Land use: Policies for a Net Zero UK

Committee on Climate Change
January 2020

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Contents

The Committee 4

Executive Summary 7

Chapter 1 - Background and context 18

Chapter 2 - Land use scenarios that deliver climate goals – evidence update 29

Chapter 3 - Costs and benefits of the scenarios 52

Chapter 4 - Policies to deliver land-based emissions reduction and carbon sequestration 74

Chapter 5 - Measures to deliver changes in consumer behaviour 105

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Executive Summary

The UK's net-zero target will not be met without changes in how we use our land. Those changes must start now. The Committee's previous work[1] has shown it is possible to reduce land-based emissions of greenhouse gases while contributing to other strategic priorities for land such as food production, climate change adaptation and biodiversity. This report focuses on the policies to drive that change. Farmers and landowners will face many challenges over this transition, but the framework set out in this report can help to make it a fair one by creating new opportunities and revenue streams that reflect the benefits they bring to society.

Current policy measures will not deliver the required ambition. Incentives for agricultural land use have not seen fundamental change for decades. Throughout the UK there is an urgent need for a new approach: the legislative opportunities for real change are available and should progress immediately.

We have reviewed the land use scenarios from our recent Net Zero report, taking account of new global and UK evidence. We conclude that they are still appropriate. In 2017, emissions from agriculture, land use and peatlands were 58 $MtCO_2e$. With ambitious steps, emissions in these sectors can be reduced by 64% to 21 $MtCO_2e$ by 2050. This will deliver a net lifetime benefit to the UK of the order of £80 billion. There are also additional annual savings (25 MtCO2e) from using the harvested materials from trees and energy crops for use elsewhere in the economy. The Government should continue to fund research to improve scientific understanding and identify opportunities to go further.

Our analysis balances the need to reduce land-based emissions with other essential functions of land, including maintaining food production. The actions we identify entail rapid changes in farming practices and consumer behaviour, such that around one-fifth of agricultural land is released by 2050 for actions that reduce emissions and sequester carbon (Figure 1).

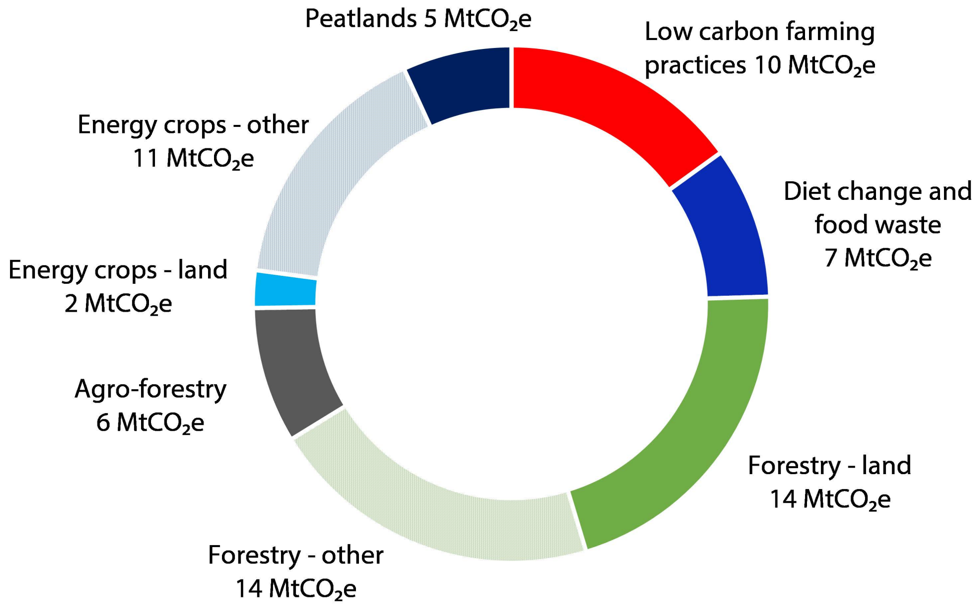
- **Low-carbon farming practices** such as controlled release fertilisers, improving livestock health and slurry acidification can reduce greenhouse gas (GHG) emissions from soils, livestock and manure management by 10 $MtCO_2e$ by 2050.[2]
- **Afforestation and agro-forestry**. Increasing UK forestry cover from 13% to at least 17% by 2050 by planting around 30,000 hectares or more of broadleaf and conifer woodland each year. Together with improved woodland management this would deliver annual emissions sequestration by 2050 of 14 $MtCO_2e$ in forests with an additional 14 $MtCO_2e$ from harvested materials. Planting trees on agricultural land, while maintaining their primary use ("agro-forestry"), could deliver a further 6 $MtCO_2e$ savings by 2050. Sustainably managed forests are important for reducing emissions across the economy. They provide a store of carbon in the landscape and harvested wood can be used sustainably for combustion and carbon sequestration in the energy sector (e.g. when used with Carbon Capture and Storage (CCS) technology) and as wood in construction, creating an additional stock of carbon in the built environment.
- **Peatlands**. Restoring at least 50% of upland peat and 25% of lowland peat would reduce peatland emissions by 5 $MtCO_2e$ by 2050, while allowing food production to continue on the most productive land.
- **Bioenergy crops**. Expanding the growing of energy crops by around 23,000 hectares each year would deliver 2 $MtCO_2e$ emissions savings in the land sector and an extra 11 $MtCO_2e$ from the harvested biomass (e.g. when used with CCS).

[1] CCC 2018 *Land use: Reducing emissions and preparing for climate change. CCC 2019 Net Zero: The UK's contribution to stopping global warming.*
[2] Relative to a business as usual scenario.

Bioenergy crops are faster growing than new woodlands and are needed as part of the overall mix of land-based measures. However, risks of negative impacts of bioenergy crops need to be managed.

- **Reducing consumption of the most carbon-intensive foods** (i.e. beef, lamb and dairy) by at least 20% per person and reducing food waste by 20% would save 7 $MtCO_2e$ of on-farm emissions by 2050. These measures imply a shift towards current healthy eating guidelines and can drive sufficient release of land to support the necessary changes in tree planting and bioenergy crops. Alongside expected population growth, they imply around a 10% reduction in cattle and sheep numbers by 2050 compared with 2017 levels. This compares with a reduction of around 20% in the past two decades.

Figure 1. GHG savings from measures to reduce agriculture and land use emissions, 2050



Source: CCC analysis.
Notes: Based on the CCC 'Further Ambition' scenario in *Net Zero - The UK's contribution to stopping global warming*. These are savings compared with business as usual GHG emissions in 2050.
'Energy crops - other' and 'Forestry - other' refer to GHG savings from the use of harvested products in other sectors of the economy (e.g. with CCS).
Savings from diet change and waste reduction are from direct agricultural emissions reduction only.

Given the extent of change, there is inevitable uncertainty around the precise levels of ambition that can be achieved in practice. Success demands on-the-ground learning and ongoing research. We are confident, however, that the measures we have identified can kick-start the necessary process of reducing emissions from land.

We estimate that delivery of these changes in land requires funding of at least around £1.4 billion per year, which can be partly provided by the private sector and partly through public funding. They will generate a net social benefit of £3.3 billion per year.

Extra funding may be required where there are additional non-financial barriers to overcome and to support other objectives, for example preparing for climate change, protecting biodiversity and ensuring a just transition for farmers. This compares to total Common Agricultural Policy expenditure in the UK of £3.3 billion in 2018.

Key objectives of the new policy framework should be delivering low-carbon farming practices and changing the use of land to reduce emissions and increase carbon sequestration. We have identified a mix of regulations and incentives that will provide land managers with the long-term clarity needed to deliver the changes set out. Key elements of our proposed approach are:

- **Strengthening the regulatory baseline to ensure low-regret measures are taken up**
  - Extend existing regulation to reduce on-farm emissions (e.g. Nitrogen Vulnerable Zones) and use new legislation to regulate additional sources of emissions not currently regulated such as enteric fermentation from livestock (e.g. the Clean Air Strategy could require feed additives that reduce methane emissions from livestock).
  - Ban damaging practices such as rotational burning on peatland and peat extraction.
  - Set an obligation for water companies to restore peatland on land they own, and on owners of peatland within a site of special scientific interest (SSSI).
- **Funding for actions above the baseline to support more costly measures**
  - The key measure for afforestation and some agro-forestry schemes should be auctioned contracts (e.g. similar to those offered for renewable electricity) or a carbon trading scheme. Either of these could be funded through a levy on greenhouse gas-emitting industries (e.g. fossil fuel providers or airlines). These need to be carefully designed to avoid potential negative impacts and ensure carbon credits from land-based solutions are not available to offset emissions reductions that are needed to meet net-zero in other parts of the economy.
  - Alongside this, public funding should be used to encourage non-carbon benefits of afforestation (e.g. alleviating flood risk, recreation). Public funding may also be needed for planting trees on farms where it would not occur through the main mechanism above (e.g. because costs are higher than the price established through the market or where there are non-financial barriers).
  - Public funding should be used to incentivise the take-up of low-carbon farming practices (e.g. precision farming) where they go beyond requirements of new regulation and where they imply costs to farmers.
  - Further peatland restoration should also receive public funding, alongside sustainable management practices on peat that remains in agricultural production. In the longer term, once emissions reductions can be verified effectively, this could move to a trading or auctioning system, as proposed for afforestation.
  - Bioenergy crops should be supported through existing instruments in the short term: continue to exclude biomass combustion from the EU ETS and to provide financial support through existing commitments (e.g. the Renewables Obligation and Contracts for Difference). In the longer term policies should reflect best use of biomass, which will change over time (e.g. in the long term best use may be in construction and with Carbon, Capture and Storage).[3]

[3] See CCC (2018) *Biomass in a low-carbon economy*.

- **Enabling measures to address non-financial barriers**
  - Support schemes to strengthen skills, training and market commercialisation of innovative low-carbon farming options (e.g. livestock breeding and diets).
  - Support the scaling-up of capacity of the domestic forestry supply chain, from nurseries to sawmills and wood processors.
  - Raise awareness and provide training on the adoption of sustainable management practices on lowland peat.
  - Additional measures to support the UK bioenergy market:
    - An agreement with biomass combustion facilities to source a minimum proportion of their feedstock from the UK.
    - Concessionary finance in the form of low-interest loans for energy crops could provide top-up funding to cover the loss of annual income while crops are being established.
  - Address contractual arrangements that may constrain uptake amongst farms that are tenanted or designated as common land.
  - The tax treatment of woodlands should be reviewed and, if necessary, amended to ensure there is no disadvantage to farmers from changing their use of land to forestry.

Wider policy levers will also be needed to support a shift in consumer behaviours and incentivise the wider food supply chain to drive change:

- Policies are needed to encourage consumers to shift diets and reduce food waste.
  - **Diets:** The 20% per capita reduction in beef, lamb and dairy consumption in our scenario is modest compared with government nutritional guidelines. Government should implement low-cost, low-regret actions to encourage this shift (e.g. the public sector taking a lead in providing plant-based options with all meals). An evidence-based strategy is required to establish which measures will successfully change behaviour, encompassing: information provision, skills support, and encouraging greater accountability of business through clear and robust metrics and mandatory reporting. If these are not enough, a second stage will need to look at stronger options, whether regulatory or pricing.
  - **Food waste:** To address the 13.6 million tonnes of food that is wasted each year in the UK, government should implement steps to reduce food waste from the farm to the householder. This should include immediate low-cost measures (e.g. target setting in the public and private sectors); measures to 'nudge' consumers towards best practice and mandatory separate food waste collection.
- Some parts of the food chain such as some food processors and supermarkets are already working with farmers to improve the carbon footprint of their products. Development of common metrics and standards and mandatory reporting of emissions should be the first step to more stringent GHG obligations on other parts of the food supply chain.

Sustainable productivity growth is a key driver in our land use scenario: it allows more to be grown with less land and other inputs - and frees up land for other uses. In our scenario this is driven by good agronomy practices and crop breeding rather than intensification of farming (which would involve increasing inputs onto land).

Government should develop an effective strategy to address the historical productivity gap in UK agriculture including: skills, training and knowledge exchange; rural infrastructure and connectivity; and delivering R&D at farm level. This will be a win-win for farmers and the wider economy.

It is possible that an even higher level of ambition may eventually be needed, given the uncertainties about policy implementation. This could require, for example, up to 50,000 hectares of new woodland each year (increasing forestry cover to 19%, still well below the EU average of 33%), restoring 75% of upland peat and 50% of lowland peat by 2050[4] and further dietary change (e.g. a 50% shift away from the most carbon-intensive foods).

This report has built on previous Committee reports in this area. The measures we set out deliver land's contribution to net-zero whilst balancing other priorities for land:

- **A strong food production sector**. Delivering emissions reduction should not be at the expense of increasing food imports that risk 'carbon leakage'. Our analysis assumes the same proportion of UK food demand is met by imports in 2050 as is the case currently; it is not designed to increase per capita imports. Leakage risks associated with reduced UK meat exports are limited and can be addressed through policy.
- **The steps we recommend would deliver £4 billion annually of wider benefits**. The largest of these is the reduction in GHG emissions, valued at £2.7 billion annually. Other impacts include the recreational benefits of creating new woodland, better air quality, improved health from increased physical activity and flood alleviation. There will also be important benefits to biodiversity and water quality, though these are not included due to the difficulty in quantifying them. There is strong evidence, however, that peatland restoration and new woodland could have significant positive biodiversity impacts.
- In aggregate these changes will make land more **resilient to climate impacts**, but policy should also reflect the need to make sure the right changes happen in the right places, particularly the planting of trees that are suitable for the current and future climate in specific areas.

We have also explored other evidence relating to the global warming effects of methane, and the impact of livestock rearing on grassland:

- **Methane** is a short-lived greenhouse gas that affects the climate in different ways to carbon dioxide. It is clear that agricultural (and other) methane emissions must be significantly reduced globally and in the UK, to meet the long-term temperature goal of the Paris Agreement and the UK's 2050 net-zero target. Our net-zero scenarios have reductions of agricultural methane consistent with the global average in 1.5°C-compatible scenarios on a per person basis and, for comparison, in the middle of the range of New Zealand's new 2050 methane target.

[4] Further restoration of peatlands may be needed as there is a risk that they could be destroyed altogether with climate impacts.

- While **livestock on non-organic grasslands** can have a positive impact on soil quality, grassland cannot continuously increase its carbon store. This means grassland cannot be used continually to offset ongoing methane emissions from livestock. Converting grassland to forest can increase the amount of carbon stored.

Building on our previous work, we have gathered extensive evidence for this report, including three newly-commissioned research projects and consultation with a broad set of stakeholders. Two advisory groups were specially-convened: a land use advisory group and an expert workshop on diets. Their independent reports are published alongside this report.

The policies we have identified provide a coherent framework that recognises the essential role of farmers as stewards of the land and encourages real change. The transition is complex, reaching across diverse agriculture sectors, actors and geographies. Success must deliver a 'just transition', where all farmers and land managers can benefit from the new opportunities.

Above all, these changes are intended to make it 'pay' for farmers to reduce emissions for the first time. Continued delay is not an option. It is critical that this change starts immediately.

Our high-level recommendations are set out in Table 1.

The rest of this report is set out in the following chapters:

Chapter 1: Background and context

Chapter 2: Land use scenarios that deliver climate goals – evidence update

Chapter 3: Costs and benefits of the scenarios

Chapter 4: Policies to deliver land-based emissions reduction and carbon sequestration

Chapter 5: Measures to shift consumer behaviour

Table 1. Key recommendations to deliver net-zero on land

Category	Recommendation	Date	Who is responsible
Low-carbon farming practices	• Adopt existing environmental stewardship rules that have benefited mitigation in UK legislation.	2020	Defra and equivalent bodies in Scotland, Wales and Northern Ireland
	• Extend coverage of Nitrate Vulnerable Zones to all of the UK.	Before 2023	
	• Include measures that reduce methane emissions in the Clean Air Strategy.	Before 2023	
	• Include low-cost and low-regret measures in future baseline regulation.	From 2021	
	• Provide public money for more expensive measures above the baseline.	Before 2023	
	• Mandate UK feed producers to incorporate methane inhibiting additives in compound feed.	Before 2023	Livestock feed producers
Afforestation, agro-forestry, hedge creation and broadleaf management	• The main instrument should be a market mechanism (e.g. trading scheme or auctioned contracts), which could be funded by emitting sectors (e.g. fossil fuel suppliers or airlines). This mechanism could also apply to agroforestry schemes that deliver clear carbon sequestration benefits.	Early 2021	Defra and equivalent bodies in Scotland Wales and Northern Ireland
	• Public money should fund the non-carbon benefits of afforestation, such as biodiversity and flood alleviation, which will also have benefits for climate change adaptation.	From 2021	
	• Public money for carbon and non-carbon benefits of and broadleaf management.	From 2021	
	• Adopt existing CAP cross-compliance[5] rules on protecting hedgerows into UK legislation.	2020	
	• The tax treatment of woodlands should be reviewed and, if necessary, amended to ensure there is no disadvantage to farmers from changing their use of land to forestry.	From 2020	

[5] See https://www.gov.uk/guidance/cross-compliance-2019

Table 1. Key recommendations to deliver net-zero on land

Upland peat restoration	• Ban rotational burning on peatlands. • Mandate all peatland within a Site of Special Scientific Interest to be under restoration. • Mandate water companies to restore peatland under their ownership. • Public money to fund the carbon and non-carbon benefits of restoration. • In the longer-term, use of market mechanisms to pay for the carbon benefits.	In 2020 Before 2023 From 2021 From 2021 By mid-2020s	Defra and equivalent bodies in Scotland, Wales and Northern Ireland
Lowland peat restoration and sustainable management	• Ban peat extraction and its sale, including of imports. • Regulate that peat soils are not left bare. • Require internal drainage boards to maintain optimal water table levels. • Public funding for sustainable management practices, and restoration of low value land (e.g. grasslands). • Research to improve verification and, in the longer-term, use of market mechanisms to pay for carbon benefits.	Before 2023 From 2021 Before 2023 From 2021 By mid-2020s	Defra and equivalent bodies in Scotland, Wales and Northern Ireland
Energy crops	• Continue to exclude combustion processes that exclusively use biomass from the EU ETS or its UK successor. • Continue to support biomass generation through existing market mechanisms in the short term. Support should transition to best uses longer term. • Introduce a requirement for biomass combustion facilities to source a fixed proportion of their crops from the UK. • Concessionary finance to top up funding to cover the loss of annual income while the crop is being established.	Ongoing Ongoing Early 2020s 2020	BEIS BEIS Defra, BEIS, and equivalent bodies in Scotland, Wales and Northern Ireland

Table 1. Key recommendations to deliver net-zero on land			
Enabling measures	• Address skills and information barriers to take-up of low-carbon farming practices. • Ensure that the application process for new afforestation schemes is as simple and streamlined as possible. • Support scaling up of capacity of the domestic forestry supply chain from nurseries to sawmills and wood processors. • Develop the Peatland Code to obtain UK Accreditation. • Raise awareness and provide training to support adoption of sustainable management practices on peatland. • Address contractual arrangements that may constrain uptake among farms that are tenanted or designated as common land. • Review the tax treatment of woodlands and, if necessary, amend it to ensure there is no disadvantage to farmers from changing their use of land to forestry.	Start in 2020	Defra, BEIS, HMT, HMRC, Scottish, Welsh and Northern Irish governments, industry, universities
Diet change	• Implement low-cost, low-regret actions to incentivise shift in diets away from red meat and dairy. Public sector should take the lead. • Develop an evidence-based strategy to shift diets that includes information provision and addressing skills. • Develop common metrics with information on life-cycle emissions of foods based on a robust, transparent methodology. • Consider stronger options (e.g. pricing or regulation) if softer measures prove insufficient.	Start in 2020 Start in 2020 Start in 2020 Review mid-2020s	Defra, DHSC and the equivalent bodies in Scotland, Wales and Northern Ireland
Food waste reduction	• Introduce low-cost measures to reduce current levels of food waste e.g. encourage reduced portion size, effective date labels, standard setting in public and private sector hospitality. • Mandate separate collection of waste across the UK.	Start in 2020 By 2023	Defra and the equivalent bodies in Scotland, Wales and Northern Ireland, business

Table 1. Key recommendations to deliver net-zero on land			
Trade policies	• UK trade policy must protect risks of carbon leakage from trade in agricultural products and avoid undermining the required changes in UK land management.	From 2020	BEIS, DIT
Wider government agricultural strategy	• Government should develop an effective strategy that delivers R&D at the farm level and addresses the historical productivity gap in UK agriculture including: tackling skills, re-training and knowledge exchange; rural infrastructure and connectivity.	From 2020	Defra, BEIS, Scottish, Welsh and Northern Irish governments, universities, industry and agricultural colleges
Monitoring, reporting and verification (MRV)	• Introduce a strong MRV system that uses latest monitoring tools and technologies and creates a strong institutional framework to verify actions across the UK.	By 2023	Defra and related bodies (e.g. Forestry Commission) and the equivalent bodies in Scotland, Wales and Northern Ireland

Chapter 1: Background and context

Introduction and key messages

This report sets out the Committee's advice on policies needed to deliver the land sector's contribution to the UK's new 'net-zero' emissions target. It follows our 2018 report *Land use: Reducing emissions and preparing for climate change* and the land use pathways set out in our 2019 report *Net Zero: The UK's contribution to stopping global warming*.

