment of the greenhouse gas emissions attributable to residents and visitors (including travel to and from the landscape), and a set of recommendations for transitioning to Net Zero. Although the UK government's Net Zero target only considers production-based GHG emissions (emissions directly produced by people or businesses within the UK, plus those produced by the electricity used in the UK), the consumption-based assessment described in this report better reflects the full climate impact of people's lifestyles, bringing important areas of climate impact into focus for policymakers. 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 protected landscapes. 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, this report also includes a simple estimate of emissions related to industries within the National Park or AONB, including their supply chains. However, 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 some overlap between emissions from agriculture as an industry sector and land-based emission within each landscape.

This report also describes a potential pathway to Net Zero for the Cotswolds National Landscape, based on ambitious targets to reduce GHG emissions across six key areas:

- 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-based non-CO_2 component (livestock, fertilizers, etc.)
- Land-based CO_2 component (sequestration, peatland degradation, etc.)

"Land-based" here refers to emissions from Land Use, Land Use Change and Forestry (LULUCF), a commonly-used way to describe land-based emissions other than those directly related to farming, as well as emissions from Agriculture (livestock, fertilizers, etc.) excluding fuel and electricity consumption by agricultural activities. The latter are included in the energy-only emissions from industry.

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. This includes limited scope to account for local variability as a result of insufficient geographical granularity of several key data sources available at present.

Nevertheless, the estimates presented in this report are based on the latest science and data, and in our view represent one of the best possible sets of carbon footprint figures for the UK's designated landscapes. Both the datasets used and our implementation of them in the carbon footprint model have varying degrees of confidence, which are reflected in the data summary table in Appendix 10.2[1].

In view of the above, we believe that these estimates are sufficiently robust to provide an evidence basis for carbon management and target-setting. Ongoing improvements in the underpinning science and data will help reduce the limitations and uncertainties in subsequent assessments.

Results

Cotswolds National Landscape

[1] See also Section 4.1 and Appendix 10.8 for the associated methodological details.

(Figure 1 – Figure 4)	
Annual consumption-based emissions from residents	**2,564,575 tCO_2e** (15.7 tCO_2e per person per year)
Annual consumption-based emissions from visitors while in the landscape	**308,806 tCO_2e** (17.0 $kgCO_2e$ per visitor-day[2])
Annual emissions from visitors travelling to/from the landscape	**1,134,848 tCO2e** (70.2 $kgCO_2e$ per person)
Annual industry emissions, including supply chains	**1,253,491 tCO_2e**
Annual emissions from through road traffic not related to the landscape	**375,055 tCO_2e**
Annual CO_2 emissions from land (including carbon sequestration)	**–260,179 tCO_2e**
Annual non-CO_2 emissions from land (including ruminants and fertiliser)	**275,968 tCO_2e**

Key findings

Residents' emissions

The Cotswolds National Landscape has the largest resident population among all UK National Parks (NPs) and AONBs. Its average resident's spending is estimated to be 13% above the UK average (excl. public services). This is higher than for most NPs and AONBs assessed as part of the current programme. Demographic data points to an ageing population, with health expenditure being particularly high.

In a given year, the residents' emissions footprint is estimated to be around 26% higher than the UK average, and is one of the highest among all NPs and AONBs on the current programme. Several fossil fuel-based sources of greenhouse gas emissions are particularly high:

- Estimated residents' emissions from household electricity and driving are, respectively, around 35% and 30% higher than for an average UK resident
- Estimated emissions from other forms of travel are about 24% higher compared to the UK averages
- Cotswolds residents' per capita footprint from flying is estimated to be over 2.5 higher that the UK average, with the number of business class flights per person being the highest among all NPs and AONBs on the current programme; the per resident economy flights are second highest

As of 2019, the share of renewable energy solutions across households (e.g., solar panels, heat pumps, electric vehicles) was comparatively low and no suitable data with sufficient geographical detail was available. Therefore, these technologies were not factored into our estimates for emissions from household fuel and electricity.

[2] Emissions "per visitor-day" mean emissions per visitor, for each day they spend in the landscape.

Visitors' emissions

Cotswolds has one of the largest annual numbers of visitors in absolute terms among all NPs and AONBs, and one of the highest proportions of overseas visitors, which is reflected in the footprint results. However, the profile is dominated by day visitors, while the estimated average duration of overnight stays is below that for most NPs and AONBs on the programme. The average one-way distance travelled on land to reach the National Landscape (mostly by road) is around 120 miles, closely matching with the mean across all NPs and AONBs on the programme.

With all the factors combined, the footprint of visitors while travelling to and from the Cotswolds is over 3.5 times higher than their footprint while in the National Landscape. The visitors' footprint of travelling to and from the Cotswolds is dominated by emissions from flights (48%) and road fuel (41%), and while in the Cotswolds by food and drink (52%).

Despite the large overall numbers of visitors to the Cotswolds, their estimated total footprint (including travel to and from) only amounts to just over a half of the residents' footprint.

Industry emissions

The industry footprint in the Cotswolds is dominated by production (23%; e.g. manufacturing, water management, mining and quarrying), agriculture and forestry (22%), construction (13%) and education (5%). The emissions are above the UK averages for all these sectors, despite the large emitters close to the National Landscape's boundary having been excluded from the estimates.

Traffic emissions

The Cotswolds is estimated to have a considerable traffic footprint from the major M, A and B roads, which amounts to around 20% compared to the consumption-based footprint of the residents, and includes road traffic from the residents, visitors and industries, as well as through-traffic. Through-traffic emissions are estimated to amount to 73% of the total vehicle footprint from the major roads, and these emissions are excluded from the consumption-based GHG baseline presented in this report.

Pathway to Net Zero

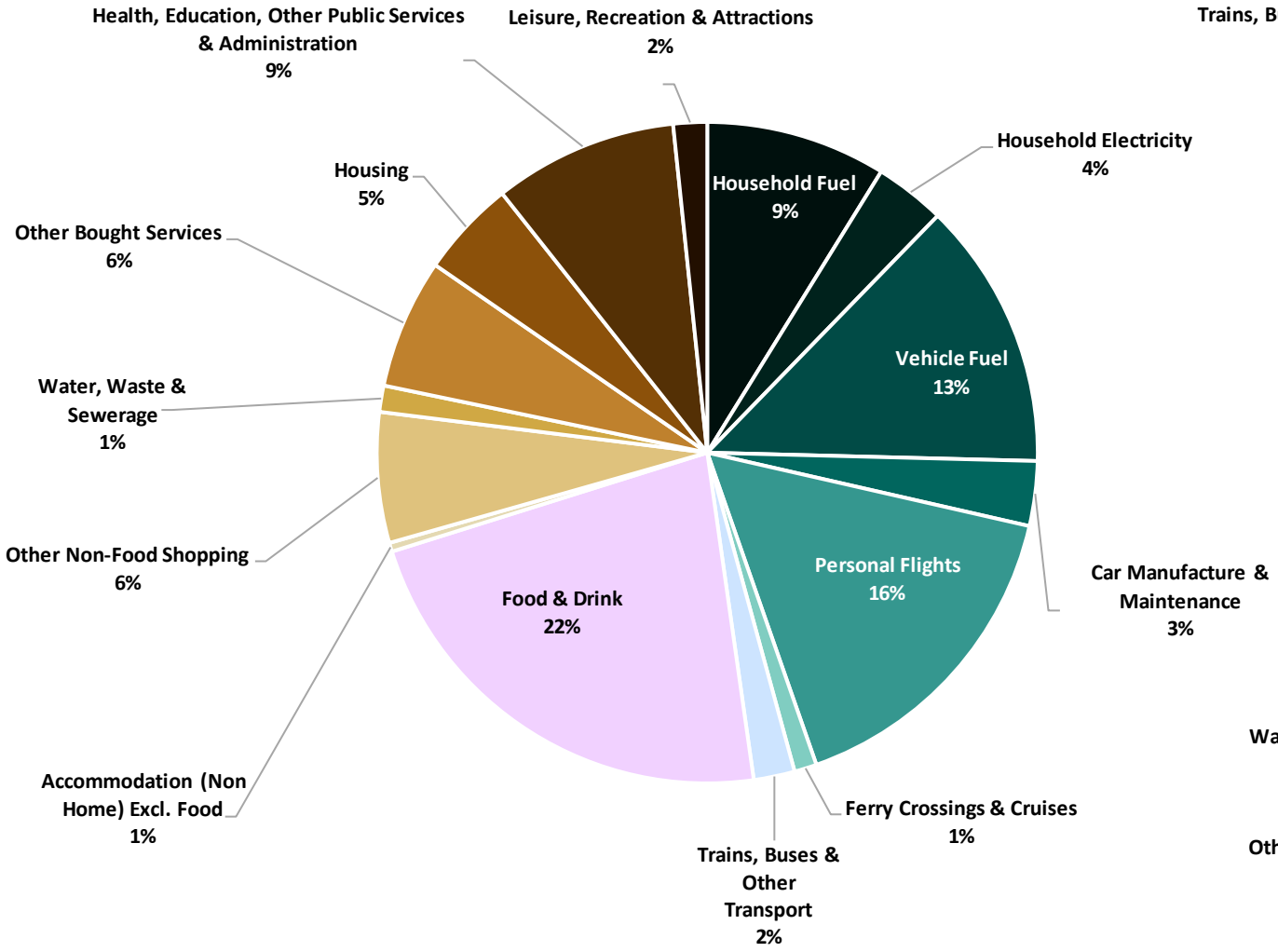
Figure 5 illustrates a potential pathway to Net Zero for the Cotswolds National Landscape based on emission reductions across six major emissions categories. Reflecting the unique characteristics of the landscape, including the land use types and their respective areas, the number of residents and visitors and their consumption patterns, and the level and type of industrial activity, these emission reductions result in a Net Zero date of 2044.

However, this 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 (2019, the most recent pre-COVID year). In reality, decarbonisation trends have been relatively small in magnitude compared to what is required to limit global heating to 1.5 °C, post-COVID emissions have largely rebounded, and the high levels of ambition for different sectors explored in this report will likely take several years to achieve.

These factors are expected to push the projected Net Zero year back by several years. Therefore, it is important to note that the Net Zero year reflects the scale of the decarbonisation challenge within

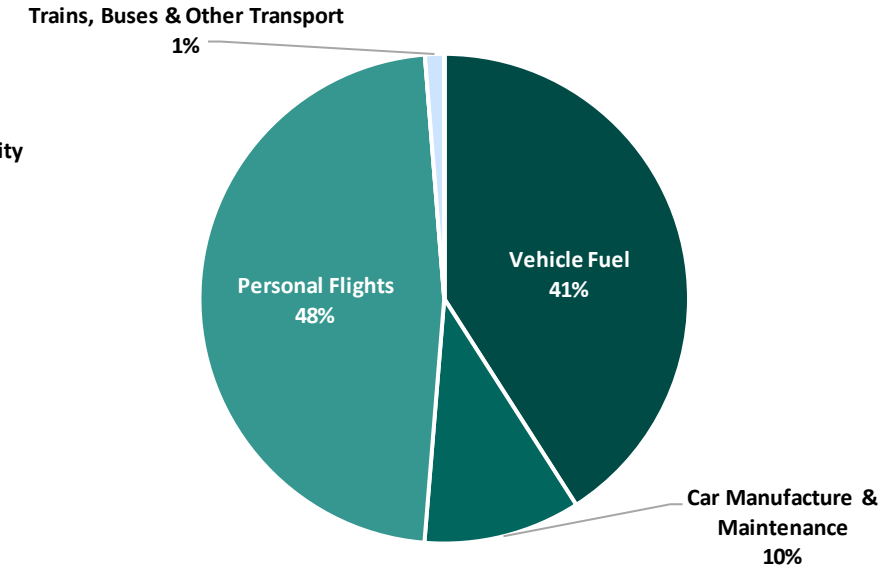
the protected landscape, and should not be taken in isolation as the Cotswolds National Landscape's level of ambition.

Residents: 2,564,575 tCO_2e



Visitors travelling to and from the National Landscape: 1,134,848 tCO_2e

SMALL WORLD CONSULTING



Visitors while in the National Landscape: 308,806 tCO_2e

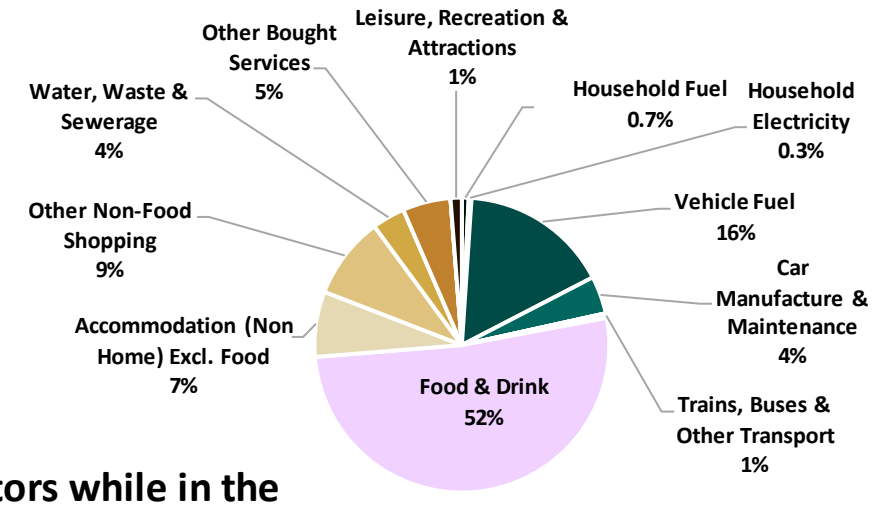


Figure 1: (left) Residents' GHG emissions in Cotswolds National Landscape, by percentage

Figure 2: (top right) Visitors' GHG emissions on the way to & from Cotswolds National Landscape, by percentage

Figure 3: (bottom right) Visitors' GHG emissions while in Cotswolds National Landscape, by percentage

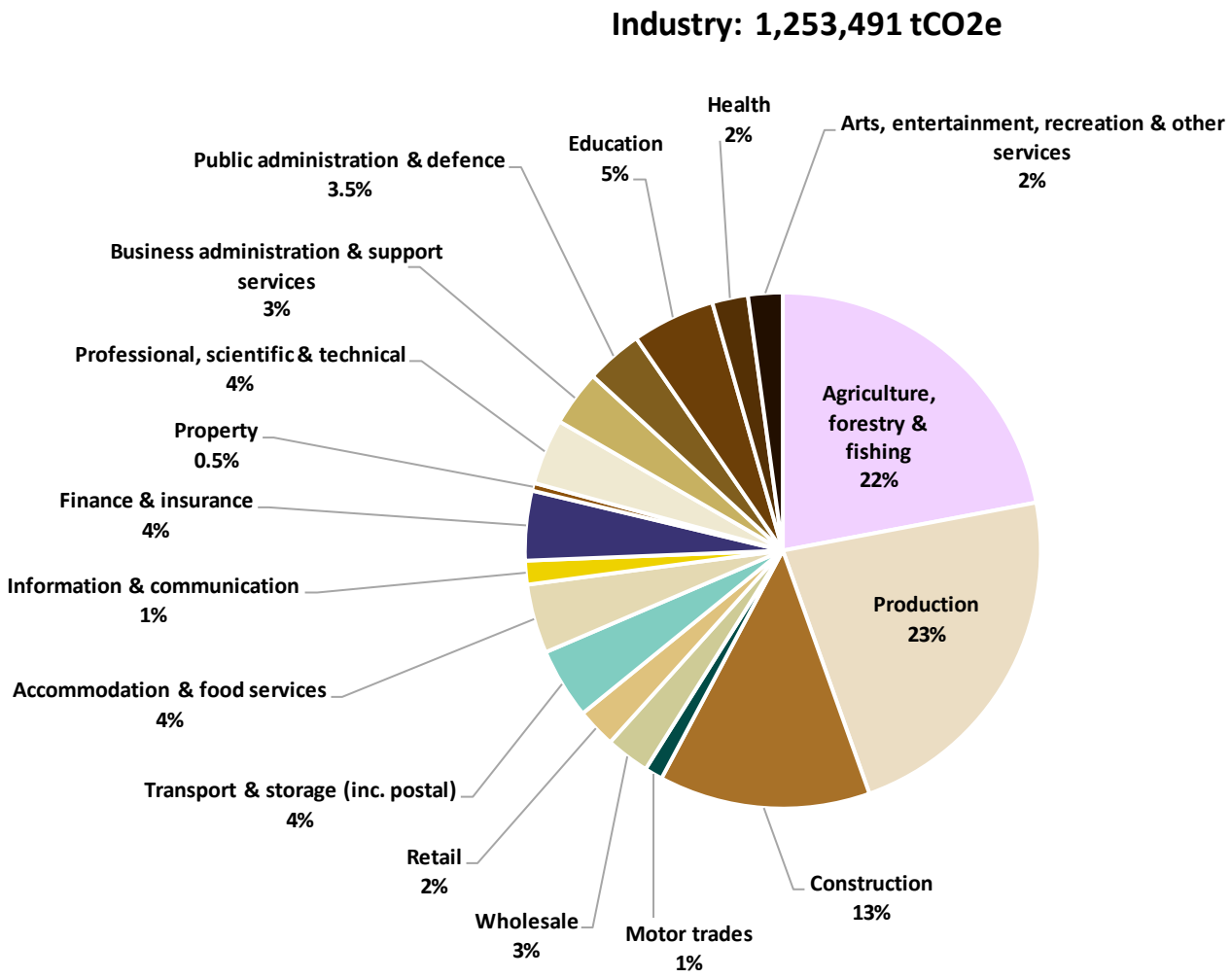


Figure 4. An estimate of emissions from industries within the Cotswolds National Landscape and their supply chains (scopes 1, 2 and upstream scope 3)

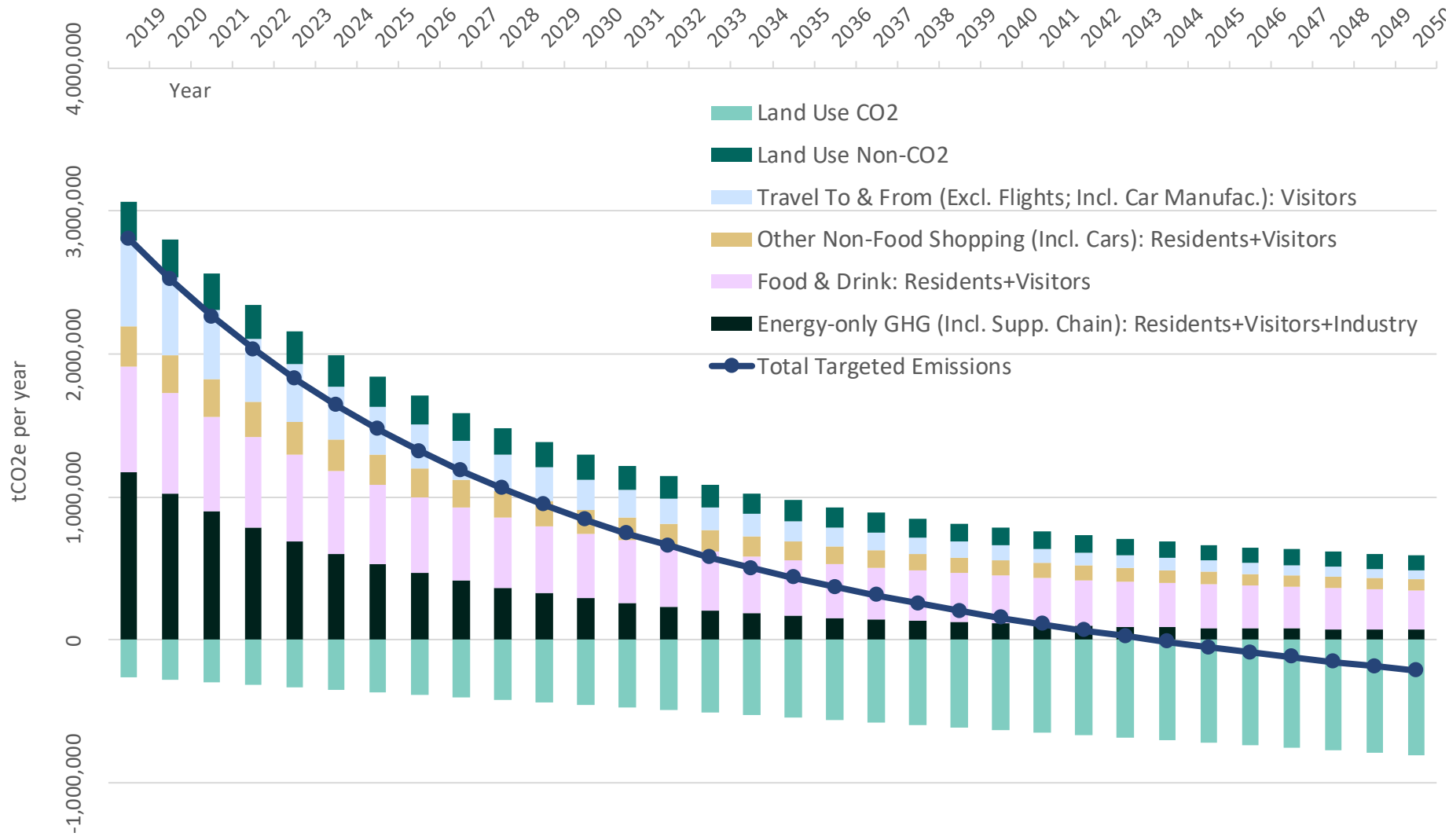


Figure 5: Recommended consumption-based target pathways resulting in net zero emissions in 2044 for Cotswolds National Landscape.

