SMALL WORLD CONSULTING

A greenhouse gas emissions assessment and target scenario for the Cairngorms National Park

A report by Small World Consulting Ltd

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Executive summary

Background

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

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

This report

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

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

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

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

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

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

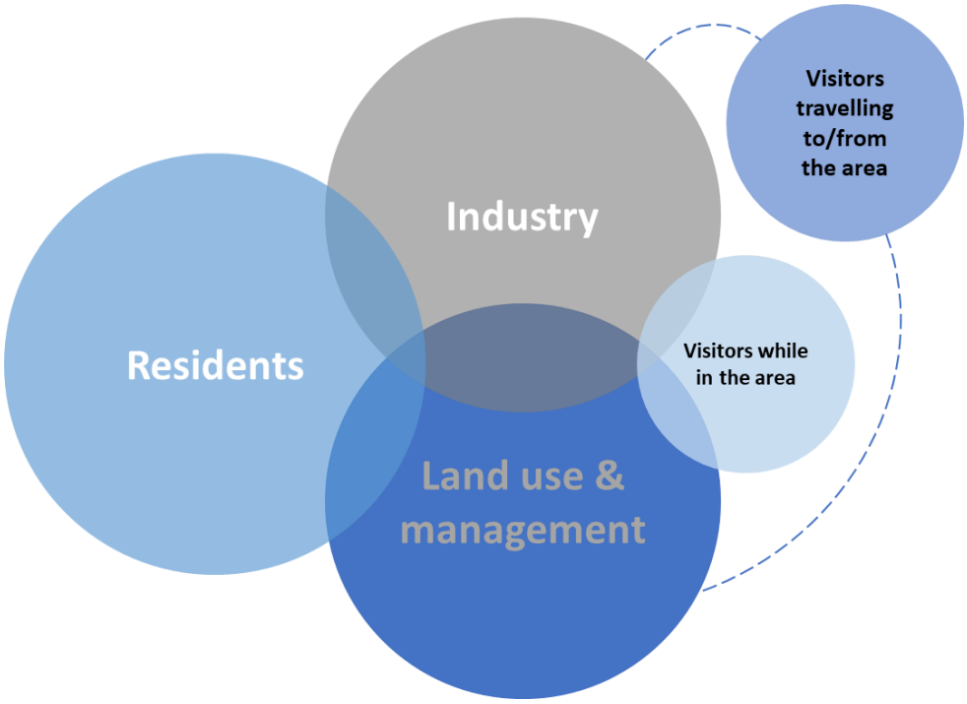


Figure 1: Boundaries of the greenhouse gas footprint assessment

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

- Energy-only emissions by residents, visitors and industry

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

Limitations and uncertainties

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

Results

Cairngorms National Park (See Figure 2 – Figure 5)	
Annual emissions from residents	**277,145 tCO_2e** (14.4 tCO_2e per person per year)
Annual emissions from visitors while in the National Park	**89,788 tCO_2e** (20.8 $kgCO_2e$ per visitor-day)
Annual emissions from visitors travelling to/from the National Park	**232,591 tCO2e (**112.5 $kgCO_2e$ per visit)
Annual industry emissions	**64,853 tCO_2e**

Key highlights

The Cairngorms encompasses the largest area of all the National Parks but has the fifth-lowest resident population. The Cairngorms residents' consumption is roughly 11% above the UK average (excl. public services), which is slightly lower than the average across all National Parks. The consumption data shows that the residents' health expenditure is nearly 36% higher than the UK average, consistent with the National Park having a disproportionately high share of the older population.

In a given year, the footprint of the residents of the Cairngorms National Park is estimated to be around 17% higher than the UK average. Several fossil fuel-based sources of greenhouse gas emissions are particularly high. The residents' emissions from flying and other forms of transport (excl. driving) are estimated to be around 29% higher than for an average UK resident. Driving emissions are around 34% above the UK average. The Cairngorms household electricity footprint is nearly 58% higher than the UK average. Household fuel emissions (excluding vehicle fuel) are just under 11% above those of an average UK resident, although this estimate has high uncertainty since multiple properties are off the gas grid in the National Park, and because there is insufficient data for residual fuel use (oil, coal, biomass). It must be noted that our estimates for emissions from household fuel and electricity use do not include renewable energy solutions such as solar panels

and heat pumps, nor do they factor in the uptake of electric vehicles. As of 2019, the share of these technologies across households was comparatively low and no suitable data with sufficient geographical detail was available.

The Cairngorms National Park has one of the highest shares of visitors staying overnight among all landscapes on the programme (just under 50%). Average duration of stay for overnight visitors is around 3.2 days which is on the lower side. Estimated average mileage travelled on land to get to the Cairngorms the highest among all National Parks and AONBs analysed (around 280 miles) and is dominated by cars. Around 27% visitors are thought to come from overseas, also the highest among all the landscapes on the programme. The visitors' footprint while travelling to and from the National Park is dominated by vehicle fuel (55%), followed by flying (26%). The footprint of travelling to and from the Park is over 2.5 times higher than while in the Park. The total footprint of all visitors (both in the Park and while travelling to and from) is slightly higher than that of the residents.

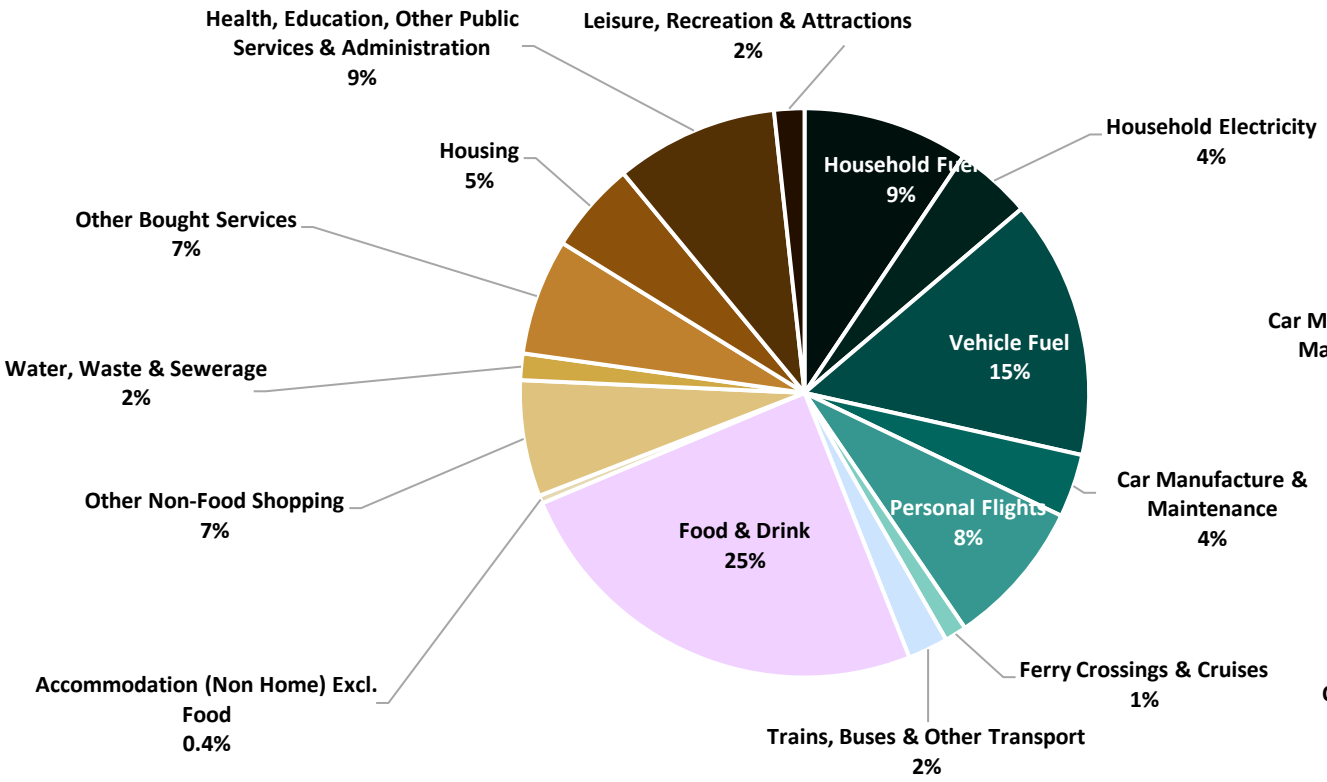
The industry footprint of the Cairngorms National Park is dominated by agriculture and forestry (30%), and accommodation and food services (16%). Farming within the National Park is predominantly sheep and cattle production. A fundamental difficulty with estimating industry footprint is that locations where companies are registered and where the required business data is available do not always match with the locations of business activities and emissions. Another challenge is the insufficient number of sectors reported in the business data that matches closely to the boundary of a protected landscape, which forces us to apply generic UK-wide emissions factors.

The Cairngorms National Park is estimated to have a sizeable traffic footprint from the major A roads (A9, A86, A889 and A95), which amounts to nearly 60% compared to the total footprint of the residents. Through-traffic is estimated to account for over 99% of the emissions from the major A roads.

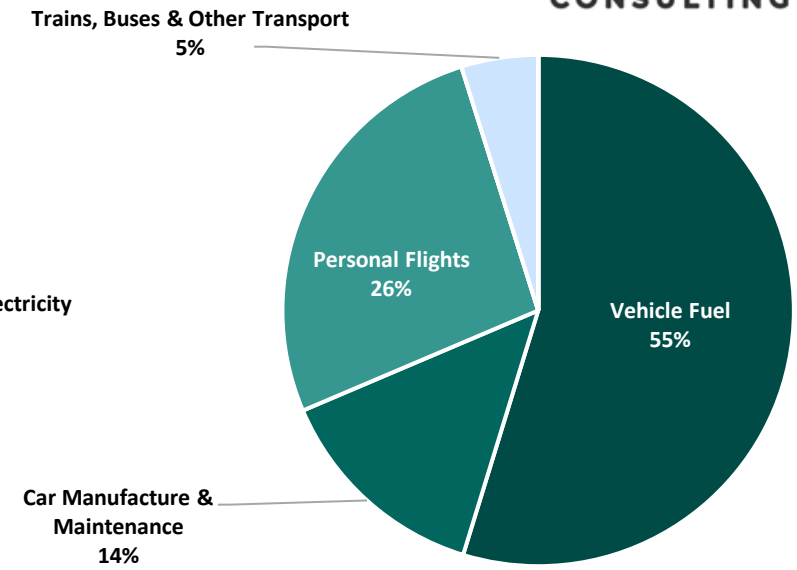
Targets scenario

A minimum Paris-aligned target trajectory has been constructed for each of the six elements of the targets, as illustrated in Figure 6. When combined, they result in a net zero date of 2024 for the Cairngorms National Park. The rationale behind selecting the six emissions categories and excluding other sources of emissions is provided in Section 6, together with an alternative pathway associated with the full consumption-based footprint. We note that the net zero date reflects 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. It also assumes the recommended decarbonisation and carbon sequestration efforts, including land use change, ratchet up to the required levels immediately in the base year of the assessment. In reality, the high levels of ambition for different sectors explored in this report are likely going take several years to achieve, given that post-COVID emissions have largely rebounded, and that decarbonisation trends to date have been relatively small in magnitude compared to what we know is required for keeping global warming below the safer 1.5°C limit from the Paris Agreement. These factors are expected to push the projected net zero year back by several years. The net zero date should therefore not be taken in isolation as a level of ambition.

Residents: 277,145 tCO_2e



Visitors while travelling to & from the area: 232,591 tCO_2e



Visitors while in the area: 89,788 tCO_2e

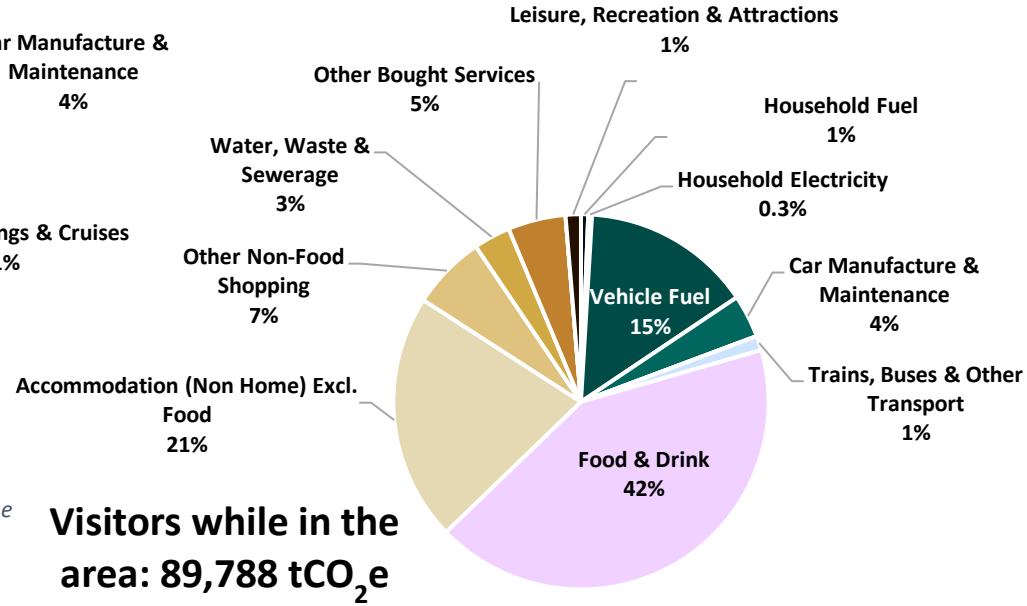


Figure 2: (left) Residents' GHG emissions in Cairngorms National Park by percentage

Figure 3: (top right) Visitors' GHG emissions on the way to & from Cairngorms National Park by percentage

Figure 4: (bottom right) Visitors' GHG emissions while in Cairngorms National Park

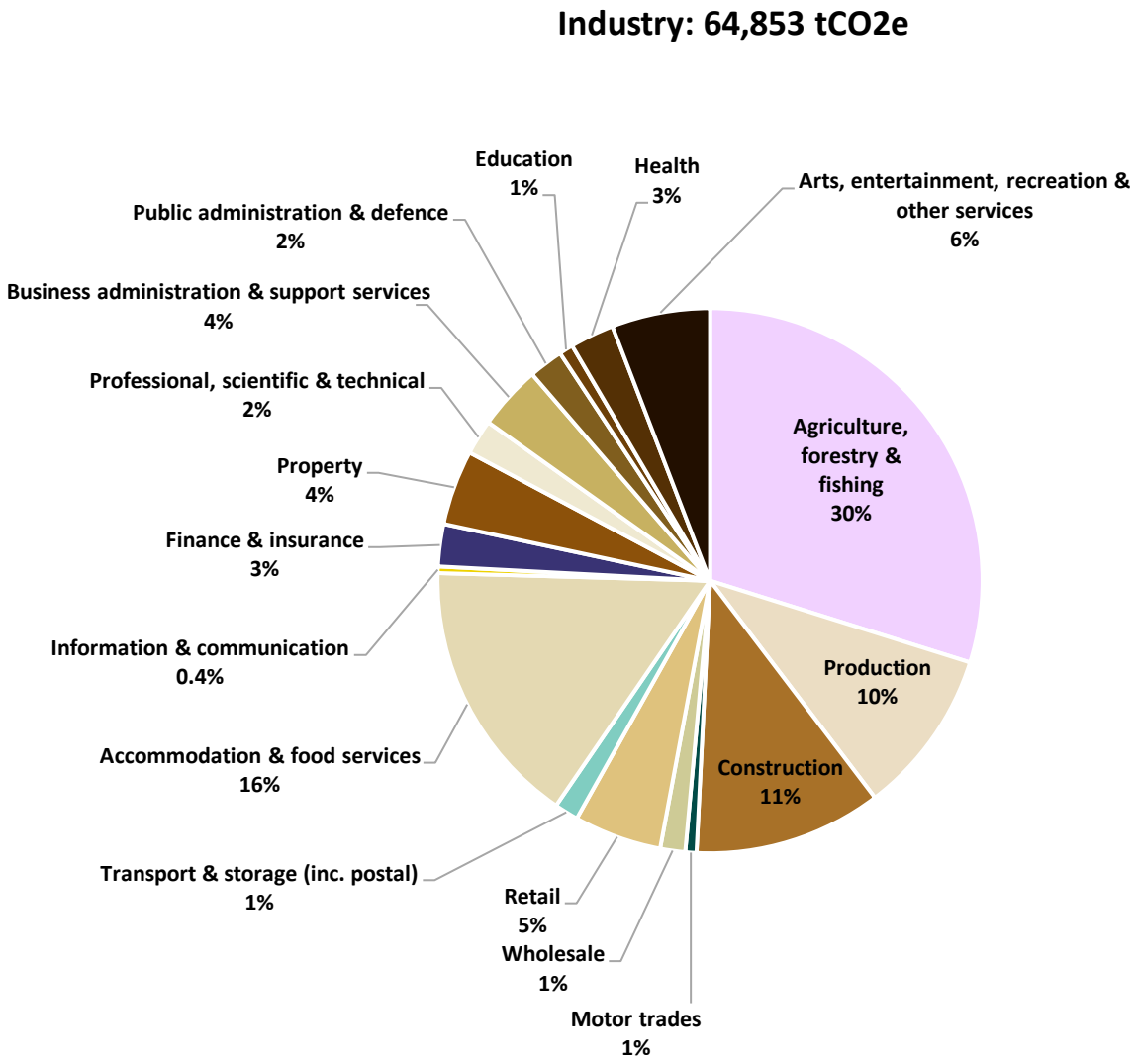


Figure 5: A estimate of emissions from industries within the Park and their supply chains (scopes 1, 2 and upstream scope 3)

Figure 6: Recommended target pathways resulting in net zero emissions for the Cairngorms National Park by 2024. The pathways are based on a range of assumptions, including using 2019 as the base year and land use targets apportioned from the Sixth Carbon Budget (Section 6.1). Alternative land use targets from the new Cairngorms National Park Partnership Plan and the associated pathway are considered in Section 6.2

1. Introduction

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

This report, for the Cairngorms National Park, is one of a series of methodologically compatible reports produced for each UK National Park, each Welsh AONB, as well as the Cotswolds and Cannock Chase AONBs in England. The baseline year for the assessment is 2019, the most recent pre-COVID year. The report also includes recommendations for Paris-aligned targets on GHG emissions reduction across six key areas, as well as for carbon sequestration through land-based climate mitigation measures. Together with the estimated 2019 GHG baseline, achieving these targets would mean the Cairngorms reaching consumption-based net zero emissions by 2024, subject to the targets being fulfilled and to the considerable uncertainties remaining in the data.

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

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

The unique characteristics of each protected landscape give rise to different priorities and opportunities for cutting greenhouse gas emissions and for sustainable land management. For example, the ratio of visitors to residents varies greatly. Some National Parks and AONBs have large industrial or military sites within their boundaries. To varying degrees, each landscape is traversed by major roads that carry considerable volumes of traffic (not necessarily stopping in the area). All these factors affect the economic makeup of each landscape's geography, and have strong implications for the associated GHG footprint and decarbonisation efforts. In terms of land management challenges and opportunities, the protected landscape vary greatly in their levels of peatland and woodland coverage, in their amount and types of agricultural land, and in the population densities of residents and visitors.

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

2. Policy drivers

2.1. Climate change policy

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

Climate change driven by anthropogenic GHG emissions, plus the wider ecological crisis, are some of the biggest challenges facing humanity today, and a joined-up response to tackling them is likely to improve both situations. A 2018 report by the Intergovernmental Panel on Climate Change (IPCC) outlined the need to reduce global greenhouse gas emissions by 45% (from 2010 levels) by 2030, and achieve net zero emissions by 2050[1]. It states that these reductions are necessary in order to limit the increase in global mean temperature to 1.5°C relative to pre-industrial levels. This is the more ambitious target of the Paris Agreement by the parties to the UN Framework Convention on Climate Change (UNFCCC); it is also understood to be a "safer" warming limit both for societies and ecosystems globally. In 2019, the UK Government agreed to a legally binding target of net zero greenhouse gas emissions by 2050.

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

The first part of the AR6, entitled "Climate Change 2021: The Physical Science Basis", was released ahead of the 26th UNFCCC Conference of the Parties (COP26) hosted in Glasgow in November 2021[2]. Notably, it affirms that the increase of carbon dioxide, methane, and nitrous oxide in the Earth's atmosphere through the industrial era, i.e. since the late 19th century, is the result of human activities. What is clear in the report is that our chance of limiting the increase in global mean temperature to 1.5°C above pre-industrial levels now appears small. Keeping warming below the "safer" 1.5°C limit will likely require the most ambitious actions – i.e. those at the top end of known technical feasibility – to reduce emissions and also upscale efforts on carbon sequestration.

The Department of Business, Energy and Industrial Strategy (BEIS) is the lead for reporting on GHG emissions in line with the UNFCCC requirements in the UK, including Scotland and Wales. An

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

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

independent body, the UK Climate Change Committee, advises the whole of the UK, including devolved administrations, on emissions targets and progress. The Sixth Carbon Budget (2020) recommends that the UK set a budget to require a 78% reduction in UK greenhouse gas emissions by 2035 relative to 1990, which is a 63% reduction from 2019 levels[3]. Further detail relating to this is provided in Section 2.4 outlining associated real-world change towards decarbonisation.

The Scottish Government published its Update to the Climate Change Plan 2018-2032: "Securing a Green Recovery on a Path to Net Zero" in December 2020. The document sets out the new ambitious targets to end Scotland's contribution to climate change by 2045 (net zero), and a commitment to reduce emissions by 75% by 2030 (compared with 1990). Recognising the role that both public and private investment must play in delivering the transition to net zero emissions, the Scottish Government launched the first tranche of its £2 billion Low Carbon Fund[4].

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

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

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

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

[3] Climate Change Committee (2020): "The Sixth Carbon Budget: The UK's Path to Net Zero," p. 13 https://www.theccc.org.uk/wp-content/uploads/2020/12/The-Sixth-Carbon-Budget-The-UKs-path-to-Net-Zero.pdf.
[4] Scottish Government (2020) Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update p.1
[5] HM Government (2021), "Net Zero Strategy: Build Back Greener" https://www.gov.uk/government/publications/net-zero-strategy.
[6] COP26, "The Glasgow Climate Pact," p.8 https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf.
[7] https://climateactiontracker.org/global/temperatures/.