This chapter provides background to this advice, including global evidence, and sets out the approach taken in the rest of this report.

Key messages in this chapter are:

- Land is a limited valuable resource. Changing the use of land in the UK - and especially agricultural land - is critical in achieving net-zero emissions by 2050. While there are multiple objectives for land use, a strategic priority must be climate change mitigation. Without significant emission reduction in the UK and globally, other goods and services from land are at much greater risk from the long-term impacts of a changing climate. Reducing emissions from land is possible while delivering other important objectives such as food production, adapting to climate impacts and other environmental services.
- This focus on land addresses a previous and ongoing lack of policy in this area. It is in line with the Paris Agreement and a recent IPCC special report which highlights the need for urgent action on land mitigation globally.
- As the UK prepares to leave the EU, there is now an opportunity to put in place new, transformative policies. The mix of incentives and measures are likely to be in place for the next 20-30 years, over the period when the UK needs to achieve net-zero greenhouse gas (GHG) emissions.
- This transition to a low-carbon use of land is challenging given the diversity of agriculture, the different actors, sectors, geography and strong interactions with other environmental services and the need to adapt to climate impacts. The policies we set out can help to make the transition a fair one: a transparent framework, capable of drawing broad support and with opportunities for new revenue streams across the sector. Where there are adverse impacts, Government will need to ensure effective support.
- Our advice builds on previous works and extensive new research and analysis. We commissioned three research projects, held extensive stakeholder engagement, conducted our own analysis and reviewed existing literature.

The rest of this chapter is set out in four sections:

1. Background
2. The need for a coherent land strategy in the UK
3. The agriculture and land sector today: the size of the challenge
4. The evidence base

1. Background

The Committee's 2018 report on land use highlighted the crucial role of land in providing essential goods and services such as food, clean water, timber, as well as natural climate mitigation and adaptation through sequestering and storing carbon and protection from natural hazards such as floods, pests and diseases.

Many of the environmental goods and services that land provides do not have a private market; their positive impacts are not priced and are under-supplied by the market. This has led to historic and ongoing degradation of land, soils, and water courses and loss of biodiversity.

Activities on land are responsible for a high proportion of global emissions. The special role of land in climate mitigation is highlighted in Article 5 of the Paris Agreement and the IPCC Special Report on Climate Change and Land:[6]

- The agriculture, forestry and other land use sector (AFOLU) is responsible for around 23% of global GHGs largely from deforestation, and agricultural emissions from soil, livestock and nutrient management. This sector accounted for around 13% of CO_2, 44% of methane (CH_4), and 82% of nitrous oxide (N_2O) emissions from human activities globally during 2007-2016.
- The 2019 IPCC report points to the importance of leveraging the mitigation potential in the sector in meeting emission reduction targets. Urgent action to use land for emission reduction will also help to reduce other negative pressures on land including enhancing climate resilience, reversing land degradation and improving biodiversity and other environmental services (Box 1.1).
- In the UK, emissions from agriculture were 46 $MtCO_2e$ in 2017, 9% of UK GHGs. The land use, land-use change and forestry (LULUCF) sector was a net sink, sequestering nearly 10 $MtCO_2e$ in 2017, equivalent to around 5% of UK GHGs. Emissions from peatlands, most of which are not currently included in the GHG inventory but taken account of in our analysis, were estimated at 23 Mt CO_2e in 2017.

As our 2018 report demonstrated, to achieve the UK's climate goals and other objectives of land, the way land is used needs to change. Climate mitigation needs to be at the heart of a new land use strategy.

Box 1.1. The IPCC Special Report on Climate Change and Land

The IPCC recently produced a special report on climate change and land (published in August 2019) that assessed literature looking at the role of climate change on desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.

A number of overarching conclusions on the role of land in climate mitigation were found:

- Land plays a critical role in supporting human society and is already under pressure from climate change. Land provides humans with food, freshwater and ecosystem services. About 70% of the planet's ice free surface is directly affected by humans in some way. Land surface temperatures have warmed by over 1.5°C from the pre-industrial period. This warming, and the associated changes in weather extremes, is already impacting on food security including crop yields and agricultural pests and diseases.

[6] IPCC (2019) *Special Report on Climate Change and Land.*

Box 1.1. The IPCC Special Report on Climate Change and Land

- Land-based mitigation can play an important role in limiting future warming. Emissions from the global food and land-use system contribute 21-37% of global GHG emissions today, but measures to reduce these exist with many bringing other co-benefits for sustainable development. There is a strong overlap between the measures identified by the IPCC and those considered for the UK in this report, including implementing low-carbon farming practices, shifts to healthier diets and waste reduction, agricultural productivity improvements, and changes in land-use and land management to sequester carbon.
- There are limits to what land-based mitigation can achieve by itself. Land will come under further pressure from future climate change and very large-scale use of land for mitigation (e.g. afforestation or biomass production) could have negative consequences for other functions of land such as biodiversity, food production and climate resilience. Rapid and deep reductions in global emissions across all sectors will be needed to keep pressures on land to a minimum and ensure that changes in land use can contribute to climate change mitigation in a sustainable way. Acting immediately to avoid over-exploitation of land can alleviate the negative impacts of climate change, ecosystems and society and would enhance food, fibre and water security and reverse land degradation.

The IPCC Special Report makes it clear that there is a scientifically robust evidence base on the effects that human land use is having on the climate and what can be done to reduce it. We will use the findings of this report to ensure that our pathways for reducing the climate impact of UK agriculture and land-use remain grounded in the most up-to-date evidence.

Source: IPCC (2019) *Special Report on Climate Change and Land.*

2. The need for a coherent land strategy in the UK

For several decades, agricultural policy in the UK has been dominated by the European Union's Common Agricultural Policy (CAP). The CAP - and policies prior to it - emphasises food production. It has led to a distorted set of uses for land that do not reflect the need to mitigate climate change and reduce the stresses on environmental ecosystems that climate change is causing.

Leaving the EU presents an opportunity to define a modern strategy that ensures land contributes fully to the UK's net-zero emissions ambition and delivers other objectives. The policy framework that replaces the CAP across the UK must provide clarity and give priority to climate mitigation.

New policies being developed across the UK must provide a coherent framework:

- The Agriculture Bill sets out provisions to transition by 2028 from the CAP subsidy scheme based on land area in agricultural production towards payments for public goods. The Environment Bill makes provision for targets, plans and policies for improving the environment. The main body of these Bills apply to England, but similar powers extend to Wales and Northern Ireland (see Chapter 4 for further details).
- In November 2019, the Scottish Government introduced an Agriculture Bill for the Rural Economy which would allow Ministers to simplify or improve elements of the CAP, and provide for the collection of agricultural data. The Scottish Government has consulted on proposals for a rural funding transition period, including a five-year period of "stability and simplicity" followed by a new scheme from 2024.

The mix of incentives and measures currently being developed is likely to be in place for the next 20-30 years - over the period when the UK is aiming to achieve net-zero GHG emissions. It is important to build in an effective approach from the outset.

The transition to a low-carbon, resilient use of land can be seen against a history of intervention in this sector, through the CAP, financial support for specific measures and regulation. Farmers and landowners have experienced a series of new regulations and orders over the past 50 years or so. The CAP has been in place in various forms since 1962.

The current scheme provides support to farmers and land managers through two main routes:

- The Basic Payment Scheme (BPS) is paid for land in agricultural use based on land area. To qualify for BPS payments, a farmer must have at least five hectares of agricultural land that is used for an agricultural activity all year round. If they have land which is used predominantly for agricultural purposes, they can still claim but payments are reduced.
- Cross compliance measures link direct BPS payments to standards governing animal health and welfare, plant health and the environment. This includes the requirement for farmers to demonstrate that they are keeping their land in 'good agricultural and environmental condition'.
- Additional CAP funding is also provided under the Rural Development Programmes (Pillar II) for farmers, land managers, woodland owners, and foresters. It comprises five main schemes, of which the Agri-Environment and Countryside Productivity Schemes have the biggest influence on land use and agricultural practices.
- In 2018, UK farmers and land managers received around £3.3 billion from the CAP, of which around 80% was used for direct payments.

The EU is currently negotiating the next CAP budget (2021-27) so there will be changes in payments for the rest of Europe regardless of the UK position. Land policies are changing in the EU and globally, not just the UK.

Other sources of funding are available through UK programmes targeted at specific sectors. These include: grants for woodland creation and peat restoration; feed-in tariffs (FITs) for renewable energy on-farm such as solar PV and anaerobic digestion (AD); grants or loans for infrastructure such as fencing.

Farmers also face a wide range of regulations and standards governing how agricultural land is used and farmed in the UK. A 2018 review by Dame Glenys Stacey[7] found:

- There are 172 Acts of parliament and other legal instruments that set standards for farming and land management, governing many diverse aspects of farming. These range from regulations around livestock health and feed, Conservation of Habitats and Species, Nitrate Pollution Prevention, Pesticide use and plant health, animal feed regulations, livestock disease controls and many more.
- There are five Defra bodies overseeing farming and land management, and comparable bodies in Scotland, Wales and Northern Ireland.
- These bodies and local authorities combined make 150,000 farm visits each year.

The transition to a new system of payment for public goods should be as seamless as possible, with incentives integrated while phasing out the BPS.

[7] Dame Glenys Stacey (2018) *Farm inspection and regulation review.*

Leaving the EU will allow for a more holistic approach in the land sector. It is important that the transition is fair and receives widespread support. The recommendations in this report will help this process by setting out a clear and transparent framework for future land policy. These are set out in Chapters 4.

3. The agriculture and land sector today: the size of the challenge

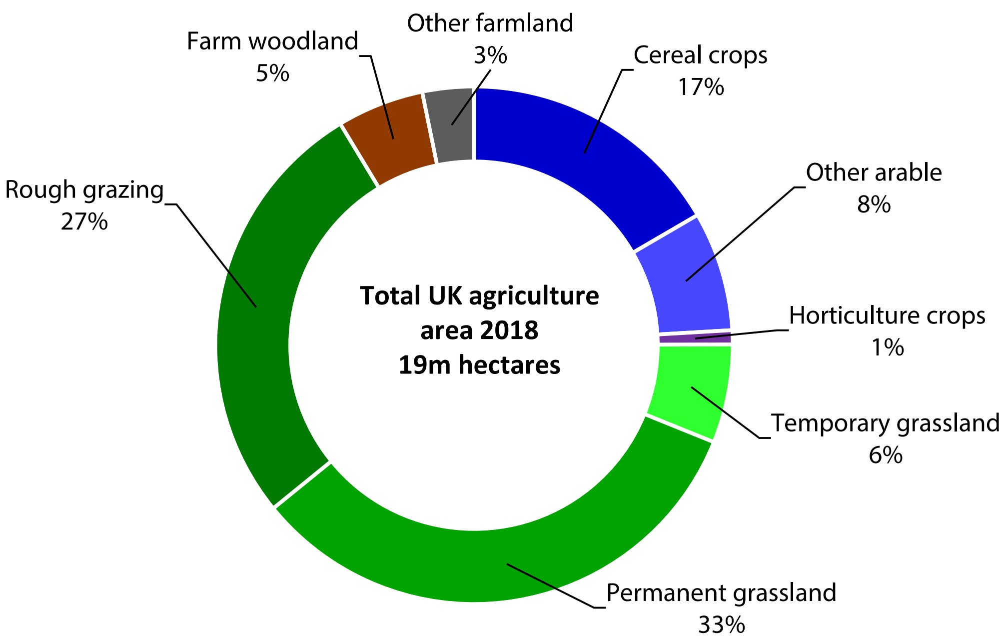
Agriculture and forestry are relatively small sectors in the UK economy but with an importance that goes beyond this:

- Agriculture contributed £9.5 billion to the UK economy in 2018, 0.6% of UK GDP. Overall the sector produces 53% of the food consumed in the UK.
- Output in the forestry sector was £0.7 billion in 2017, and supported a wider supply industry in wood processing and use. One third of UK wood consumption is produced in the UK.
- Agriculture employed 426,000 people in 2018, 1.5% of the UK labour force, with more in the food and drinks sector. Forestry employed 16,000 people in 2017.

Agriculture and forestry account for 85% of UK land area, most of which is for farming:

- In 2018 total agriculture area was 19 million hectares (77% of total land area), 60% of which is used for livestock, 31% for crops, 5% for woodland with the remainder for buildings and other agricultural activities (Figure 1.1).
- The total area of woodland (including on agricultural land) in the UK is 3.2 million hectares, 13% of land.

Figure 1.1. Agricultural land use in the UK, 2018

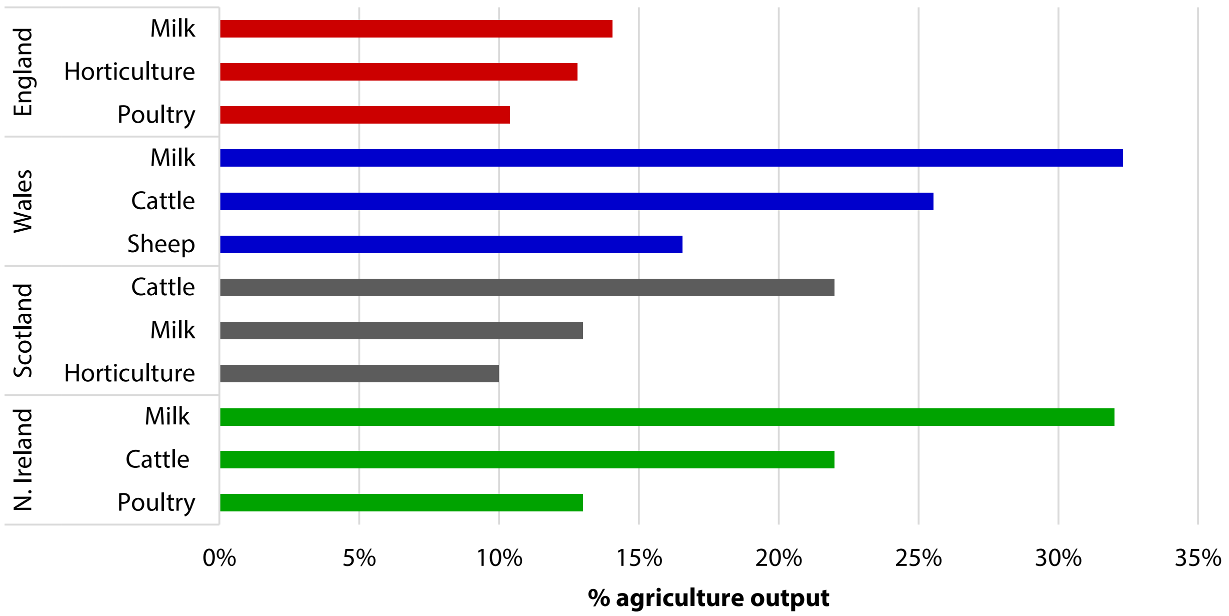


Source: Defra (2018) *Agriculture in the UK*, CCC analysis.

Agriculture in the UK is characterised by a wide range of farm types and diverse activities. Production varies across the UK:

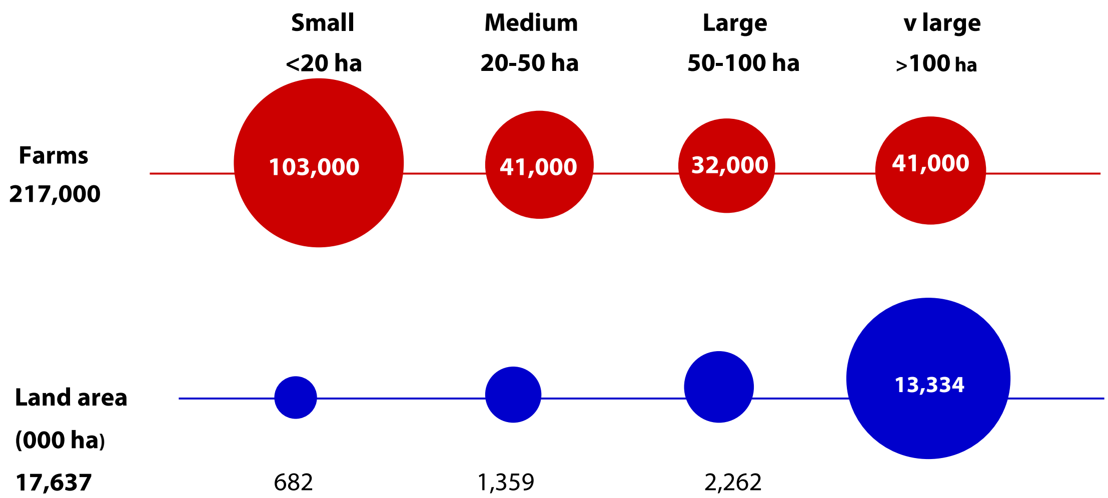
- Agricultural output by value is split roughly equally between crops and livestock. The largest crop outputs are wheat (£2.1 billion in 2018) and horticulture (£2.8 billion); the highest value livestock products are beef (£3.3 billion) and milk (£4.5 billion).
- Production in Wales and Northern Ireland is dominated by livestock production, with milk and cattle production the highest value products. While these are also important in Scotland, one-third of output comes from crops. In England the top three agricultural products are horticulture, milk and poultry, with cereals dominating the east of the country and livestock the south west (Figure 1.2).
- There were 217,000 farm holdings in the UK in 2017 which vary widely in size. Around 20% of holdings are very large, over 100 hectares, and use the majority of land (76%); 48% of farms are small (less than 20 hectares) farming just 4% of land (Figure 1.3).
- Output is also unevenly distributed. In England in 2017 a small number of large farms (7%) produced 55% of output (in value terms) using 30% of farmed area.

Figure 1.2. Top three agriculture outputs in England, Wales, Scotland and Northern Ireland, 2017-18



Source: Defra *Farm Accounts for England*, Welsh Government *Aggregate agricultural output and income in Wales*, Scottish Government *Agriculture facts and figures.* CCC analysis.

Figure 1.3. Number of farms and area farmed in the UK, 2017



Source: Defra (2017*) June Agricultural Census*.

Agricultural land and forestry is owned by a wide range of individuals and bodies across the UK. Owners can rent land out to be farmed, with tenants providing labour and provision of capital and management frequently shared. Owners and tenants can often have different motivations for farming land - making the targeting of new land use policies challenging:

- There is a wide range of different landowners including government (e.g. Forestry Commission, Ministry of Defence), charities such as the National Trust and Royal Society for the Protection of Birds, water utilities as well as investors and individuals. Nevertheless, a recent survey suggests that less than 1% of the population owns half of all land in England.[8]
- The amount of land that is mainly or fully tenanted varies by nation with 28% in England, 24% in Scotland and 22% in Wales. In Northern Ireland, around 30% of land is let in conacre - short term rental of up to 11 months. A report in 2016 found that this system impeded long-term planning and damaged environmental performance.[9]
- The average length of a tenancy in England and Wales is just 2.9 years but tenancies are frequently renewed. A survey of Scottish farm tenants[10] found half of respondents said that they or their families had farmed their main tenancy for over 50 years, while around a quarter said they or their families had farmed it for 25 to 49 years. Just 10% had farmed for less than nine years. This survey found that the vast majority of tenants were satisfied.
- Research suggests that the relationship between landowners and tenants is generally positive, with a 2014 Survey of Scottish farming indicating that only 15% of tenants were dissatisfied with landlords.