1. Introduction

As the world wakes up to the climate and wider environmental emergency, the rapid reduction of greenhouse gas (GHG) emissions and sustainable land management are becoming increasingly central to local, national and international policy agendas. In 2019, the UK strengthened its commitment to cutting its GHG emissions by setting itself a legally binding target of "Net Zero by 2050"[3]. The United Nations definition of Net Zero requires "cutting greenhouse gas emissions to as close to zero as possible, with any remaining emissions re-absorbed from the atmosphere, by oceans and forests for instance"[4].

1.1. The climate emergency

The escalating impacts of climate change, such as shifting rainfall patterns, higher temperatures, biodiversity loss, sea level rise, extreme weather events, and accelerated ice melt, are already affecting the UK's population, wildlife, and landscapes.

1.1.1. Weather

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"[5]. Total rainfall from extremely wet days increased by around 17% in the decade 2008-2017 for the UK as a whole.

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, an extreme that is projected to become 50% more likely with future warming[4]. Mean sea level around the UK has risen by about 17cm since the start of the 20th century, and coastal and surface water flooding are projected to increase in frequency and severity in the future.

1.1.2. Ecosystems

Year-to-year variations in rainfall and extreme weather events are also affecting UK biodiversity and ecosystems. Montane, wetland and coastal habitats (and the species that inhabit them) are particularly vulnerable to climate change due to their respective sensitivities to hot temperatures, changing water availability, and sea level rise[6]. Habitat fragmentation is thought to be slowing the dispersal process, changing the distributions of plants and animals across the UK.

Many species (particularly those with slow reproduction or low genetic diversity) are unlikely to be able to adapt fast enough to keep pace with climate change. The UK is estimated to have already lost almost half of its native wildlife[7], and there is strong evidence that this figure will rise as the magnitude of climate change increases.

---

[3] GOV.UK (2019), "UK becomes first major economy to pass net zero emissions law" https://www.gov.uk/government/news/uk-becomes-first-major-economy-to-pass-net-zero-emissions-law

[4] https://www.un.org/en/climatechange/net-zero-coalition

[5] 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

[6] NERC (2015), Living With Environmental Change: Report Card 2015

[7] Natural History Museum (2021), "Analysis warns global biodiversity is below 'safe limit' ahead of COP 15" https://www.nhm.ac.uk/discover/news/2021/october/analysis-warns-global-biodiversity-is-below-safe-limit.html

However, some native species with short generation times are finding ways to adapt to the impacts of climate change, such as migrating further north or shifting to higher altitudes. This is also true for species from continental Europe, which have already begun colonising large parts of the UK. Unfortunately, these include pests and diseases that did not previously reach our shores.

1.1.3. Food security

The impacts of climate change on marine, terrestrial and freshwater ecosystems is already impacting UK food security. In recent decades, warmer springs have also caused life-cycle events of many species to occur earlier in the season[5], leading to the mis-timed spring emergence of pollinators that many food crops rely on.

Although the UK's agricultural yields have been projected to increase in the absence of heat and drought stress[8], extreme temperatures could be occurring every other year by the middle of the century[9]. The 2018 heatwave, for example, reduced the growth of many staple crops (notably cereals, potatoes, salad, fruit and vegetables), increased crop damage from pests, increased cattle heat stress, reduced grazing land productivity, and forced the use of winter feed[10]. Extreme weather can also harm agricultural productivity by damaging farming infrastructure.

As an illustration of the likely impacts of changing temperature and precipitation patterns in the UK on food security, it has been estimated that maintaining our current production levels of carrots and potatoes would require a 7-fold increase in irrigation water by 2050[11]. Furthermore, sea level rise is projected to increase the salinity, compaction and inundation of the UK's coastal agricultural soils in the future[12].

The UK also relies heavily on imports for its food security: an estimated 48% of the UK's food supply (by economic value) was imported in 2015[13]. Many of the countries crucial for providing us with food are already water-stressed as a result of climate change, including Spain, Egypt, South Africa and India. A 2019 report by the Climate Change Committee (CCC) estimated that climate change could lead to a 20% (mean) rise in food prices globally by 2050, resulting in higher domestic food prices unless the UK is able to adapt[14].

1.1.4. Health and wellbeing

It has been projected that the milder winters and warmer summers associated with climate change will increase the incidence of vector-borne diseases (e.g. by ticks or mosquitoes) across the UK, as well as introduce exotic pathogens and species[15]. Pathogens that cause food-borne diseases, like Salmonella, grow more readily in food as a result of warmer temperatures, and the nutritional status of the UK population is projected to decline as extreme weather increasingly impacts the domestic and global food production.

---

[8] Defra (2018) "Climate Change Risk Assessment for the Agriculture Sector".
[9] Met Office (2018) "UKCP18 Factsheet: Temperature"
[10] Committee on Climate Change (2018) "Land use: Reducing emissions and preparing for climate change"
[11] Keay, C. A. et al. SP1104 The impact of climate change on the capability of soils for agriculture as defined by the Agricultural Land Classification. Report to Defra. (ADAS/University of Cranfield, 2014).
[12] Gould, I. J. et al (2020). The impact of coastal flooding on agriculture: A case-study of Lincolnshire, United Kingdom. Land Degradation & Development 31, 1545- 1559, doi:10.1002/ldr.3551
[13] Benton, T. et al (2017). "British Food: What role should UK producers have in feeding the UK?"
[14] Committee on Climate Change (2019) "Resilient Food Supply Chains"
[15] Health Protection Agency (2012) "Health Effects of Climate Change in the UK 2012"

Increased ambient UV levels and warmer UK summers may increase health risks associated with UV, including some skin cancers. Changes in seasonality, temperature and weather patterns could mean that existing allergy sufferers will suffer from longer pollen seasons and more rapid symptom development.

The increased incidence and magnitude of extreme weather, disease and allergies could increase the proportion of time the UK population spends indoors (90% in 2012), increasing health risks associated with building overheating, water and biological contamination of buildings, indoor air pollution, and flood damage. Hospitals, health centres and care homes would be particularly affected by high temperatures during heatwaves and flooding.

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 post-traumatic stress disorder 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)[16].

A recent report by Public Health England also suggests that underserved communities who already experiencing greater health inequality[17], are disproportionately vulnerable to the negative impacts of climate change, such as flood risk, air pollution, poor-quality river water and waste hazards.

1.1.5. Landscapes

Climate change is already impacting the Cotswolds National Landscape's natural beauty and the special qualities of the landscape directly through the increased incidence and severity of wildfires, flooding, and species loss. However, some landscape impacts are indirect, such as those resulting from human efforts to mitigate or adapt to the climate crisis.

For example, climate change is projected to result in the loss of native trees, particularly beech trees along the scarp. Increased pressures on other species and habitats that are adapted to today's climate will result in difficult decisions regarding when to abandon efforts to maintain the status quo, and when to start supporting non-native species that establish in the landscape.

Water tables are projected to fall as a result of changing rainfall patterns, which could result in important fresh water sources and habitats in the Cotswolds drying up periodically or permanently. Intensive droughts could also affect the landscape by requiring the introduction of large-scale water capture and storage infrastructure. Flood protection engineering will likely need to be built within the landscape to protect residential and agricultural land from flooding when there is heavy rainfall.

Changes in temperature and rainfall patterns are also expected to change what kind of food will be grown on the Cotswolds' soils in the future, potentially resulting in agricultural landscapes featuring olive groves and vineyards instead of barley and rape. There may also be a push to produce more biofuel crops in the landscape to replace fossil fuels, and emission reduction targets could

[16] Priest, S., Viavattene, C., and Cotton, J. (2019) Environment Agency presentation: "New economic costs for the mental health impacts of flooding."
[17] GOV.UK (2017) "Chapter 5: Inequality in health. Health profile for England: 2017"

significantly increase the presence of solar panels and wind turbines within and surrounding the protected landscape.

Growing tourism as a result of less hospitable climates in today's popular holiday destinations could amplify development pressures within the Cotswolds, as well as the growing need to accommodate climate change refugees. However, climate-driven efforts to reduce car use and increase the use of public transport have the potential to reduce traffic and new road developments in the landscape.

1.2. Role of protected landscapes

Protected landscapes are not protected from the impacts of the climate emergency, nor are they exempt from aiding the essential, far-reaching climate action that is required to meet the UK's Net Zero target.

Accounting for around 18% of total land area, the UK's 15 National Parks and 46 Areas of Outstanding Natural Beauty (AONBs) are home to over 1.5 million residents, and attract approximately 250 million visitors per year. Almost every activity connected with people living in, working in and visiting these protected landscapes gives rise to GHG emissions.

Many emission sources lie within the influence and/or management responsibilities of the National Park Authorities or Local Authorities for the AONB, such as tourism, traffic, housing, industry, land use, and land management. If the UK's protected landscapes can become exemplars of low-carbon transition and environment-conscious land management, their national and international profiles could also 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 the current science and its unique characteristics. Not only will this position National Parks and AONBs as leaders in land stewardship, but it will also create better places for people to live, work and visit. Rising to this challenge, the UK National Parks, the Welsh AONBs, Cotswolds National Landscape, and Cannock Chase National Landscape have sought to quantify their GHG emissions and are exploring potential pathways to Net Zero.

1.3. Consumption-based reporting

The UK government's Net Zero target considers the GHG emissions that are directly produced by people, businesses and land use within the UK, plus the emissions arising from the production of the electricity used in the UK. However, this production-based approach does not include the indirect emissions that are embodied in the goods and services that are consumed by residents and visitors within the UK (i.e. imports). Given that the UK is a major net importer of goods, production-based assessments significantly understate the UK's overall contribution to the climate emergency.

Consumption-based reporting is a more comprehensive approach that considers the indirect emissions associated with the goods and services that are consumed or utilised within a given area. By quantifying the full climate impact of people's lifestyles, consumption-based assessments bring important areas of climate impact into focus for policymakers.

The decision to undertake a consumption-based assessment of its GHG emissions reflects the Cotswolds National Landscape's ambition to understand the full scale of its emissions and take meaningful climate action. To support the latter, this report also recommends reduction targets

across six key GHG emission areas, as well as land-based measures to upscale carbon sequestration in the protected landscape.

2. Policy landscape

Despite the advent of the global Covid-19 pandemic in January 2020, the climate emergency has remained high on the international agenda. The climate and ecological crises are arguably the biggest challenges facing humanity today, and a joined-up response to tackling them is likely to improve both situations. This section summarises the policy drivers for ambitious climate action which the Cotswolds National Landscape may wish to respond to in delivering its statutory duties.

2.1. Decarbonisation targets

Recognising the aforementioned climate impacts, the United Nations (UN) announced The Paris Agreement in 2015, a landmark global agreement to accelerate and intensify the actions and investments required to halt the climate crisis[18]. The overarching goal of this international treaty is to keep global warming well below +2˚C relative to pre-industrial temperatures, with a more ambitious heating limit of +1.5˚C aimed at averting catastrophic impacts of climate change. Several key reports and pledges have since been published to help deliver this commitment.

2.1.1. Global Warming of 1.5°C

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the climate emergency. Bringing together the world's leading scientists, the IPCC prepares comprehensive assessment reports for policymakers about the scientific, technical and socio-economic knowledge on climate change, its impacts and future risks, and options for reducing the rate at which climate change is taking place.

The IPCC's 2018 report "Global Warming of 1.5°C" compared the potential societal and ecological impacts of the 1.5°C and 2°C global temperature increases, demonstrating the scale of harm to life that could be avoided by aiming for the "safer" 1.5°C limit. To achieve this, the IPCC called for a 45% reduction in global GHG emissions by 2030 (from 2010 levels), and set the target of Net Zero global emissions by 2050[19].

2.1.2. UK's Sixth Carbon Budget

Shortly after, in 2019, the UK Government agreed to a legally binding production-based target of Net Zero GHG emissions by 2050. The Department of Business, Energy and Industrial Strategy (BEIS) leads on reporting GHG emissions in line with the UNFCCC requirements in the UK (including Scotland and Wales), while the Climate Change Committee (CCC) provides independent advice on emission targets and progress.

In its 2020 report "The Sixth Carbon Budget: The UK's Path to Net Zero", the CCC prescribed a 78% reduction in UK greenhouse gas emissions by 2035 relative to 1990, which is a 63% reduction from 2019 levels[20]. Further detail relating to these targets is provided in Section 2.3 of this report, outlining associated real-world change towards decarbonisation.

[18] UNFCCC. "The Paris Agreement" https://unfccc.int/ process-and-meetings/the-paris-agreement/the-paris-agreement
[19] IPCC (2018) Special Report: "Global heating of 1.5°C Summary for Policymakers." https://www.ipcc.ch/sr15/chapter/spm/
[20] Climate Change Committee (2020): "The Sixth Carbon Budget: The UK's Path to Net Zero," p. 13.

2.1.3. UK's Net Zero Strategy: Build Back Greener

Ahead of the 26th UNFCCC Conference of the Parties (COP26) in October 2021, the UK Government published its "Net Zero Strategy: Build Back Greener"[21]. This document 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.

It should be noted that this strategy has since been ruled unlawful in the court of law for not meeting requirements under the Climate Change Act of 2008[22]. An update to the government's Net Zero strategy, including a quantified account of how policies will achieve climate targets, must be presented to parliament before the end of March 2023.

2.1.4. Glasgow Climate Pact

Hosted in Glasgow, COP26 concluded with the agreement of the Glasgow Climate Pact, with 153 countries putting forward new 2030 emissions targets ("Nationally Determined Contributions", NDCs)[23]. However, 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. In contrast, if existing Net Zero pledges are fully implemented, global heating could be limited to 1.8°C.[24]

2.1.5. IPCC's Sixth Assessment Report

In April 2022, the IPCC published the final volume of its Sixth Assessment Report[25]. Notably, it confirmed that our chance of limiting the increase in global mean temperature to 1.5°C above pre-industrial levels has shrunk considerably. 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 and behavioural change – to reduce emissions and also upscale efforts on carbon sequestration.

2.2. Intersectional policy drivers

Reducing our GHG emissions not only mitigates the climate emergency, but can also have significant benefits for biodiversity, human health, food security, and many other societal issues. Therefore, policies and commitments that aim to systemically address these challenges often simultaneously support ambitious climate action. The examples of intersectional policy drivers described in this section are by no means an exhaustive list.

2.2.1. UN's Sustainable Development Goals

In 2015, the United Nations launched the 17 Sustainable Development Goals (SDGs), a global call to action to protect the planet, end poverty, and ensure that all people enjoy peace and prosperity[26].

---

[21] HM Government (2021), "Net Zero Strategy: Build Back Greener" https://www.gov.uk/government/publications/net-zero-strategy.
[22] Good Law Project (2022): "We won: Government's Net Zero Strategy is unlawful" https://goodlawproject.org/we-won-net-zero/
[23] COP26, "The Glasgow Climate Pact," p.8 https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf.
[24] https://climateactiontracker.org/global/temperatures/.
[25] IPCC (2022) Climate Change 2022: Mitigation of Climate Change. https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/
[26] United Nations. "Sustainable Development Goals" https://sustainabledevelopment.un.org/

While bold action on climate change is a key area of focus (SDG 13 is "Climate Action"), this commitment also encompasses 16 other metrics of sustainability, including gender equality, quality education, and responsible consumption.

Due to the intersectional nature of the SDGs and the climate challenge, many actions that are designed to address non-climate-related SDGs, can also drive ambitious climate action. Examples include planting hedgerows and trees to support SDG 15 "Life on land", reducing emissions from fertilizers or highly polluting industries to address SDG 14 "Life below water", or improving multilateral cooperation to address SDG 17 "Partnerships for the goals".

2.2.2. UK's Clean Air Strategy

It is estimated that between 28,000 and 36,000 UK deaths each year are attributable to air pollution[27], disproportionately impacting children, older people and other vulnerable individuals. Tragically, two thirds of these deaths are preventable (Asthma UK, 2020).

While not all air pollutants are greenhouse gases (GHGs), pollution often comes from the same sources as GHGs, and some pollutants are powerful GHGs in their own right. For example, two of the worst substances causing human respiratory diseases are nitrogen dioxide (NO_2) and soot (black carbon), both of which are by-products of burning fossil fuels for transport, power, and manufacturing. Eliminating fossil fuels in line with our decarbonisation targets would therefore not only halt climate change, but could also save the lives of tens of thousands UK citizens every year.

In 2019, the UK Government published its "Clean Air Strategy 2019", proposing tough new goals to cut public exposure to particulate matter pollution, as recommended by the World Health Organization[28]. This document outlines several approaches to tackle air pollution that would simultaneously mitigate climate change, including phasing out coal-fired power stations, improving energy efficiency, shifting to cleaner power sources, ending the sale of new conventional petrol and diesel cars, giving new powers to local authorities to take action in areas of high pollution, minimising pollution from fertiliser use, and tighter emissions standards on medium combustion plants and generators.