2.2. Health impacts of air pollution

In addition to the impact of climate change on the environment, greenhouse gas emissions also have an impact on human health and well-being. It is estimated that between 28,000 and 36,000 UK deaths each year are attributable to air pollution. Poor air quality can have a disproportionate impact on the health and well-being of children, older people and other vulnerable individuals. The NHS has identified that more than 2,000 GP practices and 200 hospitals are in localities affected by toxic air. In the UK, 5.4 million people are currently receiving treatment for asthma: 1.1 million children (1 in 11) and 4.3 million adults (1 in 12). Every day, three families are devastated by the death of a loved one due to an asthma attack, and tragically, two thirds of these deaths are preventable (Asthma UK, 2020).

Almost 16% of preventable deaths in Scotland[8], compared to 30% in England, due to non-communicable diseases can be specifically attributed to air pollution (NHS Plan, 2019). While cities in Scotland have lower levels of particulate pollution than many in England, dangerous levels are still reached[9].

2.3. Climate-driven impacts in the UK

The impact of climate change on our natural world is evidenced by higher temperatures, changing rainfall patterns, changes in ecosystems, sea level rise, increasing frequency and intensity of storm surges, retreating glaciers, and melting sea ice and ice sheets. In the UK we are seeing significant changes in the winter and summer rainfall patterns. The UK Met Office's latest report states that "Winters in the UK, for the most recent decade (2009-2018), have been on average 5% wetter than 1981-2010 and 12% wetter than 1961-1990", and that "Summers in the UK have also been wetter, by 11% and 13% respectively"[10]. Total rainfall from extremely wet days increased by around 17% in the decade 2008-2017 for the UK as a whole. However, the changes are most marked for Scotland, and not significant for most of southern and eastern England. In addition to increasing precipitation volumes, climate change has already made it 12-25% more likely that the UK will again experience a summer as hot as 2018, which is projected to become 50% more likely with future warming.

In terms of human responses to flooding, a recent report by Natural England also suggests that environmental inequality is greater within deprived communities, which experience the largest negative climate impacts, e.g. flood risk, air pollution, poor-quality river water and waste hazards. Research has shown that there are significant mental health impacts associated with flooding, including a 20.1% chance of probable depression within 12 months, 28.3% probable anxiety and 32.6% probable PTSD for those individuals who directly experience being flooded (based on the cost per household over a 2-year period, ranging from £3,144 to £6,980 dependent on flood depth)[11].

[8] https://www.hps.scot.nhs.uk/web-resources-container/air-pollution-and-health-briefing-note-mortality-associated-with-exposure-to-fine-particulate-matter-pm25-attributable-mortality-in-scotland/

[9] Lee, D., Robertson, C., Ramsay, C., Gillespie, C. and Napier, G., 2019. Estimating the health impact of air pollution in Scotland, and the resulting benefits of reducing concentrations in city centres. Spatial and Spatio-temporal Epidemiology, 29, pp.85-96.

[10] 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

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

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

2.4. Real world action and behaviour change

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

- By the early 2030s, all new cars and vans, and all domestic and non-domestic replacement boilers are low-carbon – largely electric.
- By 2040 all new trucks are low-carbon.
- UK industry shifts to using renewable electricity or hydrogen instead of fossil fuels.
- UK industry captures its remaining carbon emissions and stores them safely (and permanently).
- By 2035 the UK's electricity production is zero carbon.
- Low-carbon hydrogen is scaled up as a fuel for shipping, transport and industry, and for some buildings it replaces natural gas for heating (demand for natural gas is set to double/treble by 2050).
- UK wastes fewer resources and reduces its reliance on high-carbon goods.
- UK has a national programme to improve insulation of existing buildings[12].
- Fewer miles travelled by car and air.
- Diets change, reducing consumption of high-carbon meat and dairy products[13] by 20% by 2030.
- Agriculture and the use of farmland are transformed, while maintaining the same levels of food per head produced today.
- By 2035, 460,000 hectares of new mixed woodland are planted to remove CO_2 from the atmosphere and deliver wider environmental benefits.
- By 2035, 260,000 hectares of current farmland are dedicated to producing energy crops.
- Woodland coverage of the UK's land surface rises from 13% today to 15% by 2035 and 18% by 2050.
- Peatlands are widely restored and managed sustainably.

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

[12] Building regulations for new homes have been strengthened to require high energy performance and electric vehicle charging points.

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

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"[14].

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

2.5. Policy implications for local planning authorities

Planning is one of the tools the Authority can use to address GHG emissions, specifically through decarbonising the built sector. Ideally, policies within the Local 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.

The Planning (Scotland) Act 2019 established a new duty for a planning authority, or authorities acting jointly, to prepare and adopt a Regional Spatial Strategy (RSS), which is a long-term spatial strategy designed to identify:

- the need for strategic development;
- the outcomes to which strategic development will contribute;
- priorities for the delivery of strategic development;
- proposed locations, shown in the form of a map or a diagram.

The Fourth National Planning Framework (NPF4) is a long-term development plan for Scotland looking ahead to 2045, setting out where development and infrastructure will be needed to support sustainable and inclusive growth. However, in its Management Partnership Plan, the National Park Authority outlines specific landscape qualities it wishes to protect, which have impacts for planning policy and any future applications for development. They are: 1) Protecting views to lochs, high summits and landmark features; 2) Celebrating dark skies; 3) Siting transmission lines underground where practical; and 4) Protecting tranquil qualities, particularly on undeveloped loch shores.

Planning can also inform what types of renewable energy technology that will be appropriate and where within the National Park, facilitating communities / businesses switching to non-fossil fuel sources of power and heat. The numerous rivers and burns running down steep gradients in the Cairngorms suggest there may be a good potential for hydro-electric power generation in the Park, building on several historical developments. An option appraisal in 2016 identified six further sites with technical and financial feasibility for hydro-electric power[15], although whether this will lead to further development in the Park remains to be seen. Wind power is another feasible option for renewable energy generation in the Cairngorms. However, any new plans for either hydro-electric

[14] Climate Change Committee (2020), "The Sixth Carbon Budget: The UK's Path to Net Zero," p.30.
[15] babyHydro, "Hydropower Appraisal in Cairngorms Final report (2016)."

or wind power developments within protected landscapes are subject to careful consideration and consultation with statutory agencies and the public living in and around the Park.[16]

There is also scope for planning to increase green space, through new green infrastructure, tree planting and habitat creation. Local Plan policies on Ecosystem Services and Biodiversity Net Gain have the potential to deliver biodiversity and climate change benefits through development, even though we acknowledge that more significant opportunities to deliver these benefits would come from a landscape-scale land use change. The Local Plan also makes provision for non-motorised transport routes by protecting disused railway lines which offer excellent opportunities for people to engage in active travel; this is important both for leisure and commuting within the National Park, and for the many day visits from the surrounding urban centres.

3. Cairngorms National Park: demographic profile and key statistics

In this section we consider the key characteristics of people and landscape which may call for further reflection later in this GHG emissions assessment, in terms of the likely impact on land management and behaviour arising from the changes needed to create a more sustainable long-term future for both people and nature. These insights may benefit the delivery of projects by the programme partners.

In their management plans , the Scottish National Parks set out how they aspire to address national priorities and achieve benefits for Scotland beyond the National Park boundaries. They recognise these spaces' potential to contribute to the Scottish Government's purpose: *"To focus government and public services on creating a more successful country, with opportunities for all of Scotland to flourish, through increasing sustainable economic growth*"[17]. However, this aspiration needs to be interpreted within the context of four aims set out by the National Parks (Scotland) Act 2000, namely:

- To conserve and enhance the natural and cultural heritage of the area;
- To promote sustainable use of the natural resources of the area;
- To promote understanding and enjoyment (including enjoyment in the form of recreation) of the special qualities of the area by the public;
- To promote sustainable economic and social development of the area's communities[18].

In 2022, the Cairngorms National Park Authority (CNPA) was successful in its £12.5 million bid to the National Lottery Heritage Fund's "Heritage Horizons Programme", designed to support 22 projects across the Park over the next 7 years[19,20]. Together with over 45 partners, the CNPA is embarking on a large-scale transformational change programme to deliver on collective responsibilities to tackle climate and biodiversity issues[21]. A key focus area is the people and communities that live,

[16] https://www.energyvoice.com/renewables-energy-transition/213552/wind-turbine-fears-on-horizon-at-cairngorms/
[17] Loch Lomond & the Trossachs National Park (2018) National Park Partnership Plan 2018-2023 p.10
[18] Cairngorms National Park Partnership Plan 2017-2022 p.10
[19] https://cairngorms.co.uk/wp-content/uploads/2021/10/NPPP4-draft-plan-pdf-long-format-digital-Oct-2021-FINAL.pdf
[20] Cairngorms National Park (2022) Draft National Park Management Plan 2022-2027
[21] Cairngorms National Park (2022) Heritage Horizons: Cairngorms 2030 https://cairngorms.co.uk/discover-explore/heritage/heritage-horizons/

work and spend time in the Cairngorms, aiming to build agency to help these groups make a difference. Projects are organised around the key themes of people, power and place. These include a range of workstreams such as active travel, land management, communities and landscape change, effective community engagement and research, and consulting on and managing the co-design of a Cairngorms Climate Learning Framework.

3.1. People and key characteristics

The Cairngorms residential population is among the lowest among all the UK's National Parks. Northumberland has the lowest population (1,959), followed by the Broads (6,673), Exmoor (10,284), Loch Lomond & The Trossachs (14,962) and Cairngorms (19,117). For the purposes of this GHG assessment, population estimates from mid-2019 were used, and we included all postcodes that have at least 30% of their area within the National Park boundary, which gives a total of around 19,211 people residing in the Park. This includes residents living in areas of Aberdeenshire and Moray, Angus, Highland, Perth and Kinross[22].

Over 490,000 people live within the urban centres of Aberdeen City and across Aberdeenshire, with a further 50,000 based in Inverness. Aberdeen is the nearest major city to the National Park's borders; Edinburgh is three hours away by bus, and has a population of over 500,000 people. Each year, the National Park attracts over one million day-visitors, and roughly a million of visitors staying overnight. The larger towns and villages that are home to other Highland communities predominantly lie near the borders of the National Park, along the main A-roads, including Grantown-on-Spey, Aviemore, Kingussie and Ballater. The exception, at the heart of the National Park, is the village of Braemar, also on the main A road, renowned for its Highland games and associations with Balmoral Castle close by in Crathie. There are numerous small, dispersed rural communities, some relatively remote and some accessed only by single-track roads. There are also over 160 estates, many in private ownership, forming a patchwork of land boundaries within the National Park[23] and constituting some of its key stakeholders, together with local communities.

When considering partnership-working on decarbonisation agendas, there are five local authorities represented within the National Park: the Highland Council, the Moray Council, Aberdeenshire Council, Angus Council, and Perth & Kinross Council[24]. Indices of deprivation show that the Park's population is relatively affluent, with most residential areas ranked around the 6th- 8th least deprived in Scotland. However, some pockets in Aviemore, and in Badenoch & Strathspey Central/North, are rated 5th most deprived, largely due to deficiencies in housing, education and skills.

The National Records for Scotland (2020) statistics predict growth of 3.3% in the Park's residential population by 2028, bucking the general trend within UK National Parks[25]. Population change projections (2018-2028) indicate a decline in the number children aged 0-15 years (-18.5%) but an increase in the working-age population (+5.9%). This is a positive, given that Scotland's working-age

[22] https://cairngorms.co.uk/discover-explore/facts-figures/ .

[23] Cairngorms National Park (2022), "Land Ownership," https://cairngorms.co.uk/working-together/land-management/estates-map/ .

[24] Cairngorms National Park (2022), "Supporting Communities," https://cairngorms.co.uk/working-together/supporting-communities/#:~:text=The%20Cairngorms%20National%20Park%20straddles%20five%20Local%20Authority,in%20consultation%20and%20engagement%20around%20the%20Planning%20system.

[25] National Records of Scotland (2020), "Sub-national Population Projections for Scottish Areas (2018-based): Data Tables."

population is predicted to grow by only 1.8% on average, and suggests that the National Park's strategies to maintain and support vibrant communities may be having some success. Having said that, it is interesting to note the projected growth in the pensionable-age population: over 10.2%, which is higher than the Scottish average (3.7%). Most notably, the largest projected change is within the 75 and over age range (+49.6%), significantly above the predicted average for Scotland (+25.4%)[26].

The age profile change suggests that the NHS and Local Authorities may need to plan for higher consumption of health and social care services in future years, and suitable housing to accommodate older people; this may also be an emerging issue for the National Park as a Planning Authority. Likewise, strategies for workforce planning and housing may benefit from further efforts to render the idea of living in the National Park more attractive to working-age people, encouraging migration into the area. This is especially important given the renewed and increased emphasis on nurturing natural capital to support nature, climate, and eco-tourism, with a view to meeting Scotland's strategic objectives. Consequently, there is a need for economically active people and communities, to deliver sustainable and integrated land management and generate multiple benefits.

The new Partnership Plan (currently at the consultation stage) focuses on a proactive response, to help incentivise more people of working age to live in the Park. This plan expresses the aim for the Cairngorms to have the highest proportion of living-wage employees in rural Scotland by 2030.[27] Many of these employees are expected to possess skills and training in nature-based climate solutions, essential assets for creating a low-carbon economy. However, housing may be a potential barrier to residents earning the living wage due to the high proportion of second homes in the Cairngorms National Park, where only 84% of all houses are permanently occupied. This is significantly lower than the Scottish National average of 96%, and brings considerable affordability pressures for people working in the Park[28].

Both the existing Partnership Plan (2017—2022) and the new Partnership Plan highlight the need to make room for over 500 new households, with the aim of increasing the proportion of working-age residents in the Park.[29,30] As a planning authority, the National Park is faced with the challenge of enabling the development of small, affordable homes. Tackling this challenge from another direction, the National Park could act as an influencer in addressing the proportion of vacant second homes. COVID-19 may have created an opportunity, given the increased potential for home working since 2020 and companies now being more open to flexible working by staff. This could encourage people to relocate to rural communities.

It is important to understand and reflect upon the diverse demographic profile of the landscape when considering potential opportunities to change behaviour in spending habits. Further detail pertaining to the Park's key consumption and industry characteristics can be found in Appendix 10.2.

[26] National Records of Scotland (2020), "Sub-national Population Projections for Scottish Areas (2018-based): Data Tables."
[27] "Cairngorms National Park Partnership Plan – Draft for public consultation, 2021."
[28] "Cairngorms National Park (2017-2022) Partnership Management Plan," p. 62.
[29] "Cairngorms National Park (2017-2022) Partnership Management Plan," p. 59.
[30] "Cairngorms National Park (2022) Draft National Park Management Plan 2022-2027."

3.2. Geography and landscape

In terms of its size, the Cairngorms National Park is the largest in the UK with an area of 4,528 km^2 (452,800 ha). The Cairngorms is one of the UK's most valued and wildest landscapes, with a mix of mountain plateau, moorlands, woodlands and farmed straths, and the most extensive coverage of native pinewood in Scotland.[31] In winter the Cairngorms mountain range at the heart of the National Park can experience Artic conditions. The Park also covers the upper catchments of some of Scotland's major rivers, such as the Spey, Dee and South Esk.[32] Nearly half of the Park is designated as being of European importance in biodiversity terms, and the Cairngorms is home to over a quarter of the UK's threatened or endangered species.[33] After the most recent ice age, coniferous trees colonised some 1.5 million hectares of the Scottish Highlands. Today, the globally unique Caledonian Forest exists in 35 remnants (17,900 ha) across the Highlands, and can be visited in the Cairngorms National Park[34].

The Cairngorms Natural Park plays a key role as an enabler for climate change adaptation and mitigation, not only for local communities, but for Scotland as a whole. River restoration and wetland enhancement are the main flood management strategies both in the Park and beyond, with other key conservation objectives including sustainable management and restoration of peatlands and the expansion of woodlands on appropriate soils.[35]

One of the core conservation policies in the Partnership Plan focuses on enhancing the resilience of habitats, species and land use to climate change, pests and disease[36]. Wild deer are seen as an iconic species in Scottish National Parks by the visitors. They are not only an integral part of Scotland's ecosystems, but also contribute to the rural economy, both as a source of food and through recreational activities such as sightseeing and stalking[37]. However, wild deer can have a negative impact on the environment when their population levels upset the balance of the ecosystems within their landscape habitats. There are up to one million wild deer in Scotland, the majority being red and roe deer, and there are around 25,000 non-native Sika deer, too. Where deer densities are high, the impacts on vegetation and soil structure can hinder nature restoration and carbon sequestration[38].

Scotland's "Wild Deer: A National Approach" (WDNA) is the group which assesses current wild deer management practices and sets targets by working with land managers and public bodies. A 2014 review set out targets for deer management practices in 3 core areas; helping to provide a high-quality, robust, and adaptable environment (through improved biodiversity and by helping to mitigate against, reduce and adapt to climate change), contributing to sustainable economic development, and providing social well-being[39].

[31] "Cairngorms National Park Partnership Plan (2017-2022)," p. 22.
[32] "Cairngorms National Park Partnership Plan (2017-2022)," p. 12.
[33] "Cairngorms National Park Partnership Plan (2017-2022)," p. 20.
[34] The Wildlife Trust (2022) Caledonian Forest https://www.wildlifetrusts.org/habitats/woodland/caledonian-forest
[35] "Cairngorms National Park Partnership Plan – Draft for public consultation, 2021."
[36] "Cairngorms National Park (2022) Draft National Park Management Plan 2022-2027."
[37] "Scotland's Wild Deer, A National Approach, Including 2015-2020 Priorities (2014 review)," p. 3.
[38] "Scotland's Wild Deer, A National Approach, Including 2015-2020 Priorities (2014 review)," p. 15.
[39] "Scotland's Wild Deer, A National Approach, Including 2015-2020 Priorities (2014 review)," p. 11.

The WDNA report recognises that current deer practices will need to change to meet climate mitigation targets. This is particularly relevant as an enabler for programmes of peatland restoration, and woodland creation if land use change opportunities are to be realised for multi-environmental benefits for people and nature. A recent report commissioned by Scottish Ministers on the management of wild deer in Scotland suggests consideration of public safety and deer welfare (in all circumstances), damage to public interests (in particular circumstances), and compulsory powers for control measures highlighting a number of far-ranging recommendations[40,41]. It is recognised that this is an emotive topic, with varying opinions among interest groups.

In response to these challenges, the National Park's Heritage Horizons Programme includes the development of the Strategic Land Use Plans, including a deer management plan. This aims to coordinate with current deer management groups to deliver benefits for climate and nature, as well as in economic terms.

3.3. Consumption and spending characteristics

When it comes to the National Park or AONB's residents, learning shared from a Catapult Energy Systems (2021) report suggests that people in vulnerable circumstances are at increased risk of experiencing barriers to adopting the behavioural changes identified as being key to achieving net zero GHG emissions[42]. The categories of vulnerability included: rural, low income, privately renting, residents with disabilities, pensionable age residents, the digitally excluded and those disproportionately affected by COVID-19.

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

According to the Office for National Statistics (ONS) Household Expenditure Survey for different demographic groups, the average affluence of residents in all the National Parks and AONBs who joined this programme is higher than the UK average, even though these landscapes tend to have pockets of deprivation. On average, the Cairngorms residents spend around 11% more than UK residents (Table 1), excluding public services. This is slightly below the average across all National Parks. The spending patterns of the Cairngorms residents are fairly similar to the average of all National Parks, with significantly higher levels of spend on healthcare (35.5%) and transport (29.4%), and lower spend on education (-45.1%) compared to the UK average. The notable differences in consumption patterns between the Cairngorms and other National Parks are an even higher spend on alcoholic drinks, tobacco & narcotics, and a lower spend on education.

A detailed summary of key statistics and spending habits of the Cairngorms residents can be found in Appendix 0.

[40] The Scottish Government (2019), "The Management of Wild Deer in Scotland: Report of the Deer Working Group."
[41] "Cairngorms National Park (2022) Draft National Park Management Plan 2022-2027."
[42] Catapult Energy Systems (June 2021). "Net Zero Societal Change Analysis: Summary report," p. 11.

Table 1: Relative difference in consumer spending per capita (excluding public services) between the Cairngorms National Park (CNP) and UK average, and the relative difference between all 15 UK National Parks averaged and the UK average.

Consumer Expenditure Category	Cairngorms NP vs UK Consumer Spending (Excl. Public Services)	All NPs vs UK
Food & non-alcoholic drinks	9.0%	10.2%
Alcoholic drinks, tobacco & narcotics	18.3%	14.6%
Clothing & footwear	6.4%	9.2%
Housing, fuel & power	-3.4%	-8.3%
Household goods & services	9.4%	16.7%
Health	35.5%	41.9%
Transport	29.4%	29.8%
Communication	3.8%	4.7%
Recreation & culture	18.2%	22.1%
Education	-45.1%	-39.8%
Restaurants & hotels	1.5%	3.1%
Miscellaneous goods & services	5.3%	7.8%
Other expenditure items	17.4%	23.1%
Total	**11.1%**	**12.9%**

4. GHG reporting conventions and methods

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

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

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

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

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

as woodlands, wildflower meadows, heathlands and peatlands. Land-based emissions originate predominantly from ruminants (methane), synthetic fertiliser use (nitrous oxide), and degrading peatlands (mostly CO_2). These emissions are, to a degree, compensated by carbon sequestration in existing woodlands, meadows, hedgerows, and healthy peatlands, while agricultural soils could also sequester carbon under certain types of management.

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

Figure 7 illustrates the relationship between the main components of our central assessment and the industry emissions.