[8] Guy Shrubsole (2019) '*Who Owns England?*'
[9] DAERA (2016) *'Delivering our future, Valuing our Soils: A Sustainable Agricultural Land Management Strategy for Northern Ireland'.*
[10] Scottish Government (2014) *'Views of tenant farmers and agricultural landlords on aspects of the agricultural tenancy system.'*

Tenant farmers have argued the need for landlords to take a longer term view of tenancies to encourage investment and more sustainable land management.

- Of the 3.2 million hectares of woodland in the UK 27% is owned or managed by the Forestry Commission (in England), Forestry and Land Scotland, Natural Resources Wales or the Forest Service (in Northern Ireland). The remaining 73% is privately owned.

Sustainable farming is knowledge-intensive and in order to inform decisions, farmers rely on a supply of advisory services. Farm advice operates across the public, private and voluntary sectors and on a range of issues including operational issues (e.g. pest management), strategic decisions (e.g. landscape management) and financial advisors who help with, amongst other things, regulations, tax and subsidies.

4. The evidence base

We have considered an extensive evidence base for this report, commissioned three new research projects and consulted different stakeholders (Box 1.2).

Important elements of the work include:

- A review of latest science (including from the IPCC) and other academic literature to confirm that the key measures needed to deliver deep emissions reduction set out in our previous advice remain valid (Chapter 2).
- New research to demonstrate how a land suitability modelling tool that takes account of soil series data and the impacts of future climate projections could be used to support decisions on appropriate land use now and in the future (Chapter 2).
- New research to estimate the costs and benefits of our scenario, including impacts on wider environmental services (Chapter 3).
- New research to explore the policy framework for deep emissions reduction and carbon removals in agriculture and land use. This included an extensive review of international and national evidence (Chapter 4).
- Wide stakeholder engagement including two advisory groups:
  - A land use advisory group chaired by Emeritus Professor Allan Buckwell of Imperial College and consisting of eight other members drawn from academia, industry and the voluntary sector.
  - An expert workshop on diets chaired by Professor Tim Benton of Chatham House.

A full list of the members of both groups is in Box 1.3. The Chairs' reports are published alongside this report.[11]

[11] Professor Allan Buckwell (2019) *Summary report, CCC land use advisory group;* Tim Benton (2019*) Climate change and diets: a CCC discussion meeting.*

Box 1.2. Evidence used in this report

Box 1.3. Members of the CCC land use advisory group and diets workshop

1. The CCC land use advisory group:

- Professor Allan Buckwell (Imperial College) - Chair
- Patrick Begg (National Trust)
- Simon Billing (Eating Better Alliance)
- Professor Iain Donnison (University of Aberystwyth)
- James Hepburne Scott (Forest Carbon)
- Dr Stephen Ramsden (Nottingham University)
- Professor Mark Reed (Newcastle University)
- Professor Jonathan Scurlock (National Farmers' Union)
- Susan Twining (Country Land Association)

2. The CCC diets workshop:

- Professor Tim Benton (Chatham House) - Chair
- Judith Batchelor (Sainsbury's)
- Simon Billing (Eating Better Alliance)
- Hazel Culley (M&S)
- Mike Hanson (Baxter Storey)
- Professor Susan Jebb (University of Oxford)
- Professor Dame Theresa Marteau (University of Cambridge)
- Professor Susan Michie (University College London)

Box 1.3. Members of the CCC land use advisory group and diets workshop

- Richard Sheane (3Keel)
- Kieron Stanley (Defra)
- Ana Svab (Sodexo)
- Dr Alison Tedstone (Public Health England)
- Kené Umeasiegbu (Tesco)
- Daniel Vennard (World Resources Institute)

The Committee has identified a set of key actions needed to start on the path to reducing GHG emissions and increasing carbon sequestration from this sector. This is not prescriptive. There are different combinations of these measures that will deliver broadly the same level of abatement by 2050. The policies highlighted in this report involve hundreds of decisions by different actors: farmers, government, banks, land agents, industry and the public, which will need to act together to deliver significant emissions reduction in land. It is important that they are reviewed regularly as new evidence and 'learning by doing' emerges.

The following chapters identify the policies, challenges and opportunities needed to allow the best outcomes for climate mitigation in this sector. Chapter 2 recaps the Committee's previous scenarios for land, sets out some new evidence that has emerged on valuation of methane emissions, and looks at lifecycle emissions of different foods. Chapter 3 sets out detailed analysis of the costs and benefits of our scenario including on wider environmental impacts. Chapters 4 and 5 set out our assessment of the policies needed to deliver our scenarios - Chapter 4 focusing on landowners and farmers and Chapter 5 on consumers and food demand.

Chapter 2: Land use scenarios that deliver climate goals - evidence update

Introduction and key messages

This chapter reviews the agriculture and land use scenarios produced by the Committee as part of our Net Zero report. We supplement this with consideration of the latest evidence on productivity drivers and new analysis on modelling local decisions on land. We also review additional scientific evidence regarding aspects of agricultural emissions reduction and land-use change.

A robust scientific underpinning is important for identifying appropriate measures that support global emissions reduction and carbon sequestration while maintaining other functions of land.

Our key conclusions are:

- **The way land is used must change to meet the UK's net-zero target**. The current approach is not sustainable. Fundamental change in the use of land across the UK is needed to maintain a strong agriculture sector that also delivers climate mitigation, adaptation and wider environmental objectives.
- **Our previous pathways to deep emissions reduction remain valid.** These require a high uptake of low carbon farming practices and releasing 22% of land out of traditional agricultural production for long-term carbon sequestration. This relies on improving sustainable productivity, shifting diets and reducing food waste. Given the extent of change, there is inevitable uncertainty around the precise levels of ambition that can be achieved in practice. Continued review of evidence and learning is essential.
- **Sustainable productivity in UK agriculture must be improved**. Productivity growth of UK agriculture has lagged behind other countries, and there is a wide gap between and across sectors. Government should develop an effective strategy to address the historical productivity gap in UK agriculture that includes tackling skills, rural infrastructure, knowledge exchange and delivering R&D at farm level.
- **Reducing agricultural methane emissions has clear benefits for the climate.** Methane is a short-lived greenhouse gas and affects the climate in different ways to carbon dioxide and nitrous oxide. Agricultural (and other) methane emissions must be significantly reduced globally to meet the long-term temperature goal of the Paris Agreement and in the UK to meet the 2050 net-zero greenhouse gas emissions target.
- **Agricultural emissions should not be off-shored.** Achieving emissions reduction should not be at the expense of producing less food in the UK and increasing imports. As the UK is a relatively low-greenhouse gas producer of ruminant meat, this risks exporting emissions abroad and increasing consumption emissions. Our analysis prioritises food demands from land; current per capita food production is maintained in 2050. Risks of carbon leakage should be considered in any changes to agricultural trading patterns.

We set out our analysis in the following sections:

1. Recap of scenarios to 2050 and beyond
2. Agricultural productivity
3. Short-lived climate pollutants from agriculture
4. Risks of carbon leakage

1. Recap of scenarios to 2050 and beyond

The Committee's previous work on developing scenarios for deep emissions reduction and carbon sequestration on land demonstrated that the current approach to land use is not sustainable; it will not meet rising future demand for food and settlement growth nor will it meet important environmental objectives.[12] Fundamental change in the use of land across the UK is needed to maintain a strong agriculture sector that also delivers for climate and other objectives.

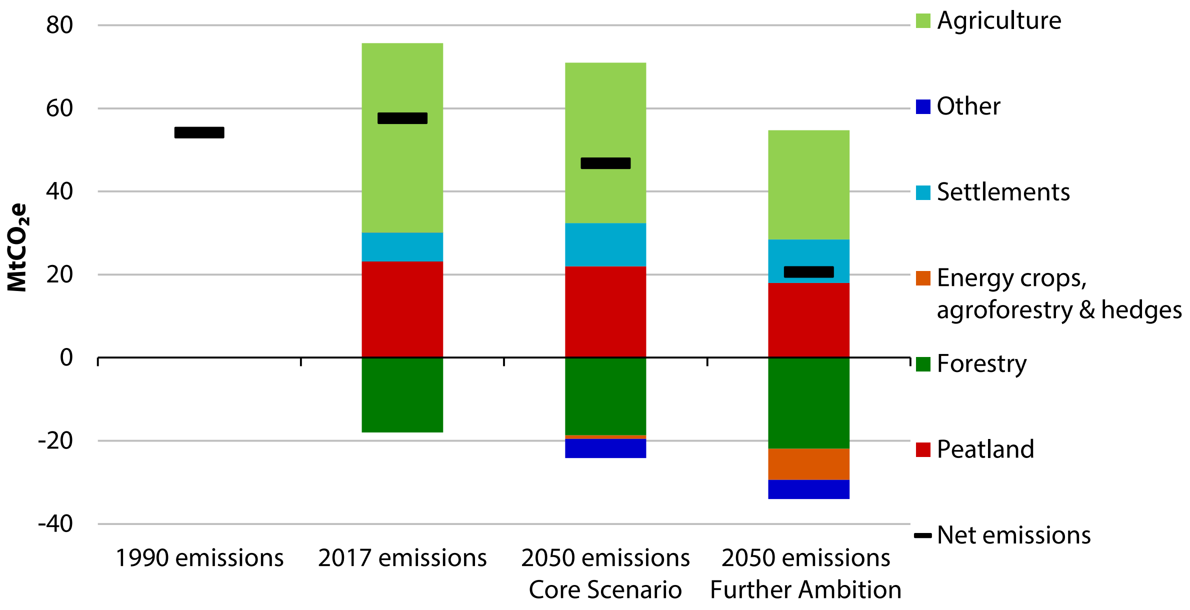
In assessing the evidence for this report, we have not changed our view of the scale of land use change required to achieve net-zero greenhouse gas (GHG) emissions by 2050. Our updated assessment of the economic impacts suggests our pathway will deliver an annual net benefit of £3.3 billion by 2050 (see Chapter 3).

In 2017, emissions from agriculture, land use and peatlands were 58 $MtCO_2e$. The 'Further Ambition' scenario for agriculture and land use set out in the 2019 Net Zero report achieved emissions reduction of 64% by 2050 compared with 2017 (Figure 2.1). Key elements of this scenario are:

- A high uptake of low-carbon farming practices aimed at reducing GHGs from soils, livestock and manure management, and a move to low-carbon fuels used in buildings and machinery. These could deliver 10 $MtCO_2e$ emissions savings by 2050.
- Releasing around 22% of land currently used for agriculture to other uses.
  - We considered five different measures that could release agricultural land: sustainably increasing crop productivity and livestock grazing intensity; shifting consumption of beef, lamb and dairy products part way towards healthy eating guidelines; reducing food waste along the supply chain and moving horticulture production indoors.
- Diet change away from beef, lamb and dairy, and improvements in productivity have the largest impact on land released (Figure 2.2). Shifting diets could result in 6 $MtCO_2e$ in direct on-farm emissions saving by 2050.

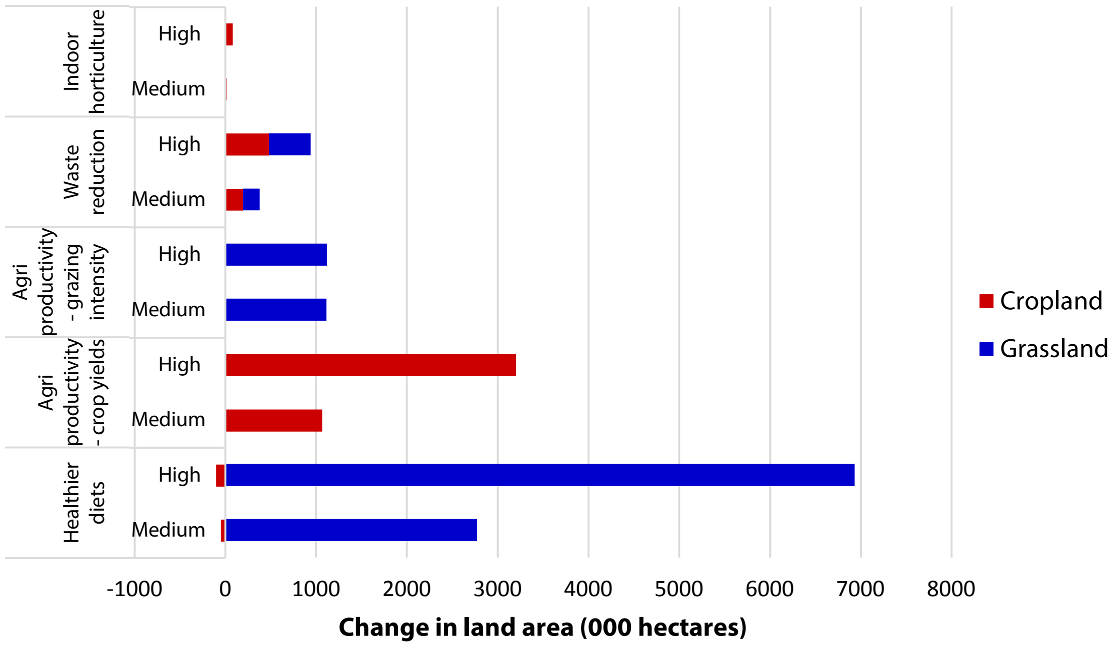
[12] CCC (2018) *Land use: Reducing emissions and preparing for climate change*.

Figure 2.1. Scenarios for very deep emissions reduction from the agriculture and land use, land-use change and forestry (LULUCF) sectors



Source: BEIS (2019) *Final UK greenhouse gas emissions national statistics 1990-2017*; Centre for Ecology and Hydrology (CEH) and Chris Evans et al. (2019) *Implementation of an Emissions Inventory for UK Peatlands*; CEH and Rothamsted Research (2018) *Quantifying the impact of future land use scenarios to 2050 and beyond*; CCC analysis.
Notes: Since our Net Zero advice, estimates for the Further Ambition scenario have been updated to take account of revised bioenergy soil carbon impacts. 'Other' includes net emissions sink/source from cropland and grassland.

Figure 2.2. Agricultural land area released by different factors compared with business-as-usual, 2050



Source: CEH and Rothamsted Research (2018) *Quantifying the impact of future land use scenarios*, CCC analysis**.**
Notes: The change in area of grassland due to grazing intensity is the same under "medium" and "high" ambitions**.**

- Using released land for carbon sequestration, habitat restoration and bioenergy production. The key measures are:
  - **Afforestation**. Our pathway requires an increase in tree planting to at least 30,000 hectares per year to 2050.[13, 14] Planting requires both productive conifers and standing broadleaved woodland.[15] An improvement in average forestry yields of 10% by 2050 is achieved through better silvicultural practices and breeding, and 80% of broadleaved woodlands are brought into active management compliant with the UK Forestry Standard by 2030. Together with improved woodland management this would deliver annual emissions sequestration by 2050 of 14 $MtCO_2e$ in forests with an additional 14 $MtCO_2e$ from harvested materials e.g. with carbon capture and storage (CCS) technologies by 2050.

    It is vital that afforestation continues to conform to these standards, in particular to ensure species and site selection takes account of the need to adapt to current and future impacts from climate change. Sustainably managed forests are important for reducing emissions across the economy. They provide a store of carbon in the landscape and harvested wood can be used sustainably for combustion and carbon sequestration in the energy sector (when used as bioenergy with carbon capture and storage - BECCS) and as wood in construction, creating an additional stock of carbon in the built environment.[16]

[13] We also considered a more speculative option to increase planting rates to 50,000 hectares per year to help close the gap between the Further Ambition scenario and economy-wide net-zero GHG emissions.
[14] Depending on planting density, 30,000 hectares equates to the planting of between 90-120 million trees per year.
[15] The Further Ambition scenario assumes a woodland creation split of 60:40 broadleaf to conifers.
[16] CCC (2018) *Biomass in a low-carbon economy*.

- **Bioenergy crops**. We assume that average planting rates of miscanthus, short rotation coppice and short rotation forestry scale up to reach 23,000 hectares per year from the mid-2020s. This will deliver 2 $MtCO_2e$ emissions savings in the land sector and a further 11 $MtCO_2e$ from harvested products e.g. with carbon capture and storage (CCS) technologies by 2050.
- **Agro-forestry and hedgerow expansion**. The area of cropland and grassland planted with trees increases to 10% by 2050, and the area of hedgerows increases to around 181,000 hectares by 2050. Planting trees on agricultural land, while maintaining land for its primary use, will deliver 6 $MtCO_2e$ savings by 2050.
- **Peatlands.** Our scenario assumes 50% of upland peat, and 25% of lowland peat is restored, and 25% of the area with low productivity trees is removed by 2050. This is a minimum level and there is a high risk that degraded peatlands will be lost due to hotter and drier conditions in the changing climate unless they are restored. These actions would reduce peatland emissions by 5 $MtCO_2e$ by 2050, while allowing food production to continue on the most productive land.

There is uncertainty in how far these levels of ambition can be achieved in practice, and in estimates of the carbon impacts. These will need to be updated with on the ground learning and ongoing research. However, the majority of measures are cost-effective from a carbon perspective and measures such as hedgerow creation, which is above current government carbon values, provide a range of other important benefits aside from carbon sequestration (e.g. reducing diffuse water pollution, providing shelter for livestock and biodiversity), and could be supported for delivering these benefits.

An effective land use strategy needs to take account of other demands on land. We have constrained our modelling to ensure that agriculture remains a strong food producing sector as well as meeting other demands:

- Per capita food production is at least maintained at current levels in 2050 and imports remain at current levels. Achieving strong GHG reductions should not be at the expense of producing less food in the UK, potentially increasing imports and offshoring emissions. Future exports are assumed to remain the same as in 2016 in absolute terms.
- Demand for housing and other economic activity is met before land is used for emissions reduction.

The net-zero analysis also outlined a more ambitious Speculative scenario which could be needed to meet the net-zero 2050 GHG target depending on progress in other sectors. This scenario assumed an even higher reduction in ruminant meat and dairy consumption and production, which reduces agricultural emissions further and releases up to 30% of agricultural land for increased afforestation (saving an additional 11 $MtCO_2e$ by 2050) and peatland restoration including seasonal management of the water table (an additional 6 $MtCO_2e$).

The analysis set out in the Net Zero report identified the key drivers and measures needed to achieve deep emissions reduction in the land sector. The Further Ambition scenario combines these in a particular way, but these are not intended to be prescriptive. Other pathways could achieve the same level of emissions by 2050. Other studies by the National Farmers' Union (NFU) and the Royal Society (RS) and Royal Academy of Engineering (RAE) for example, have set out scenarios with many of the same key elements as our pathway. The main differences are that they include measures to enhance soil carbon sequestration; more speculative options such as enhanced weathering and biochar; but do not assume changes in consumer behaviour (Box 2.1).

Box 2.1. Other land use emissions pathways

The NFU set out their assessment of how to reach net-zero agriculture emissions in England and Wales in their publication 'Achieving Net Zero Farming's 2040 goal' published in September 2019. They outline three pillars to achieving this:

- **Pillar 1** (11.5 $MtCO_2e$ by 2050) focuses on improving farming productive efficiency through measures aimed at improved soil quality, livestock health, diets and breeding, on-farm anaerobic digestion and energy efficiency of vehicles and buildings.
- **Pillar 2** (9 $MtCO_2e$ by 2050) is around increasing carbon storage in soils through measures such as hedgerows, woodland on farms, soil carbon practices, and peatland and wetland restoration.
- **Pillar 3** (26 $MtCO_2e$) uses bioenergy with CCS, using bio-based materials in industry and application of biochar to soils in the longer-term.

Bioenergy with CCS is an important component of our scenarios for achieving net-zero GHG emissions in the UK, but we do not account for the GHG removals from this technology in the agriculture and land-use sector. A joint report by the Royal Academy of Engineering (RAE) and Royal Society (RS) considered how to achieve net-zero carbon emissions in the UK by 2050 through the deployment of GHG removal measures. Their estimates for afforestation and peatland restoration are similar to ours:

- **Afforestation:** The RAE and RS estimate that increasing woodland cover from 13% currently to 18%, by planting 1.2 million hectares by 2050, could deliver annual savings of 15 MtCO2e.
- **Peatland restoration:** While the RAE and RA analysis assumes a similar area of peatland is restored as in our study, they assume net carbon sequestration occurs before 2050.