2.2.3. UK's Environment Act

On 9th November 2021, the UK's Environment Act 2021 received Royal Assent and became law 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 air quality) 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,

[27] Welsh Government (2020), "Clean Air Plan for Wales: Healthy Air, Healthy Wales," p.23.
[28] UK Government (2019), "Clean Air Strategy 2019: executive summary"

- The "polluter pays" principle (i.e. that those who produce pollution should bear the costs of managing it to prevent damage to the environment or human health).

Following these environmental principles will support the Cotswolds National Landscape to take bold climate action within the protected landscape.

2.3. The shift to "business-unusual"

In its Sixth Carbon Budget report, the CCC puts forward high-level proposals that necessitate real-world planning, action and behaviour change. Key recommendations 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).
- 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 buildings.
- Fewer miles travelled by car and air.
- Diets change, reducing consumption of high-carbon meat and dairy products 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.

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"[29].

2.4. Local planning decisions

In this changing space, planning is one of the tools that Local Authorities can use to address GHG emissions, specifically through decarbonising the built sector. Ideally, policies within the Local

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

Development Plan will influence the construction sector to consider the embodied GHG emissions in the materials used, achieve dramatic 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 that are more sustainable.

Planning can also provide information on which types of renewable energy technology will be appropriate and where to site them within the Cotswolds National Landscape, facilitating a transition by communities and businesses to non-fossil sources of power and heat. The latest Management Plan indicates the provision of renewable energy within the protected landscape as a measure to mitigate the impacts of climate change[30]. The current Climate Change Strategy identifies local authorities, renewable energy companies, businesses, and energy agencies as stakeholders for the promotion of investment in renewable energy within the Cotswolds[31].

The National Landscape's stance on renewable energy in and around the protected area has important influence. Therefore, the Cotswolds Conservation Board is currently updating its position statement on renewable energy to identify suitable opportunities and conditions for the development of wind turbines, biofuels, anaerobic digestion, solar photovoltaic, solar hot water, hydro-electric, and heat pumps within the protected landscape (publication expected later this year).

3. Demographic profile and key statistics

This section outlines the Cotswolds National Landscape's key landscape characteristics, population demographics, and consumption patterns. These factors shape the behaviour changes, land use changes and land management changes that are necessary to create a more sustainable long-term future for both people and nature in the protected landscape.

3.1. Landscape characteristics

The Cotswolds National Landscape covers an area of 2,038 square kilometres (203,800 ha), making it the largest among the AONBs and the third largest protected landscape in England[30], after the Lake District National Park and the Yorkshire Dales National Park. The Cotswolds National Landscape spans from Warwickshire and Worcestershire in the north, through Gloucestershire and Oxfordshire, to Bath and Wiltshire in the south[30]. It crosses 15 local authority areas: Bath and North East Somerset Council, Cheltenham Borough Council, Cherwell District Council, Cotswold District Council, Gloucestershire County Council, Oxfordshire County Council, South Gloucestershire Council, Stratford on Avon District Council, Stroud District Council, Tewkesbury Borough Council,

[30] CNL, Management Plan 2023-2025, https://www.cotswoldsaonb.org.uk/wp-content/uploads/2018/12/Management-Plan-2023-25.pdf.
[31] CNL, Climate Change Strategy, 2022, https://www.cotswoldsaonb.org.uk/wp-content/uploads/2022/03/CNL-Climate-Change-Strategy-Adopted-Feb-2022.pdf.

Warwickshire County Council, West Oxfordshire District Council, Wiltshire County Council, Worcestershire County Council and Wychavon District Council[32].

Across its large area, the Cotswolds has 19 principal landscape types[33] which can be grouped into three main landforms: the escarpment, the escarpment valleys and outliers, and the high wold and dip-slope[30]. A prominent, unifying characteristic of the Cotswolds is its limestone geology, which is visible in the landscape, creates an aquifer system, supports biodiversity, and is used as a local building material. The geological value is recognised in the designation of 200 Regionally Important Geological and Geomorphological Sites (RIGS) and 36 Geological Conservation Review (GCR) sites[30]. Sites of archaeological and historic importance, including Neolithic stone monuments, Iron Age forts and ancient drove roads, are other special qualities of the National Landscape[30].

3.1.1. Land ownership & use

Land ownership within the Cotswolds National Landscape is mostly private. The landscapes are accessible via an extensive network of Public Rights of Way, including two National Trails and more than a dozen long distance paths, as well as large areas of open access land[30].

Farming is the major land use in the Cotswolds[30], using 86% of the total land area across different land systems, primarily grassland (44%) and cropland and fallow (41%); these proportions are similar to the rest of England[34]. Other main land uses are woodland on farm holdings (6%, higher than England's 3%), set-aside (4%) and rough grazing (2%)[34].

There are roughly 3,400 farm holdings in the National Landscape, with an average size of about 50 hectares[30], but with many holdings (43%) being less than 5 hectares and many (21%) being 5-20 hectares[34]. With an estimated share of 70% of the agricultural land area, the Cotswold has a greater proportion of holdings over 100 hectares (14%) compared to England (13%)[34]. Categorisation of the holdings by farm type is closely related to their size, with half of all holdings identifying other land use types, associating with the smaller farms, and the next numerous categories being cattle and sheep (21%), cereals (14%; mainly winter wheat, oilseed rape and spring barley), mixed (4%) and dairy (3%)[34].

Much of the Cotswolds' land area is classed as Grade 3 (good to moderate quality) by the Agricultural Land Classification for England, indicating productive land potential for agriculture. Small areas of Grades 1 and 2 land (excellent and very good quality, respectively) are scattered across the landscape, particularly in the north (around Chipping Campden) and towards the south (around Tetbury). Areas of Grade 4 land (poor quality) are common across the National Landscape, particularly towards the northern boundary and often along road networks, while the largest patches of Grade 5 land (very poor quality) are located near to the urban centre of Stroud to the west. Areas of non-agricultural land primarily relate to woodland[35].

3.1.2. Biodiversity

The varied landscapes of the Cotswolds support diverse wildlife, including habitats and species which are rare and declining elsewhere. Priority habitats include lowland calcareous grasslands,

[32] https://www.legislation.gov.uk/uksi/2004/1777/schedule/1.
[33] CNP, Landscape Character Assessment, https://www.cotswoldsaonb.org.uk/our-landscape/landscape-character-assessment/.
[34] CNL, Farming, https://www.cotswoldsaonb.org.uk/our-landscape/farming/.
[35] https://magic.defra.gov.uk/MagicMap.aspx

arable field margins and hedgerows, lowland and ancient woodlands, and flushes, streams and rivers. The habitats support priority plant, insect, bird, mammal and fish species such as Cotswold pennycress, the pearl-bordered fritillary butterfly, corn bunting, dormouse and native brown trout[30].

The National Landscape encompasses numerous sites which are designated to protect and enhance biodiversity, including 5 Special Areas of Conservation (SACs), 89 Sites of Special Scientific Interest (SSSI), 3 National Nature Reserves (NNRs) and 2 Nature Improvement Areas, as well as many Local Wildlife Sites[30].

The geology of the landscape means that the water courses in the National Landscape are mainly fed from deep in the limestone aquifers. Most river valleys within the National Landscape form headwaters to the Thames. Of the monitored stretches of river, 35% had good ecological condition in 2016 according to Water Framework Directive data, and phosphate and sediment levels pose water quality concerns in some watercourses and groundwater supplies[30].

3.1.3. Opportunities & influence

Like all protected landscapes, the Cotswolds National Landscape has an opportunity to make use of its unique characteristics for the goals of climate change adaptation and mitigation, alongside increasing biodiversity and protecting the environment.

In its current Climate Change Strategy, the National Landscape has highlighted its aims to preserve and increase carbon storage in the landscape[31]. The Cotswolds has already developed a natural capital evaluation with opportunity mapping for habitats and nature recovery, carbon storage, farming and water flow and quality regulation[36], which contributes to the Cotswolds Nature Recovery Plan. In addition, there is growing interest in increasing the carbon sequestration in agricultural landscapes.

The influence of the Cotswolds extends beyond its geographical borders, as other areas around the country will likely look to the National Landscape as a case study for how best to take on these challenges.

3.2. Population demographics

The Cotswolds National Landscape has the largest residential population of all National Parks and AONBs on the current programme: approximately 152,000 people[37]. For the purpose of this GHG assessment, mid-2019 population estimates were used, including residents in all postcodes with at least 30% of the area within the National Landscape boundary. This assessment boundary puts the National Landscape's residential population at roughly 163,222 people.

3.2.1. Distribution of residents

While there are no major settlements within the National Landscape, popular market towns are Broadway, Chipping Campden, Moreton-in-Marsh, Stow-on-the-Wold Bourton-on-the-Water and Burford in the North Cotswolds; and Painswick, Nailsworth and Tetbury in the South Cotswolds[38]. There are numerous large urban settlements near to the National Landscape: Gloucester,

[36] Natural Capital Evaluation, A Natural Capital Evaluation of the Cotswolds National Landscape (arcgis.com).
[37] CNL, Fact File, https://www.cotswoldsaonb.org.uk/our-landscape/cotswolds-aonb-fact-file/.
[38] CNL, Towns and Villages, https://www.cotswolds.com/plan-your-trip/towns-and-villages.

Cheltenham, Cirencester, Bristol, Bath, Swindon, Oxford, and Stratford-upon-Avon[37].

Between 2012 and 2017, more new housing schemes (62) and units (2,869) were approved in the Cotswolds National Landscape than any other English AONB[39], creating a pressure for development within the protected landscape[30].

3.2.2. Ageing population

The age profile shows an ageing population, with the number of people in all age groups over 45 years being higher than the national average, and adults between 15 and 29 years along with children up to 5 years being below the national average[40]. Almost 60% of the population are of working age and 16.5% of people are retired[40].

3.2.3. Affluence & deprivation

According to Catapult Energy Systems' 2021 report, residents living in vulnerable circumstances (e.g. rural areas, low income, privately renting, disability, pensionable age, digital exclusion, etc.) experience greater barriers to adopting low-carbon behavioural changes[41]. Therefore, affluence and deprivation within the protected landscape provides important context for this consumption-based assessment and recommended behaviour changes.

The average Cotswolds resident is more affluent than the UK average. The most notable index of deprivation classes the majority of the National Landscape as less deprived, with the least deprived areas broadly located towards the north-western boundary, although there are more deprived regions near to the urban centre of Gloucester and in the south around Dyrham[42].

It is important to understand and reflect upon the 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 Cotswolds can be found in Appendix 10.1.

3.2.4. Consumption & expenditure

On average, Cotswolds residents spend around 13.0% more than UK residents (Table 1), excluding public services, which is roughly the same as the average spend across all National Parks. The spending patterns of the Cotswolds National Landscape's residents map closely to the average of all National Parks, with significantly higher levels of spend on healthcare (35.9%), transport (23.9%), and recreation and culture (23.7%), and much lower spend on education (-25.3%) compared to the UK average. This pattern is reflective of the ageing population in the National Landscape, with fewer children and working age adults and more people of retirement age compared to the UK average.

[39] Dixon, D., Sinden, N. and Crabtree, T. (2017) An Independent Review of Housing in England's Areas of Outstanding Natural Beauty 2012-2017. Commissioned by the Campaign to Protect Rural England (CPRE) and the National Association of Areas of Outstanding Natural Beauty. (Data taken from Table 4, page 26).

[40] CNL, Population and Economy, https://www.cotswoldsaonb.org.uk/wp-content/uploads/2017/07/population-and-economy-6.pdf.

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

[42] Index of Deprivation, 2019, http://dclgapps.communities.gov.uk/imd/iod_index.html.

The most notable differences in consumption patterns between the Cotswolds and the National Parks are lower spends on health, transport and alcoholic drinks, tobacco and narcotics, and higher spends on education, restaurants and hotels.

Table 1: Relative difference in citizen spending per capita (excluding public services) between Cotswolds National Landscape and the UK average, and the relative difference between all 15 UK National Parks averaged and the UK average.

Citizen Expenditure Category	CNL vs UK citizen spending (excl. public services)	All National Parks vs. UK
Food & non-alcoholic drinks	+ 9.5%	+ 10.2%
Alcoholic drinks, tobacco & narcotics	+ 9.9%	+ 14.6%
Clothing & footwear	+ 9.8%	+ 9.2%
Housing, fuel & power	- 10.2%	- 8.3%
Household goods & services	+ 20.7%	+ 16.7%
Health	+ 35.9%	+ 41.9%
Transport	+ 23.9%	+ 29.8%
Communication	+ 4.4%	+ 4.7%
Recreation & culture	+ 23.7%	+ 22.1%
Education	- 25.3%	- 39.8%
Restaurants & hotels	+ 7.6%	+ 3.1%
Miscellaneous goods & services	+ 10.2%	+ 7.8%
Other expenditure items	+ 23.6%	+ 23.1%
Total	**+ 13.0%**	**+ 12.9%**

3.2.5. Local economy

The economic activities that most influence the landscape of the Cotswolds are farming and forestry, tourism, quarrying and house building[30]. The major industries providing jobs for residents are manufacturing, real estate, renting and business activities, as well as wholesale and retail trade repairs, together accounting for just over 44% of employed people. Many residents work in the urban areas outside the Cotswolds boundary, while some people travel into the National Landscape for work[40].

Further details of the National Landscape's key consumption and industry characteristics can be found in Appendix 10.2.

3.2.6. Visitors

The Cotswolds is ringed by a number of large towns and cities (Bath, Oxford, Stratford-upon-Avon, Cheltenham, Gloucester, Stroud and Tewkesbury), making it suitable for day trips, including from London. Its ease of access means the National Landscape has one of the largest annual numbers of visitors among all National Parks and AONBs.

Connection with England's large population centres of London and Birmingham is served by the national motorway network and major roads, with road travel times to Gloucester of around 2 hours from London and 1 hour from Birmingham. The gateway settlements of Gloucester and Cheltenham

are linked by the A40 and M5; London and the South East are accessible via the A40 and M4; the South West is linked by the M5; the North is connected via the M5/M6 and M42; and Wales is reached using the A40 and M4, with Cardiff around 1 hour away.

Rail and bus connections to and within the National Landscape are relatively good, including major routes from London, the Midlands, the North, and the South West. National bus services connect to the bordering large settlements, and local services link the Cotswolds' market towns.

For visitors flying in from overseas, the closest airports are Birmingham and Bristol (each as short as a 1 hour drive away), and Heathrow (around 1.5 hours away by car). Gloucestershire Airport services travel from Belfast, the Isle of Man and Jersey, as well as chartered flights[43].

4. GHG reporting conventions and methods

This section describes the basics of GHG reporting, and the methodology behind our carbon baseline assessment and the proposed Net Zero emission reduction targets for the Cotswolds National Landscape.

4.1. Basics of GHG reporting

4.1.1. Greenhouse Gas protocol

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
- Scope 3 for indirect emissions in the value chain[44]. This scope can be split into two parts: upstream and downstream.

Combined, these three scopes provide an indication of the full "carbon footprint" of an individual or an industry (Figure 6).

[43] https://www.cotswolds.com/plan-your-trip/getting-to-and-around.
[44] 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.

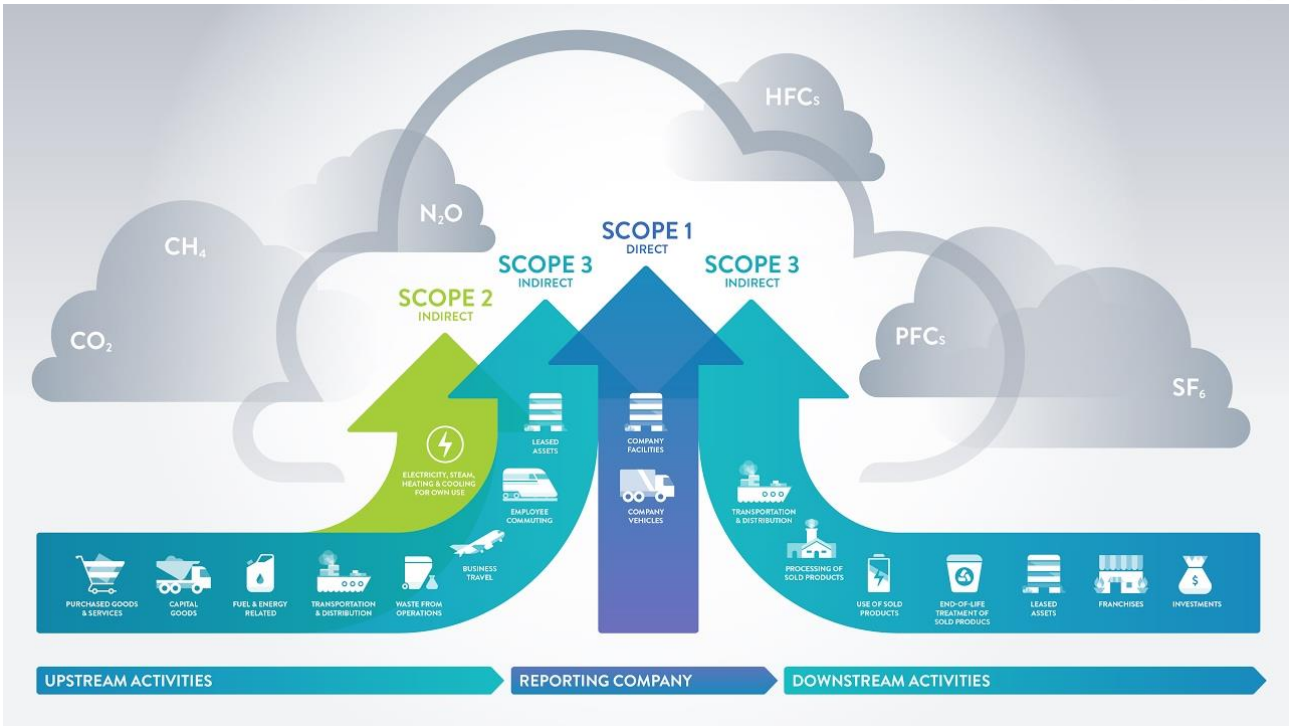


Figure 6: Types of greenhouse gas emissions and scopes used for carbon accounting. Source: Greenhouse Gas Protocol.

4.1.2. Quantifying GHG emissions

In this report, we measure greenhouse gas emissions in tonnes of carbon dioxide equivalent (tCO_2e)[45]. This unified greenhouse gas (GHG) metric is helpful for measuring climate impacts, as each GHG has different properties that affect its contribution to global heating. In line with established GHG accounting conventions, we have used 100-year conversion factors for all non-CO_2 gases in this assessment. However, it should be noted that the relative importance of shorter-lived, highly potent GHGs increases if we are looking at climate impacts by 2050.

For example, methane is 84x more potent as a GHG than carbon dioxide over a 20-year period. However, because only half of methane molecules survive in the atmosphere after 12.4 years (compared to much longer atmospheric lifetimes of CO_2), methane's global warming potential (GWP) drops to 28x that of CO_2 over a 100-year period, which is the default period for GHG reporting based on the Greenhouse Gas Protocol. In practice, since only around a quarter of methane molecules survive for 25 years and less than 1% of them survive for 100 years, the bulk of the warming and the associated climate impacts caused by methane occur in the first 20-30 years after it is being emitted.