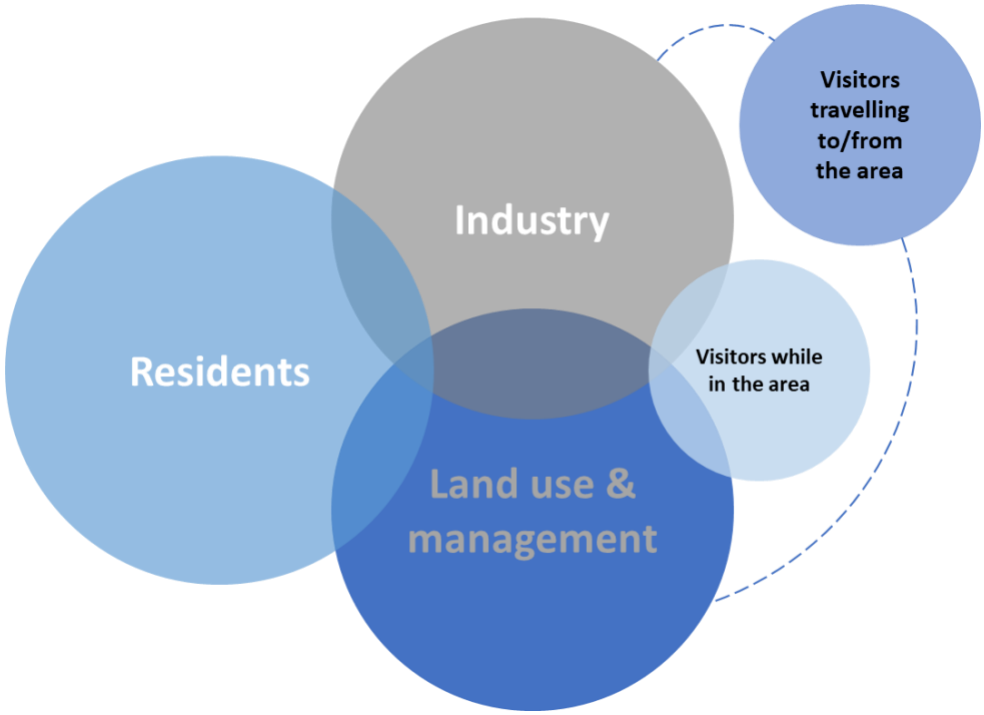


Figure 7: Boundaries of carbon footprint assessment (Repeat of Figure 1)

This report also includes a recommendation for Paris-aligned greenhouse gas targets across six key areas. These six areas have been selected in order to find a best-fit between the competing desires to cover everything of significance within the influence of policy makers, to keep the boundary simple to describe, to avoid double counting, and to make use of any data readily available for

tracking progress. As a result, the scope for the target areas is slightly different from that of the overall emissions assessment. The six target areas are:

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

The Greenhouse Gas Protocol considers six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur Hexafluoride (SF_4). It also categorises company emissions into three scopes: Scope 1 for direct emissions from company facilities and vehicles; Scope 2 for indirect emissions from electricity and steam consumed in company activity but generated elsewhere; and Scope 3 for indirect emissions in the value chain[43]. Scope 3 can be split into two parts: upstream and downstream. Our assessment of Industry emissions includes scope 1, 2 and upstream scope 3 (Figure 8). This can be thought of as the full "carbon footprint" of industry up to the point of sale. Similarly, when residents and visitors buy goods and services, we include the embodied emissions of these purchases.

In the report, we measure greenhouse gas emissions in tonnes of carbon dioxide equivalent (tCO_2e)[44]. We have used 100-year global warming potential (GWP) conversion factors for all non-CO_2 gases, in line with established greenhouse gas accounting conventions. In other words, we consider the contribution that each gas makes over a one-hundred-year period. However, it should be remembered that if we are interested in climate impacts over a shorter timescale, the relative importance of some gases increases. In particular, the relative contribution of methane is roughly doubled if we are interested in climate impacts over a period of fifty years, or roughly three times as important as represented in this report if we are looking at climate impacts by 2050.

[43] 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.

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

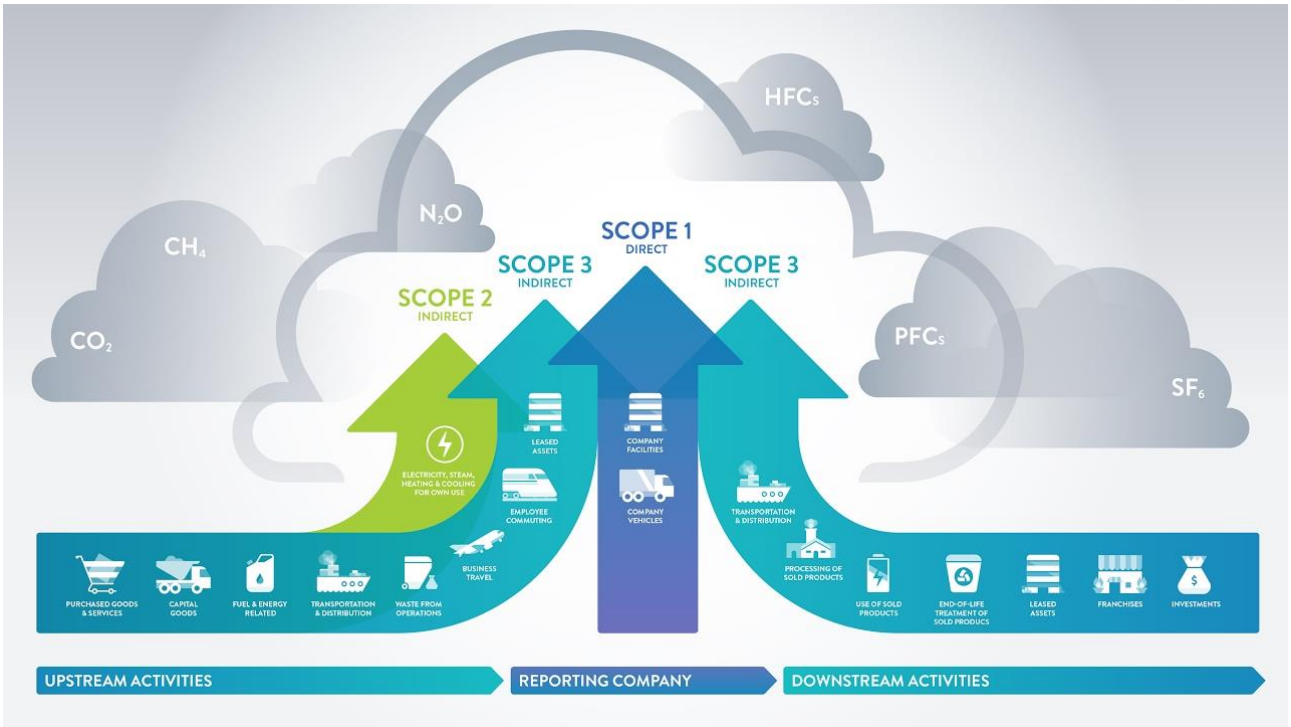


Figure 8: Types of greenhouse gas emissions used for carbon accounting. Source: Greenhouse Gas Protocol.

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

Consumption-based emissions: We assess the greenhouse gas "footprint" of residents, visitors and industry, including the supply chains of everything that residents and visitors buy and do while in the National Park. Consumption-based reporting attributes the emissions from product and service supply chains to the National Park, ***regardless of where emissions are physically released during production***. Consumption-based reporting is important for looking at the climate change impacts that people and businesses have through their entire lifestyles and operations, including the food they eat and the products and services they buy. For example, taking a consumption-based approach, the impact of driving includes not just the exhaust pipe emissions, but also emissions resulting from the manufacture and maintenance of cars, and emissions resulting from the extraction and refining of fuels and their transport to the pump. For businesses, it includes the full impact of business practices, including procurement supply chains. The footprint of the National Park's industry is reported separately, as there is some unavoidable double-counting with the footprint of residents and visitors, where people in the National Park buy from local companies.

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

emissions (i.e. removal of CO_2 from the air) that may result from Land Use, Land Use Change and Forestry (LULUCF).

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

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

5. Cairngorms National Park: Consumption-based GHG emissions

5.1. Results overview

Here, we outline our analysis of the carbon footprint of Cairngorms residents' and visitors' 2019 GHG emissions (Figure 9). Residents' emissions were estimated at 0.277 million tCO_2e (Figure 10), and visitors' emissions – from time spent in the Park and during travel to and from – were estimated at 0.322 million tCO_2e (Figure 11 and Figure 12). The resident population stands at 19,211, compared to around 2.1 million visitors per year (both single-day and overnight). A full breakdown of these figures is provided in Appendices 10.5 and 10.6. The data shows that the typical footprint resident of the Cairngorms resident is 16.8% higher than that of the average UK resident. The final annual consumption per year for residents (including public services) is around 630 million pounds.

To indicate the scale of the annual GHG emissions from Cairngorms National Park, you would need to plant over 1,600 Premier League football pitches with broadleaf trees, and let them grow for over 100 years, to mitigate the combined GHG emissions of the Park's residents and visitors for the single year of 2019. This shows the need to prioritise GHG emissions *reductions* to limit global warming, rather than just mitigating emissions through carbon removal. Emissions reductions, including decarbonisation of industry and personal consumer spending, will be challenging in our modern world, but represents the more practical option.

For simplicity in facilitating personal behaviour change, the typical UK resident's average carbon footprint can be split into four key categories: food, home and accommodation, travel, and everything else[45]. We shall use these four key categories to comment on the results, and to suggest where the local councils and partners could target initiatives aimed at behaviour change.

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

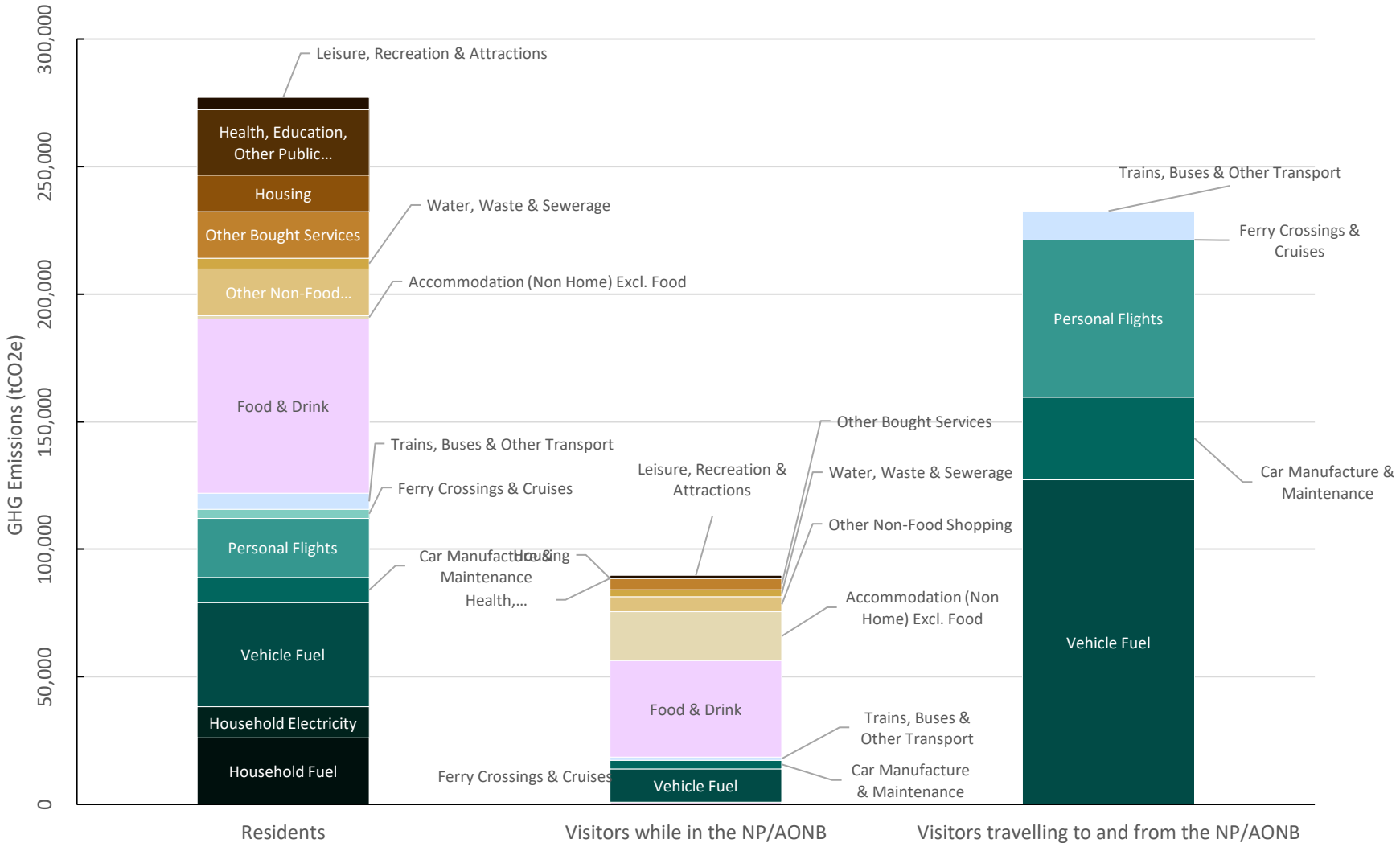
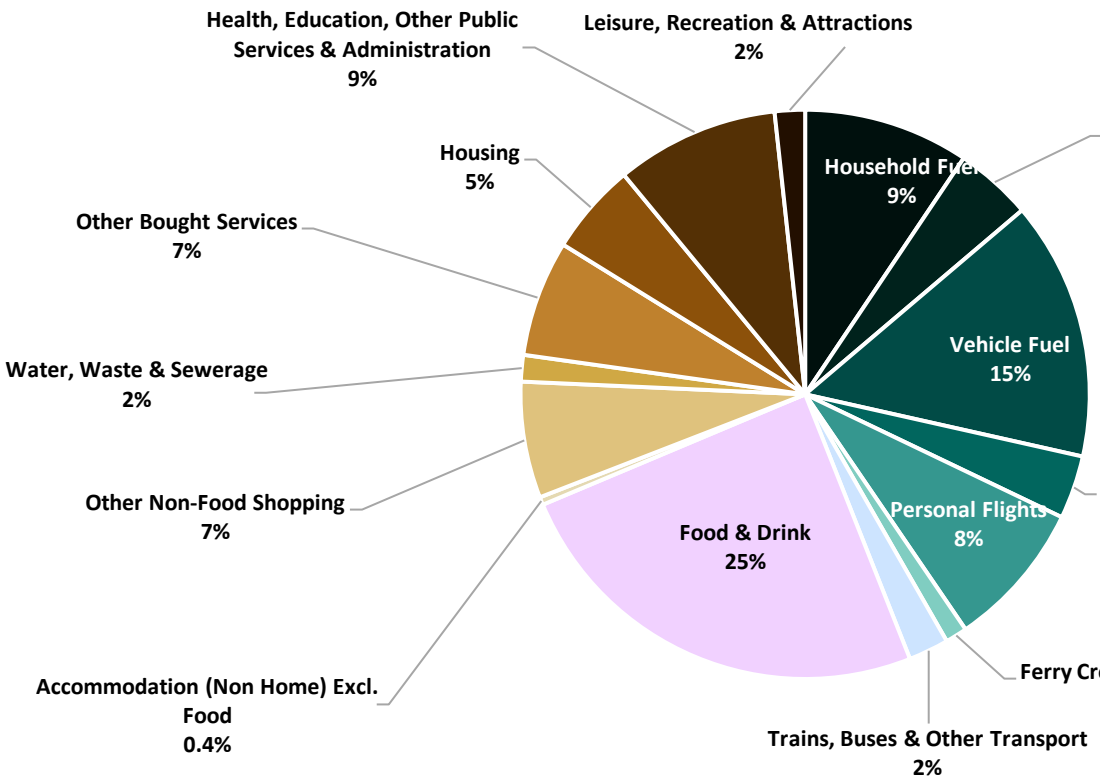
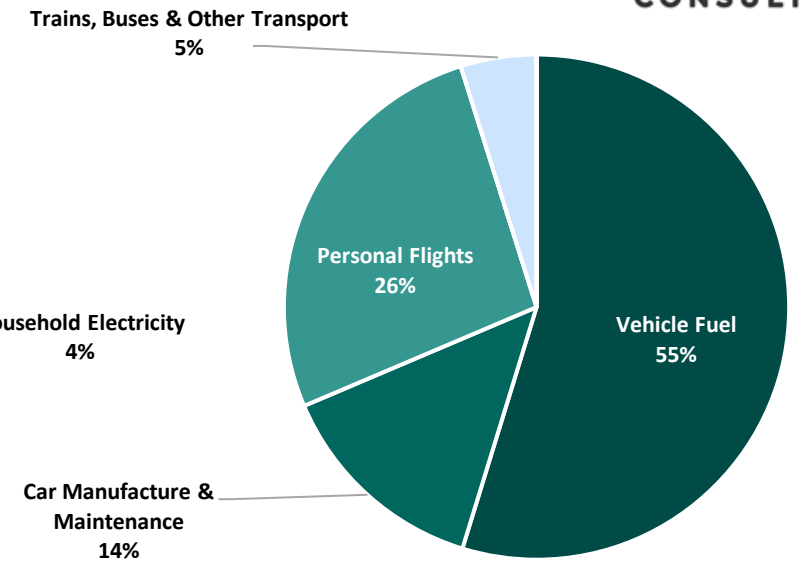


Figure 9: A consumption-based assessment of emissions relating to residents, visitors, and visitor travel to and from the Cairngorms National Park.

Residents: 277,145 tCO_2e



Visitor travel to & from the area: 232,591 tCO_2e



Visitors while in the area: 89,788 tCO_2e

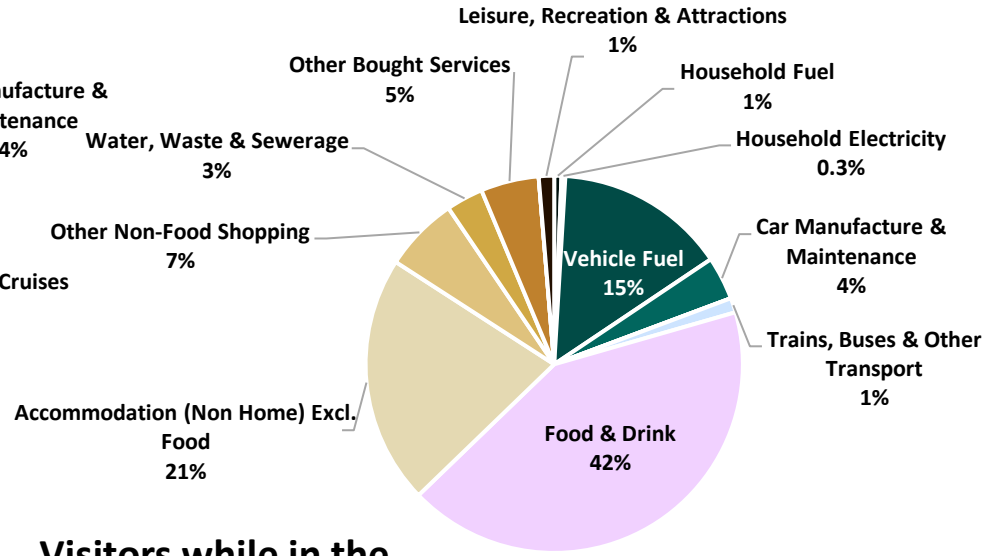


Figure 10: (left) Residents' GHG emissions in Cairngorms National Park by percentage (Repeat of Figure 2).

Figure 11: (top right) Visitors' GHG emissions on the way to & from Cairngorms National Park by percentage (Repeat of Figure 3).

Figure 12: (bottom right) Visitors' GHG emissions while in Cairngorms National Park (Repeat of Figure 4).

5.2. Residents' and visitors' GHG footprint components

Cairngorms residents' emissions totalled 0.277 million tCO_2e in 2019, with the highest emissions arising from the Food and Drink (25%), Vehicle Fuel (15%) and Household Fuel (9%) categories (followed closely by Health, Education, Other Public Services & Administration).

GHG emissions produced by visitors to the Cairngorms totalled 0.322 million tCO_2e in 2019, comprised of 232,591 tCO_2e linked to travel to and from the Park, and 89,788 tCO_2e produced while in the Park. The chart presenting visitor travel to and from the National Park indicates that GHG emissions are dominated by Vehicle Fuel (55%) and Personal Flights (26%), with only 5% arising from the remainder of public transport. Of the footprint of visitors while in the Park, 42% is linked to Food and Drink, while Accommodation (Non-Home) – excluding Food – accounts for 21%.

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 Cairngorms is considerable: for residents it is 68,360 tCO_2e (25% of residents' total), and for visitors it is 37,920 tCO_2e (42% of visitors' total); see Appendices 10.5 and 10.6 for further details.

"Buy local, eat local" has become a common aspiration among the more environmentally aware, along with eating seasonal fruit and vegetables, and varying traditional eating patterns to include more plant-based protein and meal choices (a "flexitarian" diet). It is also possible to use carbon intensity as the basis for choosing which meat to consume, with beef having the highest intensity, then in descending order: lamb, pork and chicken[46]. As well as alleviating the burden on the environment, these kinds of dietary choices can also help individuals live healthier lifestyles. This is because red meat (beef, lamb, pork) as a source of protein and fat is typically a food with moderate-to-high calorie density, and therefore needs to be consumed in moderation for a balanced healthy diet. Lean protein sources like turkey and chicken, on the other hand, have a low-calorie density. The number of calories people consume as they eat and drink has a direct impact on weight, with obesity being a key risk factor for long term conditions in later life.

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 production and consumption seem to be one of the hottest and most polarising topics, particularly given the potential impact on farming livelihoods and traditional lifestyles. We suggest that these complex topics would benefit from a collaborative approach between the agricultural industry, public health bodies and other stakeholders involved, with the goal to implement a fair and just transition of the broader food system. This needs to be done by working with and supporting the agricultural sector through change and reflecting on the

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

food security issues (Section 5.6.4). Farmers are facing a difficult socio-economic context as they try to respond to climate change, achieve biodiversity net gain and produce food, while also facing the challenge of an ageing workforce and workers opting to leave the industry.