The RAE & RS report also considered the sequestration potential of additional measures not covered in our analysis:

- **Soil carbon of agricultural land:** The RAE and RS estimate that a range of management practices deployed on cropland and grassland could lead to a soil carbon sink of 10 $MtCO_2e$ per year by 2050.
- **Biochar:** Biochar is produced from organic matter using the pyrolysis process, making it resistant to decomposition and therefore a potential long-term store of carbon. The RAE and RS estimate that biochar could sequester 5 $MtCO_2e$ per year by 2050, but this technology has not been demonstrated at scale.
- **Enhanced weathering:** Silicate rocks naturally fix carbon out of the air over geological timescales. This process can be speeded up by grinding up rocks (in order to vastly increase the exposed surface area) which can be dispersed over cropland. The RAE and RS estimate that enhanced weathering could sequester 15 $MtCO_2e$ per year by 2050. This option is not currently available at scale in the UK.

There is a lack of sufficient and robust evidence to suggest that mineral soils can continually increase carbon sequestration through management practices alone.[17] We did not include biochar and enhanced weathering in our scenarios for the net-zero analysis due to the potential for unforeseen long-term side-effects, but support research to develop these options and gain a better understanding of the potential environmental consequences of deployment in the UK.

Source: National Farmers' Union (2019) *Achieving Net Zero, Farming's 2040 goal*;
The Royal Academy of Engineering and the Royal Society (2018) *Greenhouse gas removal*.

[17] CEH (2013) *Capturing cropland and grassland management impacts on soil carbon in the UK LULUCF inventory* and Ricardo (2020) *Development of the impact of grassland management on the UK LULUCF Inventory*.

Taking account of wider objectives of land

Our work to date has focussed on setting out the strategic direction needed to deliver deep emissions reduction from the land sector. We recognise that decisions on land use need to be taken locally and that decision making is complex and multi-layered. Some of the key drivers in making these decisions are:

- Local geography (including topography, soils and climate) influence the suitability of land for a range of uses, as does future projected changes in the UK's climate.
- The markets for different products derived from land such as multiple food types, wood and timber and how these might change in the future. As well as market prices, decisions will be driven by input costs and technologies.
- Policy drivers, particularly the Common Agricultural Policy (CAP), have helped to support some agricultural activities that would not otherwise be viable.

It is important that local decisions take account of the suitability of land for different uses now and in the future. A variety of tools and data is available to help planners optimise decision making (e.g. the Sustainable Intensification Research Platform (SIP), the Outdoor recreation valuation tool (OrVAL) and the Natural Environment Valuation Online tool (NEVO)).

To demonstrate how land suitability modelling can help in this process, we commissioned Environment Systems Ltd working on the Welsh Government Capability, Suitability and Climate Programme, to consider the capability of land in Wales to support afforestation now and in the future under different climate scenarios, while taking account of other uses (Box 2.2).

Box 2.2. Suitability of land to deliver the CCC afforestation ambition in Wales

We commissioned Environment System Ltd (Envsys), utilising work from the Welsh Government Capability, Suitability and Climate Programme to assess the suitability of the CCC afforestation ambition of planting 152,000 hectares of new woodland in Wales by 2050.

The project used updated soil and Agricultural Land Classification (ALC) maps for Wales, combined with other biophysical datasets, to model land capability and suitability for growing a range of crop species. The modelling considered:

- Two species: sessile oak and sitka spruce, representing a mix of broadleaf and conifer woodland in the CCC scenario.
- Three climate scenarios: the present day, medium and high emissions scenarios for 2050 and 2080.
- A range of policy and legislative constraints that prevent or restrict tree planting, including areas of deep peat, priority habitats and Best and Most Versatile (ALC) land.
- A range of sensitivities such as historic sites with high cultural value, stone walls, acid sensitive catchments where planting might still be possible but where there are additional considerations that may affect the type and scale of woodland planting.

For each tree species, all biophysical factors were reviewed by ADAS crop specialists and Envsys ecological experts and each factor was scored as:

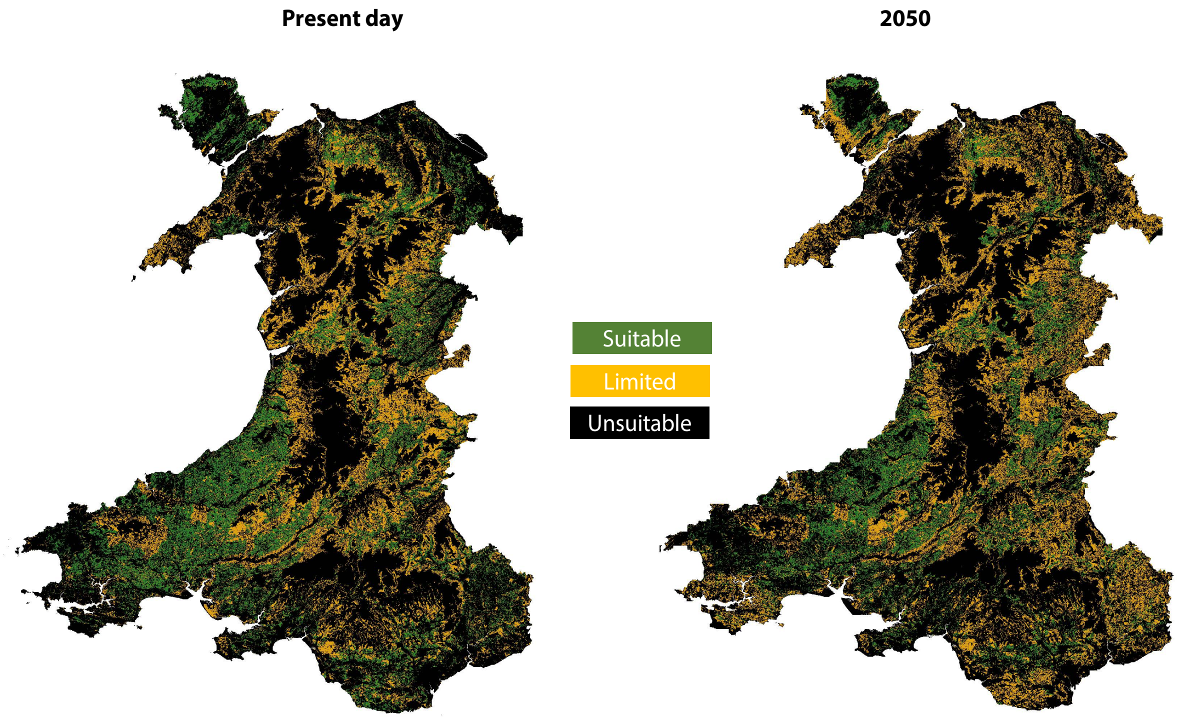
- 'Suitable' – growing conditions are optimal for the species in question.
- 'Limited suitability' – the species can be supported but yields are expected to be lower; adverse weather conditions might destroy the crop; or the crop needs to be managed intensively.
- 'Unsuitable' – the biophysical condition does not allow for crop establishment.

Land that has any constraint is classed as 'Unsuitable'; those with sensitivities are classed as 'Limited Suitability'.

The results for oak under the present day and the medium emissions scenario in 2050 are shown in Figure B2.2. They show the area of land that is 'suitable' falls from 12% of land currently to 9% by 2050, but the area classed as 'limited suitability' increases from 19% to 23%. The areas less suitable or unsuitable are towards the eastern part of Wales. Overall there is sufficient 'suitable' land to meet the CCC planting ambition for 2050 under both the medium and high emissions scenario by 2050, although this is unlikely to be the case by 2080, which could require land with 'limited suitability' to be used for this particular tree species.

Box 2.2. Suitability of land to deliver the CCC afforestation ambition in Wales

Figure B2.2. Suitability of planting oak today and under a medium emissions scenario by 2050



Overall, the analyses shows that the current tree planting ambition for Wales is achievable but could require land that is less than ideal biophysically to be used in the future. It is important that planting schemes consider the changes in biophysical characteristics such as drought, frost risk etc. to choose the most appropriate location for new woodland.

Further work could incorporate a wider range of species in order to better understand the long-term suitability trends and to promote the creation of resilience in future woodland.

Source: Environment Systems Ltd (2019) *'Tree Suitability Modelling – Planting Opportunities for Sessile Oak and Sitka Spruce in Wales in a Changing Climate'*.

The modelling found that the CCC ambition for planting 152,000 hectares of additional woodland by 2050 in Wales is achievable but could require utilisation of land that is biophysically limited or could become so in the future, and/or the selection of different species to those modelled in this report.

The CCC ambition for measures to sequester carbon are necessarily estimated at a broad geographical level and can not take account of local factors that would need to be considered when implementing these actions on the ground. This modelling has demonstrated that by using detailed soil, topography data and climate projections while taking account of other constraints on land, it is possible to locate areas most suitable for the measures in the CCC scenarios and produce detailed maps of them.

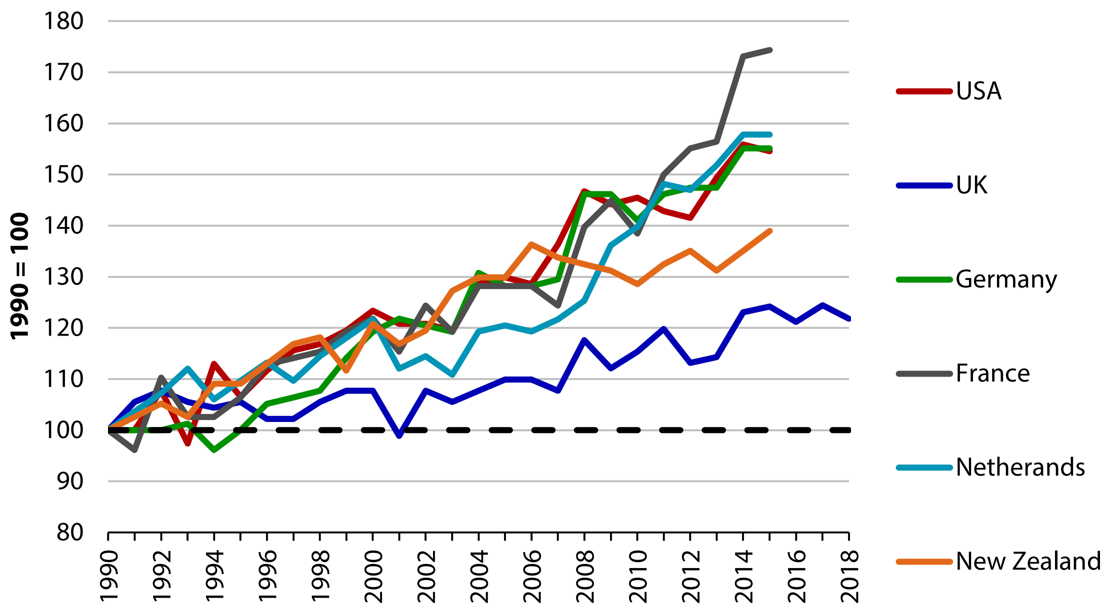
2. Agricultural productivity

Sustainable agriculture productivity growth is a key driver in our land use scenario: it allows more to be grown with less land and other inputs and enables land to be freed up for other uses. Improved productivity is not the same as intensification, however, which relies on higher levels of inputs to achieve higher outputs.

This section looks at evidence on past trends in UK productivity growth and considers policies needed to deliver future improvements in sustainable crop and livestock productivity.

Historically UK farm productivity growth has lagged behind other developed countries and in recent years remained mostly flat (Figure 2.3). Most of the loss in competitiveness has occurred since the early 1990s, with the decline mainly on livestock farms.

Figure 2.3. Comparison of agricultural productivity growth in the UK and key competitors



Source: United States Department of Agriculture (2018) *International agricultural productivity.*
Notes: Total factor productivity is a measure of how well inputs are converted into outputs and provides an indication of the efficiency and competitiveness of the agriculture industry.

A high proportion of farmers rely on CAP direct payments to break even. There is also a wide range in farm income and productivity across and within different sectors (Figure 2.4):

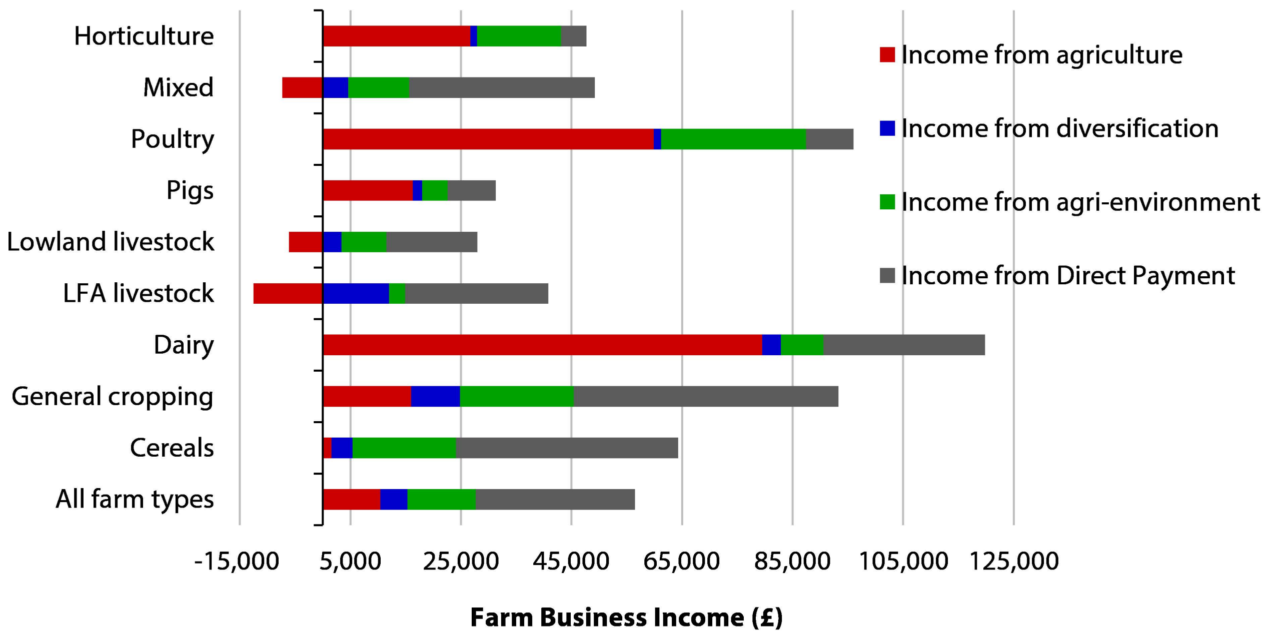
- 46% of farms in England made a loss in 2017/18 when unpaid labour is taken into account. [18] There is also a long tail making high returns, 13% of farms earned over £130,000.
- There are large differences between the best and worst farms and among sectors:
  - In England in 2017/18 the top 25% of farms were responsible for 77% of income (covering all sources of agricultural income including CAP payments).

[18] As defined by Farm Business Output per £100 input. Source: *Farm Business Survey*, 2017/18.

– Across all farm types apart from dairy, those in the bottom 25% of income were operating at a loss. Average farm income for those in the top 25% of farms was almost £174,000.
– Dairy farms had the highest median farm income in 2017/18 (£119,700) and lowland livestock grazing the lowest (£21,900).

- There is a high reliance on CAP payments (direct and agri-environment). Across all farms in England, 73% of farm income was from CAP with 18% from farming and 9% from diversification. Pig, poultry, horticulture and dairy have the lowest reliance on CAP payments, while grazing livestock and mixed farms make a loss on average and rely on CAP payments to make a profit.

Figure 2.4. Farm business income by farm type and source, England (2017/18)



Source: Defra (2018) *Farm Business Survey for England.* CCC analysis.

Productivity is driven by a number of factors such as: the business environment including level of competition, number of farms and access to capital; the state of natural capital including soils, topography and climate; skills and innovation and how open the sector is to new practices; the level of government intervention, including regulations and subsidies.

Evidence from literature and stakeholder engagement has identified key drivers of productivity that need to be addressed in the UK: [19]

- Driving effective use of data including developing Key Performance Indicators enabling better measurement of performance across the sector.
- Transforming knowledge exchange, through a knowledge hub to enable best practice to be shared across the sector and to raise standards.

[19] Food and Drinks Council (2019) *Agricultural Productivity Report.*

- Driving uptake of professional training and development to improve skills across the sector.
- A collaborative approach to innovation that aligns innovation funding with strategic priorities and brings R&D to the farm level.
- Enabling rural infrastructure by investing in 5G and upgrading electricity networks.

An important element of policy support for agriculture is to address the productivity challenge in this sector, supporting the key policies for emissions reduction (Chapter 4). Defra and the devolved governments in Scotland, Wales and Northern Ireland should develop an effective strategy to make improvements in these areas and raise performance across the sector.

3. Short-lived climate pollutants from agriculture

Global climate change is being driven largely by emissions of carbon dioxide (CO_2), however emissions of other gases, such as methane (CH_4) and nitrous oxide (N_2O) from agriculture, also make significant contributions to warming. This section considers up-to-date scientific evidence on the climate impacts of shorter-lived GHGs (such as agricultural methane) and implications for policy.

(a) The effect of shorter-lived greenhouse gases on the climate

Methane is a GHG with a much stronger near-term heat-trapping potential compared to CO_2.[20] CO_2 emissions result in raised atmospheric concentrations for thousands of years, but a tonne of methane has an atmospheric lifetime of only around 12 years, meaning it is much shorter-lived than the effect of emitting a tonne of CO_2 into the atmosphere.

These different timescales affect how the climate responds to the same amount of 'CO_2-equivalent' emissions of different GHGs (Figure 2.5):[21]

- The warming from emitting 1 $MtCO_2e$ of CO_2 persists in the long-term. Each additional tonne of CO_2 emitted creates more warming, meaning warming induced by CO_2 increases in proportion to the *cumulative total* emissions of CO_2.
- The warming from emitting 1 $MtCO_2e$ of methane is more potent than CO_2 over the first few decades but has largely disappeared by 100 years. This means that the warming from methane emissions largely depends on the *sustained rate* of methane emissions as methane does not accumulate in the atmosphere long-term.
- As N_2O has a lifetime of approximately 120 years, it affects the climate similarly to CO_2 over the first century, but has a less long-lived effect in the very long-term.

These differences mean that a steady rate of N_2O or CO_2 emissions continues to increase the level of N_2O or CO_2-induced warming, whereas a steady rate of methane emissions maintains an approximately constant level of methane induced warming.

[20] When compared on an equal mass basis.
[21] Equivalence is calculated using the standard global warming potential over 100 years (GWP_{100}).

Figure 2.5. Global warming response to a one-off pulse emission of 1 $MtCO_2e$

Source: CCC analysis.
Notes: Warming responses to the pulse emissions are calculated using the response functions for calculating emissions metrics in the IPCC 5th Assessment Report.

(b) Metrics for the CO_2-equivalence of biogenic methane

Several metrics exist to express emissions of non-CO_2 GHGs in 'CO_2-equivalent' units. The most commonly used is the *global warming potential* (GWP) metric which uses the total heat trapping potential over a specified time period (commonly 100 years - GWP_{100}) to assess 'CO_2-equivalence'.[22] This is the most commonly-used metric in climate policy due to its recommended use in past IPCC assessment reports.[23]

UK climate policy currently aggregates GHGs using the GWP_{100} metric. This is largely based on aligning with international methodologies:

- The UK Climate Change Act mandates that CO_2-equivalence is calculated 'consistent with international reporting practice'. Under the Kyoto Protocol, this required the use of the GWP_{100} metric with values from the IPCC 2nd Assessment Report. In 2014, values were updated to those from the IPCC 4th Assessment Report for reporting to the United Nations Framework Convention on Climate Change (UNFCCC).

[22] A common alternative metric is the global temperature potential (GTP). This uses the warming caused at a particular point in time from emitting one tonne of a GHG to assess 'CO_2-equivalence'. This metric is more directly connected to the effects of GHG emissions on global temperature at a particular date, but still fails to capture the largely 'flow-based' effect of short-lived GHGs on the global average surface temperature.
[23] No particular metric was recommended for use in the most recent 5th Assessment Report of the IPCC, which instead highlighted that 'the most appropriate metric depends on the particular application and which aspect of climate change is considered relevant in a given context'.

- Recently (December 2018) the 24th conference of parties to the UNFCCC decided to require the use of the GWP_{100} metric (with values taken from the IPCC 5th Assessment Report) in the Paris Agreement reporting framework. This decision will mean continued usage of GWP_{100} in the UK GHG inventory (with a higher value for methane than is currently being used).