It is also important to note that the increased relative strength of shorter-lived, highly potent GHGs does not justify any delay in making the necessary deep reductions to our CO_2 emissions. Although less potent, the global warming potential of CO_2 is cumulative, and not cutting these emissions now will disproportionately shift the burden of increased climate impacts and damages onto future generations.

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

4.1.3. Types of GHG reporting

A protected landscape's GHG emissions can be reported in three ways: consumption-based emissions, production-based emissions, or extraction-based emissions.

Consumption-based emissions

This approach assesses 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 or AONB. Consumption-based reporting attributes the emissions from product and service supply chains to the National Park or AONB, *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 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 or AONB's industry is reported separately, as there is some unavoidable double-counting with the footprint of residents and visitors, when people in the protected landscape buy from local companies.

Production-based emissions

These are the net emissions that are physically released in the National Park or AONB, most notably by burning coal, oil and gas. Production-based assessments also quantify the emissions arising from the production of electricity used in the protected landscape (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 BEIS at the local level. The approach also includes through-traffic emissions from vehicles that are passing through the National Park or AONB without stopping. However, this approach excludes the emissions arising from any production outside the landscape. Given that many of the goods and services used in the area originate from outside the landscape, this approach is likely to understate residents', visitors' and industry's overall contribution to the climate emergency.

Extraction-based emissions

An extraction-based assessment quantifies the emissions produced by burning any fossil fuels that are extracted from the ground within the protected 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 National Park or AONB.

4.2. Our carbon footprint assessment

In this assessment, we focus on a consumption-based approach and report the Scope 1, 2 and upstream Scope 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 Appendix 10.2 and 10.3.

By taking a consumption-based approach, we have included embodied, indirect emissions in everything that residents and visitors buy and do while in the National Landscape, as well as while travelling to and from the landscape. The assessment covers all six major greenhouse gases (Figure 6), 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.

The following emission sources are within the scope of the assessment:

- residents' personal travel and visitor travel to, from and around the National Landscape;
- fuel and electricity consumed in homes and places to stay;
- food and drink and other purchases;
- the use of services, including public services; and
- 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.

4.2.1. Land use and management

Accounting for emissions from land use and management is also crucial for National Parks and AONBs. These landscapes are mostly rural, with comparatively small populations 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, and agricultural soils could also sequester carbon under certain types of management.

Recognising that the land can sequester GHGs as well as emit them, the term "net emissions" is used to quantify the impact of land use and land management on climate change. To calculate net emissions, the negative emissions (i.e. removal of CO_2 from the air by trees, hedges, soils) have been subtracted from the positive emissions (i.e. GHGs from livestock, fertilizer use, tillage, peatland degradation).

4.2.2. Industry

As a separate and overlapping analysis, this report includes a simple assessment of emissions from industry within each protected landscape and associated supply chains (Scopes 1, 2 and upstream Scope 3) to indicate 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 (see Figure 7). 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.

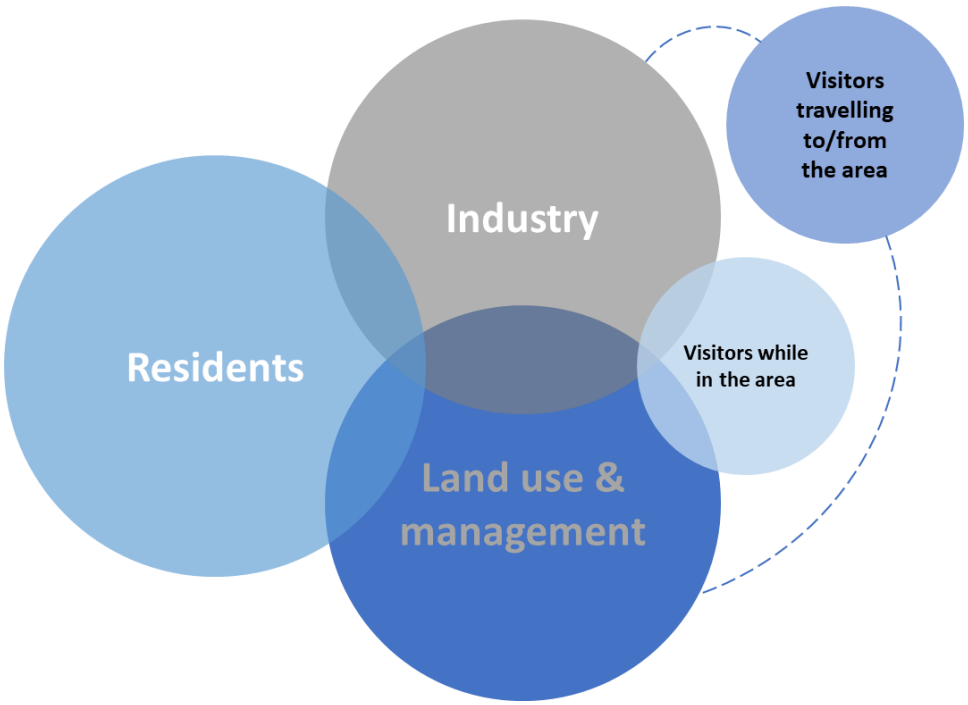


Figure 7: Boundaries of our carbon footprint assessment, illustrating the relationships and potential areas of overlap between the main components of our central assessment and the industry emissions.

4.3. Net Zero targets

This report also recommends ambitious GHG targets across six priority areas, with the aim of supporting the transition to Net Zero within the protected landscape by 2050. These six areas have been selected in order to find a best-fit between the competing desires to a) cover everything of significance within the influence of policy makers, b) keep the boundary simple to describe, c) avoid double counting, and d) 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-based non-CO_2 component (e.g. livestock, fertilizers)
- Land-based CO_2 component (e.g. sequestration, peatland degradation)

5. Cotswolds: Consumption-based GHG emissions

5.1. Results overview

Here, we outline our analysis of the Cotswolds residents and visitors' GHG emissions for 2019 (Figure 8). Residents' emissions were estimated at 2.57 million tCO_2e (Figure 9) and visitors' emissions (during their stay as well as travelling to/from the area) were estimated at 1.44 million tCO_2e (Figure 10 and Figure 11).

The resident population within the chosen assessment boundary is 163,222 people, compared to over 16 million visitors per year (both single-day and overnight). A full breakdown of these figures is provided in Appendix 10.4. The data shows that the typical GHG footprint of a Cotswolds resident is 27.2% higher than that of the average UK resident. The final annual consumption per year for the residents (including public services) is over £5.42 billion.

To indicate the scale of annual GHG footprint from the Cotswolds residents and visitors, you would need to plant over 10,800 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 heating, rather than just mitigating emissions through carbon removal. Emissions reductions, including decarbonisation of industry and personal citizen 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[46]. We shall use these four key categories to comment on the results, and to suggest where the local councils and other partners could target initiatives aimed at behaviour change.

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

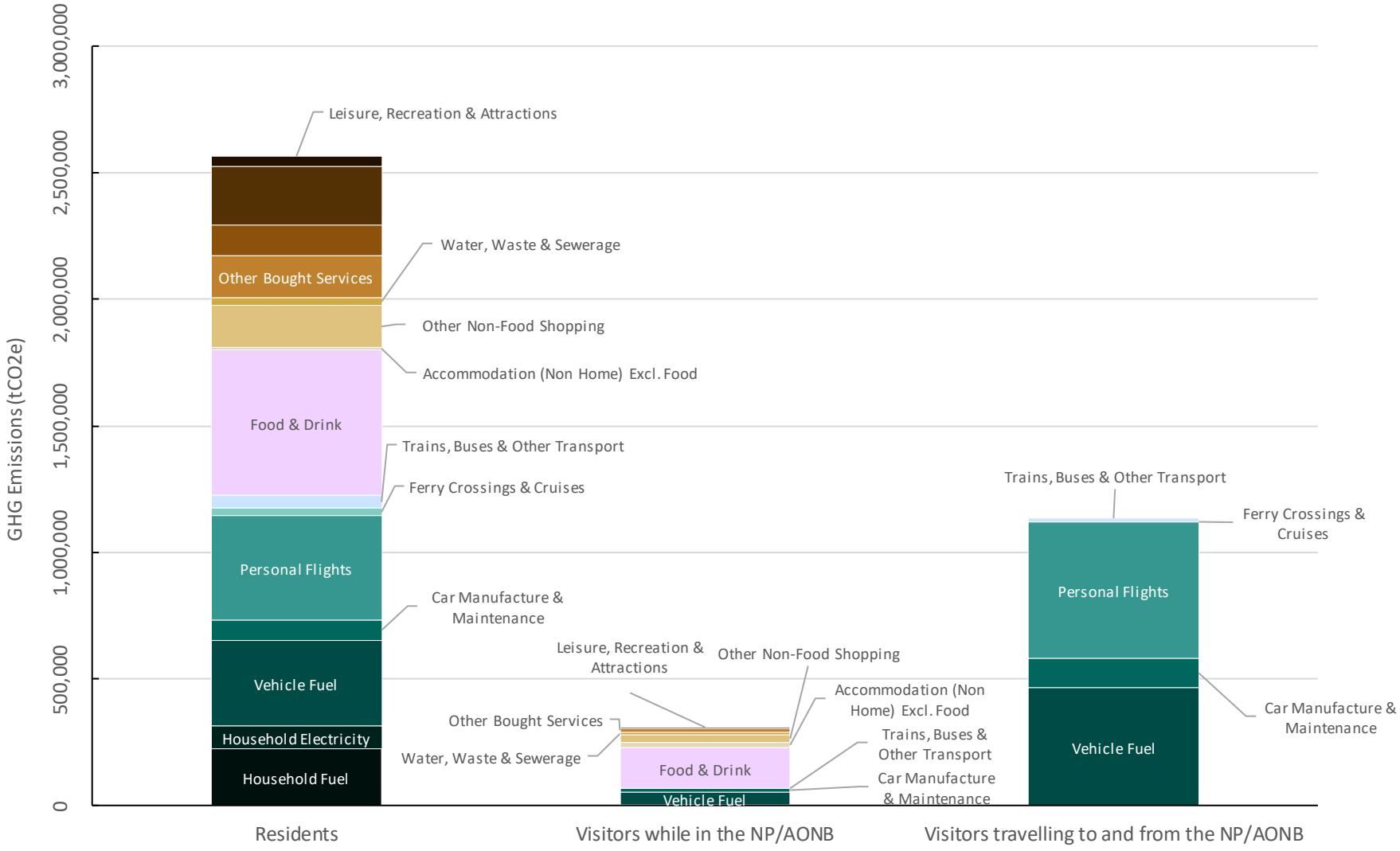
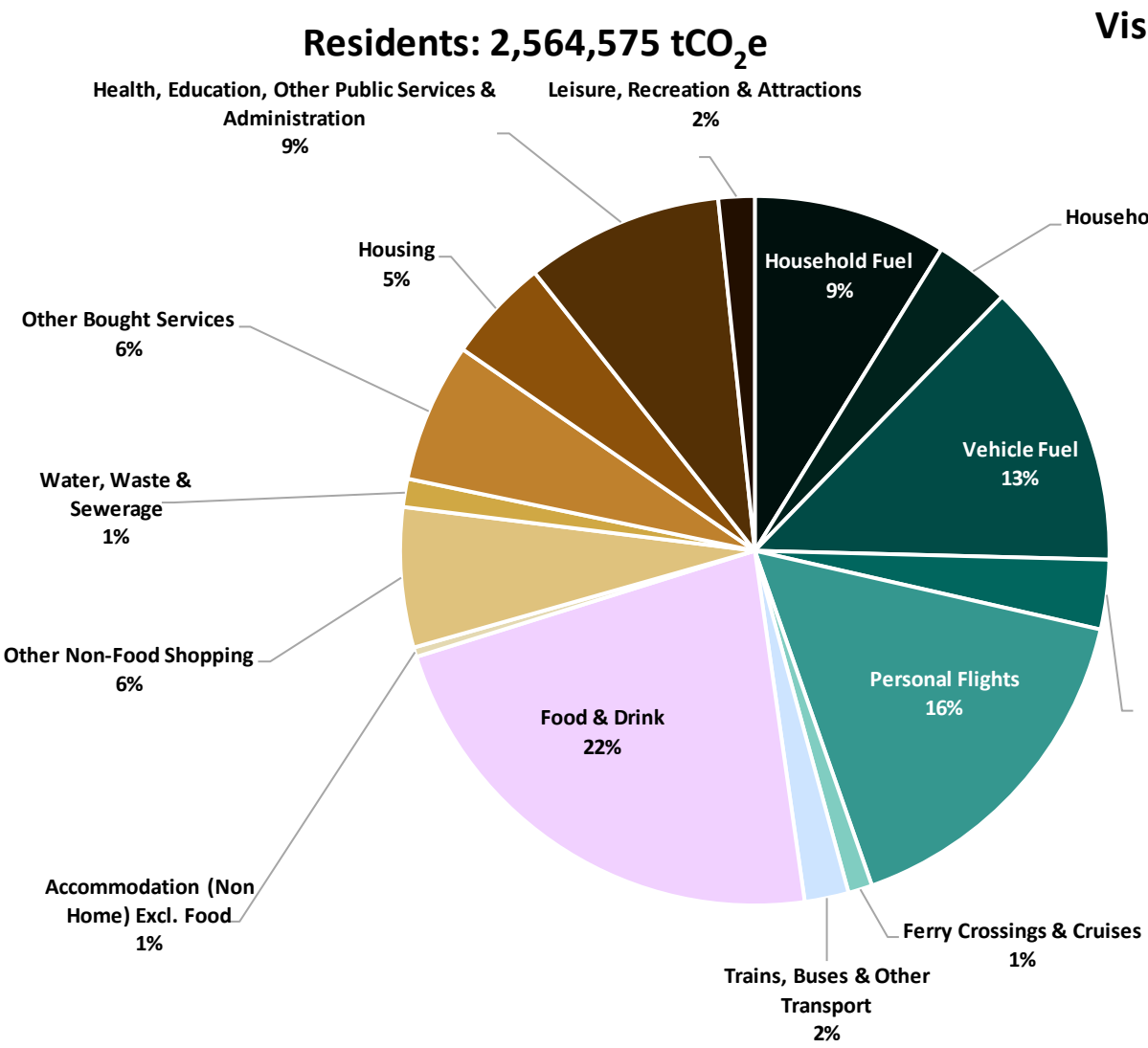


Figure 8: A consumption-based assessment of emissions relating to residents, visitors, and visitor travel to and from the Cotswolds National Landscape.



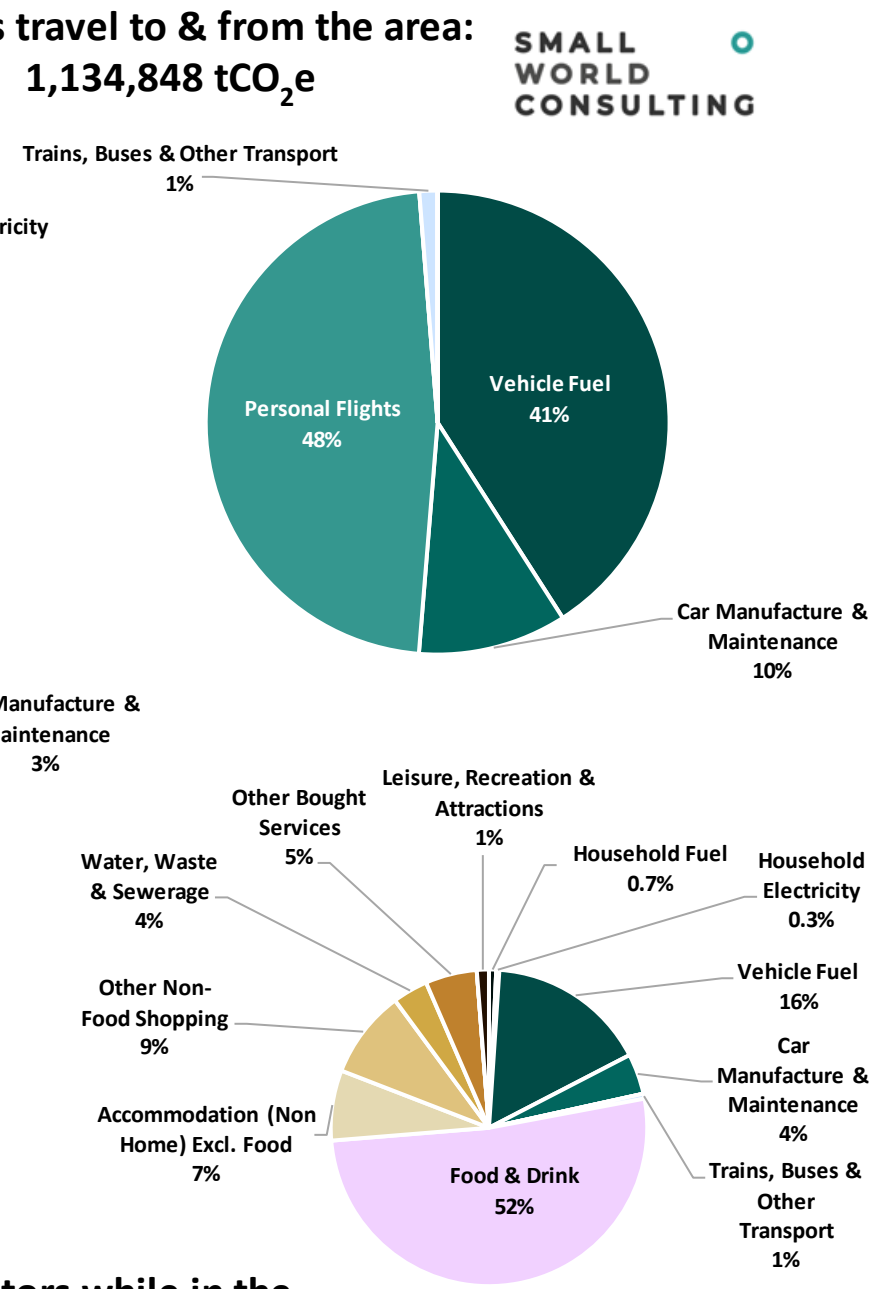


Figure 9: (left) Residents' GHG emissions in Cotswolds National Landscape, by percentage (Repeat of Figure 1)

Figure 10: (top right) Visitors' GHG emissions on the way to and from Cotswolds National Landscape, by percentage (Repeat of Figure 2).

Figure 11: (bottom right) Visitors' GHG emissions while in the Cotswolds National Landscape, by percentage (Repeat of Figure 3).

5.2. Residents' and visitors' GHG footprint components

Cotswolds residents' emissions totalled and estimated 2.57 million tCO_2e in 2019, with the highest emissions arising from food and drink (22%), personal flights (16%) and vehicle fuel (13%) (Figure 9).

GHG emissions produced by visitors to the Cotswolds totalled an estimated 1.44 million tCO_2e in 2019, comprised of 1,134,848 tCO_2e from travelling to and from the National Landscape, and 308,806 tCO2e produced while in the National Landscape. The chart presenting visitor travel to and from the National Landscape (Figure 10) indicates that GHG emissions are dominated by personal flights (48%) and vehicle fuel (41%), with only 1% arising from public transport (excluding flights). During their stay in the National Landscape, 52% of the visitor footprint is associated with food and drink, while vehicle fuel accounts for 16% (Figure 11).