Based on the science, the "National Food Strategy for England, Independent Review of England's food chain from field to fork" outlines a number of recommendations for government, with a formal response to be released in a white paper expected imminently[49]. The recommendations are targeted on achieving shifts in the national diet by 2032 (compared to 2019) to meet commitments aimed at improving health, climate and nature, including: a 30% reduction in meat consumption; a 30% increase in the consumption of fruit and vegetables; a 50% increase in fibre intake; a 25% decrease in consumption of foods high in fat, sugar and/or salt[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. Being overweight is associated with many of the most common long-term health risks, i.e. coronary heart disease, hypertension (high blood pressure), liver disease, osteoarthritis, stroke, type 2 diabetes and cancer. According to data from the Department of Health: "people with long-term conditions account for about 50% of all GP appointments, 64% of all outpatient appointments and over 70% of all inpatient bed days"[52], and treatment and care for people with long-term conditions is estimated to absorb around £7 in every £10 of total health and social care expenditure (Department of Health, 2012).

These discussions present significant challenges for the agriculture industry, regarding how to transition given the implications for livestock and food production in the UK. The National Farmers' Union (NFU) is aware of these and has set the goal of reaching net zero greenhouse gas (GHG) emissions across the whole of agriculture in England and Wales by 2040[53]. NFU Scotland is yet to publish a net zero target but acknowledges the role of Scottish agriculture in reducing emissions. 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 53,881 tCO_2e (19%) of the GHG footprint of Cairngorms residents, and 20,016 tCO_2e of the visitors' footprint (22% of their in-Park footprint). We considered the following components: household fuel, 26,083 tCO_2e (8% of residents' total

[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.

footprint); housing, 14,399 tCO_2e (5%); household electricity, 12,163 tCO_2e (4%) and accommodation away from home, 1,236 tCO_2e (0.5%); see Appendix 10.5 for further details.

The single biggest intervention the public can readily make is changing their energy supplier (switching to one that is divesting from fossil fuels) and actively sourcing a supply derived from genuinely renewable energy, e.g. solar, wind, tidal and/or hydro-electric power. The public generally lack knowledge about where their household energy comes from, with many consumers not being able to distinguish between:

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

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

5.2.3. Travel

Travel produces the majority of the GHG footprint of Cairngorms visitors: 250,192 tCO_2e, including all emissions from travel to and from the Park, and 20% of emissions while in the Park (78% of the total footprint of the visitors). The majority of this travel footprint comes from fuel burned in private vehicles (140,480 tCO_2e; 44% of visitors' total); personal flights (61,732 tCO_2e; 19%); vehicle manufacture and maintenance, (11%); and a small amount from trains, buses and other transport (4%).

Travel accounts for 30% of the residents' GHG footprint. In considering residents' travel we looked at vehicle fuel (40,769 tCO_2e; 15% of residents' footprint); personal flights (23,171 tCO_2e; 8%); vehicle manufacture and maintenance (9,974 tCO_2e; 4%); trains, buses and other transport (6,333 tCO_2e; 2%); and ferry crossings and cruises (3,438 tCO_2e; 1%); see Appendix 10.5 for further details.

Car travel is the single largest contributor to the overall footprint of the Cairngorms National Park (38% of the combined footprint of the residents and visitors).

All National Park users – whether visitors travelling to and from, or residents travelling locally – could benefit from work undertaken with local authorities to promote the use of public transport. This could explore mechanisms to help fast-track electrification of public-use vehicles such as buses, taxis and hire vehicles, and to influence Government to support the transition from diesel-powered to electric trains. The National Park is already cognisant of potential public transport improvements as outlined in its Regional Spatial Strategy, such as improvement potential for transport hubs with

better design, promotion of local rail services, new cycle-friendly bus services, and the National Walking and Cycling Network.

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

The vehicle type also affects the GHG impact. A trip from Manchester to London in an average petrol car would produce 0.11 tCO_2e of emissions, including the embodied emissions of the vehicle and its fuel. For the same journey an ordinary hybrid vehicle produces 0.08 tCO_2e, and for a plug-in electric hybrid car the figure is 0.07 tCO_2e. The average diesel car's greenhouse gas emissions are slightly lower than for petrol, at 0.10 tCO_2e, but bear in mind that while diesel vehicles produce less CO_2e per mile and deliver better fuel economy than petrol vehicles, they may perform less well in terms of soot and nitrogen oxide production. Exhaust fumes are a key contributor to air pollution, so the cleanest choice is an electric car, which would also produce the lowest emissions: 0.04 tCO_2e[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 Cairngorms 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 1.3 tCO_2e in a year and bring co-benefits for health.
- Emissions would be reduced if more people travelled more often by bicycle, perhaps on an electric bike which uses just 5% of the energy per mile of an electric car.
- Driving outside the rush hour avoids prolonged time at low vehicle speeds: an average car crawling five miles each way emits 22 $kgCO_2e$ a day, which over a year would equal 4.8 tCO_2e.

[55] Like all other road vehicles, electric cars emit particulates from tyres and brakes. Compared to tailpipe exhaust, emissions from electric vehicles mostly impact air quality rather than the climate. Since electric cars tend to be heavier on average than conventional cars, due to the battery, their emissions from tyres are marginally higher. Conversely, thanks to regenerative braking into the battery, electric cars' emissions associated with braking are lower than for 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."

- When replacing an ageing medium family-size car, downsizing to a small petrol car would save 1.1 tCO_2e a year.
- When replacing an ageing large car, downsizing to a medium family-size petrol car would save 2.7 tCO_2e a year.
- If affordable, replacing a large car with an electric hybrid car would save 4.49 tCO_2e a year. Switching to a fully electric car would provide further footprint reductions.

Where hire cars are used, it may be beneficial for the National Park to work with local providers to fast-track electrification of vehicles. Increasing the availability of electric car charging points could encourage visitors to travel by electric vehicle.

Another key issue for the National Park is international visitor travel. While it is in the economic interest of the Park to encourage overseas visitors, it is notable that the average stay by non-day visitors is just over 3 days, which means that encouraging longer stays will reduce the per-trip share of the emissions from flying. Another approach 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.

Many of the 22 projects proposed in the Heritage Horizons Programme relate to implementing and improving infrastructure for sustainable travel. It may therefore be beneficial to incorporate the findings presented here in the following workstreams:

- Sustainable Transport in Deeside & Angus focused on delivering electric public transport for the local community and visitors;
- Active travel in Badenoch and Strathspey focused on creating infrastructure to connect communities and provide alternatives for car use;
- Development of an integrated E-bike network and Active Travel Plan for the whole of the Cairngorms National Park.

Embedding our findings within these projects could act as an enabler to significantly reduce the GHG footprint associated with the Cairngorms National Park's travel in the coming years.

5.2.4. Everything else

The remainder of the residents' footprint consisted of: public services including health and education (25,679 tCO_2e; 9% of residents' footprint); other bought services (18,286 tCO_2e; 7%); other non-food shopping (18,317 tCO_2e; 7%); leisure, recreation and attractions (4,763 tCO_2e; 2%); and waste, water and sewerage (4,173 tCO_2e; 2%). The remainder of the visitors' emissions arose from: water, waste and sewerage (2,847 tCO_2e; 3% of the in-Park footprint), other non-food shopping (5,749 tCO_2e; 6%); other bought services (4,471 tCO_2e; 5%), and leisure, recreation and attractions (1,184 tCO_2e; 1%).

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

We suggest that the role played by the National Parks in enabling the public to access green/blue space – known to support mental and physical well-being – should not be underestimated. Recent research by White *et al.* (2019) identified that the amount of recreational time individuals need to spend in natural environments in order to gain self-reported health and well-being benefits is at least 120 minutes per week[59]. White *et al.* (2010) also suggest that green space combined with aquatic blue space (water) offers enhanced perceived benefits, which can be incorporated into landscape design and opportunities for improving public accessibility[60].

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

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

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

E.g.

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

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

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

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

Encouraging a circular economy within the National Park and its neighbouring Local Authorities may help reduce the emissions associated with goods and services. A circular economy is a model of production and consumption that involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible, rather than throwing them away and buying new.

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

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

[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.

[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.

Another issue to bear in mind are the interventions to "slow the flow" in flood risk areas. When choices are made around nature-based solutions in upstream areas, or civil engineering solutions downstream which are likely to use cement in their construction, we suggest that both cost and carbon benefits are considered when undertaking option appraisals. The new National Park Partnership Plan addresses these issues in the Green Engineering policy section[61].

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

Figure 13 compares the average per capita footprint of the Cairngorms residents' footprint with the UK national average.

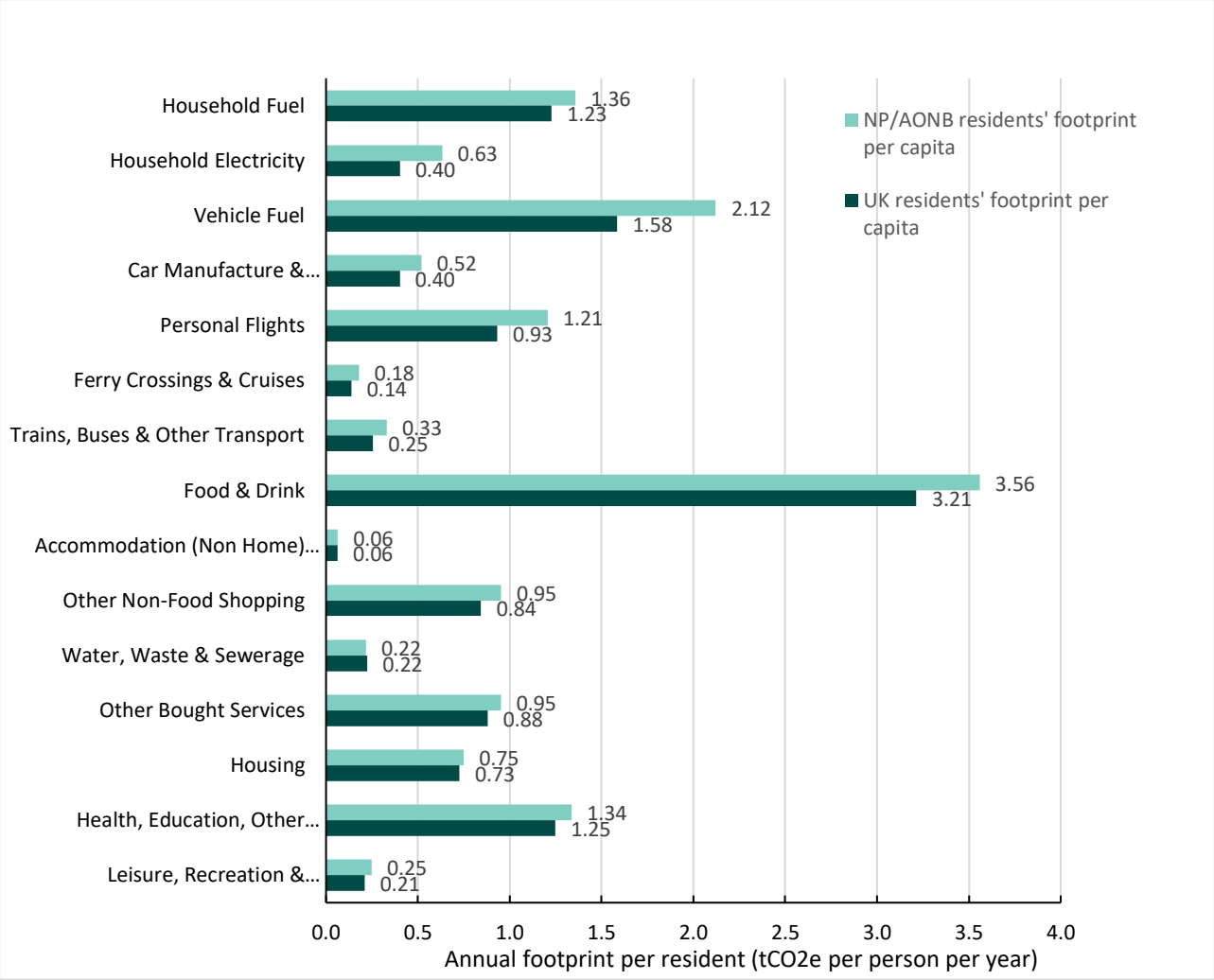


Figure 13: Residents' GHG footprints compared between Cairngorms National Park average and the UK national average

5.3. Industry assessment

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

[61] "Cairngorms National Park (2022) Draft National Park Management Plan 2022-2027."

5.3.1. Scope of industry assessment

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

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

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[62]. For transparency we include the IDBR broad industry group structure and see how this compares with the SIC (2007); see Appendix 10.7.1. When interpreting the results, please note that the IDBR production category includes mining, quarrying and utilities (Division 05/09, 35/39); added together with manufacturing (Division 10/33). Similarly, the SIC (2007) code "arts, entertainment and recreation" is aggregated to include: "Other service activities; activities of households as employers; undifferentiated goods-and-services-producing activities for own use; and activities of extraterritorial organisations and bodies", Division 90/99 respectively.

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

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

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

We now consider the results for industry-related GHG emissions in the National Park, which total 64,853 tCO_2e. Figure 14 highlights agriculture, forestry and fishing as the largest source of GHG emissions (19,356 tCO_2e; 30%), followed by accommodation and food services (10,305 tCO_2e; 16%) and construction (7,224 tCO_2e; 11%); see Appendix 10.7.2. Industry-related flights are estimated to account for 9,754 tCO_2e of the total footprint but are not separately categorised. Each of the main contributing categories is discussed in turn below.

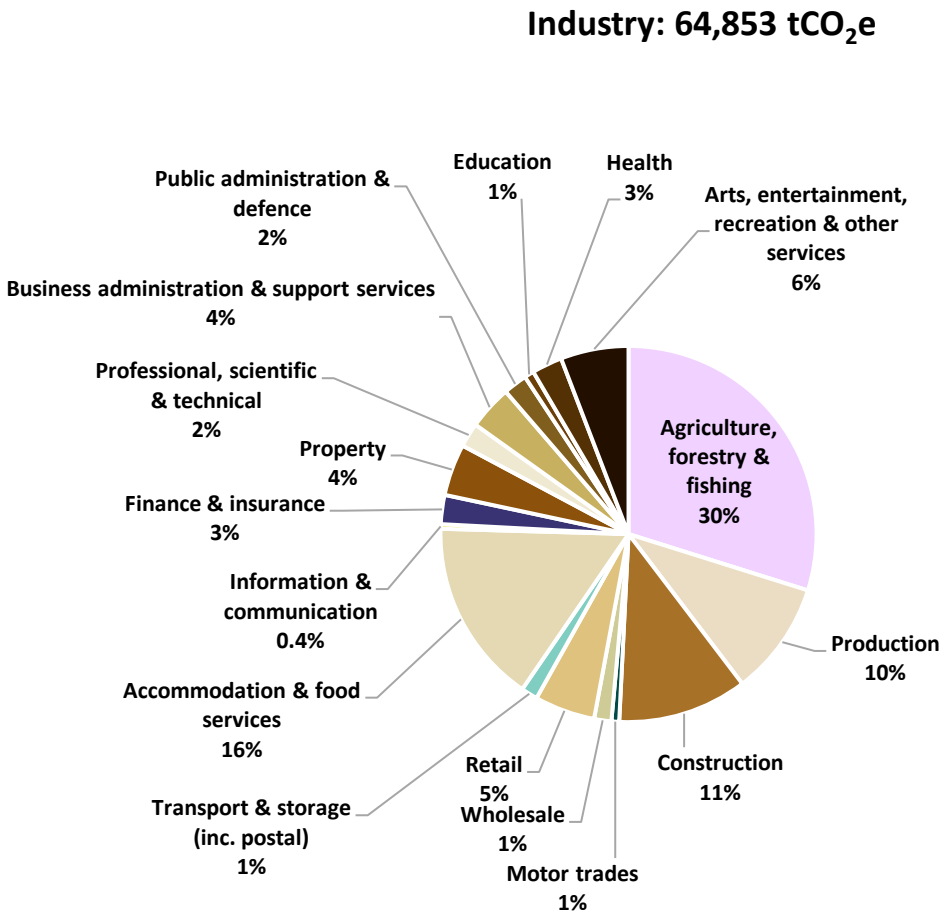


Figure 14: An estimate of emissions from industries within the National Park and their supply chains (scopes 1, 2 and upstream scope 3)

Agriculture and forestry

According to the IDBR-based estimates, agriculture and forestry is the largest industry sector in terms of GHG emissions in the Cairngorms National Park (19,356 tCO_2e; 30%). The issues pertaining to this industry are discussed in detail under Sections 5.2.1 (Food), 5.2.4 (Everything else), 5.6.4 (Agricultural landscape and food production) and 5.6.5 (UK timber production context).

Local knowledge suggests that the majority of the farms in the Park rear cows and sheep. Most of the crops cultivated in the Park are grown to feed livestock, although barley is also grown to supply local whisky distilleries[63]. The rearing of livestock, especially ruminants such as cows and sheep, is

[63] https://cairngorms.co.uk/discover-explore/landscapes-scenery/farms-crofts/

likely to be the key driver of the agriculture footprint of the Park. One of the proposed projects in the recent Heritage Horizons Programme is for "Cairngorms Future Farming". The aim of this project is to demonstrate that zero-carbon farming is not only possible but also profitable in the Cairngorms National Park. We therefore suggest that farmers not already implementing sustainable farming practices consider doing so in order to help reduce the footprint associated with food production, which also aligns with the objectives of the new Cairngorms National Park Partnership Plan[64].

Members of the National Park's agricultural industries may wish to read and reflect on the Sixth Carbon Budget (2020) "Agriculture and land use, land use change and forestry" report, which 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 (dairy farms only), 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 the numbers of cattle, sheep, pigs and poultry reared, in response to technological and dietary changes, thereby reducing areas of grassland and cropland, as well as shifting to new hydrogen technology. JCB, for example, have developed a prototype hydrogen tractor, so there may be benefits in the LEP collaborating with manufacturers that can facilitate, even accelerate, such a transition. Moving some production to greenhouses and vertical urban farms, collectively referred to as indoor horticulture, is also likely going to be required to make the UK self-sufficient in terms of food while enabling large-scale nature recovery programmes. Such technologies have been piloted successfully by other countries including the Netherlands, which has become the second-largest food exporter globally despite its comparatively small land area. Changes to a more plant-based diet will go hand in hand with the recommended scaling up of indoor horticulture. In terms of innovations, options such as lab-grown meat and insects as new sources of protein should also be on the table.

Other opportunities relate to improving productivity and efficiency, with a headroom to increase average crop yields from around 8 t/ha at present to around 11 t/ha. However, climate change is likely to pose additional risks to yields. The report suggests land management measures such as increasing soil quality, smaller tillage, nutrition and pesticide management, and opportunity mapping. Innovations in breeding are also discussed along with increasing stocking density. Another key suggestion is increasing paddock grazing to 80%, which improves the quality of grass and enhances sequestration of carbon in the soil. The report suggests that only 50% of the grass produced is actually eaten.

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

The strategic importance of and the issues facing the UK's and Scottish forestry industry are described in Sections 5.6.1 and 5.6.5. Timber production can be an important contributor to long-

[64] "Cairngorms National Park (2022) Draft National Park Management Plan 2022-2027."

term carbon sequestration efforts, while making the UK more self-sufficient in timber is important for reducing the country's global land use footprint. However, trees grown on peat soils, particularly on deep peat, could be a net source of emissions due to the resulting peat drainage and degradation[65], which calls for careful considerations when siting new productive woodlands and managing the existing ones.

Accommodation and food services

The second-largest industry for GHG emissions is accommodation and food services (10,304 tCO_2e; 16%), so there is a considerable opportunity for this sector to reduce its emissions. An estimated 48% of visitors to the Park stayed overnight; of these, 42% stayed in a hotel, motel, hostel, guest house or bed and breakfast, with a further 13% staying in a campervan, motorhome, or tent on a serviced site[66]. The accommodation sector accounts for around 9 million tCO_2e every year in the UK as a whole (over 1% of the UK's total annual emissions). Around 30% of this footprint is assigned to gas and electricity, 26% to food and drink, 6% to air travel and a further 6% to vehicle fuel[67].

Therefore, the biggest impact for accommodation and food services in the Cairngorms National Park would be for businesses to reduce their energy footprint, and thus GHG emissions. As outlined in section 5.2.2 (Homes and accommodation away from home), switching to a renewable energy supplier and/or installing renewable electricity sources, such as solar and wind, on-site would be the most impactful action in this area. Reducing gas and oil consumption by improving heating and insulation in buildings and by installing a renewable heat source such as heat pumps would also significantly cut emissions in this area. Improved insulation plays a significant part in reducing energy usage. Heating is likely to be a particularly large source of emissions in the Cairngorms due to the cold winter climate, presenting local challenges.

The second biggest impact would be for this sector to offer more sustainable food choices to consumers, as discussed in section 5.2.1 (Food). Some suggestions for achieving this include offering more plant-based options, increasing local production and consumption of seasonal arable and horticultural produce (where possible), reducing the content of meat and dairy (especially for beef and lamb), and reducing air-freighted or hot-housed foods in favour of shipped or frozen produce. Limiting food waste would also significantly reduce this sector's carbon footprint. Over 9.5 million tonnes of food are wasted in the UK each year, accounting for around 36 million tonnes CO_2e[68]. To reduce food waste, accommodation and food services can make sure they do not offer excessive portions and use kitchen leftovers for future meals.

Finally, reducing emissions arising from travel, as outlined in section 5.2.3 (Travel), by reducing flight emissions and using public transport options where possible, while simultaneously facilitating electrification of transport, would be the third most impactful action for this sector to reduce its emissions.

[65] Ricardo Energy & Environment UK NIR 2020 (Issue 1) UK GHG Inventory 1990-2019 Annex p. 854.
[66] "Cairngorms National Park Authority Visitor Survey, 2019-2020."
[67] Berners-Lee, M. (2020), "How Bad Are Bananas? The Carbon Footprint of Everything," p.109-111.
[68] WRAP 2018, "Food surplus and waste in the UK – key facts."

Construction

We estimate that construction is the third-largest GHG-emitting industry in the Cairngorms National Park (7,224 tCO_2e; 11% of total industry emissions). This aligns roughly with the UK as a whole; the Sixth Carbon budget (2020) report section on "Manufacturing and construction" showed that GHG emissions from this sector contributed 12% of the total production-based UK GHG emissions in 2019.