Based on this reasoning, the Committee interpreted the 'balance of anthropogenic sources and sinks' of GHGs in Article 4 of the Paris Agreement as a commitment to reaching net-zero GHG emissions aggregated on a GWP_{100} metric in our Net Zero report.

New usage of CO_2-equivalence metrics for biogenic methane

A new usage of the GWP_{100} metric (named GWP*) has recently been developed to recognise the difference in how sustained emissions of methane and CO_2/N_2O affect global average surface temperature, which is not fully captured by the current metric.[24] This new metric will be assessed by the IPCC as part of its forthcoming 6th Assessment Report.

- GWP* equates an increase in the sustained rate of methane emissions with a one-off emission of an amount of CO_2, no change in the sustained rate of methane emissions with zero CO_2, and a decrease in the sustained rate of methane with a one-off removal of an amount of CO_2 (Figure 2.6). This better reflects how changes in methane emissions affect global surface temperature.[25]
- The GWP* metric captures that falling methane emissions would reduce the level of methane -induced warming. This means that emissions of biogenic methane would only need to decline slowly (by less than 1% per year) to stop contributing to increasing global temperature. However, as long as methane emissions are above zero, they contribute to keeping the global average temperature raised above pre-industrial levels.

There has been growing interest in the implications of the differences between methane and long-lived GHGs for setting long-term targets for agricultural methane emissions. For instance, the New Zealand Zero Carbon Bill separated out agricultural methane reductions from their target for net-zero GHGs by 2050.[26] It has also been raised whether an appropriate target for biogenic methane reduction would be to reduce emissions only so fast as required to add no additional warming (net-zero GWP*). This would involve slower reductions in biogenic methane than in our Further Ambition scenario or the New Zealand 2050 target. The next subsection looks at what might be an appropriate contribution from UK biogenic methane mitigation in the context of global efforts to achieve the Paris Agreement.

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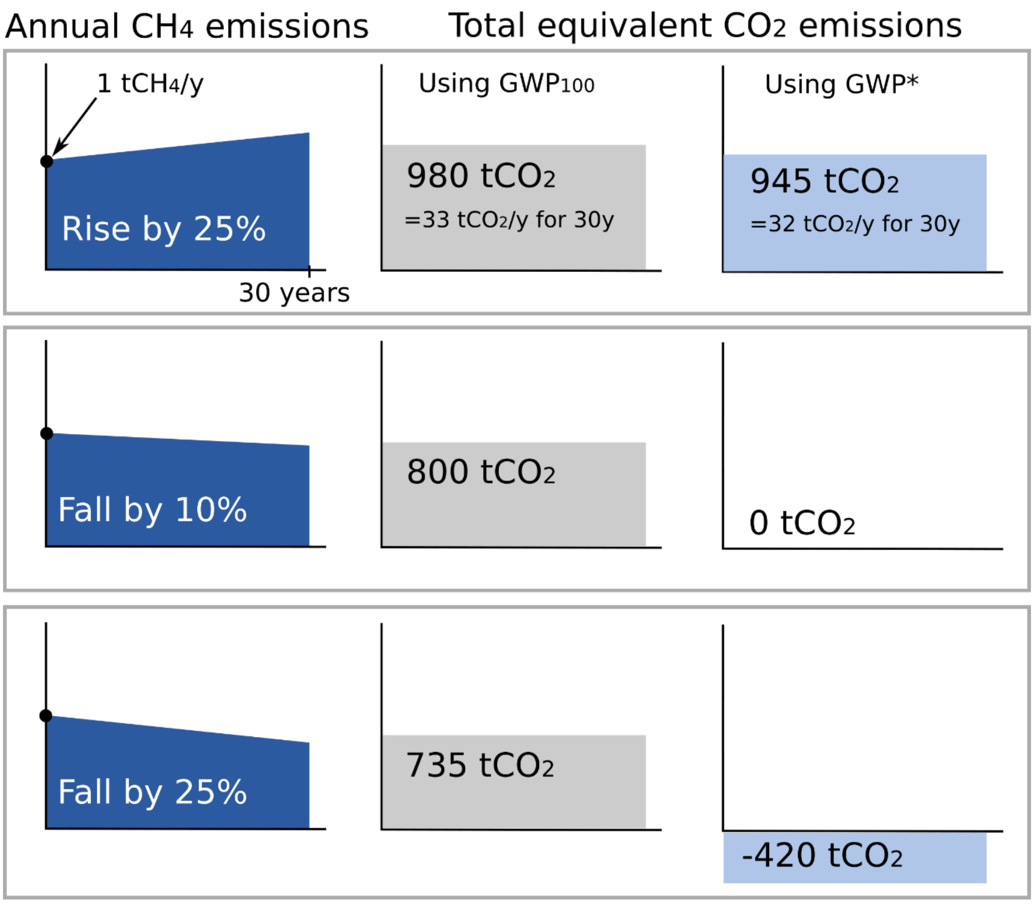
[24] Allen, M. R. et al. (2018) A solution to the misrepresentations of CO2-equivalent emissions of short-lived climate pollutants under ambitious mitigation. *npj Climate and Atmospheric Science*, 1, 16; Cain, M. et al. (2019) Improved calculation of warming-equivalent emissions for short-lived climate pollutants. *npj Climate and Atmospheric Science*, 2, 9.

[25] Annual methane emissions expressed in the GWP* metric would not contain information regarding the absolute level of warming being sustained by present levels of methane emissions. Some long-term consequences of emitting methane, such as contributing to thermosteric sea-level rise, are more accurately captured by the GWP_{100} metric.

[26] Instead the Bill committed to reduce agricultural methane emissions by 24 - 47% below 2017 levels by 2050.

Figure 2.6. Methane emissions accounting under GWP_{100} (middle column) and GWP* (right column)



Source: Oxford Martin School (2018) *Climate metrics for ruminant agriculture*.

(c) Biogenic methane mitigation in long-term emissions targets

Keeping warming to the 1.5°C end of the Paris Agreement long-term temperature goal will require rapid reductions in global emissions of long-lived GHGs to reach net-zero. Reductions in global methane emissions, including from the agricultural sector, will also be critical.

Both geophysical and techno-economic considerations underlie this:

- Global methane emissions are likely to need to fall to help offset the loss of climate cooling from aerosol pollution.
  - Global emissions of aerosols (which have a cooling effect on the climate) could be rapidly reduced by 80 - 90% over the next few decades in part due to efforts to improve global

air quality.[27] This could unmask additional GHG-induced warming currently being hidden.[28]
  - Reducing the level of warming being sustained by methane emissions would help offset this loss of aerosol cooling.

- 'Cost-optimal' models reduce both long-lived and short-lived emissions as part of global pathways to keep expected warming to the Paris Agreement long-term temperature goal. Pathways with an approximately 50% probability of keeping warming below 1.5°C with no or low overshoot reduce global methane emissions by 43 - 61% from 2010 levels by 2050. Agricultural methane emissions made up around 45% of global methane emissions in 2017, and generally fall by 24 - 47% (by 2050) in these pathways.[29] This reduction in agricultural methane emissions was used to inform the New Zealand 2050 target.

If global agricultural methane emissions are only reduced to prevent an increase in methane-induced warming (net-zero in the GWP* metric), additional reductions in cumulative long-lived CO_2 and N_2O emissions (from agriculture and other sectors of the economy) would be needed to achieve the same expected climate outcome. This would require global CO_2 emissions to fall faster, reaching net-zero around 2040 - 2045, instead of around 2050 to maintain an approximately 50% probability of keeping warming below 1.5°C with no or low overshoot.

Our assessment remains that there are strong reasons to support reducing UK agricultural methane emissions:

- On a per person basis, our 'Further Ambition' scenario reaches a level for 2050 agricultural methane emissions consistent with global pathways keeping warming below 1.5°C (Figure 2.7).[30] This would mean long-term UK agricultural methane-induced warming equal to the global average level in scenarios expected to achieve the Paris Agreement long-term temperature goal.[31]

- Many of the actions to reduce UK agricultural methane emissions within our 'Further Ambition' scenario are cost-saving on a social basis and we have estimated the level of funding required to cover any private costs where these exist (Chapter 3), alongside policy recommendations on how to implement them (Chapter 4).

- Emissions reductions will be needed in all sectors to achieve the UK's net-zero GHG emissions target by 2050. Reducing emissions in the agricultural sector does not allow other sectors to avoid action and vice versa.

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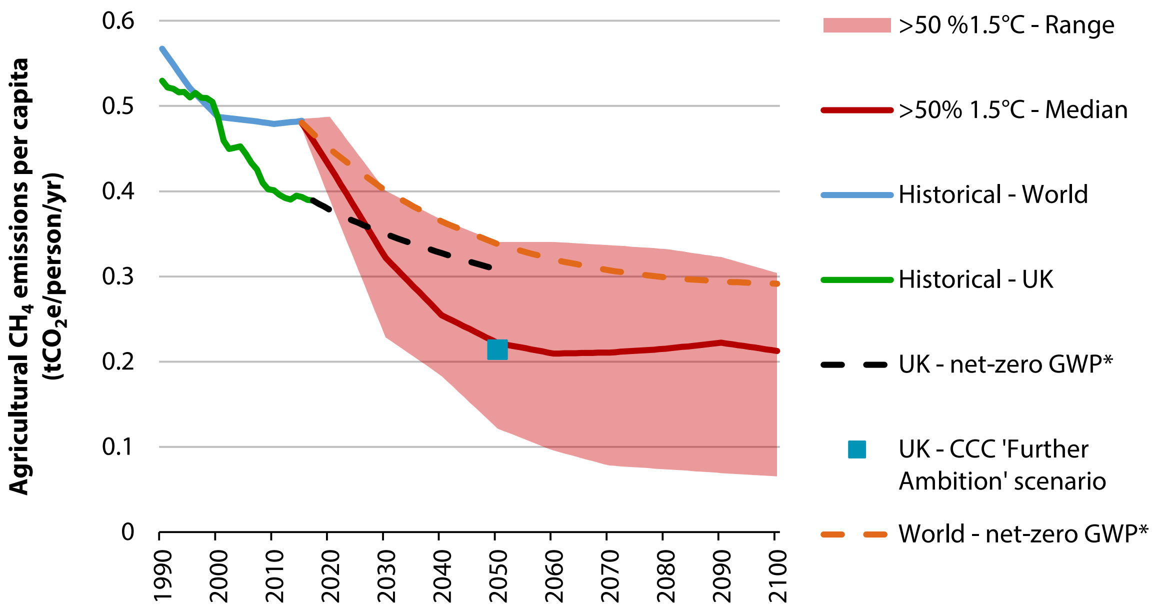
[27] Shindell, D. & Smith, C. J. (2019) Climate and air-quality benefits of a realistic phase-out of fossil fuels. *Nature*, 573, 408–411.
[28] Based on recent IPCC assessments, nearly 0.5 °C of warming is currently being masked by aerosol in the best-estimate (although there remains substantial scientific uncertainty around this value).
[29] This range is the interquartile range across the IPCC Special Report on Global Warming of 1.5°C (IPCC-SR1.5) scenarios keeping warming to below 1.5°C (~50% probability) with no or low overshoot. Many cost-optimal models have deployed non-CO_2 mitigation options to their maximum possible extent to keep warming to the well-below 2°C end of the Paris Agreement long-term temperature goal. This suggests that non-CO_2 mitigation options are more cost-effective than some very deep decarbonisation options for CO_2 and will be necessary aspects of cost-effective pathways to achieving the Paris Agreement long-term temperature goal.
[30] With approximately 50% probability and no or low overshoot.
[31] Simply avoiding adding to UK methane-induced warming presupposes that the current level of methane-induced warming is an appropriate level to maintain in the future. This would lead to UK methane-induced warming higher than the mid-century global average level in pathways consistent with the Paris Agreement.

Reducing biogenic methane emissions from UK agriculture will have unambiguous benefits for the global climate. Given the economy-wide net-zero GHG emissions target, official accounting in the agricultural sector should continue to use the GWP_{100} metric required for consistency with national and international frameworks.

Figure 2.7. Per person agricultural methane emissions in pathways consistent with the Paris Agreement



Source: IPCC-SR1.5; Hoesly, R. et al. (2018) Historical (1750–2014) anthropogenic emissions of reactive gases and aerosols from the Community Emissions Data System (CEDS). *Geoscientific Model Development*, 11, 369–408; CCC analysis.
Notes: Methane emissions are expressed using the GWP_{100} metric (values from the IPCC 4th assessment report). The plume shows the full range of 1.5°C no or low overshoot scenarios from IPCC-SR1.5, harmonised to observed emissions from Hoesly et al. in 2015. Global average population is projected forward using the SSP2 scenario for the 'World - net-zero GWP*' case and the UK population using the ONS principal long-term projection (until 2050 only) for the 'UK - net-zero GWP*' case. The net-zero GWP* cases are consistent with reducing methane emissions only so far as to not add additional methane-induced warming.

4. Risks of carbon leakage

Any increase in emissions overseas as a result of measures to reduce emissions in the UK is known as carbon leakage. This section looks at how current trade patterns for ruminant meat (both beef and lamb consumption reduce in our scenario) affect the risks of carbon leakage from efforts to reduce UK agricultural emissions.

(a) Current UK agricultural trade patterns

Agriculture and food products are traded globally, with 47% of food consumed in the UK imported and 18% of UK-produced food exported.[32] Agriculture makes up 0.6% of the UK's gross value added (GVA), within a wider agri-food sector contributing 6.6% of national GVA.

[32] Defra (2019) *Agriculture in the United Kingdom*. Based on the farm-gate value of raw food production.

Exported food, feed and drink makes up 6.2% of the UK's total exports and 1.9% of global agricultural export flows.

Current UK trade in ruminant meat is largely with the EU and New Zealand:

- **Beef and veal.** The UK is around 80% self-sufficient in beef production. Exports account for 15% of domestic production and the vast majority is exported to the EU (89%). Exports from the UK are 1.2% of global export flows. Imports of beef to the UK also generally come from EU countries (94%), predominantly the Republic of Ireland, and make up 32% of total consumption. Most exported beef and veal is meat for processing or lower-value products for which there is greater demand overseas.
- **Sheep meat.** The UK is approximately self-sufficient in lamb production. Exports account for 32% of domestic production and the vast majority is exported to the EU (96%). Exports from the UK are 7.2% of global export flows. Imports of lamb to the UK (32% of total consumption) generally do not come from EU countries (78% of imports come from outside the EU), with most coming from New Zealand.

These trade flows are underpinned by the system of environmental standards and tariffs restricting imports from non-EU regions and those without quota or tariff-free access to EU markets.

(b) The GHG-intensity of international ruminant meat production

Lifecycle assessment (LCA - see Chapter 5) can be used to calculate the total amount of GHG emissions from the full supply chain of food production.

Evidence from the latest LCA synthesis suggests that UK-produced beef generally has a lower GHG-intensity compared to the global average (Figure 2.8):

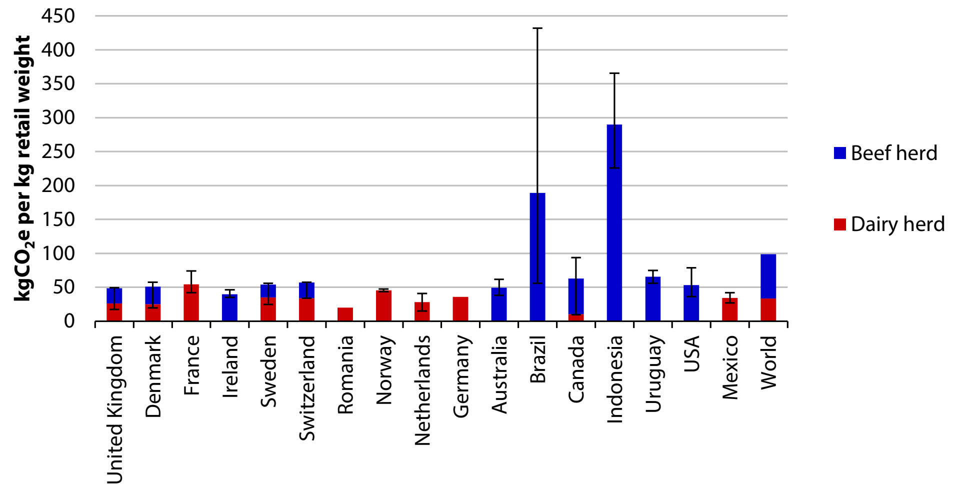
- The GHG intensity of UK-produced beef is estimated at around 48 $kgCO_2e$ per kg of meat from dedicated beef herds (beef from dairy herds is less GHG intensive at around 26 $kgCO_2e$ per kg).[33] This is lower than the average production of the globe as a whole from dedicated beef herds (99 $kgCO_2e$ per kg).[34]
- Some other EU beef producers have similar GHG-intensities to the UK, but on average across the LCA database, the GHG intensity of EU production is around 14% larger than the UK.[35]
- The GHG intensity of producers from elsewhere in the world can be greater again. Brazil and Indonesia rank particularly high due to land-use change emissions associated with clearing high-carbon land for grazing, whereas UK and European production benefits from having access to land which was already deforested centuries ago, helping to avoid these emissions.

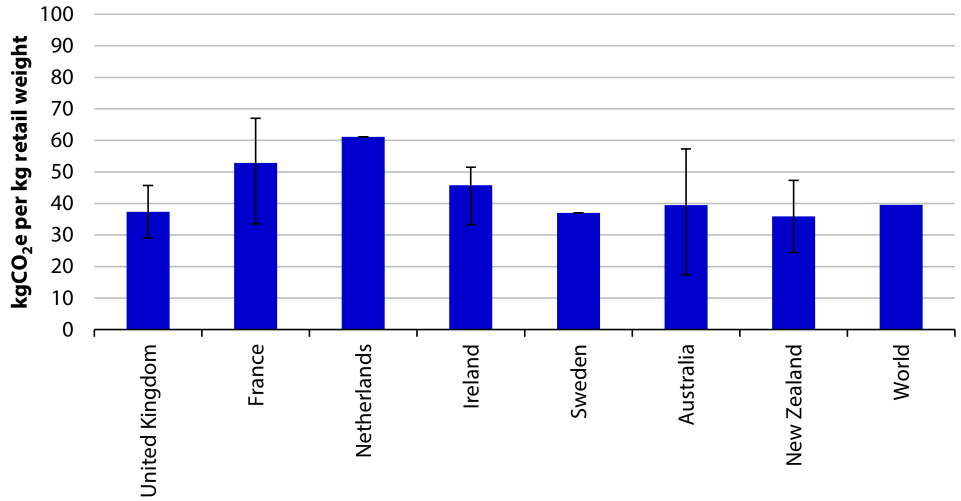
There is more limited evidence available regarding the comparative GHG-intensities of lamb production in the UK and abroad. Available evidence indicates that UK production may be less GHG-intensive than other European producers, but more GHG-intensive than lamb produced in New Zealand.[36]

[33] The range across both UK beef and dairy herds is 17 to 49 $kgCO_2e$ per kg of meat.
[34] This conclusion is also supported by other datasets that don't consider all components of the full lifecycle assessment, such as the Food and Agriculture Organisation of the United Nations (FAO).
[35] This is based on averaging across both beef herd and dairy herd production in equal proportion.
[36] Transportation (via shipping) of New Zealand lamb to the UK is included in one of the studies for New Zealand lamb in Figure 2.8 and is only a small contributor to the total GHG footprint.

The current trade flows of ruminant meat make significant contributions to the overall emissions footprint of UK food consumption. UK consumption of agricultural products has a GHG footprint approximately 10% higher than the total GHG emissions produced from the UK's agricultural sector, with around half of this consumption footprint falling within UK borders (and appearing within UK territorial emissions accounts).[37]

Figure 2.8. Lifecycle assessment of the GHG intensity of beef producers (top) and lamb producers (bottom)





Source: Poore, J. & Nemecek, T. (2018) Reducing food's environmental impacts through producers and consumers. *Science, 360 (6392), 987-992.*
Notes: Bars show the mean life cycle emissions associated with producing 1 kg of retail weight beef (top) and lamb (bottom) from different countries. Production methods are weighted by their share of national production. Beef production is separated between beef from dairy herds (red) and dedicated beef herds (blue). Error bars indicate the minimum and maximum GHG-intensity from the LCA database (across both dairy herd and beef herd in top panel).

[37] This is based on the 'Products of agriculture, hunting and related services' sector in the UK consumption emissions accounts. Consumption emissions here do not correspond to a full LCA GHG footprint and do not include land-use change emissions associated with food and feed production.