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 Cotswolds is considerable: for residents it is 574,855 tCO_2e (22% of the residents' total), and for visitors 159,522 tCO_2e (52% of the visitors' total); see Appendices 10.4 and 0.

"Buy local, eat local" has already 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, low-carbon dietary choices can also improve population health. As a moderately-to-high calorie density food, red meat (beef, lamb, and pork) should be consumed in moderation to achieve a balanced healthy diet. Lean protein sources like turkey and chicken, on the other hand, have a low-calorie density. Calorie consumption has a direct impact on body 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[47]. Ship-transported and frozen produce are also good low-carbon alternatives, as the emissions per item are far lower than for air-freighted goods [48].

In farming communities particularly, food system emissions is one of the most crucial and polarising topics, given its potential impact on farming livelihoods and traditional lifestyles. We suggest that a collaborative approach between the agricultural industry and other land managers, together with

[47] 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.
[48] Berners-Lee, M. (2010) "How Bad Are Bananas – The Carbon Footprint of Everything," p. 26-29.

the NHS and public health bodies, is necessary to achieve an acceptable transition pathway that acknowledges the myriad of complex challenges facing food producers in the UK. These challenges include responding to climate change and achieving biodiversity net gain while producing sufficient, healthy food for the UK population, as well as workforce issues such as coping with an ageing population of farmers and the overall decline in the total number of agricultural workers.

Based on the latest research, 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[49]. The recommendations are designed to achieve 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[50].

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"[51].

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. 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"[52]. 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' Union (NFU) is aware of these challenges and has set the goal of reaching Net Zero greenhouse gas (GHG) emissions across the whole of agriculture in England and Wales by 2040[53]. 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[54].

5.2.2. Homes and accommodation away from home

The "Home and accommodation" category accounts for 447,611 tCO_2e (17%) of the footprint of Cotswolds residents, and 25,412 tCO_2e of the visitors' footprint (8% of their footprint while in the

[49] National Food Strategy Independent Review, The Plan Chapter 16: The Recommendations.
[50] National Food Strategy Independent Review, The Plan p.147.
[51] The Sixth Carbon Budget, "Agriculture and land use, land use change and forestry" section, p.21.
[52] Department of Health (2012) Policy Paper. "Long-term conditions compendium of Information: 3rd edition."
[53] National Farmers Union (2021), "Achieving Net Zero, Farming's 2040 goal."
[54] The Sixth Carbon Budget, "Agriculture and land use, land use change and forestry" section.

National Landscape). We considered the following components: household fuel (226,315 tCO_2e; 9% of residents' total footprint), housing (121,410 tCO_2e; 5%), household electricity (88,751 tCO_2e; 3%), and accommodation away from home (11,135 tCO_2e; 0.4%); see Appendix 10.4 for further details.

The single biggest intervention the public can readily make is changing their energy supplier 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). Public knowledge about where household energy comes from is generally poor, with many citizens 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 and 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, so this strategy 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 Cotswolds visitors (1,199,683 tCO2e, 83% of the total visitors' footprint), including the entire footprint of travelling to and from the National Landscape and 21% of the visitors' emissions while in the National Landscape. The majority of this travel footprint comes from personal flights (538,389 tCO_2e; 37% of visitors' total), fuel burned in private vehicles (514,976 tCO_2e; 36% of visitors' total), vehicle manufacture and maintenance (9%), as well as comparatively small amount from the use of trains, buses and other transport (1%).

Travel accounts for 35% of the residents' GHG footprint. In considering residents' travel we looked at personal flights (412,325 tCO_2e; 16% of total residents' footprint), vehicle fuel (336,412 tCO_2e; 13%), vehicle manufacture and maintenance (81,118 tCO_2e; 3%), trains, buses and other transport (51,508 tCO_2e; 2%) and ferry crossings and cruises (28,126 tCO_2e; 1%). See Appendix 10.4 for further details.

Car travel is one of the largest contributors to the overall consumption-based footprint of the Cotswolds, amounting to 27% of the combined footprint of the residents and visitors (this includes embedded emissions of manufacturing and maintaining cars).

All National Landscape 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 work may involve exploring ways to help fast-track electrification of public-use vehicles such as buses, taxis and hire vehicles, as well as influencing national government to support the transition from diesel-powered to electric trains.

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 transporting 4 or 5 people.

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[55]. 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[56]. 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[57]. As the Cotswolds 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[58]. Walking an additional 2.5 miles per week for local journeys, e.g. visits to local shops or the school run, could save 70 kg CO_2e in a year and bring co-benefits for health.

[55] 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.
[56] https://www.ft.com/content/d57efdf6-ffad-11e9-be59-e49b2a136b8d https://www.ft.com/content/d57efdf6-ffad-11e9-be59-e49b2a136b8d.
[57] https://www.bbc.co.uk/news/science-environment-5136612354981425
[58] Department of Transport (2019), "National Travel Survey (England): 2018".

- 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 medium-sized petrol car with an electric car would save 2.2 tCO_2e a year. If you replaced a large petrol car with a medium electric car the savings would be 5.5 tCO_2e a year.

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 Cotswolds National Landscape 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.

5.2.4. Everything else

The remainder of the residents' footprint consisted of: public services including health and education (230,953 tCO_2e; 9% of residents' footprint), other bought services (162,843 tCO_2e; 6%), other non-food shopping (163,523 tCO_2e; 6%), leisure, recreation and attractions (42,343 tCO_2e; 2%), and waste, water and sewage (32,958 tCO_2e; 1%).

The remainder of the visitors' emissions arose from: water, waste and sewerage (11,136 tCO_2e; 4% of footprint while in the National Landscape), other non-food shopping (27,814 tCO_2e; 9%), other bought services (16,275 tCO_2e; 5%), and leisure, recreation and attractions (3,812 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, AONBs and Local Authorities to decarbonise, as well as benefiting health and well-being.

The role played by the National Parks and AONBs 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[59]. White *et al.* (2010) also suggest that green space combined with aquatic blue

[59] 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.

space (water) offers enhanced perceived benefits, which can be incorporated into landscape design and opportunities for improving public accessibility[60].

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 GHG footprints of residents and visitors.

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

Interventions designed to "slow the flow" in flood risk areas are another important consideration. When undertaking option appraisals, we recommend considering the cost and carbon benefits of nature-based solutions in upstream areas, and civil engineering solutions downstream (this is particularly important when these require cement in their construction).

[60] 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.

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

Figure 12 compares the per capita footprint of the average Cotswolds resident with the UK national average.

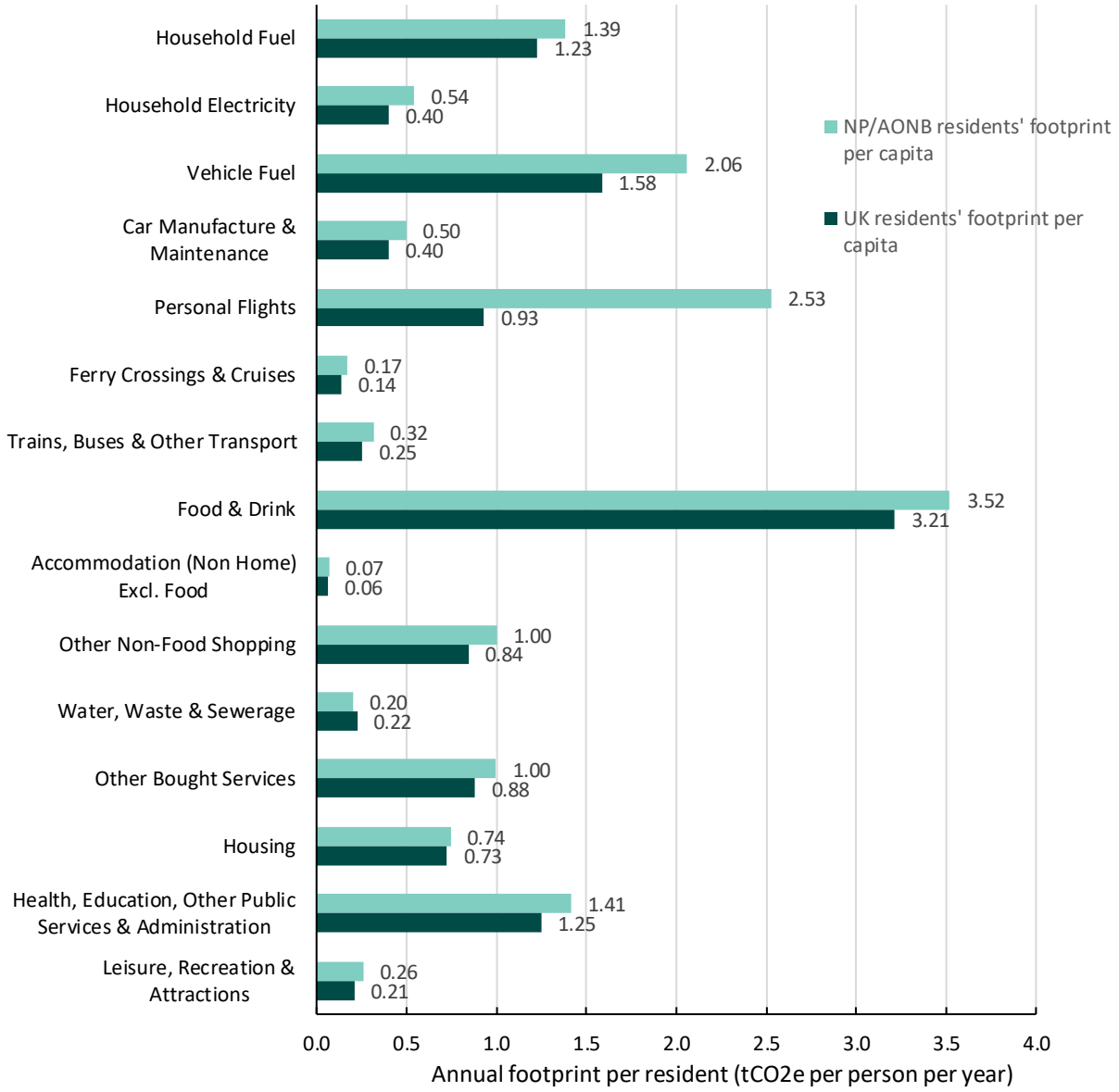


Figure 12: Residents' GHG footprints compared between the Cotswolds National Landscape average and the UK national average, by category

5.3. Industry assessment

This section presents estimates of the GHG emissions from industry within the National Landscape, first outlining the scope of the industry assessment.

5.3.1. Scope of industry assessment

Aside from the footprint of residents and visitors, we also provide a rough assessment of the footprint of industries and their supply chains, for perspective. We use data from the Office for National Statistics' Inter-Departmental Business Register (IDBR) for business turnovers in Census

Output Areas (COAs). This data is favoured compared to the Local Authority Gross Value Added (GVA) data because it is more geographically-specific (see Appendices 10.6.1 to 10.6.3). 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.

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[61]. For transparency we include the IDBR broad industry group structure and see how this compares with the SIC; see Appendix 10.6.1.

When interpreting the results, please note that the IDBR production category includes mining, quarrying and utilities (Division 05/09, 35/39), together with manufacturing (Division 10/33).

It is also important to note that the national IDBR 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 for the Cotswolds, which are estimate to be 1,253,491 tCO_2e. Figure 13 highlights production as the largest source of GHG emissions (282,479 tCO_2e; 23%); followed by agriculture, forestry and fishing (275,968 tCO_2e; 22%) and construction (165,959 tCO_2e; 13%), see Appendix 10.6.2. Industry-related flights account for 172,388 tCO_2e of the total footprint but are not separately categorised. Each of the main contributing categories are discussed in turn below.

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

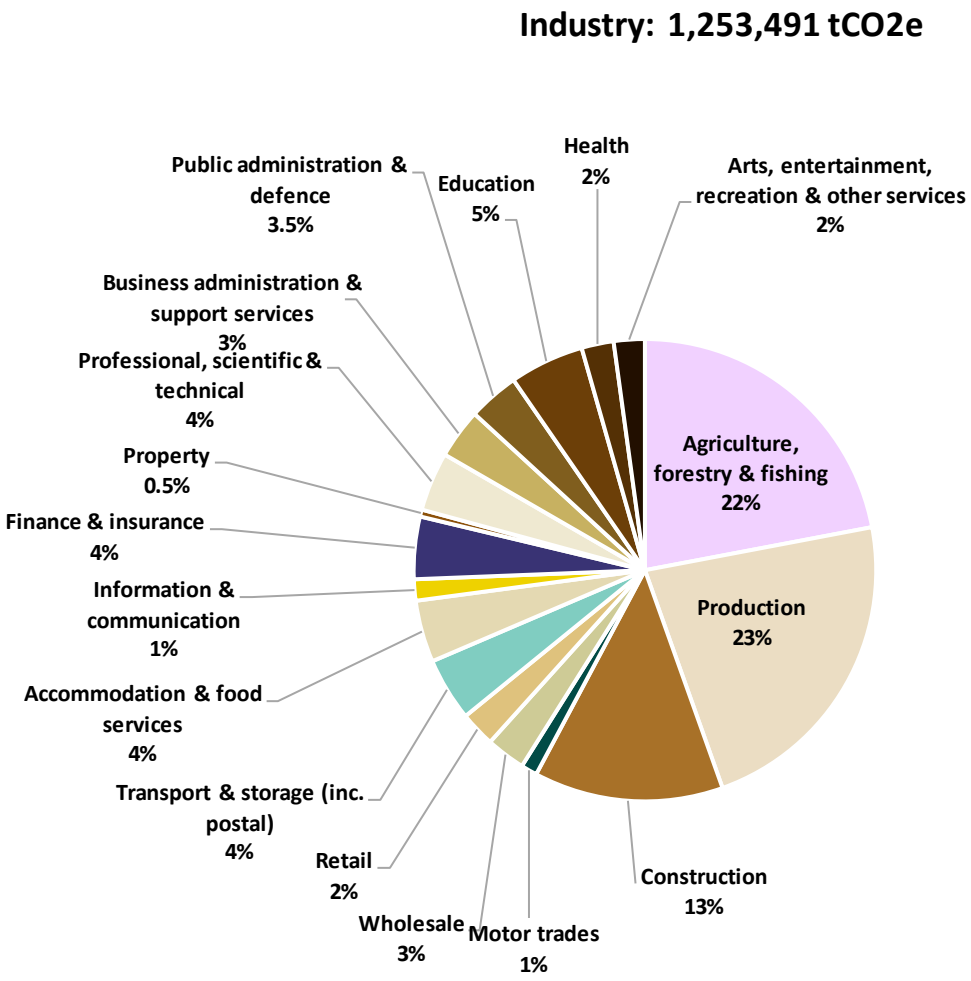


Figure 13: An estimate of emissions from industries within the Cotswolds National Landscape and their supply chains (scopes 1, 2 and upstream scope 3) (Repeat of Figure 5)

Production

Production (referring to manufacturing industries as well as extraction) plays an important role in the National Landscape (282,479 tCO_2e; 23% of the estimated total industry footprint in the region). Among the production industry categories, the highest source of emissions is manufacturing of basic metals (90,431 tCO_2e). Other main sources of production emissions are water supply, sewerage and waste management (55,266 tCO_2e) and mining and quarrying (48,396 tCO_2e). Manufacturing is also one of the main sources of employment for people living in the Cotswolds National Landscape, although mining and quarrying is categorised separately and employs a very small proportion of the resident population[62].

It must be noted that there are inevitable overlaps between the National Landscape and the nearby regions when it comes to industry data since it is being sourced from the coarse COA geographies

[62] https://www.cotswoldsaonb.org.uk/wp-content/uploads/2017/07/population-and-economy-6.pdf.

instead of the postcodes. While these overlaps cannot be eliminated until a more spatially granular data becomes available, we suggest that production 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 is agriculture, forestry and fishing (275,968 tCO_2e; 22%). In terms of economic activity, fewer than 5% of the resident population are employed in the sectors of agriculture, hunting, forestry, mining and quarrying[62]. The issues pertaining to this industry are discussed in detail under 3.1.1 (Land ownership & use), 5.2.1 (Food) and 5.2.4 (Everything else). 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 Local Enterprise Partnership (LEP) collaborating with manufacturers who may be able to assist such a transition.

Moving some production to greenhouses and vertical urban farms (collectively referred to as indoor horticulture) will likely 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 considered.

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 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. Data in the Sixth Carbon Budget shows that between 3.6 and 13.6 million tonnes of UK food is wasted per year.

Construction

We estimate that construction is the third largest GHG-emitting industry in the Cotswolds National Landscape and the adjacent region (165,959 tCO_2e; 13% of the total). 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[63].

IDBR and GVA based emissions comparison

We undertook a comparison between IDBR data (mapped on the Cotswolds from the overlapping COA geographies) and GVA data (mapped on the Cotswolds from the overlapping Local Authorities), as we know that economic reporting often uses GVA as the primary measure upon which many LEPs base their workforce planning. When the GVA dataset is compared to IDBR, this indicates a potential under-reporting of GVA-based emissions from agriculture, forestry and fishing, construction, and education, as well as over-reporting of emissions form production and several other sectors (Figure 14, Appendix 10.6.1). The Cotswolds National Landscape may wish to discuss this with Local Enterprise Partnerships in the area.