One of the key policy opportunities in the Cairngorms Local Development Plan is the aspiration for new housing development, which may significantly impact on the Construction industry footprint in the Park.[69] As stated in section 3.1, the Cairngorms has an increasing population of older residents[70]. Current policies are therefore in place for new, affordable housing development to attract more working-age people to live in the Park. The priority for housing is to construct new-builds, and to expand existing rural communities outwards without increasing the number of existing buildings by more than a third, and where this is not possible, to build homes on rural brownfield sites.[71]

In addition, there are two historic and architecturally significant buildings located on large estates within the Park: Balmoral Castle and Blair Castle. The former is privately owned, whereas the latter appears to be owned by the Blair Charitable Trust/the Bruar Trust. The upkeep of these buildings may also have an impact on the Cairngorms NP's construction footprint, and present challenges due to their nature as heritage buildings.

Taken together, the construction of new houses and the upkeep of the historic buildings in the Park will almost certainly increase the footprint of the Park's construction industry in the coming years, so we suggest that sustainable construction practices should be applied wherever possible to minimise GHG emissions in this sector. 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.

[69] "Cairngorms National Park Local Development Plan 2021," p. 21.
[70] National Records of Scotland (2020), "Sub-national Population Projections for Scottish Areas (2018-based): Data Tables."
[71] "Cairngorms National Park Local Development Plan 2021," p. 22.

- 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[72].

Production

Production (referring to manufacturing industries) is estimated to account for around 10% of the . of total industry emissions in the Park. The Cairngorms National Park Partnership Plan (2017-2022) suggests that manufacturing makes up roughly 6% of the business base, which would correspond to the employment of over 600 people.[73] Of note, the Cairngorms National Park is famous for its whisky and beer production, and is currently home to eight distilleries and at least 20 breweries.[74] Brewing and distillation are therefore two of the biggest production industries in the Park, and as mentioned in the Agriculture section, locally grown barley is often used in the production process. Local Enterprise Partnerships may therefore wish to focus efforts on encouraging these brewing and distillation companies to undertake assessment of their Scope 1, 2 and 3 GHG emissions. We suggest giving priority to carbon reduction planning, in order to decarbonise these industries and reduce the Park's production footprint.

IDBR and GVA-based emissions comparison

We undertook a comparison between IDBR data and GVA data, as we know that economic reporting often uses GVA as the primary measure upon which many LEPs base their workforce planning, see Appendix 10.7.3. When the GVA dataset is compared to IDBR, this indicates a potential over-reporting of GVA-based emissions from agriculture, production and construction (Figure 15). The National Park may wish to discuss this with Local Enterprise Partnerships in the area.

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

[73] Cairngorms National Park Partnership Plan 2017-2022, "Strategic Environmental Assessment Scoping Report. Appendix 2: Environmental Baseline Topic 8: Population and Human Health," p. 185, Fig. 99.

[74] https://www.visitcairngorms.com/things-to-do/attractions-sightseeing/distilleries-breweries-cairngorms/.

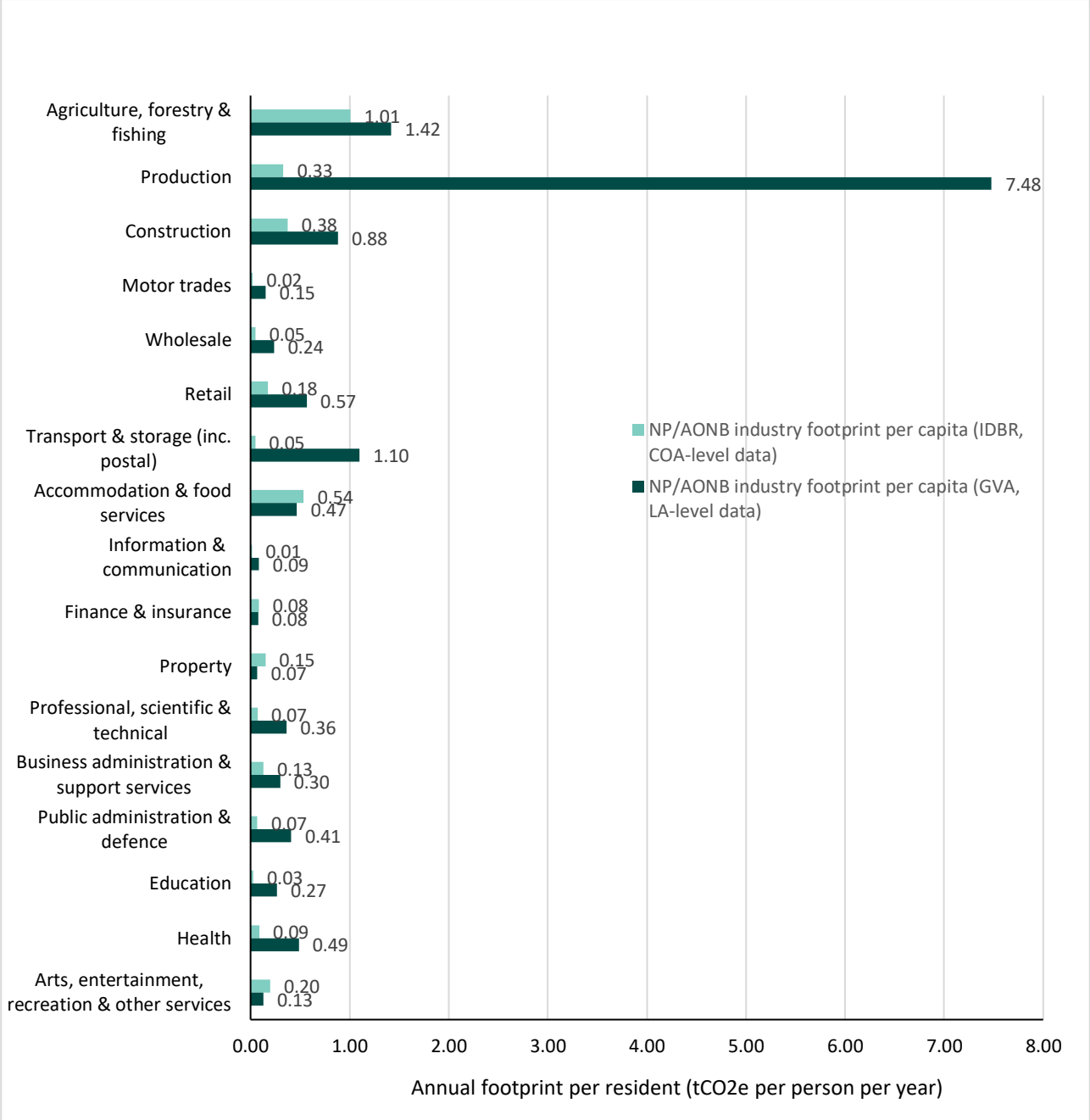


Figure 15: Cairngorms National Park Industry Footprint Estimates: IDBR vs GVA

5.3.3. Energy-only industry analysis

This analysis is a subset of the industry carbon footprint estimate. Energy is estimated to make up 48% of emissions from industry (31,334 tCO_2e). Table 2 shows the breakdown of industry emissions from electricity and fuels for the Cairngorms.

Table 2: Energy-only industry (subset of industry) – Cairngorms National Park

Industry Electricity	9,206 tCO_2e per year
Industry Fuels Excl. Road	13,872 tCO_2e per year
Industry Road Fuels	8,255 CO_2e per year
Total	**31,334 tCO_2e per year**

5.3.4. Large emitters analysis

As a further component of the industry GHG footprint analysis, the BEIS Pollution Inventory (2018) enables us to identify specific large emitters within each UK National Park (see Appendix 10.7.4). The estimated total volume of carbon dioxide relating to large emitters in the Cairngorms is zero tCO_2. 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[75].

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 Cairngorms, a total of 4.2% of the estimated business turnover has been suppressed in the COA-based dataset.

5.3.5. Comparison of annual industry footprint with UK averages

It may be helpful for the National Park to compare itself with the UK national average for each industry category. This helps to identify patterns and pinpoint where it would be beneficial to focus partnership-working with Local Authorities. The results (Figure 16) show higher-than-national-average figures for: agriculture, forestry & fishing, accommodation and food services, and arts, entertainment, recreation, and other services.

As background to influencing change, the UK Government enacted legislation on the 1st of October 2013 making it mandatory for the UK's largest quoted companies to report their GHG emissions (Statutory Instrument (SI) 2013/1970:5). In 2018, this SI 2013 was amended to include "emissions, energy consumption and energy efficiency action by quoted companies" (SI 2018/1155, Part 6) to reflect the true impact of their operations[76]. This was extended to all large companies, including the public sector. Due to this legislation, one should expect all large organisations to be in the process of assessing their full GHG emissions and preparing carbon reduction plans aimed at reaching net zero. However, large businesses fall under the new statutory reporting requirements and are new to carbon accounting may find the process challenging, so joined-up approaches may be helpful, particularly in the public sector.

Some organisations are attempting to encourage a sector-wide approach, e.g. the National Farmers Union of Scotland 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.

[75] "UK local authority and regional carbon dioxide emissions national statistics: 2005-2018."
[76] "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.

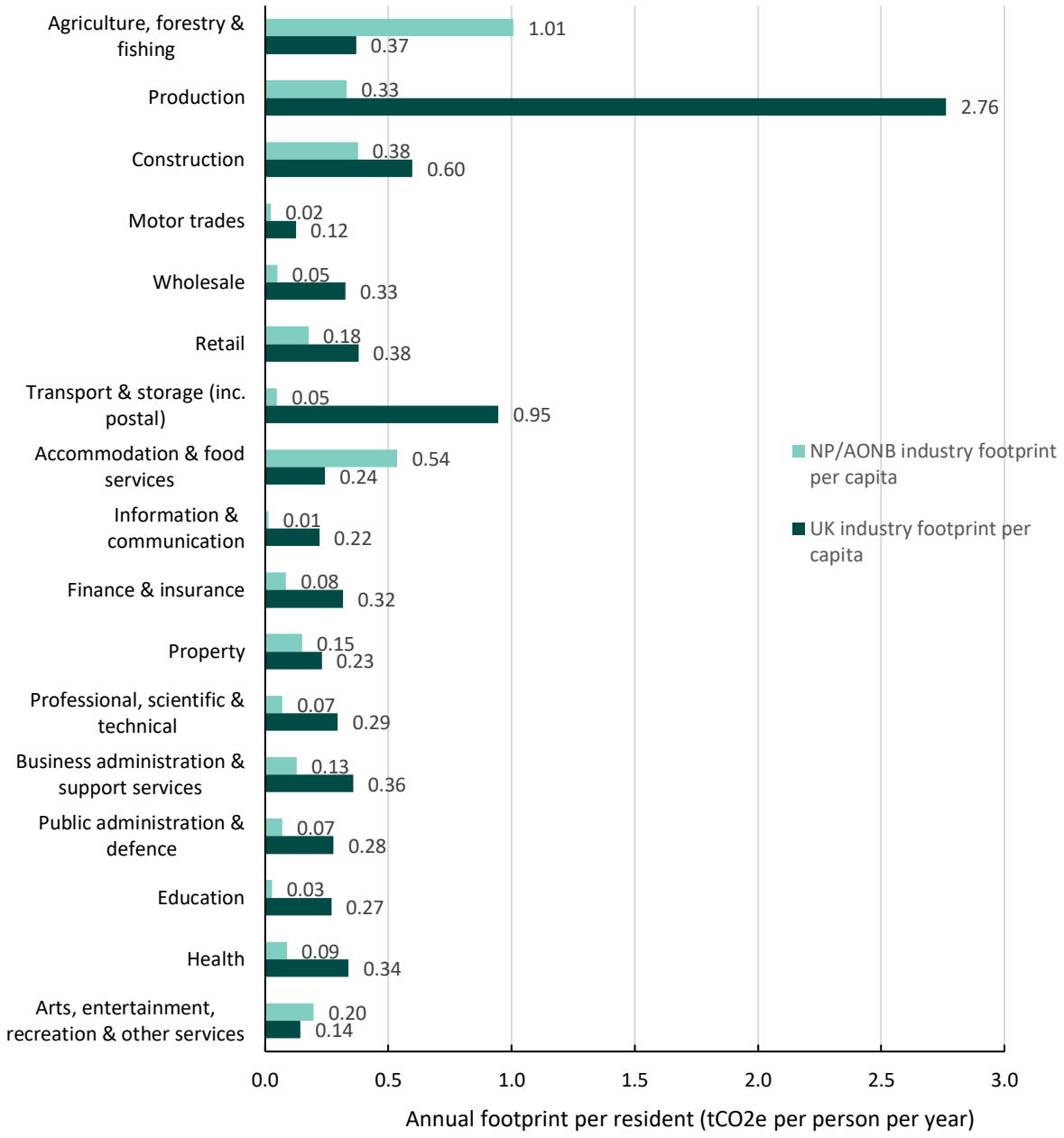


Figure 16: Cairngorms National Park industry GHG emissions compared with UK national average, by sector.

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

The analysis of the impact of through-traffic has been included at the request of several National Park Authorities and Local Authorities for AONBs (see Appendix 10.8). Through-traffic refers to vehicles passing through the National Park or AONB without visiting, regardless of their origin and destination. Its footprint is estimated by comparing total traffic point counts with pump-level fuel sales within each National Park or AONB, along with assumptions about commuting in out of the area. The estimate represents the emissions from through-traffic that occur within the geographical

boundary of the National Park or AONB, unlike the total driving footprints of the residents and visitors that mostly occur outside of the boundary. The purpose of reporting the through-traffic emissions is to show how much of the geographical footprint due to road traffic within the National Park or AONB boundary is not related to living in or visiting the area, which could be used to support new road electrification infrastructure as well as public transport.

For the Cairngorms National Park, estimated total through-traffic emissions from cars, buses, motorbikes, vans and lorries are **161,209 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 and B roads, which carry elements of through-traffic as well as traffic from residents, visitors and industry. The selected roads assessed for Cairngorms are the A9, A86, A889 and A95 (Appendix 10.8). The estimated footprint of these roads within the Cairngorms geographical boundary is 161,971 tCO_2e per year across all vehicle types. This amounts to around 58.4% compared to the total footprint of the residents.

5.5. Land use emissions

The land use sector differs from other sectors in the Greenhouse Gas Inventory in that it contains both sources and sinks of greenhouse gases. The sources, or emissions to the atmosphere, are given as positive values; the sinks, or removals from the atmosphere, are given as negative values, see Table 3. Our definition of the land use sector includes emissions from livestock (mostly methane), synthetic fertiliser use (mostly N_2O), degrading mineral and organic soils (peat) (mostly CO_2), and lost biomass (CO_2), as well as carbon sequestration in soils and biomass through woodland creation, peatland restoration and regenerative agriculture practices. The net land use GHG flux are 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 – Cairngorms National Park

Land use CO_2	-101,873 tCO_2e per year
Land use non-CO_2	85,612 tCO_2e per year
Total: Land use	**-16,260 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) through three subcontractors – Ricardo Energy & Environment, Centre for Ecology and Hydrology, and Forest Research – in accordance with the requirements to report UK Greenhouse Gas Emissions for the United Nations Framework Convention on Climate Change (UNFCCC). There is a risk that future improvements to the methodology for reporting land use GHG emissions might shift the sector from a net sink to a net source of emissions, as indicated within the Sixth Carbon Budget (2020).

There are no Government datasets for land use GHG emissions currently available for AONBs. As a result, we had to reconstruct them 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 10.8.8).

Although the latest (BEIS) land use emissions estimates (2019) are more accurate than in previous years, they remain subject to considerable uncertainty. This is due to an evolving methodology and a process to refine the measurement of emission factors for UK peatlands, attempting to take into account transitions from heavily modified peatlands (forested land, cropland, grassland, peat extraction, eroding bog) and semi-natural peatlands (heather-dominated and grass-dominated bogs). Peatlands in their semi-natural state may be near-natural, modified, or rewetted. The estimates for CO_2 emissions in the form of dissolved organic carbon (DOC) use Tier 1 emission factors, and therefore are the least robust of all (IPCC 2014). Tier 2 emission factors for the UK-relevant peat condition categories were subsequently developed by Evans *et al.* (2017), providing estimates for "particulate organic carbon" (POC) emissions, as well as direct CO_2 emissions. The Tier 2 estimations add more granularity and are country-specific, being tested for robustness using at least four different study locations considered reliable enough to replace Tier 1 values. The CARBINE Tier 3 carbon accounting model developed by Forest Research was employed to derive the emission factor for forested peatland between 1990 and 2019, and was tested using field data[77]. For the full set of assumptions made in order to estimate peatland emissions in the National Parks using the latest (2019) land use emissions data released by BEIS, please see Table 11 in Appendix 0 (Table A.3.4.28 in the BEIS methodology annex).

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

- The 25-Year Environment Plan[78]
- 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).

In total, peatlands cover more than 20% of Scotland's land area. It is estimated that 70% of Scotland's blanket bog and 90% of raised bog area has been damaged to some degree[79]. Scotland's National Peatland Plan outlines the government's aspirational targets for peatland restoration, and goes over and above the UK's Sixth Carbon Budget aspirations. We estimate that peatland covers over 133,500 ha in the Cairngorms National Park (29.5% of the Park's total land area),[80] of which nearly 100,000 ha are thought to be in various forms of modification and degradation. Restoring peatland can therefore make a very considerable contribution to reducing land-based emissions in the National Park.

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

[77] Ricardo Energy & Environment, UK NIR 2020 (Issue 1): "UK GHG Inventory 1990-2019," Annex p. 854.
[78] HM Government (2018), "A Green Future: Our 25-Year Plan to Improve the Environment."
[79] Scottish Natural Heritage, "Scotland's National Peatland Plan: Working for our future," p. 2.
[80] The estimate is based on the NatureScot Carbon and Peatland Map; see Appendix 10.9.8.

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 hectares-per-year targets for creating native non-commercial woodland, planting new commercial woodland,[81] restoring peatland, adopting agroforestry practices and increasing the extent of hedgerows (both of which improve grassland and cropland), adding legume species to improved grassland, and adopting winter cover cropping for cropland (if applicable).

Please note that the land use GHG estimates for National Parks are published by BEIS, and given the existing levels of uncertainty they are expected to change in the future. Any changes introduced to the figures may impact on the proposed glide paths to net zero for all the UK National Parks 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 -5.6.4 discuss the importance of woodland, peatlands, and agricultural landscapes when developing subsequent strategies for the implementation of LULUCF targets in supporting climate adaptation and mitigation.

5.6.1. Trees, woodlands and forestry

The notional target of 2,000 ha of new woodland per year proposed in Section 6 is based on apportioning UK-wide woodland targets from The Sixth Carbon Budget. 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 non-native conifers with native broadleaf/mixed/conifer species), peatland and protected habitats such as lowland heathland, while also reflecting on the agricultural make-up of the area. A detailed description of the methodology behind the woodland target is provided in Appendix 10.9.8. However, we recognise that this 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. We therefore also consider an alternative woodland target of 1,400 ha per year from the new Cairngorms National Park Partnership Plan[82].

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[83]. There are also practical considerations in the choice of tree species to foster long-term resilience to the anticipated average temperature increases, increased average rainfall, more frequent flood events, and more severe drought periods driven by climate change. The Met Office

[81] We do not consider mixed confer plantation in this exploratory scenario assessment and focus on a generic high-yielding variety in line with the Sixth Carbon Budget’s net zero scenario (Appendix 10.9.8). It is worth noting that current Scottish Government woodland scheme encourages diverse confer plantations; https://www.ruralpayments.org/topics/all-schemes/forestry-grant-scheme/woodland-creation/diverse-conifer/

[82] “Cairngorms National Park (2022) Draft National Park Management Plan 2022-2027.”

[83] Forestry Commission (2017), “The UK Forestry Standard: The governments approach to sustainable forestry.”

has recorded a 1.17°C increase in average monthly maximum temperatures over the last 60 years or so, for the weather station on the Cairn Gorm summit[84].

There is an added complication for the Cairngorms National Park due its comparatively low mean annual temperature of around 3.7°C, which is much lower than the averages for Scotland (11.7°C) and the UK (12.8°C)[85]. Winter temperatures are coldest in February, with temperatures at the Cairn Gorm summit typically ranging from -2.8°C to 0.3°C. July is the hottest month, with summer temperatures ranging from 8°C to 11.5°C. Therefore, temperature factors also affect the selection of "right tree, right place'" for the Cairngorms, including species, impacts on tree growth, and the best time of year for planting. Natural England *et al.* (2020) published a helpful report, worthy of review, considering the relative sensitivity of habitats to climate change[86]. Native tree species comprise 79% of the National Park's woodlands, representing a quarter of Scotland's entire native woodland resource[87]. However, productive and native conifer species overlap in the Cairngorms, where the native Scots pine is grown as productive commercial woodland. This is particularly notable given the importance of Scotland to UK timber production (see section 5.6.5 for further details).

Any new woodland planning requires multi-benefit opportunity mapping to identify the optimum strategic placement and economic considerations for farmers (e.g. "a wood that pays is a wood that stays"). Another key factor to consider is the UK's demand for productive woodland to supply the construction and biomass industries, along with sustainable woodland management.

The Cairngorms National Park's Forest Strategy (2018) already addresses some of the issues discussed in this section, even though it may need to be updated in light of the climate and biodiversity crises.

5.6.2. Local authority opportunities

There are other opportunities to establish trees, some of them particularly town-friendly, for example by 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, too, and the costs paid by local authorities to maintain these stretches can be reduced by changing grass-cutting regimes[88].

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[89]. In the UK, peat soils account for nearly 33% of land cover[90]. According to the UK Peatland Strategy (2018) peatlands form the UK's largest

[84] Met Office (2022) UK climate averages: Cairn Gorm Summit (Moray) Climate period 1961-1990.
[85] Met Office (2022) UK climate averages: Cairn Gorm Summit (Moray) Climate period 1991-2020. https://www.metoffice.gov.uk/research/climate/maps-and-data/uk-climate-averages/gfjkvjeuz
[86] Climate Change Adaptation Manual Evidence to support nature conservation in a changing climate.
[87] Cairngorms National Park (2013) "Cairngorms Nature Action Plan 2013-2018," p.12.
[88] Example pollinator strategies in Scotland: NatureScot (https://www.nature.scot/doc/pollinator-strategy-scotland-2017-2027); Stirling Council (https://www.stirling.gov.uk/news/2020/october-2020/new-pollinator-strategy-to-help-wildlife-and-nature-flourish/).
[89] IUCN National Committee United Kingdom (2021) "About Peatlands"; https://www.iucn-uk-peatlandprogramme.org/about-peatlands.
[90] IUCN National Committee United Kingdom (2018) "UK Peatland Strategy 2018-2040", p. 25.