(c) Leakage risks from reducing UK consumption

The 'Further Ambition' scenario contained a 20% reduction in the per person consumption of beef and lamb. Given expected population growth by 2050, this would reduce total levels of UK beef consumption by around 9% from today's levels, and would require a similar reduction in the number of animals.

The differences between the GHG-intensity of UK and overseas beef production mean that the effect of this reduced beef demand on UK consumption emissions will be somewhat sensitive to the breakdown between consumption of domestic production and imports (Figure 2.9):[38]

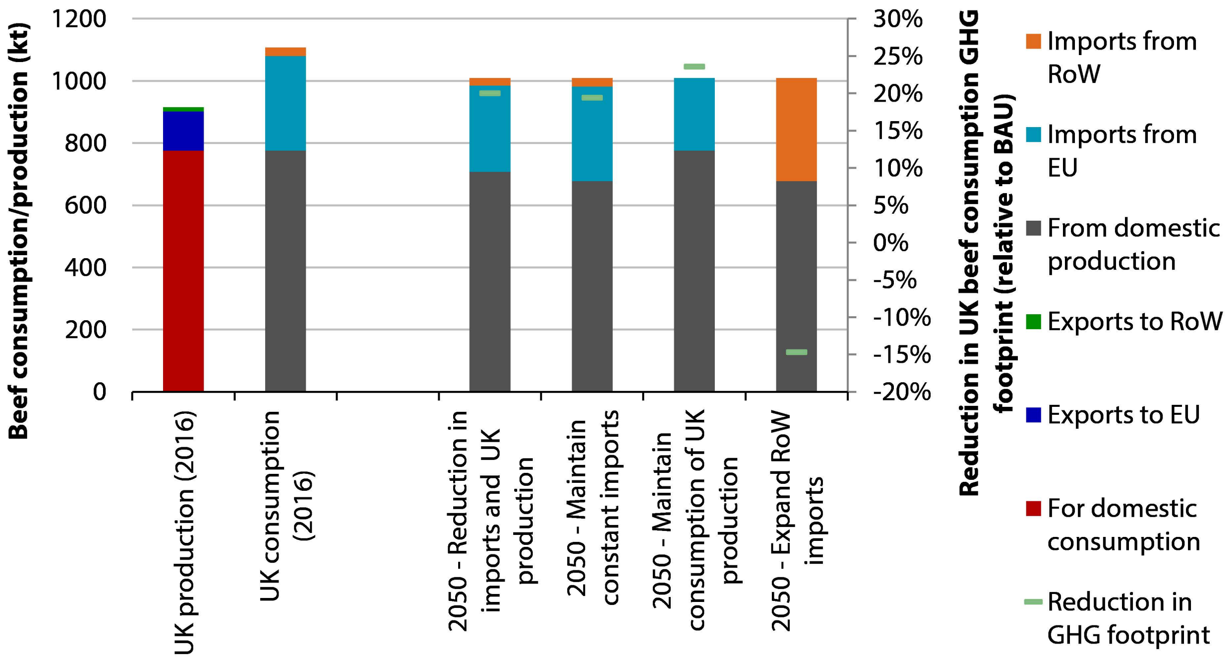
- If the fractional demand for domestic supply and imports is maintained as it is today, the lifecycle emissions directly associated with UK beef consumption would also fall by 20% compared to maintaining per person consumption at today's levels.[39]
- Achieving the same levels of overall demand reduction while instead maintaining the absolute level of imports would still reduce the total lifecycle emissions directly associated with UK beef consumption, but would have slightly smaller direct savings (around 19%). A smaller fraction of the 2050 beef consumption footprint would appear in the UK territorial accounts in this case.
- If instead the consumption of domestic production is maintained, this would lead to the greatest overall reduction in the direct emissions footprint of UK beef consumption (around 24%), but would show the smallest reduction in UK territorial emissions from beef production and would have the smallest amount of land made available for carbon sequestration in the UK.
- A change in current agricultural trade patterns to enable more imports from non-EU producers could present substantial carbon leakage risks. If imports from the EU were replaced by products with the global average GHG-intensity of beef this could offset the benefits of reduced overall consumption and lead to a 15% increase in the lifecycle emissions from UK beef consumption.

There are smaller fractional variations in the GHG-intensity of lamb production between major producers (New Zealand and Australia) and the UK, so the savings from reduced UK consumption are less sensitive to the breakdown between domestic production and imports.

Under current trade patterns, which largely involves importing ruminant meat from the EU or other similar GHG-intensity producers, there is limited risk of significant carbon leakage from reducing demand in the UK. However, the potential for carbon leakage should be considered in any future trade discussions seeking to change the current patterns.

[38] The estimated consumption emissions savings given here don't account for improvements in the life-cycle GHG-intensity of UK or overseas production, any carbon storage in land made available by these consumptions changes or any additional emissions from food consumption that may replace the reduced ruminant meat consumption.
[39] This assumes a similar fractional breakdown between imports from the EU and the rest of the world as today.

Figure 2.9. Hypothetical scenarios of 2050 UK beef consumption (20% reduction in per person consumption) and lifecycle emissions saving



Source: CCC analysis.

Notes: Reduction in GHG footprint is expressed relative to business-as-usual (BAU) and is only defined on the right hand axis. Exports and imports are split according to those going to/coming from the EU and the rest of the world (RoW). UK and EU average GHG-intensity is assumed to be the average of the beef herd and dairy herd estimates, RoW GHG-intensity is assumed to be the global average beef herd intensity. This analysis assumes no changes in the relative GHG-intensity of different beef producers between now and 2050. The emissions savings are defined relative to a BAU with per person beef consumption maintained at 2016 levels. Savings do not consider any carbon sequestration on land made available due to diet change or emissions associated with producing other foods that might substitute for the reduced beef consumption.

(d) Leakage risks from UK ruminant meat exports

Domestic production of ruminant meat is determined by demand from domestic consumption and the demand for exported UK meat.

As the UK is a relatively low-GHG producer of beef, reductions in exported UK ruminant meat could lead to carbon leakage if replaced by other more GHG-intensive producers. However, the risks of substantial carbon leakage are limited by economics and current trade patterns:

- For the large fraction of exports that currently go to the EU, alternative producers (e.g. EU or other developed countries such as New Zealand) generally also have similar GHG-intensities and are also setting economy-wide net-zero targets. This means that any increases in agricultural emissions in these regions would have to be compensated with additional emissions reduction in other parts of the economy.
- Relatively small amounts of UK exported ruminant meat go to non-EU destinations, where the risks of a high-GHG alternative supplier could be larger and where beef demand is

projected to increase in the future.[40] These regions generally favour lower cost producers and it may be challenging for high-quality high-value producers such as the UK to compete with for prime-cut exports to this growing market.[41]

Ensuring that domestic emissions from agriculture are reduced in ways consistent with minimising GHG leakage through international trade and are not undermined by trade arrangements will be an important part of delivering an effective transition in the agricultural sector.

The next chapter (Chapter 3) looks at the costs and benefits of implementing the low-carbon farming practices and land use changes identified in our scenarios.

[40] According to FAO projections beef consumption growth is primarily concentrated in the developing world, which is projected to grow by 17% over the period to 2028, although consumption would remain less than half that in the developed world on a per person basis. Developed regions as a whole show much slower increases in demand for ruminant meat (7% increase), with approximately constant levels of consumption projected for Europe.

[41] Agriculture and Horticulture Development Board (2019) *Brexit prospects for UK beef and sheep meat trade.*

Chapter 3: Costs and benefits of the scenarios

Introduction and key messages

In this chapter we assess the costs and benefits to the sector and the wider UK economy of reducing emissions from agriculture and land use to meet the 2050 target of net-zero emissions.

We consider the market costs and benefits that would be incurred to those undertaking the land-based investments as well as wider societal impacts. The assessment of benefits includes greenhouse gas (GHG) impacts, and, where possible, quantifies wider benefits to society, including benefits for climate change adaptation.

Our estimates are based on the latest available literature, market data and discussions with practitioners working across the land sector. Our assessment is that when delivered in full by 2050, our scenario represents a strong net social gain to the UK economy; requiring investment with net lifetime costs of £17 billion but delivering at least £96 billion in benefits. Our key conclusions are:

- **Our scenario will deliver a net gain to the UK economy**. While market costs outweigh market revenues, the scenario will deliver a net lifetime gain of £80 billion to society when taking account of the social benefits.
- **There is a gap between market costs and benefits that will need to be funded.** The minimum funding that will be required to facilitate the changes in land use set out in Chapter 2 is around £1.4 billion per year based on an assessment of the private costs and revenues of the land based investments identified by the Committee. Extra funding may be required where there are additional non-financial barriers to overcome. This level of funding is well below Common Agricultural Policy expenditure in the UK of £3.3 billion in 2018.
- **The majority of measures in our scenario are cost-effective from a carbon perspective.**[42] The social cost-benefit ratio of individual measures ranges from 0.2 to 5.9. Many measures represent good value for money.
- **Our scenario will deliver significant wider environmental and other benefits**. We estimate lifetime benefits of £96 billion (£4.0 billion per year) from carbon and wider environmental and other impacts, including benefits for climate change adaptation. The largest of these is from GHG emissions reduction and carbon sequestration (£2.7 billion per year). The remaining (£1.3 billion per year) is from recreational benefits of creating new woodland, improved air quality, improved health from increased physical activity and flood alleviation. Important benefits to biodiversity and water quality will also arise, though these could not be quantified.

Our assessment is that the 'Further Ambition' scenario from the Committee's 2019 Net Zero advice continues to present a strong case for action. The private funding gap of £1.4 billion per year can be met through a mix of private and public funding (see Chapter 4).

The rest of the chapter is set out in the following sections:

1. Background
2. Summary of UK results
3. Results by measure
4. Results for England, Scotland, Wales and Northern Ireland

[42] Apart from hedgerow creation and short rotation forestry.

1. Background

The Committee has previously set out the economic costs and benefits from measures to reduce GHGs in our advice to the Government on setting a net-zero target. We have extended that analysis in the following ways:

- We have updated estimates of costs and benefits based on latest available evidence, literature and discussion with stakeholders.
- We present analysis of economic impacts on a private as well as a social cost basis.
  - Estimating private costs and benefits to the individual or company making land use changes helps to inform decisions on funding needed for policies.
  - For the social cost-benefit analysis we include wider non-market impacts, as many of the measures aimed at reducing land based emissions also have other environmental and social co-benefits. These include increased recreational opportunities, improved health from increased physical activity, improved air quality, and improvements in flood alleviation, which is an important component of climate change adaptation.
  - Other impacts such as biodiversity and water quality improvements are not easy to value in monetary terms, but are nevertheless important and are discussed qualitatively.
  - Many of the wider impacts are environmental objectives set out by Defra and equivalent bodies in Scotland, Wales and Northern Ireland.

The approach taken to estimating costs and benefits is set out in Box 3.1. As far as possible this follows HMT Green Book methodology and BEIS supplementary guidance on valuation of GHG emissions for appraisal.[43]

Box 3.1. Approach and assumptions to value costs and benefits used in the analysis

The approach to the analysis presented in this chapter is as follows.

- Costs are shown in present value terms until 2100 for forestry and peatland measures and 2050 for all other measures to represent the lifetime costs and benefits of the land use change. They are discounted at the HMT social discount rate.
- For all options, private costs, private benefits and social benefits are calculated, and the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) are used to assess impacts to the UK and to an individual or private business of the land use change.
- Private costs assessed across all options are land acquisition costs (or alternatively the opportunity cost of using the land for something other than its original use), capital expenditure (e.g. planting costs, machinery costs) and operational expenditure (e.g. maintenance costs, fertiliser costs). Learning and economies of scale are not included. Land acquisition costs are maintained at the current levels throughout the time period to 2050, although we recognise that this could change in the future, e.g. when the UK exits from the EU and the Common Agricultural Policy.
- Examples of private benefits include the value of harvested timber, the value of thinnings from forest management, revenue from the sale of bioenergy products and lower fertiliser costs.

[43] There are no net-zero consistent carbon values therefore we have used existing BEIS guidance based on a 80% GHG reduction by 2050, which will be lower, and therefore understate carbon benefits.

Box 3.1. Approach and assumptions to value costs and benefits used in the analysis

- Examples of the social benefits include GHG emission reductions, carbon sequestration, the value of additional recreational opportunities, improved air quality, flood alleviation and improved health from increased physical exercise. There are additional fundamental social benefits that were not simple to value in monetary terms so have not been quantified here, including improved biodiversity and water quality improvements.
- The benefits to soils and productivity from a range of measures such as agro-forestry, reduced soil compaction and reduced fertiliser use are difficult to assess and therefore not quantified in monetary terms. They are nevertheless important and qualitatively discussed in the relevant sections below.

Source: HMT (2018) *The Green Book: central government guidance on appraisal and evaluation*; CCC analysis based on Vivid Economics and Centre for Ecology and Hydrology (CEH) (2019) *Economic impacts of land use scenarios* published alongside this report.

We commissioned Vivid Economics and the Centre for Ecology and Hydrology (CEH) to assess the economic and social costs and benefits. Overall results for the UK, by main mitigation measure, and by country are set out below.

2. Summary of UK results

Our analysis shows that to deliver the net-zero land use scenario will require a total annual additional expenditure of £1.4 billion to fund measures that are not cost-effective to the land manager without financial support (Table 3.1). As well as reduced GHG emissions and increased carbon sequestration, this investment will generate co-benefits, including recreational benefits, air quality improvements, and public health improvements from increased physical activity. These result in total benefits to society of £4.0 billion per year. This compares with a business as usual scenario of continuing current limited tree planting, peatland restoration and uptake of low-carbon farming practices of £1.0 billion per year. The overall social NPV of our scenario is £3.3 billion per year.

Table 3. 1. Lifetime and annualised private and social costs and benefits for all measures (2018 prices)

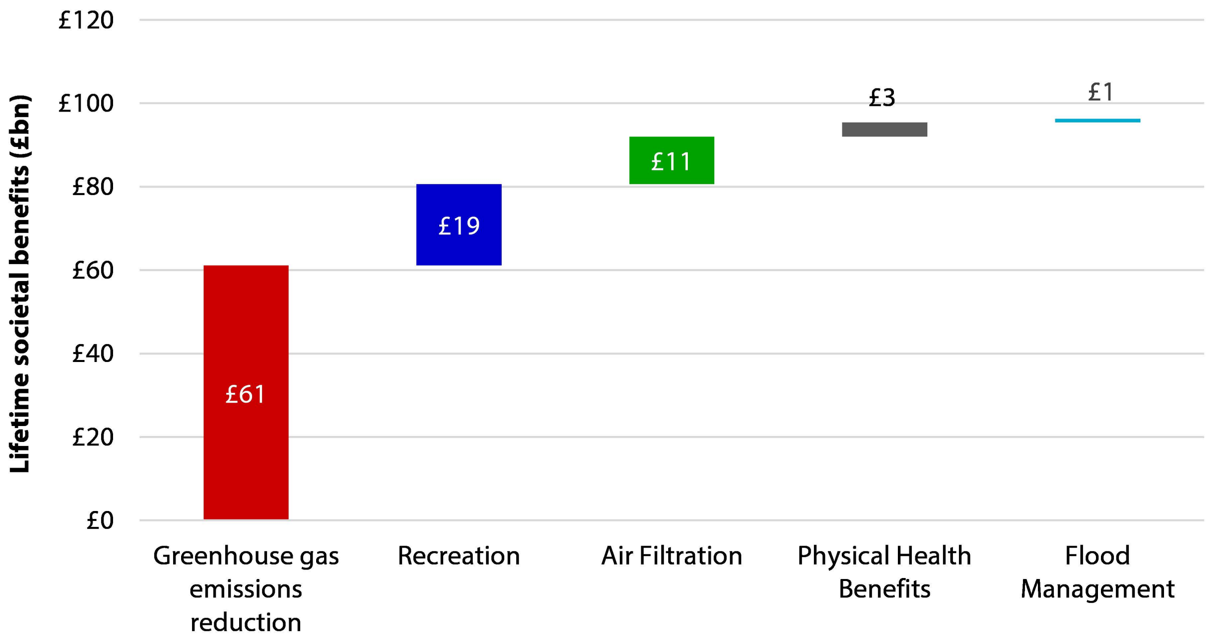
£ billion	Business as usual		Further Ambition scenario	
	Lifetime	Annualised	Lifetime	Annualised
Private costs	8	0.3	39	1.8
Private benefits	1	0.0	23	1.1
Overall private NPV	-7	-0.3	-17	-0.7
of which:				
• NPV for measures requiring funding	-7	-0.3	-31	-1.4

• NPV for measures that are cost-saving	0	0	15	0.7
Social benefits	20	1.0	96	4.0
Social NPV	12	0.7	80	3.3

Source: CCC analysis based on Vivid Economics and Centre for Ecology and Hydrology (2019) *Economic impacts of Land use scenarios* published alongside this report.
Notes: Lifetime estimates rounded to nearest £1 billion; annualised estimates to the nearest £0.1 billion.

The largest quantifiable benefit is from GHG emissions reduction, with a lifetime benefit of £61 billion, followed by recreation, valued at £19 billion. Lifetime benefits from better air quality, health impacts and flood management are around £15 billion (Figure 3.1).

Figure 3.1. Lifetime societal benefits of the 'Further Ambition' scenario by type in 2050



Source: CCC analysis based on Vivid Economics and Centre for Ecology and Hydrology (2019) *Economic impacts of Land use scenarios* published alongside this report.

A breakdown of costs and benefits shows:

- **Private costs**. Woodland creation represents the largest share of the £39 billion lifetime private costs, with coniferous woodland representing 16% of the total costs and broadleaved woodland 24%. The majority of private costs from woodland creation are from land acquisition costs, followed by financing costs and planting and establishment costs.
- **Private benefits.** Improvements to livestock farming practices (e.g. take-up of improved breeding practices), the anaerobic digestion of waste on farms, the sale of wood and bioenergy products from woodland creation, broadleaf management and bioenergy crop

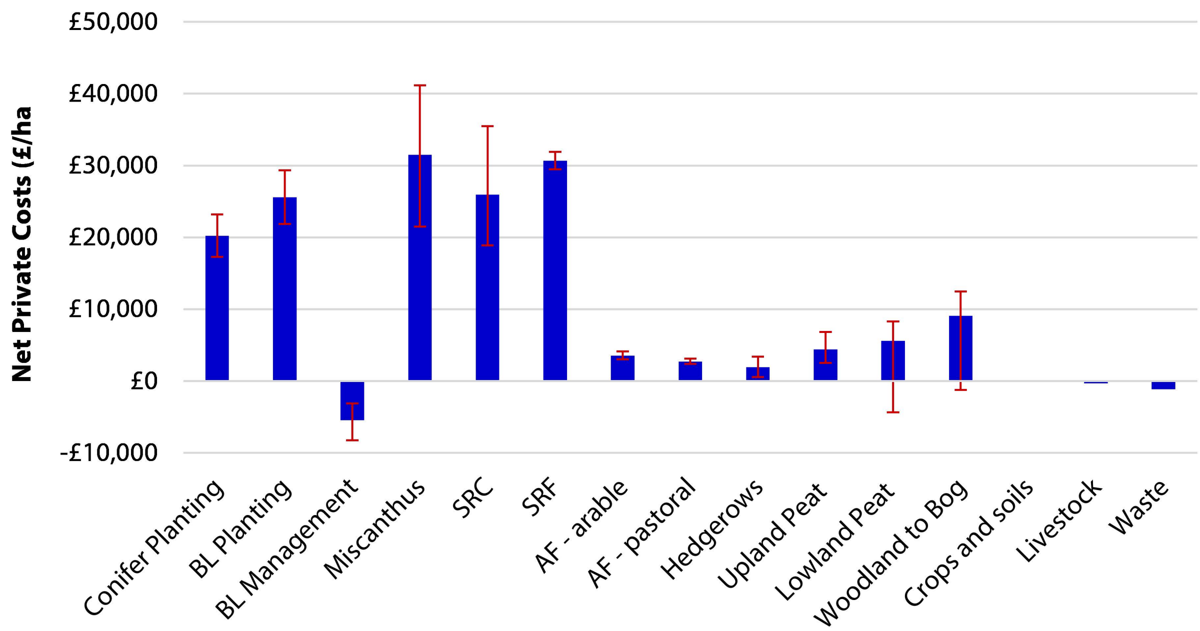
production represent nearly all of the £23 billion lifetime private benefits. Take-up of low-carbon farming practices represents 33% of the private benefits and the anaerobic digestion of waste on farms represents 13%. New tree planting represents 10% of the private benefits, broadleaf woodland management 32% and bioenergy crops planting 9%.