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

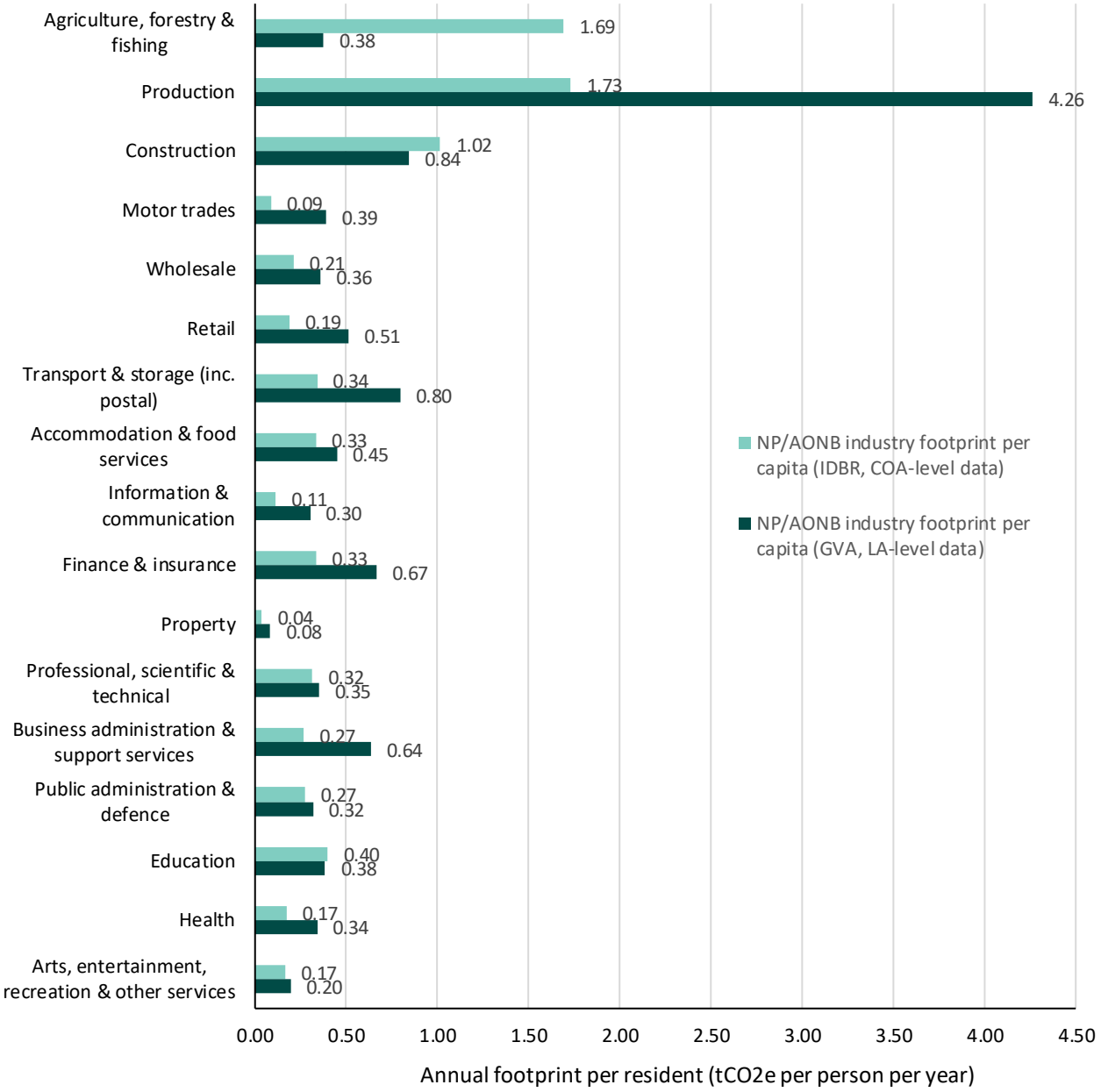


Figure 14: The Cotswolds National Landscape industry footprint estimates: IDBR vs GVA, by sector

5.3.3. Energy-only industry analysis

This analysis is a subset of the industry carbon footprint estimate. Energy is estimated to make up 37% of emissions from industry (467,481 tCO_2e). Table 2 shows the breakdown of industry emissions from electricity and fuels in the Cotswolds National Landscape.

Table 2: Energy-only industry (subset of industry) – Cotswolds National Landscape

Industry Electricity	169,863 tCO_2e
Industry Fuels Excl. Road	255,949 tCO_2e
Industry Road Fuels	41,668 tCO_2e

Total	**467,481 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 10.6.4). For the Cotswolds National Landscape, there are no large emitters within the Cotswolds area. If at a future date large emitters emerge within the park it may be possible to engage with them either directly or through the relevant Local Authorities. The aspiration is to promote carbon assessment of Scope 1, 2, and 3 GHG emissions, and carbon reduction planning with a view to Net Zero[64].

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 Cotswolds National Landscape, 48.24% of the IDBR data was found to be suppressed, which includes the finance & insurance and publica administration & defence sectors.

5.3.5. Comparison of annual industry footprint with UK averages

It may be helpful for the National Landscape 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 15) show higher-than-national averages for: agriculture, forestry and fishing, construction, accommodation and food services, finance and insurance, professional, scientific and technical, education, and arts, entertainment and recreation.

As background to influencing change, the UK Government enacted legislation on the 1st 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[65]. 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 that 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.

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.

[64] UK local authority and regional carbon dioxide emissions national statistics: 2005-2018.
[65] 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.

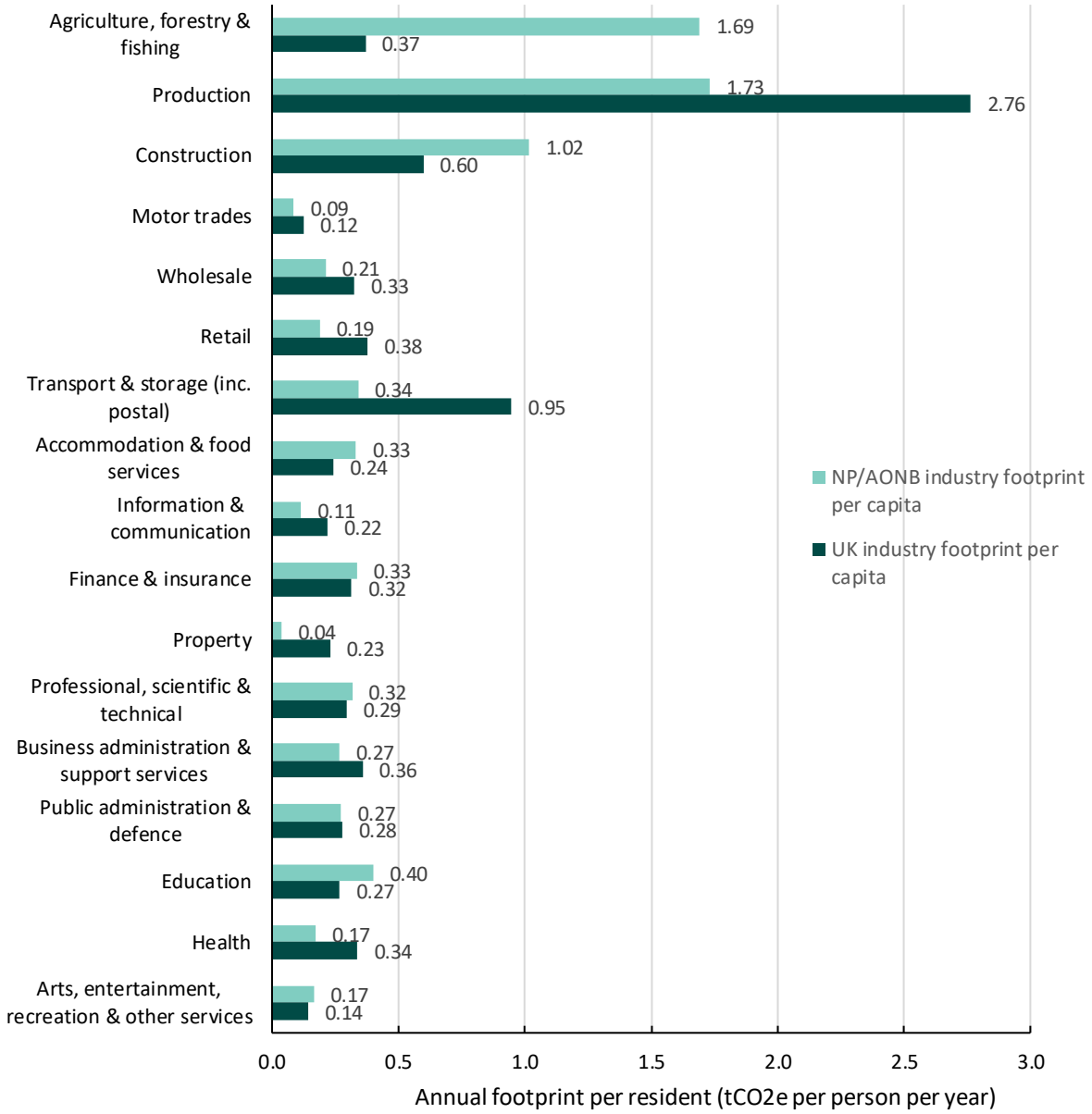


Figure 15: The Cotswolds National Landscape industry GHG emissions compared with UK national average, by sector

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 10.7). 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 through traffic 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 Cotswolds National Landscape, estimated total through traffic emissions from cars, buses, motorbikes, vans and lorries are **375,055 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 Cotswolds are the M4, A40, A417, A420, A424, A3400, A36, A419, A43,3 A435, B4077, B4632, A363, A4, A4135, A429, A436, A44, A46, B4066 and B4068 (Appendix 10.7). The estimated footprint of these roads within the Cotswolds geographical boundary is 514,244 tCO_2e per year across all vehicle types. This amounts to around 20.1% 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 (CO_2). 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 Cotswolds National Landscape

Land use CO_2	–260,179	tCO_2e per year
Land use non-CO_2	275,968	tCO_2e per year
Total: Land use	**15,790**	**tCO_2e per year**

Land use GHG emissions data for all National Parks is prepared by the Department for Business, Energy and Industrial Strategy (BEIS) in accordance with the requirements to report UK Greenhouse Gas Emissions for the United Nations Framework Convention on Climate Change (UNFCCC). However, there are no Government datasets for land use GHG emissions currently available for AONBs.

As a result, we had to reconstruct the land use GHG emission estimates using the IDBR industry data for agriculture (for "land use non-CO_2"), and the habitat and peat data provided by each AONB (for "land use CO_2"; see Appendix 10.8.9). Our approach uses the latest BEIS emission factors for the

most common habitat and peat types in the UK, which are still subject to considerable uncertainty due to the data limitations and complexities involved.

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[66]
- 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).

The next section reflects upon this guidance in terms of target setting.

5.6. Factors for consideration in land use target setting

To increase reliability of the land use data, the National Park 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.

Please note that the land use GHG estimates for National Parks are published by BEIS, and are expected to change in the future given the existing levels of uncertainty. 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 land use 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 land use targets that support climate adaptation and mitigation.

5.6.1. Trees, woodlands and forestry

The target of 700 ha of new woodland per year proposed in Section 6 is based on apportioning UK-wide woodland targets from The Sixth Carbon Budget, and is described in detail in Appendix 10.8.9.

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.

[66] HM Government (2018), "A Green Future: Our 25 Year Plan to Improve the Environment."

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[67].

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 1.2°C increase in average monthly maximum temperatures over the last 60 years or so for the weather station in Cirencester[68]. Natural England published another helpful report, worthy of review, examining the relative sensitivity of habitats to climate change[69].

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".

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[70]; see Box 1.

[67] Forestry Commission (2017), "The UK Forestry Standard: The governments approach to sustainable forestry."
[68] https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gcnw5nzzf.
[69] Climate Change Adaptation Manual Evidence to support nature conservation in a changing climate
[70] Lancaster City Council (2021), "Grassland Management Strategy"; https://www.lancaster.gov.uk/news/2021/feb/implementation-of-new-grassland-management-strategy.

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[71]. In the UK, peat soils account for nearly 33% of land cover[72]. 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[73].

There are three broad types of peatland in the UK:

- Blanket bog (globally rare and typically found in uplands)
- Raised bog (mainly found in lowlands)
- Fens (fed by both surface and groundwater)

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,

[71] IUCN National Committee United Kingdom (2021) "About Peatlands"; https://www.iucn-uk-peatlandprogramme.org/about-peatlands.
[72] IUCN National Committee United Kingdom (2018) "UK Peatland Strategy 2018-2040", p. 25.
[73] IUCN National Committee United Kingdom Peatland Programme (2021) "Peatland Damage"; https://www.iucn-uk-peatlandprogramme.org/about-peatlands/peatland-damage.

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[74].

We estimate that there is only 16.3 hectares of peat soils in the Cotswolds National Landscape's land area, consisting entirely of fens. Restoring peatland is therefore a comparatively small, but nevertheless important, consideration for the National Landscape's decarbonisation journey. The Cotswolds has already undertaken a Natural Capital opportunity mapping project[75], and further assessment focusing on the fens should shed light on the peatland condition, including the habitat types and the associated areas featuring peat soils, which will enable priorities for restoration to be identified.

It would also be useful to assess the soil depth, which could present opportunities to employ citizen science. 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 Regional Plan and Water Resources Management Plan.

5.6.4. 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 16). Only 55% of food consumed in the UK (by economic value) is of UK origin, with 26% imported from Europe[76].

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 16.

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

[75] A Natural Capital Evaluation of the Cotswolds National Landscape (arcgis.com).

[76] 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.

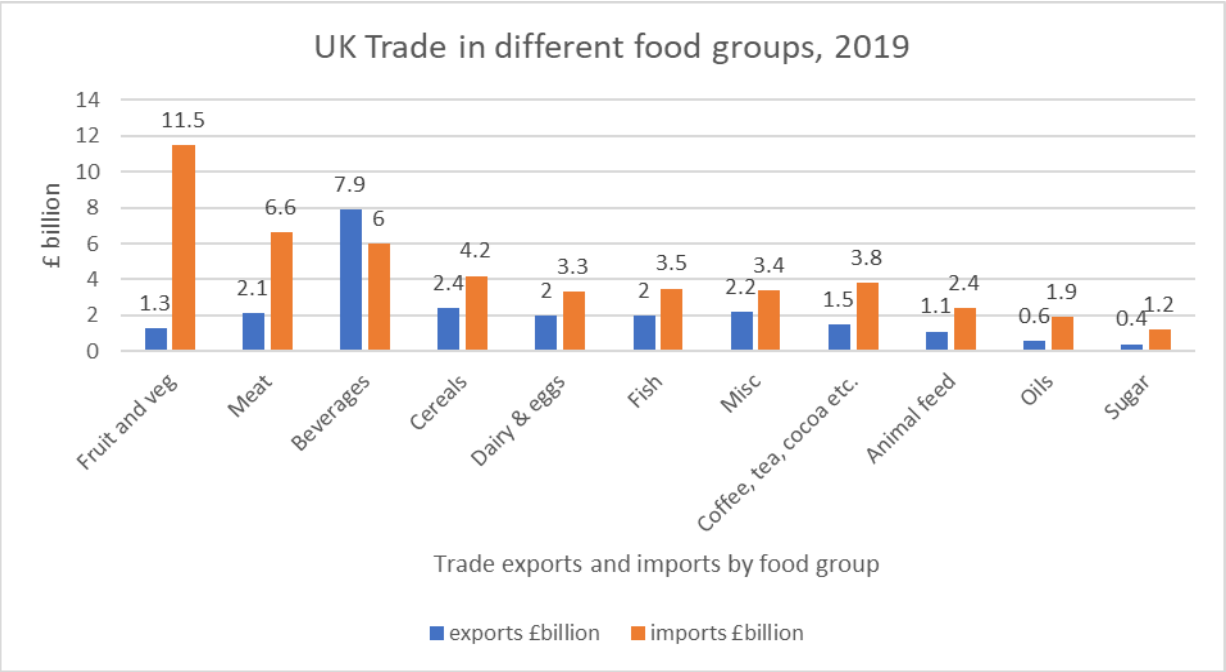


Figure 16: UK trade in different food groups, 2019

5.6.5. 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[77]. 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[78].

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

[77] Forest Research (2021) "UK Wood Production and Trade: 2020 Provisional Figures."

[78] 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/.

geography and productive capacity of the woodland resource, with large areas of low-quality softwood, remote from timber markets and often challenging to harvest"[79].

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[80]. This is in contrast to carbon credits (for carbon sequestration) sold on the UK open market at £10-25 per tCO2e[81] (Forest Research states 1.25 to 1.43 cubic metres per tonne for roundwood).

Figure 17 illustrates timber production and trade in the UK, as reported by Forest Research.

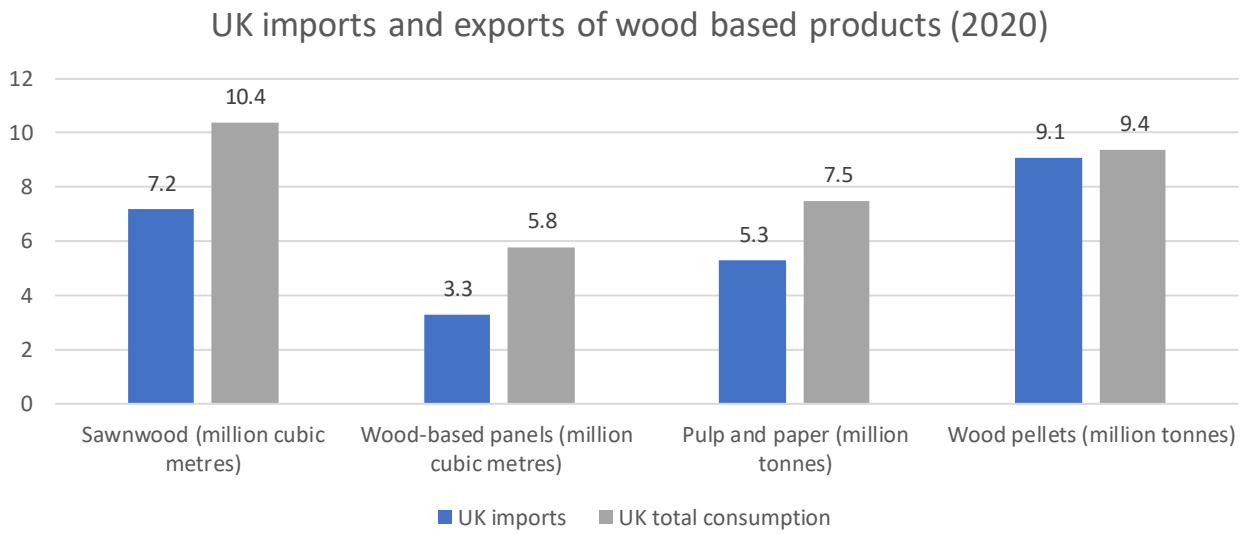


Figure 17: Self-generated from Forest Research (2021) UK Wood Production and Trade: provisional figures 2020 release

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

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

In setting a challenging glide path to reach a consumption-based target of Net Zero by 2044, this section outlines how Cotswolds National Landscape's could become one of the "lungs" of the west of England and significantly contribute towards UK's national Net Zero target. This section also outlines the planning assumptions used.

To set certain sector targets (e.g. energy), we have taken a pro-rata approach for all National Parks and AONBs based on a percentage of GHG emissions. However, the land use sector requires a bespoke approach of apportioning UK targets to reflect known key habitats within the Cotswolds National Landscape boundary, using 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:

1. Cover everything of significance within the influence of policy-makers;
2. Keep the target simple enough to describe;
3. Avoid double-counting;
4. 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 Section 10.8.5.

Target Category 1: Energy-only greenhouse gas emissions. This category includes emissions relating to energy use within the National Park or AONB by residents, visitors and industry. It includes emissions from roads, except those from (estimated) through-traffic that does not stop in the National Park or AONB. 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 category 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 category 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 CNL's carbon management agenda.

Target Category 4: Visitor travel to and from the area. This category only includes travel within the UK, not visitor travel to/from the UK. International travel is omitted purely due to the practical

difficulty of tracking change (as described in Appendix 10.8). That said, visitor aviation emissions remains an important consideration for policymakers.

Target Category 5: Land use non-CO_2 component. This category includes all net non-CO_2 emissions from land within the CNL, and most notably includes the digestive emissions from sheep and cattle, as well as 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 category most notably includes emissions from degrading peat and carbon sequestration by woodland, farm trees, hedges and soils (including healthy peat) within the protected landscape. 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 within the National Landscape.

Across these six categories, the 2019 carbon baseline for the Cotswolds National Landscape is estimated at 2,806,129 tCO_2e per year (Figure 18).