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. In total, peatlands cover more than 20% of Scotland's land area[91].

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[92]. In Scotland, around 70% of blanket bog and 90% of raised bog areas are thought to have been damaged to some degree[93], with nearly 100,000 ha of peatland estimated to be in various forms of modification and degradation in the Cairngorms National Park alone (Appendix 10.9.8).

There are three broad peatland types 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, 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[94].

We therefore suggest that National Parks with peatland should continue assessing the peat condition and habitat types to enable priorities for peat restoration to be identified. It would also be beneficial to assess soil depth, and this 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. Working with Catchment Management Partnerships is therefore recommended.

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 17). Only 55% of food consumed in the UK (by economic value) is of UK origin, with 26% imported from Europe [95].

[91] Scottish Natural Heritage, "Scotland's National Peatland Plan: Working for the future."

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

[93] Scottish Natural Heritage, "Scotland's National Peatland Plan: Working for the future."

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

[95] 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 .

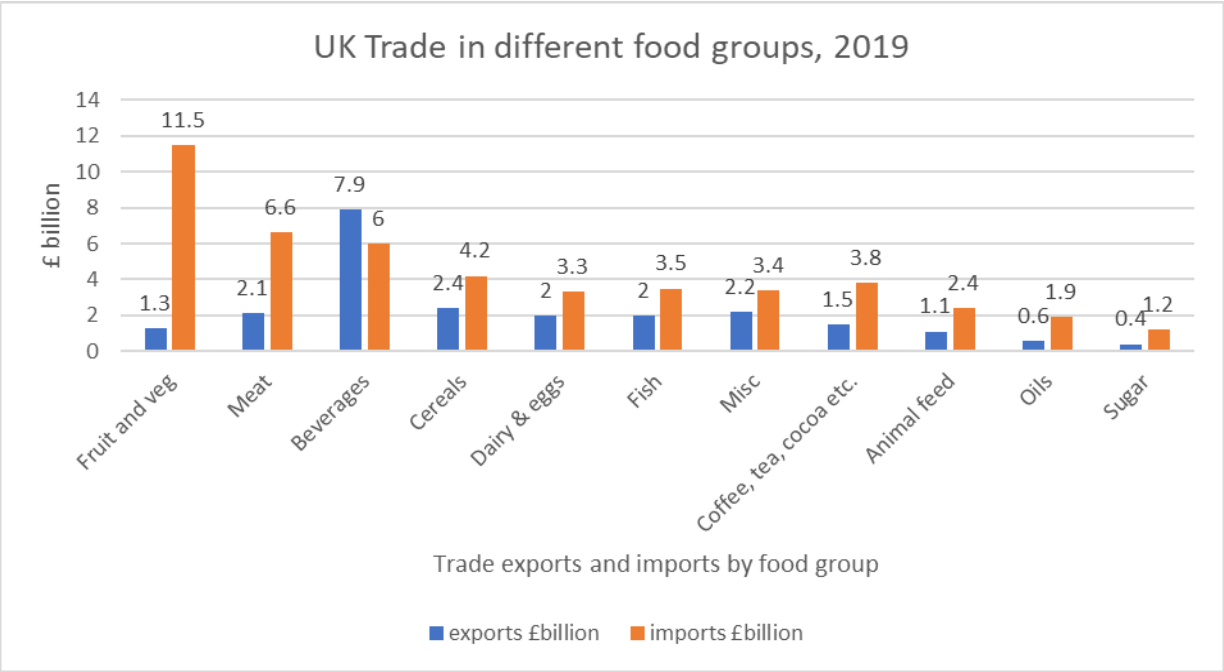


Figure 17: UK trade in different food groups, 2019

The Land Capability Classification for Agriculture used in Scotland ranks land on the basis of its potential productivity and cropping flexibility, determined by the extent to which its physical characteristics (soil, climate and relief) impose long-term restrictions on its agricultural use[96]. Seven classes are described:

- Class 1. Land capable of producing a very wide range of crops with high yields
- Class 2. Land capable of producing a wide range of crops with yields lower than Class 1
- Class 3. Land capable of producing good yields from a moderate range of crops
- Class 4. Land capable of producing a narrow range of crops
- Class 5. Land suited only to improved grassland and rough grazing
- Class 6. Land capable only of use as rough grazing
- Class 7. Land of very limited agricultural value

Level 6 and 7 may 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, it is suggested that all opportunity-mapping should be reviewed in the context of regional food production and security, given the UK is a net importer of food; see Figure 17. The Cairngorms National Park is an important regional food producer of beef, lamb, and mutton.

5.6.5. UK timber production context

Scotland is by far the largest producer of timber in the UK. However, the UK as a whole is heavily reliant on imported timber; timber products worth £7.5 billion entered the UK in 2020, compared

[96] https://data.gov.uk/dataset/72ba06ca-0239-4e99-a9ad-4a48f755a3bd/land-capability-for-agriculture-scotland

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[97]. 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[98]. Scotland could play a major role in helping achieve a much greater self-sufficiency in timber for the UK.

Figure 18 outlines UK timber production and trade as reported by Forest Research. Demand for wood from UK forests continues at unprecedented levels, but the market remains constrained by a lack of supply. There is rising demand for wood, but limited availability due to long rotation periods, diversification into tangible assets, and increasing recognition of the environmental benefits of woodlands. There may also be new opportunities for monetisation, such as woodland carbon code credits. Capital values are therefore rising, although there is concern within the industry as to whether this trend is sustainable. The value of growth for the UK forestry market in 2018 showed a 19% drop in supply; however, the overall market value went up by nearly 6%, meaning a 30% increase in the average value per gross hectare, although this value varies according to region. In contrast, Savills (2019) states that in the north of Scotland prices are relatively low and static, indicative of "the geography and productive capacity of the woodland resource, with large areas of low-quality softwood, remote from timber markets and often challenging to harvest"[99]. 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[100]. This is in contrast to carbon credits (for carbon sequestration) sold on the UK open market at £10-25 per tCO_2e[101] (Forest Research states 1.25 to 1.43 cubic metres per tonne for roundwood).

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

[98] 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/.

[99] Savills (2019) "The Forestry Market: UK Rural – March 2019," p.3.

[100] Forest Research (2021) Timber Price Indices https://www.forestresearch.gov.uk/tools-and-resources/statistics/statistics-by-topic/timber-statistics/timber-price-indices/.

[101] Strutt & Parker (2021) Rural Hub: "5 ways to generate income from carbon farming."

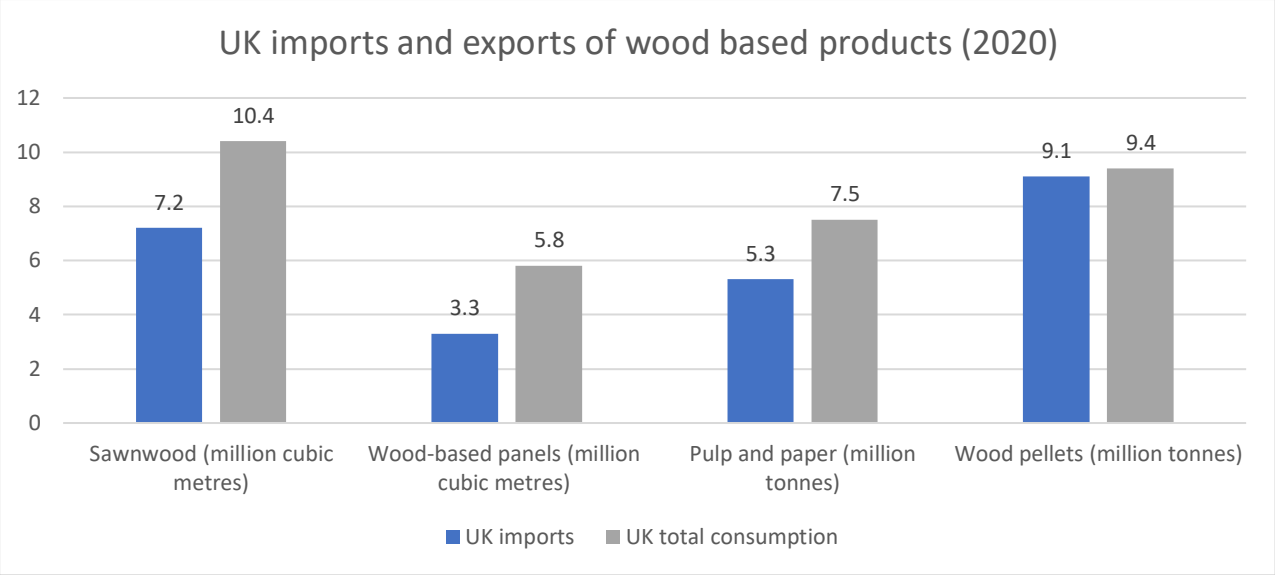


Figure 18: Self-generated from Forest Research (2021) UK Wood Production and Trade: provisional figures 2020 release

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

This section outlines the aspiration for the Cairngorms National Park in setting a challenging glide path to reach a consumption-based Net Zero by 2024 and beyond, to become a carbon sink as one of the "lungs" of Scotland, contributing to the UK's Net Zero target. It also outlines the planning assumptions used.

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

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

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 and contains elements of both the consumption-based and production-based footprint estimates (Section 4). The six target categories are summarised below, with further supporting data in Appendix Section 10.9.4.

- **Target Category 1: Energy-only greenhouse gas emissions.** This includes emissions relating to energy use within the National Park by residents, visitors and industry. It includes emissions from roads, except those from (estimated) through-traffic that does not stop in the National Park. This target has been chosen because relatively high-quality data is regularly published by BEIS, and because it covers a significant proportion of the total emissions. Furthermore, its selection allows us to draw on a robust tool developed by the Tyndall Centre for Climate Change to help local authorities establish Paris-aligned trajectories for energy-only emissions reduction in local areas.
- **Target Category 2: Food and drink consumed by residents and visitors.** This includes food and drink at the point of purchase in shops as well as from hospitality businesses. A food and drink target is important because when measured on a consumption basis, this category represents roughly a quarter of UK residents' emissions.
- **Target Category 3: Other goods purchased by residents and visitors while in the area.** This includes all purchases of tangible non-food and drink items such as clothing, electronic equipment, furniture, soft furnishings and cars. This target is important because it brings two particular elements into the landscape's carbon management agenda: sustainable consumption of non-edible products, and circular economy principles into the National Park's carbon management agenda.
- **Target Category 4: Visitor travel to and from the area.** We include here only travel within the UK, not visitor travel to the UK. International travel is omitted purely due to the practical

difficulty of tracking change (as described in Appendix 10.9), visitor aviation emissions are still an important consideration for policymakers.

- **Target Category 5: Land use non-CO_2 component.** This includes all net non-CO_2 emissions from land within the National Park, and most notably includes enteric emissions from ruminants, and emissions from manure and fertilizer use. A comparatively small contribution to the non-CO_2 land use emissions comes from a range of ecosystems, in both near-natural and modified states, for example from peatlands releasing methane.
- **Target Category 6: Land use CO_2 component.** This most notably includes emissions from degrading peat and carbon sequestration by woodland, farm trees, hedges and soils (including healthy peat) in the National Park. 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 modified practices for managing agricultural soils. Therefore, the CO_2 land use component could well enable "net zero" and "net negative" emissions in any of the National Parks.

Across these six categories, the 2019 consumption-based carbon baseline for Cairngorms National Park (with elements of production-based territorial emissions; Section 4) is estimated at 423,718 tCO_2e per year.

Following the principles outlined above, some components of the wider carbon footprint of the Cairngorms National Park presented in the previous sections have been excluded from the 2019 consumption-based carbon baseline and the associated emissions reduction targets. These excluded components are:

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

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

Our recommended target trajectories are summarised in Table 4 and represent the minimum that can be considered to be Paris-aligned, with the caveat that the chosen emissions baseline is

predominantly consumption-based with some production-based features (Section 4). For some of the target areas where primary data is lacking, an element of expert judgement has been applied to determine what is required. The targets have been set to fit with the best available science and the latest policy recommendation. Some or all will require appropriate support from government in order to be feasible, and part of the role of each Local Authority may be to push for the necessary support.

Table 4. Decarbonisation targets for the selected components of carbon footprint. For further details, see Appendix 10.9.4

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

The six elements outlined above can be combined into an overall decarbonisation pathway, which in the case of Cairngorms National Park results in a net zero date of 2024. Note that targets 1 to 4 should be adjusted in proportion to any significant changes in resident and visitor numbers in the National Park.

Each trajectory, apart from that for the land use CO_2 component, has been based on exponential decay (emissions decreasing by the same proportion each year) towards residual unavoidable emissions in the long run. The proposed reductions are broadly aligned with the Paris Agreement and 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 a 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. As a default for all National Parks and AONBs on the programme, the rate of change has been drawn from the Sixth Carbon Budget, apportioned to the Cairngorms National Park according to its land characteristics (see Appendix 10.9.8 for further details). The associated scenario is presented in Section 6.1. We also consider the National Park's own woodland expansion and peatland restoration targets included in the new Partnership Plan[102], which are introduced in a separate Section 6.2.

[102] "Cairngorms National Park (2022) Draft National Park Management Plan 2022-2027."

6.1. Scenario based on land use targets apportioned from the Sixth Carbon Budget

When the Sixth Carbon Budget's apportionment methodology is applied for the Cairngorms, 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 restored peatland target is the highest at 2373 ha/yr., followed by new non-commercial woodland at 1000 ha/yr., and new commercial woodland also at 1000 ha/yr[103]. Other measures are comparatively small. When converted to changes in carbon sequestration fluxes, the new commercial woodland (-22,117 tCO_2e per year added each year) provides around 20% more sequestration compared to the second-largest contribution from new native non-commercial woodland (-18,456 tCO_2e per year added each year), and roughly 2.1 times more sequestration compared to the third-largest contribution from restored peatland (-10,3468 tCO_2e per year added each year; Table 5). This clearly illustrates the priorities for land use measures in order to achieve Net Zero.

We emphasise that priority must also 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[104]. 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[105]. Typical sequestration values associated with regenerative agricultural practices (such as agroforestry, hedging, and growing legume-rich grasses and cover crops, where applicable) 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 benefits typically achieved by creating new woodland (sequestration) or restoring peatland (emission reduction) on similar timescales[106]. Woodland creation, due to is natural simplicity and its age-old familiarity, is always going to be the main source of carbon sequestration while also delivering 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 peatland restoration programmes.

Table 5: Cairngorms National Park: 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 2050 under the proposed pathway. We use generic definitions of the land use options adopted for all the landscapes on the programme, even though some of them are either less relevant (cover cropping) or need a more nuanced interpretation (native and productive conifers) in the Cairngorms context

Proposed Land Use Targets	Value	Units
New Non-Commercial Woodland	1000	ha per year
New Commercial Woodland	1000	ha per year

[103] For the Cairngorms National Park, Scots Pine is the dominant species both for non-commercial and commercial woodland plantations.

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

[105] 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.

[106] Carbon sequestration in restored peatland is a comparatively slow process, so the focus is on stopping emissions from degrading peat. For further details, see 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."

Restored Peatland	2373	ha per year
Agroforestry (improved grassland & cropland)	27.8	ha per year
New Hedgerows (improved grassland & cropland)	1.6	ha per year
Legumes (improved grassland)	215	ha per year
Cover Cropping (cropland)	*1.3*	*ha per year*
Associated Carbon Sequestration	**Value**	**Units**
New Non-Commercial Woodland	-18,456	tCO_2e per year per year
New Commercial Woodland	-22,117	tCO_2e per year per year
Restored Peatland	-10,368	tCO_2e per year per year
Agroforestry (improved grassland & cropland)	-65	tCO_2e per year per year
New Hedgerows (improved grassland & cropland)	-16.9	tCO_2e per year per year
Legumes (improved grassland)	-441	tCO_2e per year per year
Cover Cropping (cropland)	*-1.5*	*tCO_2e per year per year*

Based on the target-setting assumptions outlined in Table 5 and in Appendix 10.9.8, the Cairngorms National Park could see a total cumulative reduction in the net annual GHG emissions of 2,012,841 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.

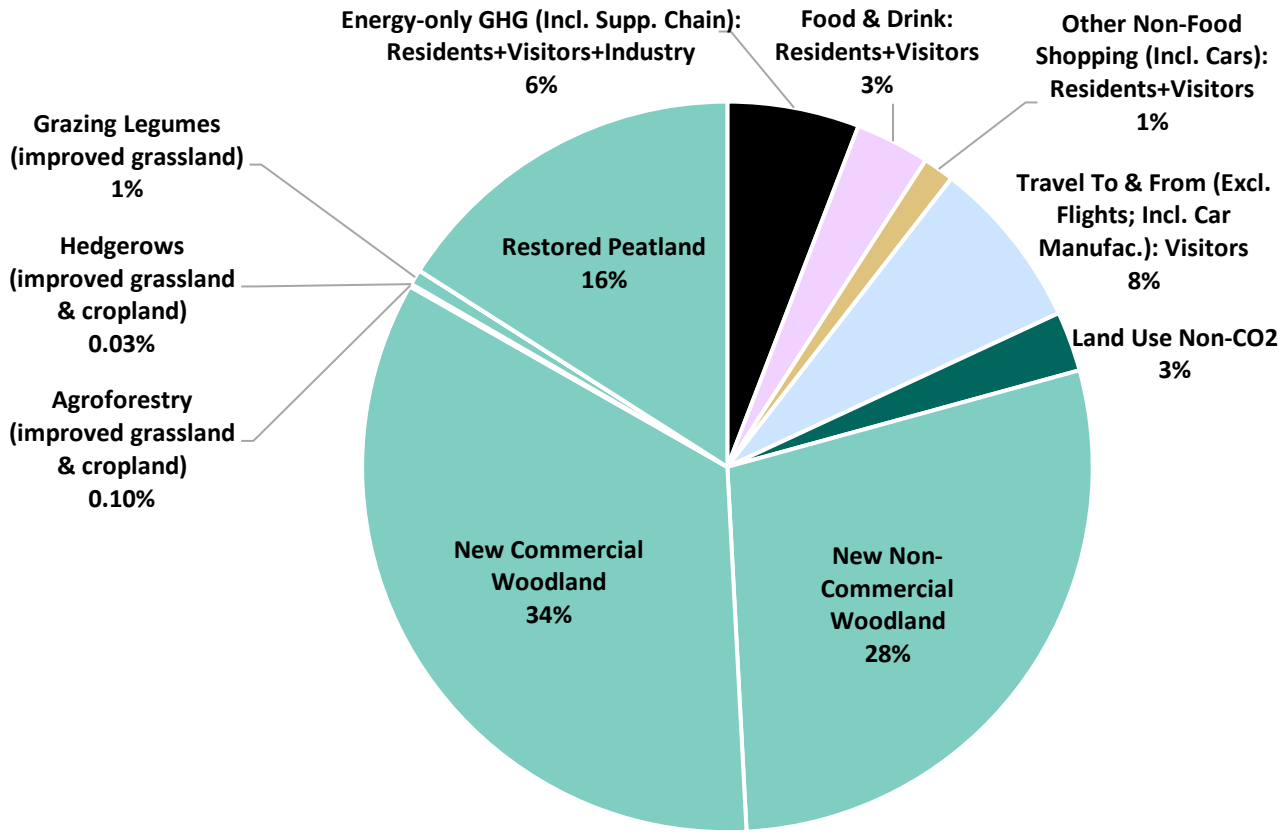


Figure 19. Percentage breakdown of the projected cumulative reduction in net annual GHG emissions for the Cairngorms National Park between the base year (2019) and 2050 according to the individual emitting categories and carbon sequestration measures considered in this assessment. The estimated are based on land use targets apportioned from the Sixth Carbon Budget

The assumptions above imply that the Cairngorms National Park would reach Net Zero emissions in 2024 and would 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 Appendix 10.9.4 for the target figures). It also assumes the recommended decarbonisation and carbon sequestration efforts, including land use change, ratchet up to the required levels immediately in the base year of the assessment. In reality, the high levels of ambition for different sectors explored in this report are likely going take several years to achieve, given that post-COVID emissions have largely rebounded, and that decarbonisation trends to date have been relatively small in magnitude compared to what we know is required for keeping global warming below the safer 1.5°C limit from the Paris Agreement. These factors are expected to push the projected net zero year back by several years. The stated net zero date on its own should therefore not be taken as the main level of ambition to decarbonise for a given landscape.