- **Social benefits.** Over 68% of the £97 billion lifetime social benefits arise from woodland creation, with new coniferous planting representing 33% and new broadleaved planting 35%. Carbon sequestration represents the largest benefit of woodland creation followed by recreational benefits. Significant social benefits also arise from upland peat restoration (6%), livestock low-carbon farming measures (9%) and crops and soils low-carbon farming measures (6%).

As set out above, for many of the measures private costs outweigh private benefits resulting in an annual funding requirement of £1.4 billion to 2050. Funding will be needed for (nearly) all mitigation options (Figure 3.2). The measures to deliver the net-zero ambition for land will not be achieved if left to the market itself:

- The largest gap between private costs and private benefits on a lifetime £ per hectare basis is for miscanthus (-£31,500), followed by short rotation forestry (-£30,700) and short rotation coppice (-£25,900).
- Broadleaf management and many of the low-carbon farming practices are cost-effective on a private basis, indicating that there are other non-financial barriers preventing these measures from being deployed. Measures to overcome these are considered in Chapter 4.

Figure 3.2. Lifetime net private costs for all measures (£ per hectare).



Source: CCC analysis based on Vivid Economics and CEH (2019) *Economic impacts of Land use scenarios* published alongside this report.
Notes: Uncertainty ranges are not available for low-carbon farming measures.

We estimate that implementing these land use changes will result in significant benefits to the UK economy totalling at least £4.0 billion annually and contribute to the 25 year Environment Plan goals. For most measures they result in cost-benefit ratios of greater than 1 (Table 3.2):

- The majority of the benefits without a market value come from carbon sequestration at £61 billion in total, followed by recreational benefits at £19 billion and benefits arising from improved air quality leading to public health improvements at £11 billion.
- The largest social benefit-cost ratios on the basis of what has been quantifiable are for new coniferous planting (5.9), followed by new broadleaf woodland planting (4.2), and upland peat restoration (4.1).
- The benefit cost ratios were more marginal or less than 1 for short rotation coppice, short rotation forestry, silvopastoral agro-forestry and hedgerows.

The costs presented above are average costs across the UK. In practice there will be a range around these due to the variation in costs by region and according to the characteristics of the site (e.g. the level of degradation of peatland). As an example, taking account of these factors could lead to costs being up to 56% lower or 43% higher for upland peat restoration.

For all measures except short rotation coppice, short rotation forestry, silvopastoral forestry and hedgerow expansion, the social benefits outweigh the costs of implementation (Figure 3.3). When the social benefits aside from greenhouse gas emissions reductions are considered, the majority of the measures reduce carbon at a cost of less than £100 t/CO_2e (Figure 3.4).

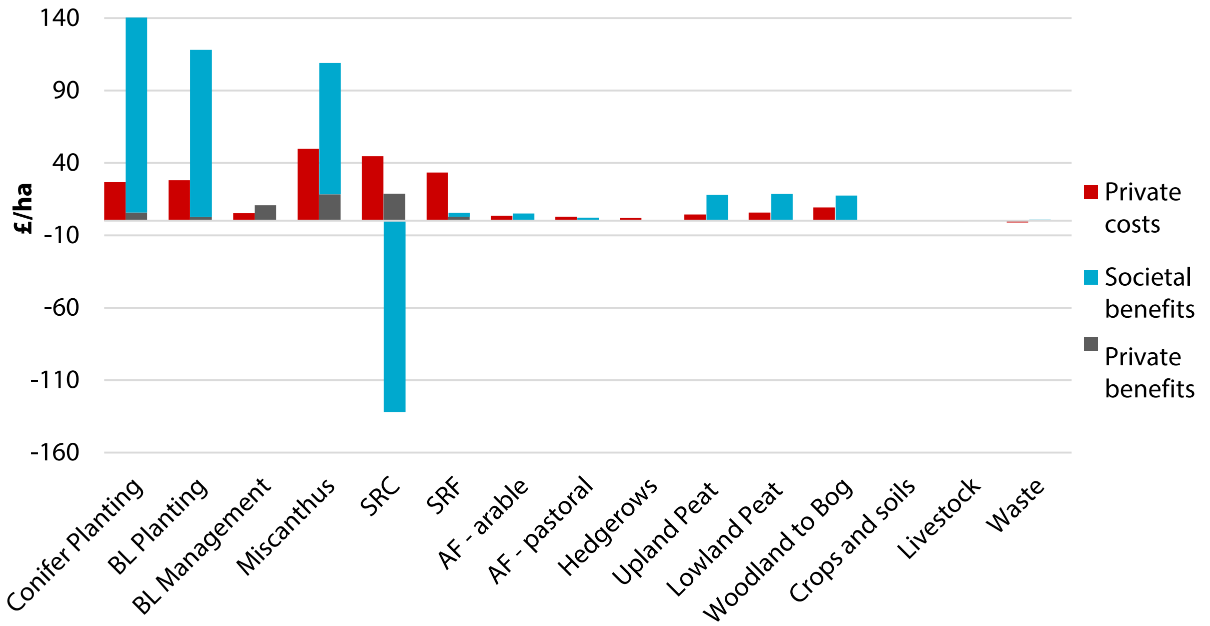
Table 3.2. Private and social net present values and benefit-cost ratios for all measures on a per hectare basis.

Measures	Private NPV	Social NPV	Private BCR	Social BCR
New coniferous woodland planting	-£21,000	£130,100	0.2	5.9
New broadleaved woodland planting	-£25,600	£89,900	0.1	4.2
Broadleaved management	£5,500	£5,500	2.0	2.0
Miscanthus	-£31,500	£59,300	0.4	2.2
Short rotation coppice	-£25,900	-£158,200	0.4	-2.6
Short rotation forestry	-£30,700	-£28,100	0.1	0.2

Silvoarable agro-forestry	-£3,500	£1,400	0	1.4
Silvopastoral agro-forestry	-£2,700	-£800	0	0.7
Hedgerow expansion	-£1,900	-£1,600	0	0.2
Upland peat restoration	-£4,400	£51,800	0	4.1
Lowland peat restoration	-£5,600	£12,900	0	3.3
Woodland to bog	-£9,100	£8,400	0	1.9
Farming practices: Crops and soils measures	£100	£400	-	-
Farming practices: Livestock measures	£300	£500	-	-
Farming practices: Waste and other measures	£1,200	£1,900	-	-

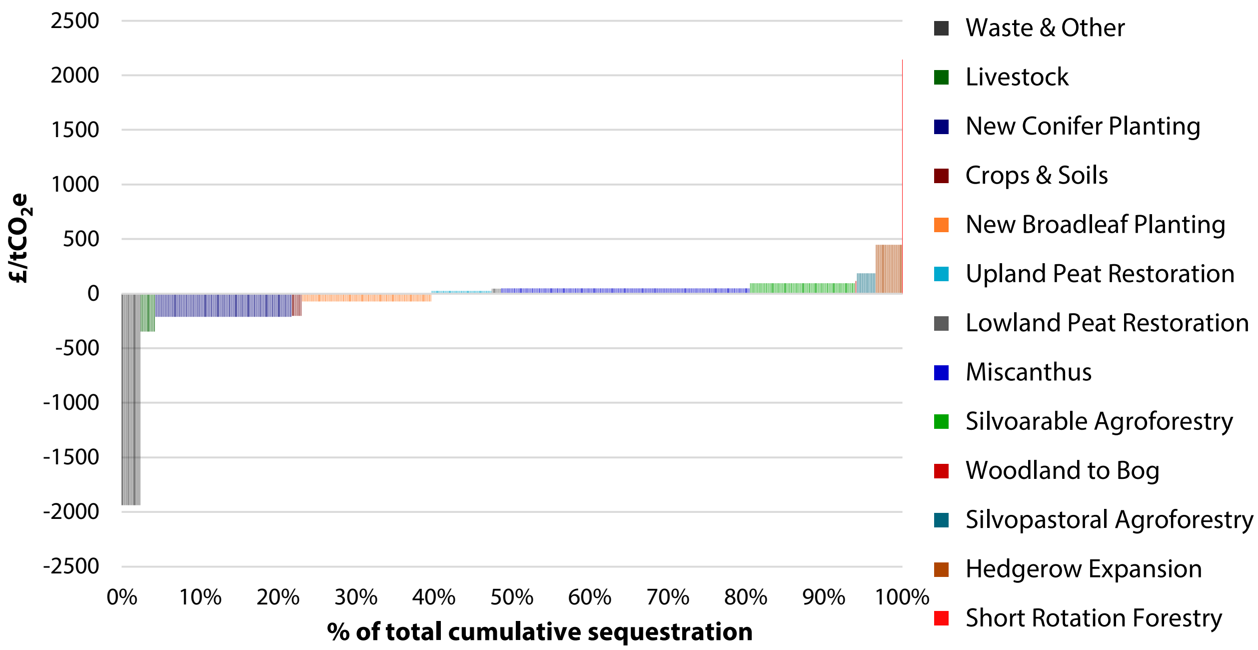
Source: CCC analysis based on Vivid Economics and Centre for Ecology and Hydrology (2019) *Economic impacts of Land use scenarios* published alongside this report.
Notes: BCRs are not available for farming practices as only net cost data are available.

Figure 3.3. Private and social costs and benefits (£/hectare)



Source: CCC analysis based on Vivid Economics and Centre for Ecology and Hydrology (2019) *Economic impacts of Land use scenarios* published alongside this report.
Notes: Livestock costs are per 1000 livestock.

Figure 3.4. Marginal Abatement Cost Curve by measure (£/tCO_2)



Source: CCC analysis based on Vivid Economics and Centre for Ecology and Hydrology (2019) *Economic impacts of Land use scenarios* published alongside this report.

The social benefits are likely to be significantly underestimated as they are based on relatively conservative assumptions[44] and do not include the value of biodiversity, improved water quality and other impacts such as soil health. These are important for afforestation, peatlands, agro-forestry and hedgerows. Risks of biodiversity loss can arise for bioenergy crops or planting large monocultures for example and these need to be managed. Other benefits such as health improvements from diet change were outside the scope of this study:

- There is evidence of the high biodiversity value of restored peatlands from species such as sphagnum moss, invertebrate and bird species.[45] Some studies indicate that drain or gully blocking can lead to an increase in indicator species like sphagnum moss and the recovery of aquatic macro-invertebrate fauna.
- Research is ongoing to determine the impact of restoring degraded peatlands in reducing water company costs.
- Agro-forestry and hedgerows are likely to provide biodiversity benefits (e.g. by providing habitats for insects, birds and small mammals), reduced water pollution, improved soil health and for grazing livestock shelter from wind and shade from the sun. Over 600 plants, 1,500 insects, 65 birds and 20 mammals species utilise UK hedgerow habitats.[46] Numerous studies have shown the removal of hedgerows and the abandonment of hedge management on farmland is likely to have adversely affected different species groups, for instance yellowhammers (a declining species) in southern England.[47]
- Planting bioenergy crops could have negative impacts on biodiversity, soil health, water quality and invasive species, particularly if planted on grasslands. These risks need to be managed, for example by taking into account local geographies and species-appropriate planning.
- The evidence on health impacts of diet change, to a level of meat consumption more in line with Government guidance, were considered as part of the Net Zero report. This concluded that our scenarios would have significant health benefits - based on a study by Ricardo for the Committee in 2013 the health impacts of reducing red meat consumption by 50% would represent 0.5% of GDP in 2030. The impact on air quality and water quality from the corresponding reduction in livestock numbers due to diet change has been included in our analysis.
- Other measures in our scenario are also likely to have significant positive impacts on biodiversity, including contributing to the goals of the government's 25 Year Environment Plan. The best way to maximise improvements in biodiversity should be carefully considered when planning the locations of land use changes such as planting forests.

3. Results by measure

(a) Forestry

As set out earlier in this report, the 'Further Ambition' scenario for achieving net-zero by 2050 requires increasing planting rates to around 30,000 hectares of new woodland per year.

[44] See the Vivid Economic Impacts report published alongside this report for further details.
[45] Bain, C.G. et. al. (2011) *Commission of inquiry on peatlands.*
[46] Graham, L. et al. (2018) *The influence of hedgerow structural condition on wildlife habitat provision in farmed landscapes.*
[47] Bradbury, R et. al. (2001) *Habitat associations and breeding success of yellowhammers on lowland farmland.*

We estimate that the private net present value (NPV) of planting trees is -£21,000 per hectare for conifers and -£25,600 per hectare for broadleaves, assessed over the time period from now until 2100. This indicates there will be an ongoing need for additional funding to ensure afforestation occurs at the levels required to meet the net-zero target. Box 3.2 sets out the key elements of afforestation costs.

Box 3.2. Private costs and benefits of afforestation

Planting trees has high upfront costs, with the most significant private benefit being the sale of the harvested material from thinnings and timber from mature trees. The key assumptions used to calculate the private costs and benefits of planting forests are:

- The cost of acquiring the land is the largest cost element. Land acquisition costs are based on industry estimates of average land prices for the types of land that will be used for the planting of new forests, a mixture of permanent grassland and rough grazing land.
- There will be on-going maintenance costs for thinning and felling (as well as general fence maintenance, pest control and fire protection). Costs incurred after the harvested material has been sold are not included (e.g. sawmilling costs), but a healthy market is assumed to exist for both timber and thinnings.
- Given the lengthy time it takes for trees to reach maturity (at which point the timber can be harvested), only revenue from thinnings is available in the nearer term. Thinning is the selective removal of trees to improve the growth rate and health of the remaining trees, and thinnings are the removed material. Thinning has been assumed to begin 25 years after planting for coniferous woodland and 30 years after planting for broadleaved woodland.
- Conifers are faster growing than broadleaves, assumed in this analysis to typically take around 60 years to reach maturity, compared to 90 years for broadleaves. Revenue from thinning and timber sales is therefore significantly discounted, making it difficult to build a commercial case to plant trees as a private investor. Given that our analysis spans the period from now until 2100, for broadleaved forests, the revenue from the sale of timber from mature trees is not included, as only revenue from thinnings is available over this time period.
- Trees have different growth rates and levels of productivity as measured by their yield class (YC). For new woodland, improved yields can be achieved by adopting best practice in silviculture (e.g. good soil preparation, careful selection of the right trees for the site and ensuring adequate protection for young trees against deer) and from the use of breeding and genetics to improve the nursery stock. Improving yields enables trees to be more productive both in terms of the amount of CO_2 they can sequester and the volume of harvested products. YC7 is assumed here for broadleaves (e.g. oak) and YC13 for conifers (e.g. Douglas fir and sitka spruce). This is a simplification for modelling purposes, as the actual trees planted would cover a larger range of species with a wide variety of yield classes.
- Costs and revenues may vary if land has to be cleared or drained before planting, and if there are access difficulties (e.g. planting in the uplands). Timber and fuel wood prices may also vary over time, but a single average price of timber has been assumed here.

Source: CEH for the CCC (2018) *Quantifying the impact of future land use scenarios to 2050 and beyond - Final Report.* Vivid Economics and CEH (2019) *Economic impacts of Land use scenarios* published alongside this report.

There are significant non-market benefits from planting woodland, including carbon sequestration, recreational opportunities, air quality improvements, public health benefits from additional physical activity and flood alleviation. These benefits have been estimated and assigned a monetary value (Box 3.3). These estimates are based on conservative assumptions and do not include biodiversity and water quality impacts, and therefore are very likely to be an underestimate of the actual benefits. The benefit calculation also does not make assumptions about future climatic suitability, growth rates or risks to productivity (e.g. from pests and diseases) for particular tree species in a changing climate. From a social perspective, the net present value of planting broadleaves is £89,900 per hectare and conifers is £130,100 per hectare:

- For broadleaf forests, the largest contribution to the social benefits is from carbon sequestration at £79,800 per hectare, followed by recreational benefits £26,900 per hectare.
- For conifer forests, the largest contribution to the social benefits is from carbon sequestration at £87,000 per hectare. This is larger than for broadleaf woodlands because conifers sequester more carbon over the time period up to 2100, as well as growing more quickly, which enables more recreational opportunities over the time period.
- Forests can provide different eco-system services depending on the type of forest and location. Locating broadleaf forests in peri-urban areas can increase benefits from the provision of recreational opportunities to £66,600.
- The emissions impacts shown here only relate to the carbon impacts from the land use change; in the Committee's scenarios for the advice to the government on setting a net-zero target the impacts on GHGs of processing and use as energy fuels are assessed in the end-use sectors themselves.

From a carbon sequestration perspective alone, the net present value of planting conifers per hectare is £66,000 and for planting broadleaves per hectare is £49,400.

Box 3.3. Valuation of non-market benefits of afforestation

Carbon sequestration

Carbon sequestration benefits were estimated for each land use change intervention by the Centre for Ecology and Hydrology as part of the Committee's work for the 2018 land use report. These were monetised using BEIS non-traded carbon values. These are consistent with an 80% reduction in GHGs by 2050 rather than a net-zero target, and are likely to be underestimated.

Recreational benefits

An Outdoor Recreation Valuation tool (ORVal) produced by the University of Exeter was used to model the number of additional visits to woodland the planting of a new forest would generate. It was assumed that new visits do not occur until 10 years after planting, and annual visits increase as trees approach maturity. A £/visit willingness to pay for these visits was used from a large-scale cross European Union stated preference survey assessing how much people would be willing to pay to visit woodland.

Box 3.3. Valuation of non-market benefits of afforestation

Air quality

Ammonia is emitted during the storage and spreading of manures and slurries and from the application of inorganic fertilisers, and can contribute to particulate pollution in urban areas, leading to increased cardiovascular and respiratory disease. Low-carbon farming practices can reduce ammonia emissions, improving air quality. This was valued using the latest damage cost values for air quality appraisal from Defra.

Increased vegetation can also sequester air borne pollutants such as particulate matter, improving air quality. A study commissioned by the ONS from the Centre for Ecology and Hydrology estimated the reduction in hospital admissions (from respiratory and cardiovascular conditions) from natural vegetation removing pollutants from the air. This model was adapted for use in this study. However, given that the forests in this study are predominantly located in peri-urban and rural areas, the population density is relatively low so the benefits are smaller than in studies which look at locating trees in urban areas.

Flood risk alleviation

Woodland in the upper catchments of rivers can help to alleviate flood risk by slowing down the flows of water, though the exact benefits depend on a number of factors including location and planting density. Furthermore, targeting woodland planting onto the most sensitive soils or in key locations can intercept and help absorb surface run-off generated from the adjacent ground. This is valued using a recent report by Forest Research that looked at the costs involved in holding the amount of water held in all UK woodlands in UK reservoirs (a replacement expenditure approach). This UK wide value is then scaled down to a per hectare basis.

Health improvements from increased physical activity

Natural environments are often used for walking, running and playing sports, leading to physical health benefits for the visitors. These benefits can lead to improved long-term health outcomes, which is measured in terms of a relative reduction in the risk of premature death. The value of this relative reduction in the risk of premature death has been calculated in many research papers, using surveys which elicit the value that individuals are willing to pay to improve their quality and length of life. In order to prevent an overestimate of physical health benefits, it is assumed some visitors to woodland would have engaged in a different form of exercise if they hadn't exercised in the woodland, so conservatively, only 10% of the exercise from recreation in the woodland is attributed to the creation of the woodland.

Source: CEH (2018) *Land use: Reducing emissions and preparing for climate change*; Day, B.H. et. al (2018) *Outdoor Recreation Valuation (OrVAL) User Guide;* Scarpa, R. (2003) *The recreation value of woodlands;* Defra (2019) *Clean Air Strategy;* Defra (2019) *Air quality damage cost guidance;* CEH for ONS (2019) *Developing estimates for the valuation of air pollution removal in ecosystem accounts;* Forest Research (2018) *Valuing flood regulation services of existing forest cover to inform natural capital accounts;* Natural England (2019) *Monitor of Engagement with the Natural Environment (MENE);* Vivid Economics (2019) *Greenkeeper.*

While many UK conifer forests are actively managed, the majority of broadleaf woodlands are not. Bringing these forests into active management has a positive net present value of £5,500 per hectare (assessed over the time from now until 2050). The costs included in this analysis are detailed in Box 3.4.