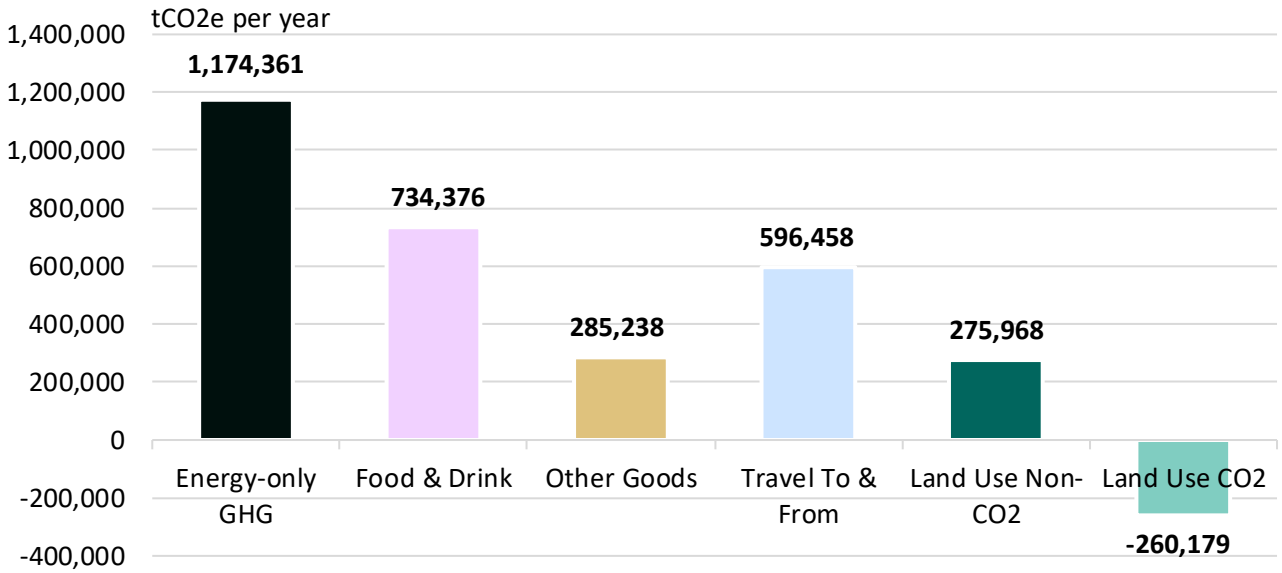


Figure 18: Estimated 2019 Cotswolds carbon baseline emissions

Following the principles outlined above, some components of the wider carbon footprint of Cotswolds National Landscape 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 resident's travel outside of National Park or AONB is beyond the scope of influence by local authorities

- Residents' holiday accommodation outside the National Park or AONB
- Residents' housing (construction and maintenance). Local construction companies' energy use will be counted through the energy GHG emissions linked to local industry (Target Category 1 above)
- Residents' health, education and other public services. Local providers' energy use will be counted through the energy GHG emissions linked to local industry (Target Category 1 above)
- Residents' and visitors' other bought services (e.g. financial, telecoms, travel agents, hairdressers). Local providers' energy use will be counted through the energy GHG emissions linked to local industry (Target Category 1 above)
- Residents' and visitors' art, sport and other leisure activities. Local providers' energy use will be counted through the energy GHG emissions linked to local industry (Target Category 1 above)
- Residents' and visitors' water, waste and sewerage. Local providers' energy use will be counted through the energy GHG emissions linked to local industry (Target Category 1 above)
- Industries' supply chains (both within and outside the National Park or AONB)

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 recommendations. 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 10.8.5

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	**13.6%** (specific to Cotswolds National Landscape) 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	**30%** of present-day emissions for the non-CO_2 component only; Achievable ceiling is not

	components. See Appendix 10.8.9 for further details	applicable for the CO_2 component in the current assessment

The six categories outlined above can be combined into an overall decarbonisation pathway, which in the case of Cotswolds National Landscape results in a Net Zero date of 2044. Note that targets 1 to 4 should be adjusted in proportion to any significant changes in resident and visitor numbers in the National Landscape.

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 land use 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 Cotswolds according to its land characteristics (see Appendix Section 10.8.9).

When the Sixth Carbon Budget's apportionment methodology is applied to the Cotswolds National Landscape, 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 cover cropping target comes on top at 2,438 ha/yr., followed by new native broadleaf / mixed woodland at 700 ha/yr., and legumes in improved grassland at 363 ha/yr. Other measures are comparatively small, and we assume no new conifer plantations in the Cotswolds (prioritising native broadleaf species instead), while none of the estimated 16.3 ha of peatland requires restoration at present.

When converted to changes in carbon sequestration fluxes, the native broadleaf / mixed creation (-12,919.2 tCO_2e per year added each year) provides more than 4.5 times more sequestration compared to the second-largest contribution from cover cropping, and over 15 times more sequestration compared to the third-largest contribution from agroforestry applied to improved grassland and cropland (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[82]. 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[83].

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

[83] 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.

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 Cotswolds National Landscape: 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	700	ha per year
New Productive Coniferous Woodland	0	ha per year
Restored Peatland	0	ha per year
Agroforestry (improved grassland & cropland)	360	ha per year
New Hedgerows (improved grassland & cropland)	20.6	ha per year
Legumes (improved grassland)	363	ha per year
Cover Cropping (cropland)	2,438	ha per year
Associated Carbon Sequestration	**Value**	**Units**
New Native Broadleaf / Mixed Woodland	-12,919	tCO_2e per year per year
New Productive Coniferous Woodland	0	tCO_2e per year per year
Restored Peatland	0	tCO_2e per year per year
Agroforestry (improved grassland & cropland)	-845	tCO_2e per year per year
New Hedgerows (improved grassland & cropland)	-219	tCO_2e per year per year
Legumes (improved grassland)	-745	tCO_2e per year per year
Cover Cropping (cropland)	-2861	tCO_2e per year per year

Based on the target-setting assumptions outlined in Table 5 and in Appendix 10.8.9, the Cotswolds National Landscape has the capacity to achieve a total cumulative reduction in the net annual GHG emissions of 3,020,956 tCO_2e per year between the base year (2019) and 2050. The net estimate includes both reductions in emissions and increases in 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 19.

The assumptions above imply that Cotswolds National Landscape could achieve Net Zero emissions in 2044 and act as a net carbon sink in subsequent years (Figure 20). We note that the Net Zero date reflects the unique characteristics of the area, including the quantity and type of land, the number of residents and visitors and their consumption patterns, and the level and type of industrial activity (see Section 6 for the target figures).

The Net Zero date also assumes the recommended decarbonisation and carbon sequestration efforts, including land use change, ratchetted up to the required levels back in 2019. In reality, decarbonisation trends have been relatively small in magnitude compared to what is required to limit global heating to 1.5°C, post-COVID emissions have largely rebounded, and the high levels of ambition for different sectors explored in this report will likely take several years to achieve. These factors are expected to push the projected Net Zero year back by several years.

An alternative target trajectory for the Cotswolds using all consumption emissions (from residents and visitors) and landscape-based emissions as the baseline is given in Figure 21. The resulting 2019 baseline is higher for the Cotswolds, which delays the net zero date until 2051.

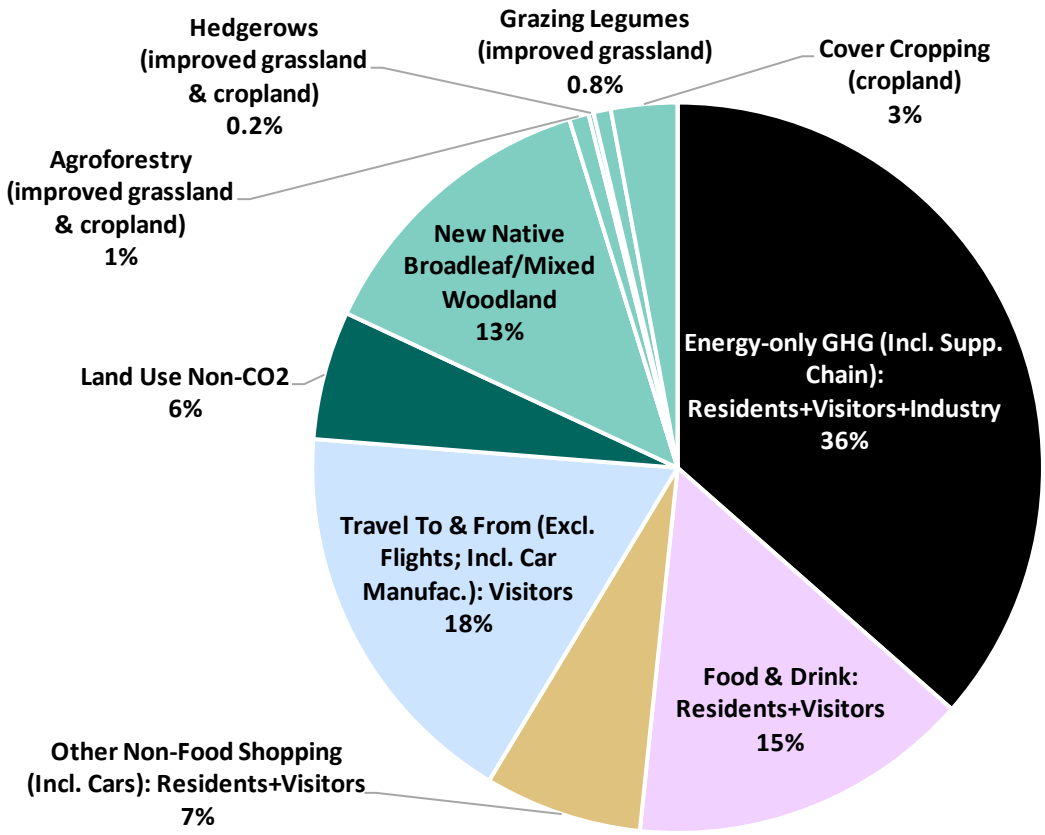


Figure 19. Percentage breakdown of the projected cumulative reduction in net annual GHG emissions for the Cotswolds National Landscape between the base year (2019) and 2050 according to the individual emitting categories and carbon sequestration measures considered in this assessment

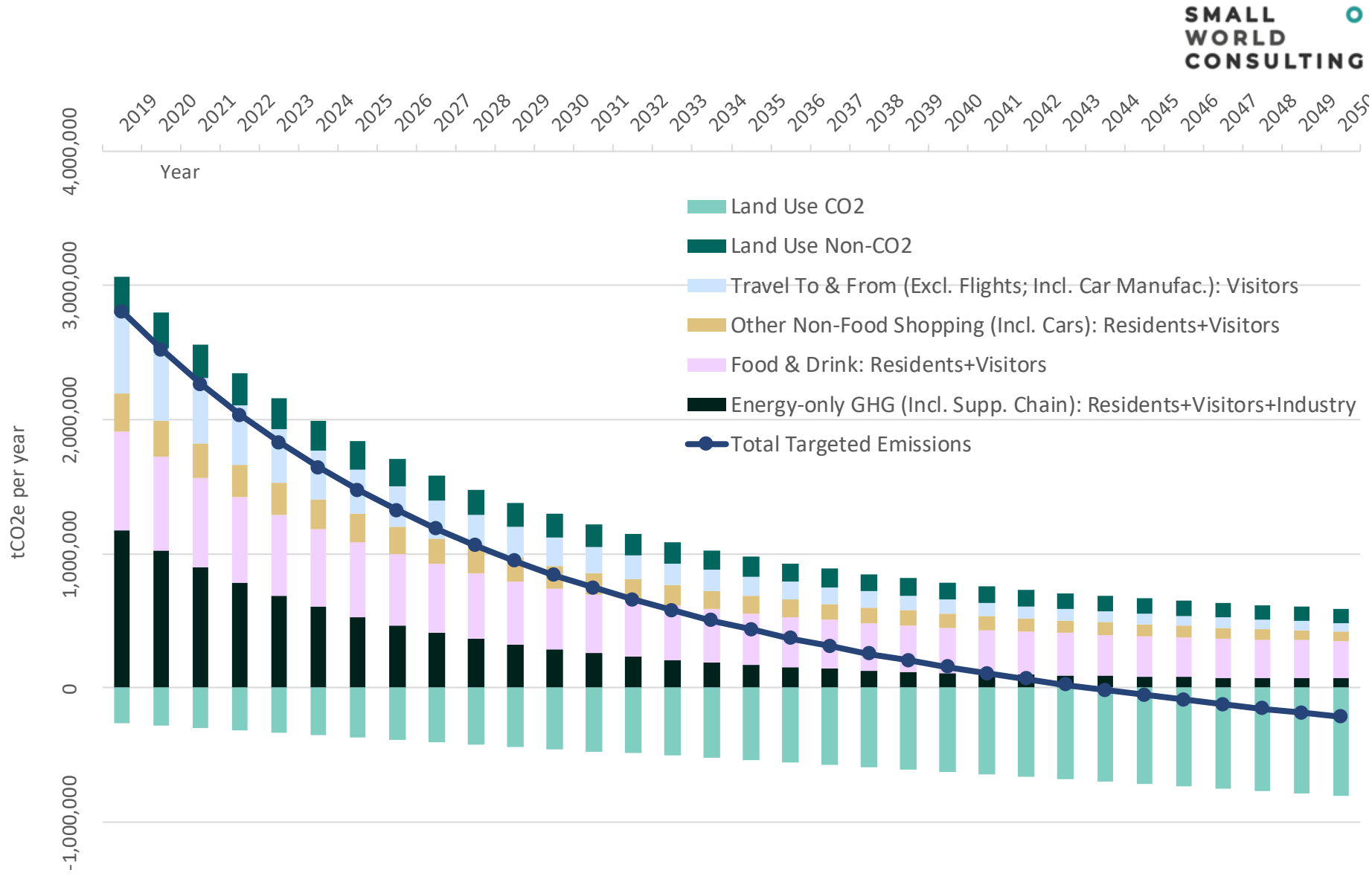


Figure 20. Cotswolds National Landscape: Pathway to Net Zero (Repeat of Figure 5)

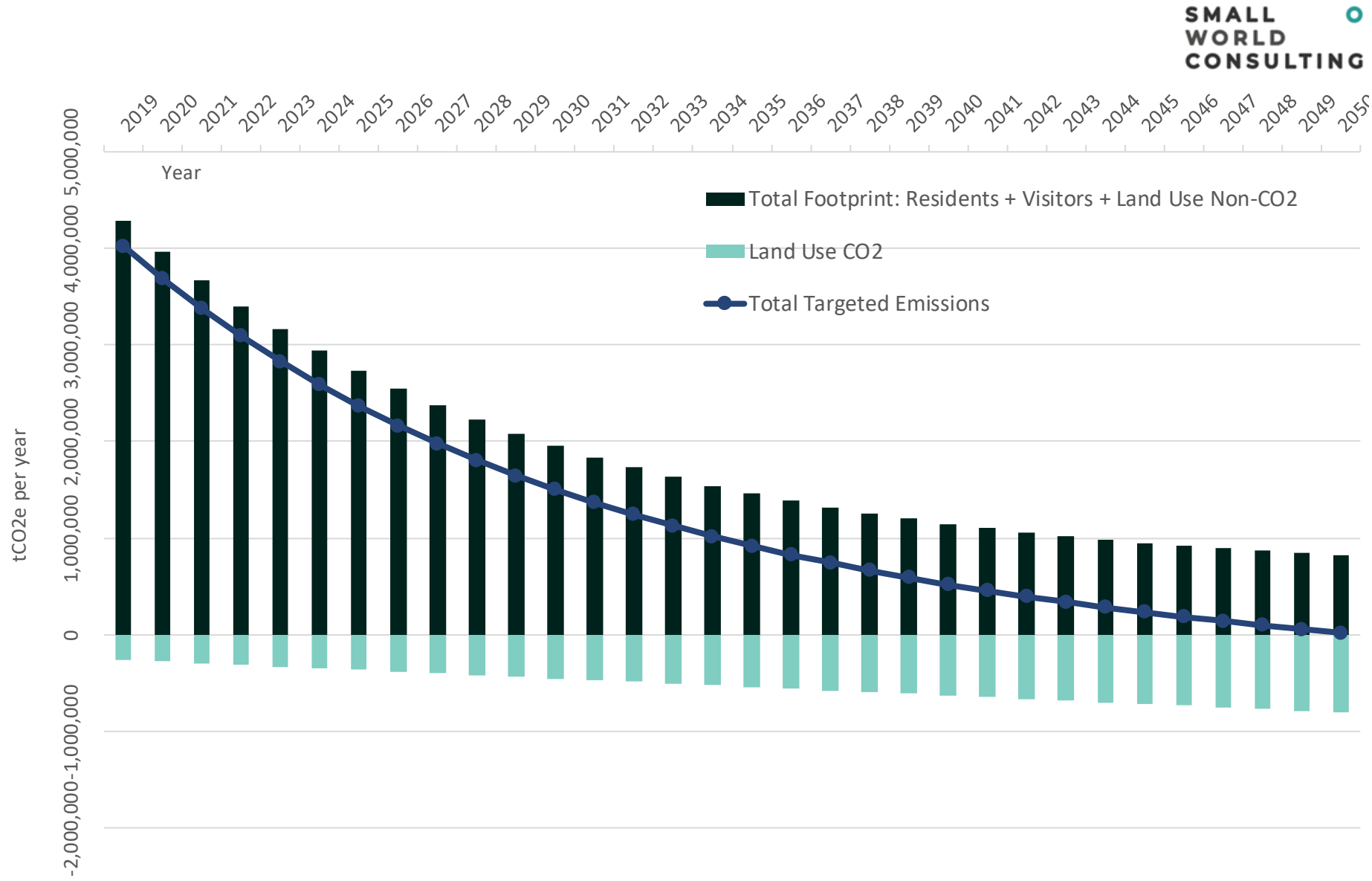


Figure 21. The Cotswolds National Landscape: Alternative pathway to Net Zero (based on full consumption and land use footprint in the area)

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 Cotswolds National Landscape 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 use and land management.

The challenge for the Cotswolds National Landscape and its partners 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 protected landscape.

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.
- Encouraging refurbishment of existing buildings to ensure they are energy-efficient and supplied with low/zero-carbon energy

If all the targets proposed in this report were met, the Cotswolds could achieve Net Zero GHG emissions as early as 2044. It could subsequently reach negative emissions of approximately -214,827 tCO2e per year by 2050, with annual carbon sequestration in the protected landscape scaling up to around -805,459 tCO2e per year, and residual emissions dropping roughly to 590,632 tCO2e across the shortlisted policy priority areas (21% of the present-day carbon footprint baseline).

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 we now find ourselves. The Cotswolds National Landscape Net Zero date of 2044 should not be interpreted to mean that the target recommendation is stronger than the UK's 2050 net zero target, but rather as a reflection of the landscape's proportionately greater capacity for carbon sequestration compared to the UK as a whole.

In meeting the targets, some help from outside the National Landscape can be expected, thanks to anticipated changes in the UK and global economy. For example, the electricity grid is expected 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, it is likely that businesses will 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 Cotswolds will be to push for the support needed to ensure the National Landscape 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 Cotswolds – will become a reality.

Land management is central to all National Parks and AONBs and deserves a separate discussion. The wide-ranging land use measures proposed for Cotswolds, dominated by new native broadleaf / mixed woodland and cover cropping, 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 (where applicable) and regenerative farming, in line with current recommendations by the UK Government.[84]

Most UK National Parks and AONBs have considerable areas of low-grade grassland and moorland, which create the iconic 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 to meet our 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[85]. 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.