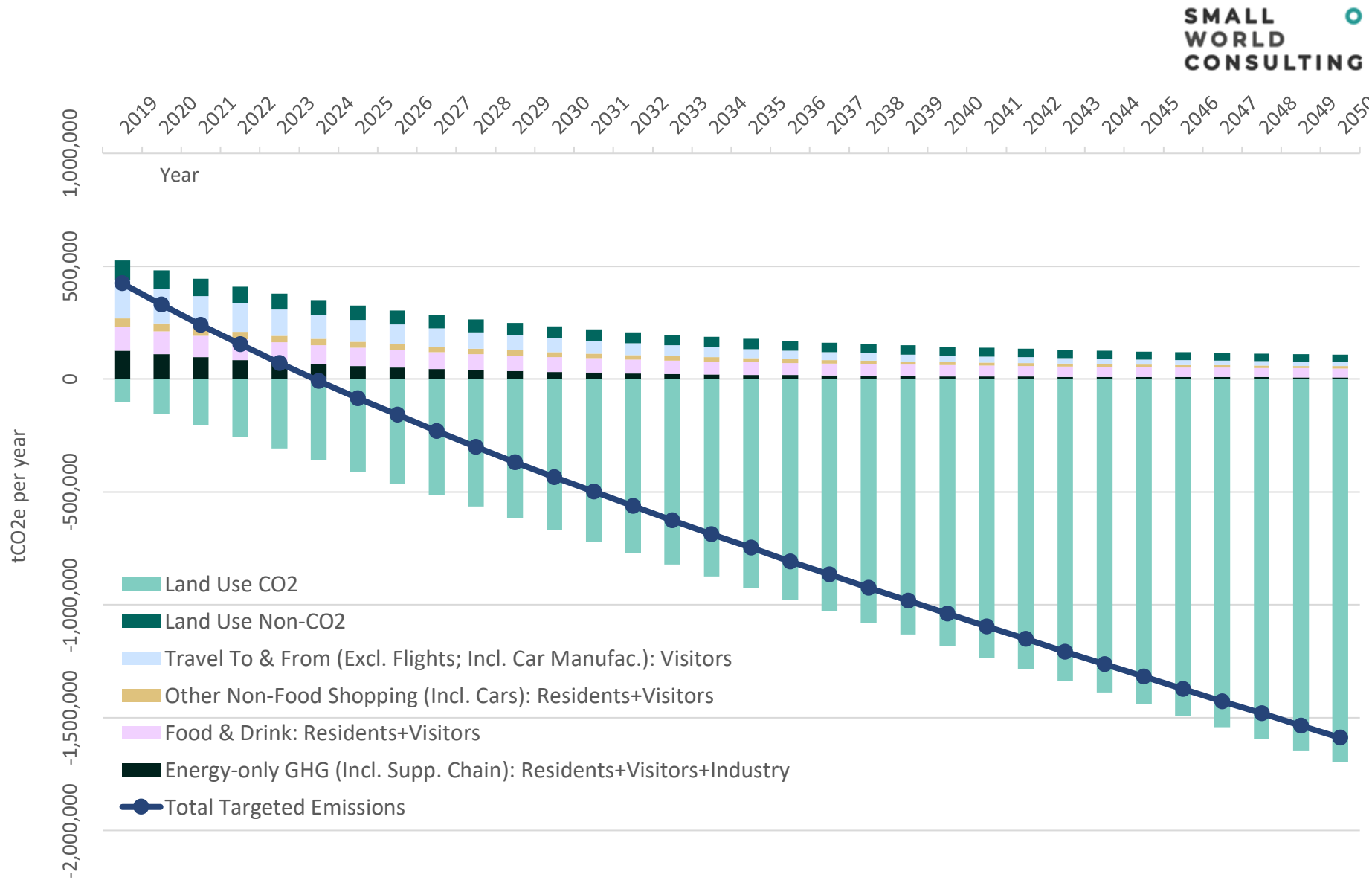


Figure 20. Cairngorms National Park: Pathway to Net Zero based on land use targets apportioned from the Sixth Carbon Budget (Repeat of Figure 6)

6.2. Scenario based on land use targets from the new Partnership Plan

The 2022-2027 Cairngorms National Park Partnership Plan includes woodland and peatland targets that differ from those based on the Sixth Carbon Budget (Section 6.1). The targets, broken down into short-term (to 2027) and long-term (to 2045), are summarised in Table 6.

Table 6. Woodland and peatland targets from the 2022-2027 Partnership Plan. The targets in bold are used for the alternative scenario explored in this section

	Target total 2027 (ha)	**Annual rate to 2027 (ha/yr)**	**Target total 2045 (ha)**	**Annual rate to 2045 (ha/yr)**
Woodland expansion	7,000	**1,400**	35,000	1,521
Peatland restoration	6,500	**1,300**	38,000	1,652

In this section, we consider an exploratory scenario, which assumes that the short-term targets for **woodland expansion** (1,400 ha/yr.) and **peatland restoration** (1,300 ha/yr.) from the Partnership Plan persist between the base year of the assessment (2019) and 2050. Such a scenario could be considered as a lower-end alternative to the default scenario presented in Section 6.1, with the latter based on the woodland and peatland targets of 2,000 and 2,372.5 ha/yr., respectively. In the alternative scenario, all the other land-based measures and decarbonisation efforts not involving land follow the default assumptions made in Section 6.1. We also assume, in line with the default scenario, that the woodland target is split equally between productive commercial woodland and permanent woodland for environmental benefits.

Based on the adjusted target-setting assumptions outlined in Table 6, the Cairngorms National Park could see a total cumulative reduction in the net annual GHG emissions of 1,490,220 tCO_2e per year between the base year (2019) and 2050. Recall that the default scenario resulted in the reduction of 2,012,841 tCO_2e per year during the same period. As before, 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 21.

The adjusted land use targets imply that the Cairngorms National Park would reach Net Zero emissions in 2026 and would act as a net carbon sink in subsequent years (Figure 22). As with the default scenario, the actual net zero date is likely to be delayed by several years given the comparatively limited progress in reducing emissions and scaling up land-based measures in the UK to date, which means it could take some time to reach the recommended levels of ambition.

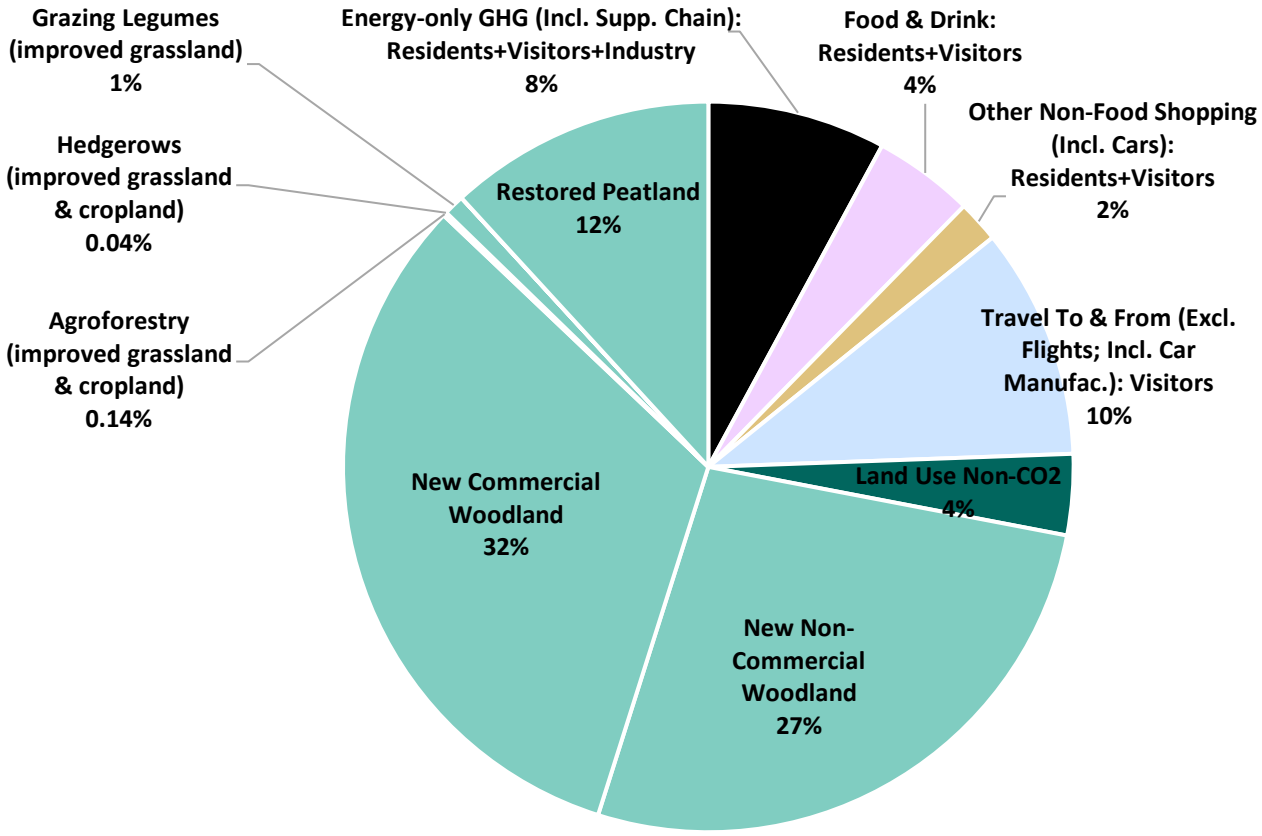


Figure 21. Percentage breakdown of the projected cumulative reduction in net annual GHG emissions for the Cairngorms National Park between the base year (2019) and 2050 according to the individual emitting categories and carbon sequestration measures considered in this assessment. The estimated are based on land use targets from the new Partnership Plan

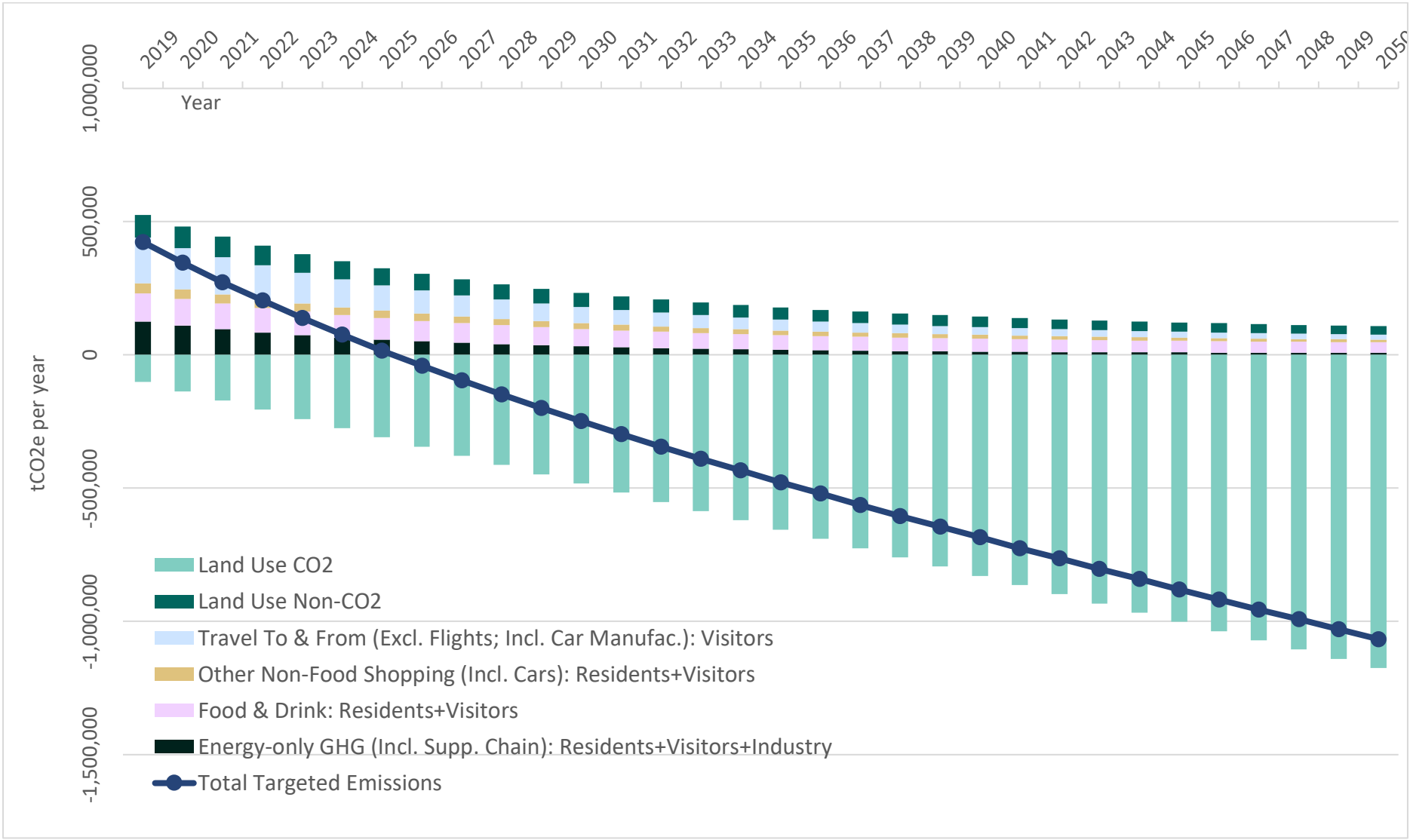


Figure 22. The Cairngorms National Park: Alternative pathway to Net Zero based on the woodland and peatland targets from the new Partnership Plan

7. Conclusions and recommendations

The emissions assessment in this report is designed to bring every relevant area of carbon management into perspective for policymakers. A transition to a low-carbon future for the Cairngorms entails strong action in many areas: construction, home energy, food production and diets, travel and transport, business energy use, the nature of tourism and the visitor experience, the circularisation of the material economy (including repair, maintenance, renting and reselling of consumer goods), and significant changes in land management. Many of these are outside the scope or statutory responsibilities of the National Park Authority, and would depend upon action by many other local, regional and national bodies.

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

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

- Preparing the construction sector for zero-carbon building (embodied GHG emissions),
- Ensuring that new buildings are energy-efficient and supplied with low/zero-carbon energy (operational energy / GHG emissions),
- Encouraging low/zero-carbon transport in new developments (cycling, electric vehicles, etc.),
- Implementing Ecosystems Services-oriented policies and Biodiversity Net Gain initiatives in new-builds.[107]

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

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

If all the targets proposed in this report were met, the Cairngorms National Park would reach net zero GHG emissions in 2024. It would subsequently reach negative emissions of approximately -1,589,123 tCO_2e per year by 2050, with annual carbon sequestration in the Park scaling up to around -1,697,297 tCO_2e per year, and residual emissions dropping roughly to 108,174 tCO_2e across the shortlisted policy priority areas (26% of the present-day carbon footprint baseline).

[107] https://www.transformingplanning.scot/national-planning-framework/draft-npf4/?id=3904#?id=3904

Although designed as the minimum to attain Paris-aligned targets for predominantly consumption-based footprint estimates with some production-based features (Section 6), the trajectories for each of the six components of the target are steep and challenging. This reflects the severity of the climate emergency in which the world now finds itself. The Cairngorms net zero date of 2024 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 Park's proportionately greater capacity for carbon sequestration compared to the UK as a whole.

To meet the targets, considerable help from outside the National Park would be necessary. Some such help can already 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, businesses would also want to play an active role in the transition to low carbon by cutting their direct emissions, while simultaneously opting for suppliers that provide products and services with lower embedded carbon, thus accelerating the transition across the whole value chain.

A degree of help can also be expected to come from government policies, and where this is not sufficient, part of the role of the Cairngorms National Park Authority and its local partners will be to push for the support needed to ensure the National Park attains the recommended targets. This will require active engagement with all stakeholders, drawing on existing relationships and nurturing future ones, including partnership programmes with local organisations, with neighbouring Unitary Authorities, with the Scottish and UK Governments, 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 Cairngorms – will become a reality.

Land management is central to all National Parks and deserves a separate discussion. The wide-ranging land use measures proposed for the Cairngorms National Park, dominated by new woodland and peatland restoration, must be ambitious enough and sustained for long enough, for the sequestration flux to scale up sufficiently year on year, in line with the suggested land use CO_2 pathway. Establishing irreversible carbon sinks (with biodiversity co-benefits) relies on the availability of suitable incentives enabling land managers to implement land use changes such as woodland creation, peatland restoration and regenerative farming, in line with current recommendations by the UK Government.[108]

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

[108] UK Sixth Carbon Budget: "Agriculture, Forestry and Other Land Use" section.

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.

The Scottish National Parks may also be challenged with mediating a pragmatic solution with stakeholders and special interest groups to the competing land pressures for UK food production, UK timber production, peatland restoration, and associated deer management, biodiversity net gain and the need to grow and support local communities.

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

Three new schemes were piloted in England during 2021, and launched in 2022, to reward environmental land management: the Sustainable Farming Incentive, Local Nature Recovery, and Landscape Recovery[109]. 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.

In Scotland, argi-environment schemes are currently available through the Scottish Rural Development Programme[110].

Woodland grants and incentives[111]

- Woodland Carbon Code or Scottish Forestry Grant Scheme
- Woodland Carbon Guarantee

Peatland restoration

- Scottish Government's £22 million peatland restoration fund (£250 million over 10 years)
- NatureScot Peatland ACTION fund
- Peatland Code
- Nature for Climate Peatland Grant Scheme

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

[109] https://www.gov.uk/government/publications/environmental-land-management-schemes-overview/environmental-land-management-scheme-overview.
[110] https://www.gov.scot/policies/agriculture-payments/scottish-rural-development-programme-srdp/
[111] 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
NFU	National Farmers' Union
N_2O	Nitrous Oxide
ONS IDBR	Office of National Statistics' Inter-Departmental Business Register
PFCs	Perfluorocarbons
POC	Particulate organic carbon
SPD	Sustainable Construction Supplementary Planning Document
SF_4	Sulphur Hexafluoride

9. Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Electric vehicle: A car, a van, a bus or a lorry that uses electric motor and battery storage as sole means of propulsion and energy. Electric vehicles do not generate direct emissions apart from those associated with tyres and 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 warming potential, global temperature change potential and others, as well as the chosen time horizon). See also "Net zero CO_2 emissions", "Negative emissions" and "Net negative emissions" (IPCC, 2018: Annex 1: Glossary [Matthews, J.B.R. (ed)]).

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

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

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

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

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

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

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

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

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

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

Public health prevention: This is split into three categories:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Turnover: A synonym to business revenue.

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

10. Appendices

10.1. Appendix: Scottish Policy Comparison to UK/ England

UK or England Policy / Targets	Reserved matters or devolved	Equivalent Scottish Policy / Targets	Level of Aspiration	Scottish Policy Link	Notes
Net Zero by 2050	Reserved matters	Net Zero by 2045	Higher	www.legislation.gov.uk/asp/2019/15/enacted	The UK target applies to Scotland, but Scotland has its own sub-target.
Climate Change Act (2019 amendment)	Reserved matters	Climate Change (Scotland) Act 2019	Higher	www.legislation.gov.uk/asp/2019/15/enacted	The UK policy applies to Scotland, but Scotland has its own, consistent, decarbonisation plan.
Environment Act 2021	Partially devolved	Environmental Standards Scotland	N/A	N/A	Scotland has accepted some of the Environment Act as reserved matters, but not all.
HM Government (2021) Net Zero Strategy: Build Back Greener	Reserved matters	Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update	Higher	www.gov.scot/publications/securing-green-recovery-path-net-zero-update-climate-change-plan-20182032/	Scottish document is working to more ambitious near-term targets of emissions reductions by 2030.
The Companies Act 2006 (Strategic Report and Directors' Report) Regulations 2013	Reserved matters	N/A	N/A	N/A	This is the mandatory reporting of GHG emissions requirement for large UK companies.
N/A	Devolved	Land use - getting the best from our land: strategy 2021 to 2026	Higher	www.gov.scot/publications/scotlands-third-land-use-strategy-2021-2026-getting-best-land/	Neither the UK as a whole or England have a specific land use policy document, only having the policy recommendations from the CCC.
Biodiversity 2020: A strategy for England's wildlife and ecosystem services (2011)	Devolved	2020 Challenge for Scotland's Biodiversity (2013). However, Biodiversity Strategy 2022 is pending publication.	Similar		Similar overall topics, tone and aims. English report quantifies funding more concretely. Both address each of the Aichi Targets.
The 25 Year Environmental Plan (2018)	Devolved	The Environment Strategy for Scotland: Vision and Outcomes (2020)	Not Comparable	www.gov.scot/publications/environment-strategy-scotland-vision-outcomes/documents/	The English document is a more detailed and comprehensive plan, whereas the Scottish strategy is more

					of an overview, so not easily comparable.
CCC (2020): Land Use: Policies for a Net Zero UK	Reserved matters	N/A	N/A	N/A	CCC advice and targets cover the entire UK.
CCC (2020): The Sixth Carbon Budget Agriculture and land use, land use change and forestry	Reserved matters	N/A	N/A	N/A	CCC advice and targets cover the entire UK.
England Peatland Action Plan (2021)	Devolved	Scotland's National Peatland Plan: Working for our future (2015)	Higher	www.nature.scot/doc/scotlands-national-peatland-plan-working-our-future	The Scottish plan and recent funding states greater hectare targets and greater funding, but does have a greater area of peatland to restore.
National Food Strategy Independent Review: The Plan	Devolved	Recipe for Success: Scotland's National Food & Drink Policy Becoming a Good Food Nation	Lower	www.gov.scot/policies/food-and-drink/good-food-nation/	Climate change is only mentioned as a threat to global food supply and no behaviour change recommendations around reducing meat.
National Farmers Union (2021) Achieving Net Zero Farming's 2040 goal.	Separate Organisations	NFU Scotland has yet to publish a Net Zero target	Lower	www.nfus.org.uk/policy/campaigns/farming-for-the-future.aspx#:~:text=NFU%20Scotland%20recognises%20that%20Scottish,biodiversity%20in%20the%20farmed%20landscape.	States: "NFU Scotland recognises that Scottish agriculture must take significant steps if the sector is to achieve net zero greenhouse gas emissions by 2045 - the target set by the Climate Change (Emissions Reduction Targets) (Scotland) Act 2019."