[84] UK 6th Carbon Budget; Agriculture, Forestry and Other Land Use section

[85] https://www.gov.uk/government/publications/environmental-land-management-schemes-overview/environmental-land-management-scheme-overview.

Woodland grants and incentives[86]

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

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

[86] https://www.gov.uk/government/publications/woodland-grants-and-incentives-overview-table/woodland-grants-and-incentives-overview-table.

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 citizens 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 brake 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 heating 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: National Landscape key statistics

Output Variable	Value	Unit	Source
Land Area	**204,270**	ha	Official Figures / CEH LCM
Resident Population	**163,222**	persons	ONS Mid-2019 LSOA Population; ONSPD 2019; BEIS 2019 Postcode Electricity Meters; Custom Postcodes
Resident Population Density	**0.80**	persons per ha	Based on the Above
Annual Final Consumption (Households + Public Services)	**33,201**	£ per person per year	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes
Annual Household Fuel per Resident	**6,354**	kWh per person per year	BEIS 2019 Postcode Gas; BEIS 2018 Residual Fuels; ONSPD 2019; Custom Postcodes
Annual Household Electricity per Resident	**1,604**	kWh per person per year	BEIS 2019 Postcode Electricity; ONSPD 2019; Custom Postcodes
Annual Vehicle Fuel per Resident	**6,258**	kWh per person per year	BEIS 2018 Road Fuels; ONSPD 2019; Custom Postcodes
Annual Personal Flights per Resident, Economy Class	**1.63**	fraction	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes; SWC Population Estimate
Annual Personal Flights per Resident, Business Class	**0.020**	fraction	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes; SWC Population Estimate
Average Resident One-Way Mileage per Flight, Economy Class	**2,160**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes
Average Resident One-Way Mileage per Flight, Business Class	**3,257**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes
Annual Business Turnover, COA-based	**15,525,976,000**	£ per year	IDBR 2019; ONSPD 2019; Custom Postcodes
Percentage of Suppressed Turnover Output, COA-based	**48.24%**	percentage	IDBR 2019; ONSPD 2019; Custom Postcodes

Output Variable	Value	Unit	Source
Average Visitors Per Day	**49,633**	persons	STEAM 2019
Visitor Population Density	**0.24**	persons per ha	Based on the Above
Annual Visitors Spend	**562,736,889**	£ per year	STEAM 2019
Annual Visitors All Types	**16,157,161**	persons per year	STEAM 2019
Percentage of Visitors Staying Overnight	**6.6%**	percentage	STEAM 2019
Average Duration of Stay for Overnight Visitors	**2.9**	days	STEAM 2019
Average Visitor Party Size	**3.0**	persons	Visitor Survey
Average Visitor One-Way Road/Train/Boat Mileage Travelled	**117**	miles	Visitor Survey
Estimated Fraction of Trips by Car	**81.2%**	percentage	Visitor Survey
Estimated Fraction of Trips Involving Flights	**16.7%**	percentage	Visitor Survey
Average Visitor One-Way Mileage per Flight, Economy Class	**2,979**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes
Average Visitor One-Way Mileage per Flight, Business Class	**385**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes

10.2. 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

10.3. 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

10.4. Appendix: Residents GHG emissions

Residents GHG emissions: Cotswolds National Landscape

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

Resident Expenditure Categories Summary	ALL Scopes	Units
Household Fuel	226,315	tCO2e per year
Household Electricity	88,751	tCO2e per year
Vehicle Fuel	336,412	tCO2e per year
Car Manufacture & Maintenance	81,118	tCO2e per year
Personal Flights	412,325	tCO2e per year
Ferry Crossings & Cruises	28,126	tCO2e per year
Trains, Buses & Other Transport	51,508	tCO2e per year
Food & Drink	574,855	tCO2e per year
Accommodation (Non Home) Excl. Food	11,135	tCO2e per year
Other Non-Food Shopping	163,523	tCO2e per year
Water, Waste & Sewerage	32,958	tCO2e per year
Other Bought Services	162,843	tCO2e per year
Housing	121,410	tCO2e per year
Health, Education, Other Public Services & Administration	230,953	tCO2e per year
Leisure, Recreation & Attractions	42,343	tCO2e per year
Total	**2,564,575**	**tCO2e per year**

10.5. Appendix: Visitors GHG emissions

Visitors GHG emissions: Cotswolds National Landscape

Visitor Expenditure Categories Summary	In NL	To & From NL	Units
Household Fuel	2,284	0	tCO2e per year
Household Electricity	971	0	tCO2e per year
Vehicle Fuel	50,490	464,486	tCO2e per year
Car Manufacture & Maintenance	12,783	117,600	tCO2e per year
Personal Flights	0	538,389	tCO2e per year
Ferry Crossings & Cruises	0	0	tCO2e per year
Trains, Buses & Other Transport	1,562	14,372	tCO2e per year
Food & Drink	159,522	0	tCO2e per year
Accommodation (Non Home) Excl. Food	22,156	0	tCO2e per year
Other Non-Food Shopping	27,814	0	tCO2e per year
Water, Waste & Sewerage	11,136	0	tCO2e per year
Other Bought Services	16,275	0	tCO2e per year
Housing	0	0	tCO2e per year
Health, Education, Other Public Services & Administration	0	0	tCO2e per year
Leisure, Recreation & Attractions	3,812	0	tCO2e per year
Total	**308,806**	**1,134,848**	**tCO2e per year**

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

10.6. Appendix. Industry footprint estimates

10.6.1. 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

Industry GHG emissions (IDBR-based): Cotswolds National Landscape

Industry Categories Summary (IDBR sectors)	ALL Scopes	Units
Agriculture, forestry & fishing	275,968	tCO2e per year
Production	282,479	tCO2e per year
Construction	165,959	tCO2e per year
Motor trades	14,232	tCO2e per year
Wholesale	34,426	tCO2e per year
Retail	30,839	tCO2e per year
Transport & storage (inc. postal)	55,479	tCO2e per year
Accommodation & food services	54,259	tCO2e per year
Information & communication	18,647	tCO2e per year
Finance & insurance	54,670	tCO2e per year
Property	6,118	tCO2e per year
Professional, scientific & technical	51,589	tCO2e per year
Business administration & support services	43,620	tCO2e per year
Public administration & defence	44,651	tCO2e per year
Education	65,262	tCO2e per year
Health	28,124	tCO2e per year
Arts, entertainment, recreation & other services	27,170	tCO2e per year
Total	**1,253,491**	**tCO2e per year**
ENERGY-ONLY INDUSTRY (subset of INDUSTRY) -- Cotswolds		
Industry Road Fuels	169,863	tCO2e per year
Industry Fuels Excl. Road	255,949	tCO2e per year
Industry Electricity	41,668	tCO2e per year
Total	**467,481**	**tCO2e per year**
LARGE EMITTERS (Scope 1) * -- Cotswolds		
Large Emitters	**-**	**tCO2e per year**
INDUSTRY-RELATED FLIGHTS (subset of INDUSTRY) ** -- Cotswolds		
Industry-related flights	**172,388**	**tCO2e per year**
LULUCF -- Cotswolds		
Land Use CO2	**-260,179**	**tCO2e per year**
Land Use Non-CO2	**275,968**	**tCO2e per year**

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

10.6.3. Appendix: IDBR vs GVA industry footprint estimates

SMALL WORLD CONSULTING

IDBR vs GVA Industry Footprint Estimates: Cotswolds National Landscape

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	1.69	0.38	tCO2e/person/year
Production	1.73	4.26	tCO2e/person/year
Construction	1.02	0.84	tCO2e/person/year
Motor trades	0.09	0.39	tCO2e/person/year
Wholesale	0.21	0.36	tCO2e/person/year
Retail	0.19	0.51	tCO2e/person/year
Transport & storage (inc. postal)	0.34	0.80	tCO2e/person/year
Accommodation & food services	0.33	0.45	tCO2e/person/year
Information & communication	0.11	0.30	tCO2e/person/year
Finance & insurance	0.33	0.67	tCO2e/person/year
Property	0.04	0.08	tCO2e/person/year
Professional, scientific & technical	0.32	0.35	tCO2e/person/year
Business administration & support services	0.27	0.64	tCO2e/person/year
Public administration & defence	0.27	0.32	tCO2e/person/year
Education	0.40	0.38	tCO2e/person/year
Health	0.17	0.34	tCO2e/person/year
Arts, entertainment, recreation & other services	0.17	0.20	tCO2e/person/year
Total	**7.68**	**11.26**	**tCO2e/person/year**

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

10.6.4. 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)**
The 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

10.7. Appendix: Emissions from major roads

SMALL WORLD CONSULTING

Emissions from major roads: Cotswolds National Landscape

SELECTED A ROADS - SMALLER SUBSET -- Cotswolds National Landscape		
Road Names, Smaller Subset	M4 A40 A417 A420 A424 A3400 A36 A419 A433 A435 B4077 B4632	
Cars, Buses & Motorbikes	147,528	tCO2e per year
Vans & Lorries	88,338	tCO2e per year
Total	**235,866**	**tCO2e per year**
SELECTED A ROADS - LARGER SUBSET -- Cotswolds National Landscape		
Road Names, Larger Subset	A363 A4 A4135 A429 A436 A44 A46 B4066 B4068	
Cars, Buses & Motorbikes	332,459	tCO2e per year
Vans & Lorries	181,785	tCO2e per year
Total	**514,244**	**tCO2e per year**
THROUGH TRAFFIC -- Cotswolds National Landscape		
Cars, Buses & Motorbikes	239,994	tCO2e per year
Vans & Lorries	135,061	tCO2e per year
Total	**375,055**	**tCO2e per year**

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

10.8. Appendix: Methodology

10.8.1. 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.

10.8.2. 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 10.2.

10.8.3. 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 Landscape and within the National Landscape 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 Landscape, 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 10.2.

10.8.4. Appendix: Assumptions for visitors' surveys

Visitor party size

No data were available for the Cotswolds National Landscape. Where visitor party size is not stated in the visitor's survey report, we can infer from a nearby National Park or AONB, or take the average from several nearby protected landscapes which present suitable data. For this report, the party size was estimated from the average of three nearby protected areas: South Downs National Park, Brecon Beacons National Park and Wye Valley AONB.

Modes of transport

No data were available for the transport modes to or within the Cotswolds; therefore inferences were made using data for the nearby Brecon Beacons National Park.

Inferring flights share

The Economic Impact of Gloucestershire's Visitor Economy report[87] provides data on the numbers of domestic and overseas visitors, from which the proportion of overseas visitors was calculated as 23.4%. The proportion of overseas visitors as the European and non-European split, and the European visitors flights share, were inferred from data for the nearby Brecon Beacons National Park.

Using Brecon Beacons data to infer distances travelled by road from mainland Europe

Data for the Cotswolds National Landscape provide no granularity other than whether visitors are domestic or travel from overseas. An estimate of domestic road distance was therefore made from the distance from Central London to the Cotswolds' top destination (Bourton-on-the-Water). The average European road distance was inferred from data for the nearby Brecon Beacons National Park. It is noteworthy that because of a high percentage of overseas visitors, the weighted average distance to National Landscape is quite high.

10.8.5. 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 land use targets reflect the feasibility assessment in line with the Sixth Carbon Budget's 2050 Net Zero pathway for the UK.

Table 6 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 and AONB 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

[87] Economic impact report, 2016, https://www.cotswolds.com/dbimgs/Gloucestershire%20&%20districts%202015.pdf.

may not be entirely possible to achieve real zero emissions in these sectors given that there will always be residual emissions.

Table 6: High level comparison between Cumbria and new National Park/AONB target setting methodology and assumptions used.

Category (Priority Area)	Previous Model for Cumbria (2020)	New Model for All National Parks (2021) – 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[88]). Includes Scope 1 and 2 carbon dioxide emissions only (excluding motorways).	**13.6%** (specific to the Cotswolds National Landscape) 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 GHG energy emissions expressed at 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% per year from dietary change (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), stating 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. Includes cars. This assumes that sectors such as cement and steel, which feed into complex supply chains (incl. making cars), will take time to decarbonise globally and won't reach zero emissions in large exporters like China by 2050.	**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 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	**7.5%** of present-day emissions. This is our expert judgement for embedded emissions across various forms of renewable energy, and from the sectors (via supply chains) such as

[88] A budget tool for energy only CO2 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/

		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.	cement and steel that will take time to decarbonise globally (affecting car manufacturing, buildings, etc.).
Land Use	Expert judgement based on discussions with stakeholders involved	We have split land use into Land Use Non-CO_2 and Land Use CO_2. See Table 7 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 the land use targets are derived, and the relevant planning assumptions, can be found in 10.8.9. Table 7 below provides a brief overview.

Table 7. 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 or AONB; see Table 12. 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 Cotswolds, the proposed land use measures are estimated to add -17,590 tCO_2e/year to the total carbon sequestration flux in the landscape each year (i.e. an extra 17,590 tCO_2e removed per year in each of the subsequent years).

10.8.6. 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[89]. 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 8 and Table 9. 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 8: UK baseline for Agriculture emissions (2018) using Global Warming Potential of IPCC AR5 for methane

	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 $MtCO_2e$
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 9: Baseline for Agriculture emissions (2018) using Global Warming Potential of AR5 for methane

	Percentage of UK Agriculture emissions	**Quantity of CO_2 equiv.t**
Agriculture Breakdown		*SWC planning assumptions*

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

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		

10.8.7. 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[90]. 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.

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

10.8.8. 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[91]. 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[92].

Although the latest (BEIS) LULUCF estimates (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 10). 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.

Given that only 13% of England's peatlands are estimated to be in a near natural state at present, the Peatland Action Plan by the UK Government explicitly states that: "We will support National

[91] 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.
[92] Ricardo Energy & Environment UK NIR 2020 (Issue 1), UK GHG Inventory 1990-2019, Annex p. 854.

Parks and Areas of Outstanding Natural Beauty teams to deliver significant amounts of peatland restoration over the next 10 years[93]."

Table 10. 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.

[93] UK Government (2021), "England Peat Action Plan", p.12.

10.8.9. 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)[94] 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[95], which is based on the assessment by Evans *et al.* (2017)[96].

For the Cotswolds National Landscape, the current land use distribution is illustrated in Table 11. It uses results of an earlier Natural Capital assessment for the National Landscape based on remote sensing data[97]. The UK-wide areas of the selected land use (habitat) types and the corresponding percentages accounted for by the National Landscape are shown for context in Table 12.

[94] UK's Sixth Carbon Budget: "Agriculture and land use, land use change and forestry" (AFOLU) report. Climate Change Committee, 2020.
[95] Ricardo Energy & Environment, UK NIR 2020 (Issue 1) "UK GHG Inventory 1990-2019," Annex p. 854.
[96] 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.
[97] https://www.arcgis.com/apps/dashboards/3652fdb534cf47e58b7262cdb2345366.

At roughly 204,270 ha, the Cotswolds National Landscape accounts for around 0.842% of the UK's total land area, while the National Landscape's current share of tree cover is 3% lower than the UK average. There may be an opportunity to considerably expand the existing woodland area. We propose all tree planting to be native broadleaf trees, recognising that a native permanent woodland also has multiple co-benefits in addition to carbon sequestration, that cannot be matched by productive coniferous forestry.

The estimated occurrence of peat soils in the Cotswolds National Landscape (16.3 ha within the fen habitat) is far lower than the UK average per unit area, and 100% of the peat is understood to be in healthy condition.

The Cotswolds National Landscape's improved grassland and cropland areas are estimated to be 64% lower and 155% higher than the respective UK averages. There is 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, some of the least productive and lowest grade farmland would need to be taken off agricultural production to enable new woodland plantations.

Table 11. Cotswolds National Landscape: Key land use types by area (present-day)

Land Cover (Habitat) Type	**Habitat Area (ha)**
Broadleaved woodland	24,445.0
Coniferous woodland	1,841.7
Arable and horticulture	124,244.4
Improved grassland	18,498.3
Neutral grassland	9,804.1
Calcareous grassland	5,351.2
Acid grassland	0.0
Fen, marsh, swamp	328.7
Heather	0.0
Heather grassland	0.0
Bog	0.0
Saltmarsh	0.0
Urban	7,737.5
Suburban	0.0
Total	**192,251.0**

Table 12. Cotswolds National Landscape: Areas of the main land cover (habitat) types compared with the relevant UK totals

Land Cover Type	**Current UK Area (ha)**	**Current NP/AONB Area (ha)**	**NP/AONB Area as % of UK Area**
Broadleaf Woodland	**1,572,900**	**24,445**	**1.545%**
Coniferous Woodland	**1,637,100**	**1,842**	**0.112%**
Improved Grassland (mineral soils only)	**6,161,798**	**18,498**	**0.300%**

Cropland (mineral soils only)	**5,788,356**	**124,244**	**2.146%**
Degraded Peatland (all types)	**2,182,455**	**0**	**0.000%**
Total Woodland Area (Broadleaf + Coniferous)	**3,210,000**	**26,287**	**0.819%**
Total Agricultural Area (Improv. Grassland + Cropland)	**11,950,154**	**142,743**	**1.194%**
Total Area of Selected Land Cover Types (above)	**17,342,609**	**169,029**	**0.975%**
Total Area (incl. urban, rough grassland, water, rock, etc)	**24,249,500**	**204,270**	**0.842%**

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 12 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 Cotswolds in Table 13. 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). Based on these principles, the custom woodland target for the Cotswolds is 700 ha/yr.

Table 13. Three ways of setting new woodland targets in the Cotswolds National Landscape.

Woodland target apportioned by woodland land cover area in the National Park or AONB	407	ha/yr
Minimum woodland target apportioned by suitable habitat areas in the National Park or AONB	333	ha/yr
Custom woodland target in the National Park or AONB	700	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 Cotswolds National Landscape, 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[98]. 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

[98] UK's Sixth Carbon Budget, AFOLU report, page 27.

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)[99].

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 10.8.8). The sub-targets are based on the estimated current surface areas of the relevant types of degraded peatland (Table 11).

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 10.8.8). 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 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

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

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 Cotswolds

Table 14 summarises the proposed land use change and management targets for the Cotswolds National Landscape, which follow the principles outlined above.

Table 14. Land use targets and the associated additional carbon sequestration fluxes per year (emissions reduction for peat) for the Cotswolds National Landscape.

Land Use / Management Category	**Land Use Change Target (ha/yr)**	**Change in Carbon Flux (tCO_2e/yr/yr)**
New Native Broadleaf/Mixed Woodland	700	-12,919
New Productive Coniferous Woodland	0	0
Agroforestry (improved grassland & cropland)	360	-845
Hedgerows (improved grassland & cropland)	21	-219
Grazing Legumes (improved grassland)	363	-745
Cover Cropping (cropland)	2,438	-2,861
Restored Eroding Modified Bog (bare peat), Drained	0	0
Restored Eroding Modified Bog (bare peat), Undrained	0	0
Restored Modified Bog (heather/grass dominated), Drained	0	0
Restored Modified Bog (heather/grass dominated), Undrained	0	0
Restored Cropland Peat, Drained	0	0
Restored Intensive Grassland Peat, Drained	0	0
Restored Extensive Grassland Peat, Drained	0	0
Restored Forested Peat, Drained	0	0
Total	**3,882**	**-17,590**