10.2. Appendix: National Park key statistics

Output Variable	Value	Unit	Source		Output Variable	Value	Unit	Source
Land Area	**452,800**	ha	Official Figures / CEH LCM					
Resident Population	**19,211**	persons	ONS Mid-2019 LSOA Population; ONSPD 2019; BEIS 2019 Postcode Electricity Meters; Custom Postcodes		Average Visitors Per Day	**11,798**	persons	STEAM 2019
Resident Population Density	**0.04**	persons per ha	Based on the Above		Visitor Population Density	**0.03**	persons per ha	Based on the Above
Annual Final Consumption (Households + Public Services)	**32,642**	£ per person per year	ONS 2019 Consumption; ONSPD 2019; ONS 2011 Census Demographics; Custom Postcodes		Annual Visitors Spend	**207,736,128**	£ per year	STEAM 2019
Annual Household Fuel per Resident	**6,247**	kWh per person per year	BEIS 2019 Postcode Gas; BEIS 2018 Residual Fuels; ONSPD 2019; Custom Postcodes		Annual Visitors All Types	**2,066,827**	persons per year	STEAM 2019
Annual Household Electricity per Resident	**1,868**	kWh per person per year	BEIS 2019 Postcode Electricity; ONSPD 2019; Custom Postcodes		Percentage of Visitors Staying Overnight	**48.2%**	percentage	STEAM 2019
Annual Vehicle Fuel per Resident	**5,675**	kWh per person per year	BEIS 2018 Road Fuels; ONSPD 2019; Custom Postcodes		Average Duration of Stay for Overnight Visitors	**3.2**	days	STEAM 2019
Annual Personal Flights per Resident, Economy Class	**1.35**	fraction	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes; SWC Population Estimate		Average Visitor Party Size	**3.1**	persons	Visitor Survey
Annual Personal Flights per Resident, Business Class	**0.000**	fraction	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes; SWC Population Estimate		Average Visitor One-Way Road/Train/Boat Mileage Travelled	**279**	miles	Visitor Survey
Average Resident One-Way Mileage per Flight, Economy Class	**797**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes		Estimated Fraction of Trips by Car	**64.4%**	percentage	Visitor Survey
Average Resident One-Way Mileage per Flight, Business Class	**443**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes		Estimated Fraction of Trips Involving Flights	**20.0%**	percentage	Visitor Survey
Annual Business Turnover, COA-based	**461,584,000**	£ per year	IDBR 2019; ONSPD 2019; Custom Postcodes		Average Visitor One-Way Mileage per Flight, Economy Class	**2,229**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes
Percentage of Suppressed Turnover Output, COA-based	**4.21%**	percentage	IDBR 2019; ONSPD 2019; Custom Postcodes		Average Visitor One-Way Mileage per Flight, Business Class	**0**	miles	CAA 2019 Passenger Survey; ONSPD 2019; Custom Postcodes

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

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

10.4. Appendix: Carbon footprint definitions and data sources

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

10.5. Appendix: Residents GHG emissions

SMALL WORLD CONSULTING

Residents GHG emissions: Cairngorms National Park

Consumer Expenditure Categories Summary	ALL Scopes	Units
Household Fuel	26,083	tCO2e per year
Household Electricity	12,163	tCO2e per year
Vehicle Fuel	40,769	tCO2e per year
Car Manufacture & Maintenance	9,974	tCO2e per year
Personal Flights	23,171	tCO2e per year
Ferry Crossings & Cruises	3,438	tCO2e per year
Trains, Buses & Other Transport	6,333	tCO2e per year
Food & Drink	68,360	tCO2e per year
Accommodation (Non Home) Excl. Food	1,236	tCO2e per year
Other Non-Food Shopping	18,317	tCO2e per year
Water, Waste & Sewerage	4,173	tCO2e per year
Other Bought Services	18,286	tCO2e per year
Housing	14,399	tCO2e per year
Health, Education, Other Public Services & Administration	25,679	tCO2e per year
Leisure, Recreation & Attractions	4,763	tCO2e per year
Total	**277,145**	**tCO2e per year**

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

10.6. Appendix: Visitors GHG emissions

SMALL WORLD CONSULTING

Visitors GHG emissions: Cairngorms National Park

"Household Fuel" & "Household Electricity" apply to visitors staying with friends and relatives

"Accommodation" includes electricity, gas and other fuels used by hotels and B&Bs

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

Consumer Expenditure Categories Summary	In NP	To & From NP	Units
Household Fuel	554	0	tCO2e per year
Household Electricity	296	0	tCO2e per year
Vehicle Fuel	13,153	127,327	tCO2e per year
Car Manufacture & Maintenance	3,330	32,237	tCO2e per year
Personal Flights	0	61,732	tCO2e per year
Ferry Crossings & Cruises	0	0	tCO2e per year
Trains, Buses & Other Transport	1,119	11,294	tCO2e per year
Food & Drink	37,920	0	tCO2e per year
Accommodation (Non Home) Excl. Food	19,166	0	tCO2e per year
Other Non-Food Shopping	5,749	0	tCO2e per year
Water, Waste & Sewerage	2,847	0	tCO2e per year
Other Bought Services	4,471	0	tCO2e per year
Housing	0	0	tCO2e per year
Health, Education, Other Public Services & Administration	0	0	tCO2e per year
Leisure, Recreation & Attractions	1,184	0	tCO2e per year
Total	**89,788**	**232,591**	**tCO2e per year**

10.7. Appendix. Industry footprint estimates

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

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

IDBR

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

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

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

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

Source: IDBR Meta Data

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

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Industry GHG emissions (IDBR-based): Cairngorms National Park

** Large emitters report Scope 1 only; depending on the underlying IDBR data quality, they may not be fully included in the industry figures*

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

Industry Categories Summary (IDBR sectors)	ALL Scopes	Units
Agriculture, forestry & fishing	19,356	tCO2e per year
Production	6,361	tCO2e per year
Construction	7,224	tCO2e per year
Motor trades	429	tCO2e per year
Wholesale	961	tCO2e per year
Retail	3,371	tCO2e per year
Transport & storage (inc. postal)	923	tCO2e per year
Accommodation & food services	10,305	tCO2e per year
Information & communication	254	tCO2e per year
Finance & insurance	1,625	tCO2e per year
Property	2,884	tCO2e per year
Professional, scientific & technical	1,350	tCO2e per year
Business administration & support services	2,467	tCO2e per year
Public administration & defence	1,327	tCO2e per year
Education	537	tCO2e per year
Health	1,694	tCO2e per year
Arts, entertainment, recreation & other services	3,785	tCO2e per year
Total	**64,853**	**tCO2e per year**
ENERGY-ONLY INDUSTRY (subset of INDUSTRY) -- The Cairngorms National Park		
Industry Road Fuels	9,206	tCO2e per year
Industry Fuels Excl. Road	13,872	tCO2e per year
Industry Electricity	8,255	tCO2e per year
Total	**31,334**	**tCO2e per year**
LARGE EMITTERS (Scope 1) * -- The Cairngorms National Park		
Large Emitters	**-**	**tCO2e per year**
INDUSTRY-RELATED FLIGHTS (subset of INDUSTRY) -- The Cairngorms National Park		
Industry-related flights	**9,754**	**tCO2e per year**
Land use -- The Cairngorms National Park		
Land use CO_2	**- 101,873**	**tCO2e per year**
Land use non-CO_2	**85,612**	**tCO2e per year**
Total	- 16,260	tCO2e per year

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IDBR vs GVA Industry Footprint Estimates: Cairngorms National Park

Industry Categories Summary (IDBR sectors)	NP OA-based IDBR Industry Footprint (per resident)	NP LA-based GVA Industry Footprint (per resident)	Units
Agriculture, forestry & fishing	1.01	1.42	tCO2e/person/year
Production	0.33	7.48	tCO2e/person/year
Construction	0.38	0.88	tCO2e/person/year
Motor trades	0.02	0.15	tCO2e/person/year
Wholesale	0.05	0.24	tCO2e/person/year
Retail	0.18	0.57	tCO2e/person/year
Transport & storage (inc. postal)	0.05	1.10	tCO2e/person/year
Accommodation & food services	0.54	0.47	tCO2e/person/year
Information & communication	0.01	0.09	tCO2e/person/year
Finance & insurance	0.08	0.08	tCO2e/person/year
Property	0.15	0.07	tCO2e/person/year
Professional, scientific & technical	0.07	0.36	tCO2e/person/year
Business administration & support services	0.13	0.30	tCO2e/person/year
Public administration & defence	0.07	0.41	tCO2e/person/year
Education	0.07	0.27	tCO2e/person/year
Health	0.09	0.49	tCO2e/person/year
Arts, entertainment, recreation & other services	0.20	0.13	tCO2e/person/year
Total	**3.42**	**14.48**	**tCO2e/person/year**

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

10.7.4. Appendix: Pollution inventory for large emitters

Pollution Inventory: Large Emitters All National Parks (2018 data)					
National Park	**LAD14NM**	**Operator**	**Site**	**Postcode**	**CO_2 emissions (kt)**
The Broads National Park	Broadland	British Sugar Plc	Cantley	NR133ST	120.77
Peak District National Park Borders	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	1,048.88
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	201.6
New Forest National Park	New Forest	Cleansing Service Group Ltd	Poundbottom Landfill	SP52PU	13.4
North York Moors National Park	Redcar and Cleveland	Cleveland Potash Ltd	Saltburn-By-The-Sea	TS134UZ	13.7
New Forest National Park	Wiltshire	Renewable Power Systems Ltd	Poundbottom Landfill Site	SP52PU	3.8

10.8. Appendix: Emissions from major roads

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Emissions from major roads: Cairngorms National Park

This analysis of the impact of transit traffic has been included at the request of several NPs

(*) Through Traffic refers to vehicles passing through the NP without visiting. It is not included in the residents', visitors' or industry footprints. It is estimated by comparing total traffic point counts with pump-level fuel sales within each NP

(**) The Larger and Smaller subsets of selected A roads include elements of transit traffic as well as traffic from residents, visitors and industry.

SELECTED A ROADS - SMALLER SUBSET ** -- The Cairngorms National Park		
Road Names, Smaller Subset	A9	
Cars, Buses & Motorbikes	59,480	tCO2e per year
Vans & Lorries	72,506	tCO2e per year
Total		
SELECTED A ROADS - LARGER SUBSET ** -- The Cairngorms National Park		
Road Names, Larger Subset	Smaller Set + A86 A889 A95	
Cars, Buses & Motorbikes	73,666	tCO2e per year
Vans & Lorries	88,306	tCO2e per year
Total	**161,971**	tCO2e per year
THROUGH TRAFFIC * -- The Cairngorms National Park		
Cars, Buses & Motorbikes	66,573	tCO2e per year
Vans & Lorries	94,562	tCO2e per year
Total	**161,135**	**tCO2e per year**

10.9. Appendix: Methodology

10.9.1. Appendix: History of model development

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

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

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

10.9.2. Appendix: Model development for National Park 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 datasets used in the carbon footprint model is provided in Appendix 10.3.

10.9.3. Appendix: Outline of emissions estimation methodology

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

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

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

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

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

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

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

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

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

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

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

The data sources used are listed in Appendix 10.3.

10.9.4. Appendix: Target setting rationale

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

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

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

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

Table 7: High level comparison between Cumbria and new National Park target setting methodology and assumptions used.

Category	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[112]). Includes Scope 1 and 2 carbon dioxide emissions only (excl. motorways).	**13.3%** (specific to Cairngorms National Park) per year reduction in energy-related CO_2 as prescribed by the Tyndall Carbon Budget Tool, and extended to other GHGs. Includes Scope 1, 2 and 3 energy-related GHG emissions expressed as tCO_2e for residents, visitors and industry.	**5%** of present-day emissions. This is our expert judgement for embedded emissions across various forms of renewable energy, for example assuming little or no CCS
Food consumed by residents and visitors	5% reduction per year	**5%** reduction per year. This assumes 3% of emissions reduction per year from dietary changes (National Food Strategy: 30% in 10 years), 1% per year from waste reduction and 1% per year from other changes incl. technology.	**30%** of present-day emissions. This is based on the Sixth Carbon Budget (AFOLU section), 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%** reductions per year. Includes cars. This assumes that sectors such as cement and steel, which feed into complex supply chains (incl.	**10%** of present-day emissions. The is our expert judgement for residual emissions from sectors such as cement and steel that will

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

		making cars), will take time to decarbonise globally and won't reach zero emissions in large exporters like China by 2050.	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 in the transport footprint (roughly halving emissions from cars in 20 years, leaving predominantly the embedded footprint of car manufacturing), and a 2% per year shift in the share from cars	**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 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 8 for further details.	**30%** of present-day emissions for land use non-CO_2 only, which follows the arguments for the Food & Drink category. Land use CO_2: achievable ceiling is not applicable in this assessment due to 2050 being a comparatively short horizon in terms of land-based carbon sequestration measures

A detailed breakdown of how the land use targets are derived, and the relevant planning assumptions is included Appendix 10.9.8. Table 8 below provides a brief overview.

Table 8. Land Use target assumptions for National Parks.

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

	becomes negative when the carbon sink quantities exceed carbon emissions from land. The assumed year-on-year changes to land use are based on apportionment of the Sixth Carbon Budget targets according to present-day land use in each National Park; see Table 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 Cairngorms, the proposed land use measures are estimated to add -51,445 tCO_2e/year to the total carbon sequestration flux in the Park each year (51,445 tCO_2e removed per year).

10.9.5. Appendix: Assumptions for land use sector

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

The LULUCF sector differs from other sectors in the Greenhouse Gas Inventory in that it contains both sources and sinks of greenhouse gases[113]. The sources, or emissions to the atmosphere, are given as positive values; the sinks, or removals from the atmosphere, are given as negative values.

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

Table 9: UK baseline for Agriculture emissions (2018) using Global Warming Potential of IPCC AR5 for methane

	Percentage of UK emissions	**Quantity of CO_2 equiv.t**
Summary Agriculture	**10%**	**54.6 $MtCO_2$**
Breakdown		*SWC planning assumptions*
Methane (CH_4) from livestock	63%	34.4 $MtCO_2$

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

Nitrous oxide (N_2O) mostly from soil	26%	14.2 $MtCO_2$
Carbon dioxide from fossil fuel use	11%	6.0 $MtCO_2$
Total	**100%**	**54.6 $MtCO_2$**
Data Source: The Sixth Carbon Budget: Agriculture and land use, land use change and forestry, p.6		

Table 10: Baseline for Agriculture emissions (2018) using Global Warming Potential of AR5 for methane

	Percentage of UK emissions	**Million tonnes of CO_2**
Agriculture Breakdown		*SWC planning assumptions*
Methane from livestock (Enteric fermentation digestion process of ruminant livestock)	53%	28.9 $MtCO_2$
Agricultural soils	21%	11.5 $MtCO_2$
Waste and manure management	16%	8.7 $MtCO_2$
Stationary machinery	8%	4.4 $MtCO_2$
Other	2%	1.1 $MtCO_2$
Total	**100%**	**54.6 $MtCO_2$**
Data Source: The Sixth Carbon Budget Agriculture and land use, land use change and forestry p.6 Figure M.7.1		

10.9.6. Appendix: Land class categories for reporting nationally

For reporting purposes all land in the country must be identified as having remained in one of six classes since a previous survey, or as having changed to a different (identified) class in that period[114]. 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) to describe the carbon pool in harvested wood products.

For the Scottish highland context, both grass- and heather-dominated moorland is classified as “4C: Grassland”, while blanket bog belongs to "4D: Wetlands”[115].

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

In 2017 the Centre for Ecology and Hydrology proposed changes to the methodology for reporting emissions from peatlands[116]. 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

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

[115] https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/GPG_LULUCF_FULL.pdf

[116] 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.

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[117].

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

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

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

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

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

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

10.9.8. Appendix: Target setting methodology for land use change

The land use change and management targets in each National Park, 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)[118] according to present-day land use distribution in each National Park. 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 teams on the ground, with a preference (in most cases) for native non-commercial woodland (either broadleaved, mixed or coniferous) in order to achieve broader environmental benefits across protected landscapes, such as those in National Parks.

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:

- Non-commercial woodland on mineral soil
- Commercial 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[119], which is based on the assessment by Evans *et al.* (2017)[120].

For the Cairngorms National Park, the current land use distribution is illustrated in Table 12. It is based on the 2019 CEH Land Cover Map and the 2016 NatureScot Carbon and Peatland Map. The UK-wide areas of the selected land use (habitat) types and the corresponding percentages accounted for by the National Park are shown for context in Table 13.

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

At roughly 452,800 ha, Cairngorms accounts for around 1.867% of UK's total land area. However, the Park's current share of forest cover on mineral soils is 11% lower than the UK average. There is likely going to be an opportunity to considerably expand the existing woodland area. Due to strategic importance of commercial forestry for Scotland, we propose an equal split between new non-commercial and commercial woodland as an illustrative scenario for this assessment, while also recognising that a native permanent woodland also has multiple co-benefits in addition to carbon sequestration.

The estimated occurrence of peatland in the Cairngorms is around 2.5 times higher than the UK average per unit area. Restoring peatland can therefore make a very significant contribution to reducing land-based emissions in the National Park.

The Cairngorms' share of improved grassland and cropland covers are estimated to be much lower than the respective UK averages. This means there is limited 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. Some of the least productive and lowest grade farmland, including rough grazing, may need to be taken off agricultural production to enable new woodland plantations and peatland restoration.

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

Land Cover Type	**Habitat Area (ha)**	**Peat Area (ha)**	**Estimated % of Peat Area in Healthy Condition**
Broadleaved woodland	10,156.9	316.3	100%
Coniferous woodland	47,800.7	4,429.1	50%
Arable and horticulture	67.7	0.5	0%
Improved grassland	11,076.4	138.7	0%
Neutral grassland	0.0	0.0	N/A
Calcareous grassland	0.0	0.0	N/A
Acid grassland	68,502.0	19,278.7	25%
Fen, marsh, swamp	964.5	87.5	25%
Heather	228,293.7	95,162.7	25%
Heather grassland	6,702.6	2,077.7	25%
Bog	15,601.7	12,029.1	25%
Saltmarsh	65.7	19.7	100%
Urban	14.5	0.0	0%
Suburban	1,507.8	23.1	0%
Total	**390,754.1**	**133,563.1**	N/A

Table 13. Cairngorms: Areas of the main land cover (habitat) types compared with the relevant UK totals

Land Cover Type	**Current UK Area (ha)**	**Current NP Area (ha)**	**NP Area as % of UK Area**
Broadleaf Woodland (mineral soils only)	1,572,900	**9,841**	**0.626%**

Coniferous Woodland (mineral soils only)	1,637,100	**43,372**	**2.649%**
Improved Grassland (mineral soils only)	6,161,798	**10,938**	**0.178%**
Cropland (mineral soils only)	5,788,356	**67**	**0.001%**
Degraded Peatland (all types)	2,182,455	**98,788**	**4.526%**
Total Woodland Area (Broadleaf + Coniferous), mineral soils only	3,210,000	**53,212**	**1.658%**
Total Agricultural Area (Improv. Grassland + Cropland, mineral soils only	11,950,154	**11,005**	**0.092%**
Total Area of Selected Land Cover Types (above)	18,070,094	**163,005**	**0.940%**
Total Area (incl. urban, rough grassland, water, rock, etc)	24,249,500	**452,800**	**1.867%**

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 non-commercial woodland[121]
- New commercial woodland (where applicable)
- Peatland restoration (across all degraded types, where applicable)
- Agroforestry (for improved grassland and cropland, where applicable)
- Hedgerows (for improved grassland and cropland, where applicable)
- Introducing legume grass species (for improved grassland, where applicable)
- Introducing cover crops (for cropland, where applicable)

Each of these measures is described in the subsections below.

Woodland creation

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

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

[121] For the Cairngorms National Park, Scots Pine is the dominant species both for non-commercial and commercial woodland plantations.

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 Cairngorms in Table 14. For most protected landscapes, the ambition is around two times the minimum target based on suitable areas. This reflects on unique opportunities that Protected Landscapes have in terms of attracting both public and private grants to expand the woodland cover, and the central role they ought to play for meeting ambitious nature recovery goals across the UK. The proposed higher ambition approach is supported by field-level woodland opportunity mapping performed by several landscapes (e.g. Cotswolds, Northumberland). Based on these principles, the custom woodland target for Cairngorms is 2,000 ha/yr.

Table 14. Three ways of setting new woodland targets in Cairngorms.

Woodland target apportioned by woodland land cover area in the National Park or AONB	824	ha/yr
Minimum woodland target apportioned by suitable habitat areas in the National Park or AONB	1014	ha/yr
Custom woodland target in the National Park or AONB	2000	ha/yr

The combined woodland target is then divided between native non-commercial and commercial woodland. As a default position, we opted to use a 100%-0% split in favour of native non-commercial 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 non-commercial 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 50%-50% woodland cover split for the Cairngorms National Park, to balance the broader environmental and social benefits of native non-commercial woodland with the economic importance commercial forestry in Scotland.

Our woodland biomass carbon sequestration estimates employ yield class (YC) 8 for non-commercial woodland (attributed to high-yielding SAB broadleaved trees; 1.5 m spacing) and YC 18 for commercial woodland (attributed to high-yielding Douglas Fir coniferous trees; 1.7 m spacing), as per the Sixth Carbon Budget recommendations[122]. For the Cairngorms, Scots Pine is the dominant species both for non-commercial and commercial woodland plantations. Its YC6 and YC8 tree sub-species (both with 1.4 m spacing) result in approximately the same carbon sequestration rates as the SAB and Douglas Fir species in the adopted generic non-commercial and commercial woodland setting for the National Parks, respectively. We use 30-year average sequestration fluxes for trees from these yield classes inferred from the Woodland Carbon Code (WCC) to match with the timescales of the Net Zero target in 2050. Different trees will have ages between 0 and 30 years leading to the 2050 time horizon, which is why we adopt the 30-year average sequestration flux value in our calculations. We also add representative soil carbon sequestration estimates for woodland from a recent literature review by Bossio et al (2020)[123] to the biomass carbon sequestration inferred from the WCC.

Peatland restoration (where applicable)

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

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

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

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

Agroforestry uptake (where applicable)

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 (where applicable). Agroforestry is assumed to be current practice on 1% of UK farmland; we do not have definitive figures at this stage. Agroforestry is different from present-day farm woodland, which is estimated to cover 5% of the total farmland area in the UK.

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

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

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

Hedgerows expansion (where applicable)

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 (where applicable), 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 (where applicable)

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 (where applicable). 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 (where applicable)

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 (where applicable). 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 Cairngorms

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

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

Land Use / Management Category	**Land Use Change Target (ha/yr)**	**Change in Carbon Flux (tCO_2e/yr/yr)**

New Non-Commercial Woodland	1,000	-18,456
New Commercial Woodland	1,000	-22,117
Agroforestry (improved grassland & cropland)	28	-65
Hedgerows (improved grassland & cropland)	2	-17
Grazing Legumes (improved grassland)	215	-441
Cover Cropping (cropland)	1	-2
Restored Eroding Modified Bog (bare peat), Drained	0	0
Restored Eroding Modified Bog (bare peat), Undrained	218	-2,652
Restored Modified Bog (heather/grass dominated), Drained	2,098	-7,448
Restored Modified Bog (heather/grass dominated), Undrained	0	0
Restored Cropland Peat, Drained	0	0
Restored Intensive Grassland Peat, Drained	3	-92
Restored Extensive Grassland Peat, Drained	0	0
Restored Forested Peat, Drained	53	-176
Total	**4,618**	**-51,465**