The Further Ambition scenario in the Committee's Net Zero advice includes bringing 80% of broadleaf forests in the UK into active management compliant with the UK Forestry Standard by 2030. Given the positive benefits to the private owner from bringing broadleaf forests into management, it is clear that there must be other barriers (e.g. knowledge, and lack of local market for the harvested product) to doing so.

Box 3.4. Costs and benefits of bringing broadleaf forests into active management

The analysis here considers the increased management of existing broadleaf forests in line with the UK Forestry Standard. This assumes that all conifer forests are already actively managed, although not necessarily in line with the UK Forestry Standard. The costs included in the analysis are as follows:

- Management of broadleaf woodland increases the operational costs, but can also increase revenues. In remote areas, capital expenditure may be required to purchase equipment and enable access to the forests. It is assumed to cost £5,300 per hectare on average.
- Management of broadleaf woodlands allows for the harvesting of biomass. This harvested wood will generally be of poor quality, given that the woodland has not previously been managed, and hence we assume most of the material is used as fuel wood. Revenues generated are assumed to be £10,700 per hectare.

Source: CEH for the CCC (2018) *Quantifying the impact of future land use scenarios to 2050 and beyond - Final Report.* Vivid Economics and CEH (2019) *Economic impacts of Land use scenarios* published alongside this report.

(b) Agro-forestry and hedgerows

Growing trees on farms and planting hedgerows offer further opportunities to increase carbon sequestration. Trees on farms have varying economic impacts dependent on whether they are planted alongside and on arable (known as a silvoarable system) or grassland (known as a silvopastoral system). The costs of growing trees on farms outweigh the benefits to the farmer or landowner by £2,800 per hectare for silvopastoral system and £3,500 per hectare for a silvoarable system (Box 3.5).

Box 3.5. Costs and benefits of growing trees on farms

The costs and benefits of growing trees on farms included in the analysis are:

- Acquisition and planting costs for trees on farms.
- Revenue is generated by selling timber from mature trees. In silvoarable systems, tree density is assumed to be 188 trees per hectare and the species of trees planted is poplar, which are yield class 12. In silvopastoral systems, 400 trees are assumed to be planted per hectare, but the tree species is assumed to have a lower productivity of yield class 6 (e.g. oak). Trees must be chosen carefully to ensure compatibility with existing crops and livestock systems and take account of future climate.
- Revenue from agro-forestry is dependent on the type of tree planted. Fruit trees are commonly chosen for agro-forestry and the most common type of silvopastoral system in the UK is a grazed orchard. In these cases, revenue can be generated from the sale of fruit, which could lead to higher profits than assumed here.

Source: CEH for the CCC (2018) *Quantifying the impact of future land use scenarios to 2050 and beyond - Final Report.* Vivid Economics and CEH (2019) *Economic impacts of Land use scenarios* published alongside this report.

- Growing trees on farms has carbon sequestration benefits with a value of £4,900 per hectare for silvoarable systems and £1,900 for silvopastoral systems, leading to a social net present value of £1,400 for silvoarable systems and -£800 for silvopastoral systems.
- There are additional benefits from increasing the uptake of agro-forestry which have not been valued here due to insufficient evidence. These include moderating downstream flood flows from slowing the flow of run-off from farms, reducing soil erosion, increasing the diversity of species on farms and providing shelter to grazing livestock.[48] Trees on farms can also improve soil quality and farming productivity.

Increasing the planting of hedgerows has similar benefits to growing trees on farms. The costs of growing hedgerows outweighs the benefits to the farmer by £1,900 per hectare. Including the carbon sequestration benefits, the social NPV is -£1,600 per hectare:

- The most significant costs include the planting and maintenance costs of growing the hedgerow.
- Hedgerows can generate revenue by producing wood fuel, timber, fruit or nuts. The revenue estimated here assumes the hedgerow produces wood fuel.
- The social NPV only includes carbon impacts for hedgerows, suggesting that they are not cost-effective from a carbon perspective alone. However there are additional benefits, including increased biodiversity, shelter belts, and value to wildlife and landscape that have not been possible to value here.

(c) Bioenergy crops

Land can also be used to grow bioenergy crops, including miscanthus, short rotation coppice (SRC) and short rotation forestry (SRF), to produce energy for other sectors. Our 'Further Ambition' scenario assumes bioenergy crops are grown on 0.7 million hectares of land by 2050 (23,000 hectares per annum) to produce 15 oven-dried tonnes (odt) per hectare by 2050, after improvements in agronomic practice and breeding. These crops can generate revenue by being sold to produce bioenergy. Based on the cost of growing the crops and the likely revenues generated, the total private NPV of energy crops in our scenario ranges from -£25,900 per hectare for SRC to -£31,500 per hectare for miscanthus:

- These values assume a mixture of grassland and cropland are used to plant bioenergy crops, and include land acquisition costs. Over the time period between crops first being planted and 2050, there will be multiple cycles of planting and harvesting, with operational expenditure being higher in years where planting and harvesting is occurring. Miscanthus and SRC are assumed to require replanting every 20 years.
- Miscanthus is assumed to be planted on existing cropland, whereas SRC and SRF are assumed to be planted on grassland. This leads to higher land acquisition costs for miscanthus planting, resulting in overall higher costs in comparison to SRC and SRF.
- The modelling assumes prices for energy crops based on average current values. In practice there will be variations in revenue over time due to price volatility and changes in demand and supply. Over time, as emissions targets tighten internationally, the value of biomass is likely to rise significantly.[49]

[48] Soil Association (2019) *The Agro-forestry handbook*.
[49] CCC (2018) *Biomass in a low-carbon economy*.

Sustainable biomass will always be able to provide additional opportunities for carbon reduction or sequestration, and therefore its value will be affected by the value of carbon reductions more generally.

- There are also non-financial barriers to the planting of energy crops. These are discussed further in Chapter 4.

While the majority of benefits from growing bioenergy crops arise from the sale of the crops, there are also carbon sequestration benefits. Including these carbon sequestration benefits, the NPV ranges from £59,300 per hectare for miscanthus to -£28,100 per hectare for short rotation forestry. The emissions impacts shown here only relate to the carbon impacts from the land use change; in the Committee's scenarios for the advice to the government on setting a net-zero target the impacts on GHGs of processing and use as energy fuels are assessed in the end-use sectors themselves.

(d) Peatlands

50% of upland peatlands and 25% of lowland peatlands are restored in the Further Ambition scenario of our Net Zero advice. This increases to 75% of upland peatlands and 50% of lowland peatlands in the Speculative scenario. The Speculative scenario also included seasonal management of the water table on 25% of lowland peat area to deliver a further reduction in peatland emissions. However, further restoration of peatlands may be needed as there is a high risk that degraded peatlands will be destroyed altogether under the hotter and drier conditions projected with climate change. Peatlands in good condition with a healthy sphagnum moss layer may still be at risk of loss, but are likely to have a better chance of withstanding these conditions in future.

There may be lost revenue in restored areas where lowland peat is profitably farmed, although sustainable management techniques (e.g. seasonal raising of the water table) exist to allow for continued farming on peatlands. The total costs of upland peatland restoration average around £4,400 per hectare and £5,600 per hectare for lowland peat, but vary considerably with level of degradation - eroding upland peatland costing £5,600 per hectare and near natural upland peatland £3,100 per hectare to restore[50] (Box 3.6). Peatland restoration will therefore need to be funded.

Box 3.6. Costs and benefits of peatland restoration

There are large differences in the costs of restoration for upland and lowland peatland, which in part is determined by the accessibility of the sites and the level of degradation:

- The private costs of the restoration of peatlands include upfront capital works (e.g. blocking drainage), maintenance (e.g. repairing dams), management (scrub clearance), monitoring (e.g. checking site condition) and any income foregone. Restoration costs also vary due to the accessibility of the peatland, which can require road construction or the use of helicopters to transport equipment.
- A large proportion of lowland peatland represents some of the UK's most fertile soils and is used for horticulture, generating large profits, resulting in higher land acquisition costs than for upland peatland. By re-wetting the land, conventional agricultural production is no longer viable. Upland peatland is also used for agriculture, but is dominated by sheep grazing which is less profitable, resulting in lower land acquisition costs.

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[50] Including both restoration costs and recurring costs.

Box 3.6. Costs and benefits of peatland restoration

- Upland and lowland peat restoration requires different techniques, resulting in different costs of restoration. Lowland peat farming after full or partial restoration include the growth of reeds, alder and sphagnum moss (a practice known as paludiculture or 'wet-farming'), which can generate some revenue from the restored land, but is not quantified here as the potential opportunities are still uncertain.
- The four condition categories for peatland are bare, drained, modified and near-natural. Different costs are used to restore each of these, as the costs associated with moving from bare and eroding peat are very different to costs associated to moving from drained peat to restored peatland. Bogs with bare peat require both drainage blocking to raise the water level and re-vegetation of bare peat. It may also be necessary to restrict grazing and remove scrub and trees.

Source: Bain C.G. et. al. (2011) *Commission of inquiry on peatlands.* Vivid Economics and CEH (2019) *Economic impacts of Land use scenarios* published alongside this report.

Restoring peatlands can generate significant carbon sequestration benefits. Historic and on-going drainage of lowland peat for crop and grassland use has led to significant degradation, so although the costs of restoring lowland peat are larger, the opportunity to reduce carbon lost by doing so is significant. Upland peat can be relatively cheap to restore by comparison. Therefore, including both the carbon sequestration benefits and the recreational benefits, the social NPV per hectare are not very different - around £12,900 for lowland and £13,400 for upland peat:

- Taking account of carbon sequestration alone, the net present value of restoring upland peat is £10,300 per hectare and for lowland peat is £9,800 per hectare.
- The removal of peat sediment and dissolved organic carbon (DOC) from degraded peatlands represents a large cost in water treatment for water utilities. Over the last 30 years, the amount of DOC, the brown colour of peaty water, has doubled across many UK catchments.[51] Research is ongoing to determine the impact of restoring degraded peatlands in reducing water company costs. Several water companies are already undertaking restoration projects in their water catchments to improve water quality, but further evidence is required before the value of this can be calculated.
- While it was not possible to value the biodiversity benefits of restoring peatlands, it is widely agreed that the plants and animals are of high biodiversity importance because of their rarity or threatened state, nationally and internationally. This includes sphagnum moss, invertebrate and bird species.[52] Some studies indicate that drain or gully blocking can lead to an increase in indicator species like sphagnum moss and the recovery of aquatic macro-invertebrate fauna.[53]

In the 'Further Ambition' scenario, 21,000 hectares of low-productive forests grown on peatlands are removed in order to restore the peatlands. Compared to unforested peat, the costs of removing trees and restoring the peat are higher and carbon savings lower, resulting in a lower social NPV:

[51] Labadz J. et. al. (2010) *Peatland Hydrology.*
[52] Bain C.G. et. al. (2011) *Commission of inquiry on peatlands.*
[53] Artz et. al (2018) *Peatland restoration - a comparative analysis of the costs and merits of different restoration methods.*

- The cost of removing trees from peatland and restoring it to its natural state is £9,100 per hectare.
- The carbon sequestration benefits of removing low-productive woodland from peatlands and restoring them are lower compared to restoring unforested peatland, as the carbon stored in the trees must be accounted for. This results in a social NPV of £12,400.

Previous research commissioned by the CCC investigated potential net benefits of implementing early intervention peatland restoration activities to insulate against increasing climate hazard risks from severe droughts and summer heatwaves over the 2018 to 2100 period. A case study analysis on peatland assets in the Moor House and Tees Dale catchment in Cumbria, found the total NPV of carbon sequestration services provided by the land at the location was £167 million higher in the anticipatory scenario,[54] when compared to a business as usual scenario.[55]

(e) Low-carbon farming practices

Our scenario set out a range of measures that can be used to reduce on-farm methane and N_2O emissions from soils, livestock and manure management. These farming practices can have multiple other benefits including improved air, water and soil quality, reduced pests and diseases and improved soil structure. When considering just the emissions reductions and reduced air pollution benefits, these outweigh the costs of implementing these measures in aggregate.

These measures result in considerable private benefits to farmers e.g. from reduced fertiliser costs, lower veterinary bills from improved livestock health and higher yields from improving soils. These result in overall lifetime savings to farmers of £8.3 billion in total. These estimates are based on work by SRUC and Ricardo-AEA for the Committee's advice on the 5th Carbon Budget and Net Zero report:[56]

- Estimates exclude monitoring, reporting and verification costs. Given the large number of farms in the UK (218,000 farm holdings) and with 48% of these farms being small (less than 20 hectares), these costs could be substantial.
- The net costs of the measures were based on the estimated technical costs and benefits of the mitigation measures at the farm.
- The most cost-effective measures from a mitigation perspective are improving livestock health, precision farming for crops, preventing soil compaction and anaerobically digesting maize silage and pig/poultry manure with maize silage. Several measures are cost effective on a private basis, including controlled release fertilisers, loosening soil compaction, and measures to improve sheep health.

[54] The research considered three different adaptation (decision-making) scenarios to test the effect of pursuing different long-term strategies: (i) a business as usual scenario, assuming no land-use change interventions; (ii) an anticipatory scenario, assuming land-use change happens before a climate hazard threshold event occurs; and (iii) a reactionary scenario, assuming land-use change occurs after the climate hazard threshold event. A climate hazard threshold in this context relates to a given level of a climate hazard that, once reached, will make it cost-prohibitive to maintain the current land use and the ecosystem services it has provided to date.
[55] JBA Consulting for the CCC (2018) *Exploring the economics of land use change for increasing resilience to climate change in England.*
[56] SRUC and Ricardo-AEA for the CCC (2015) *Review and update the UK Agriculture Marginal Abatement Cost Curve to assess the greenhouse gas abatement potential for the 5th Carbon Budget period and to 2050.* SRUC, ADAS and Edinburgh University for the CCC (2019) *Non-CO2 abatement in the UK agricultural sector by 2050.*

- Many of these measures lead to improved soil and livestock productivity for farmers. Improving livestock health in general has significant benefits for the sector, as it is estimated that Bovine Viral Diarrhoea (cows), mastitis (cows) and intestinal parasites (sheep) cost the agriculture sector over £300m per annum.[57]

Ammonia contributes to particulate pollution in urban areas therefore avoided ammonia emissions can have a demonstrable effect on air quality, which can reduce healthcare costs. In total, these low-carbon farming measures can deliver air quality improvements, which have a value over the lifetime of the measures of £10.5 billion:

- The largest co-benefit from an air quality perspective is the reduction in livestock numbers due mainly to diet change. This contributes £3.9 billion of benefits from air quality improvements.
- Significant improvements to air quality can also be achieved by adding strong acids (e.g. sulfuric acid or hydrogen chloride) to slurry, in the storage tank or before field application, representing £1.9 billion of benefits from air quality improvements.
- The remaining benefits from air quality improvements arise from nitrogen use efficiency measures that reduce ammonia emissions. These include precision farming for crops (obtaining precise information on soil and crop qualities and applying variable levels of fertilisers within fields as a result), manure planning, using legumes and planting triticale as an alternative to wheat, and using controlled release fertilisers. There is also a small air quality benefit from planting high sugar grasses in grassland-based dairy systems. Measures applied to crops and soils have air pollution benefits of £4.1 billion in total.

Farming can also have a significant impact on nearby water courses, leading to significant investment by water companies in improving the purity and colour of water. By reducing nitrate and phosphorus leaching from soils, farms can reduce water companies' water treatment costs:

- While it was not possible to estimate the value of these costs as part of this project, the reduction in nitrates was estimated. The largest water quality improvement arose from reducing livestock numbers.
- The remainder of the improvements in water quality arose from crop measures that reduce nitrate run-off from farms, most significantly from the use of controlled release fertilisers and the implementation of precision farming.
- Precision farming for crops can reduce phosphorus leaching, but growing legumes can increase the need for phosphorus application leading to increased leaching.

There are also additional benefits from the implementation of low-carbon farming practices that have not been possible to quantify here:

- Several of the measures can improve soil quality by reducing nitrogen accumulation within the soil. The amount of soil organic matter and soil porosity would also be improved.
- Biodiversity may also be improved, leading to increased numbers of pollinators and earthworms, alongside improvements to the health of micro-organisms and organisms living in the soil (e.g. bacteria, fungi, spiders and insects).

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[57] CCC (2018) *Land use: Reducing emissions and preparing for climate change.*

The general increase in the number of invertebrates is good for farmland birds and other species higher up the food chain. Some of the measures may also increase resilience of the landscape in question to climate impacts.

The social net present value (including the costs of implementing the measures, the value of the emission reductions and the value of the air quality improvements) of crops and soils measures in aggregate is £460 per hectare, for livestock measures in aggregate is £420 per 1,000 animals and for wastes in aggregate is £1,950 per hectare. From an emissions saving perspective (i.e. without air quality benefits) the net present value is £220 per hectare for crops and soils measures, £460 per 1000 animals for livestock measures and £1,390 per hectare for waste measures.

4. Results for England, Scotland, Wales and Northern Ireland

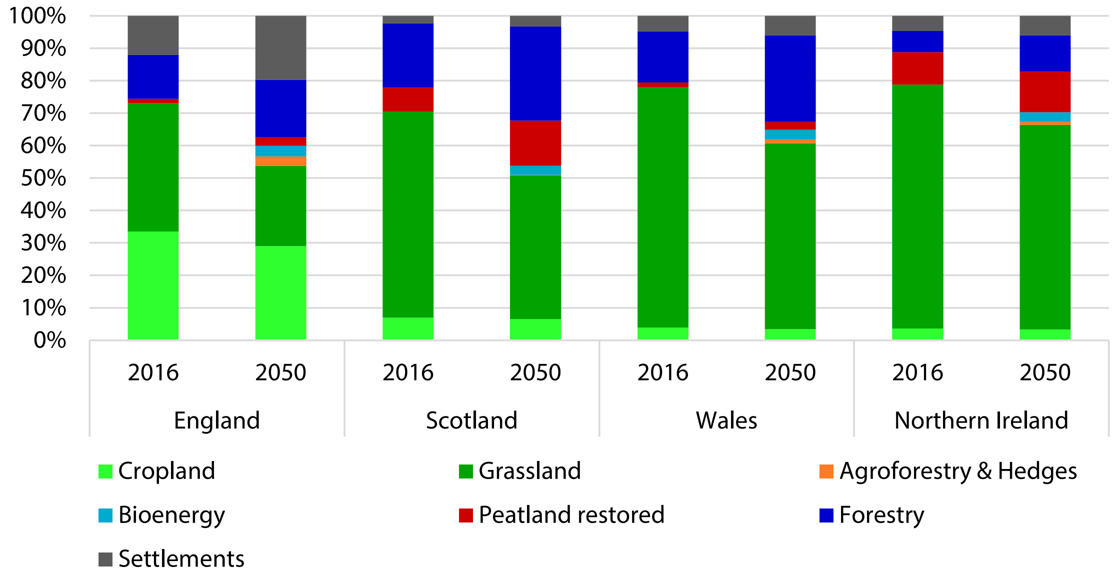
Across the UK, there are regional differences in the types of existing land use, the types of land use change needed to deliver land's contribution to the net-zero target and the costs of making the changes. As a result, the costs and benefits for England, Scotland, Wales and Northern Ireland differ to the results for the UK as a whole.

The two main differences across the UK that have been incorporated in our estimates are:

- There will be different combinations of measures deployed across England, Scotland, Wales and Northern Ireland based on differences in geographies and existing land use (Figure 3.4).
- Differences in land acquisition costs in England, Scotland, Wales and Northern Ireland. Other costs are also likely to vary (e.g. based on remoteness of land) but it has not been possible to take this into account.

The differences between private and social costs and benefits are summarised in Table 3.3.

Figure 3.4. Land use in the Further Ambition scenario in 2050 by country



Source: CEH and Rothamsted Research (2018) *Reducing emissions and preparing for climate change* and CCC analysis.

Table 3.3. Lifetime private and social costs and benefits of the Further Ambition scenario across England, Scotland, Wales and Northern Ireland

	Private NPV (£ billion)	Private Benefit Cost Ratio (BCR)	Social NPV (£ billion)	Social Benefit Cost Ratio (BCR)
England	-£9	0.6	£30	2.5
Scotland	-£6	0.5	£34	3.9
Wales	-£2	0.5	£11	3.3
Northern Ireland	-£0	1.0	£6	3.9
UK	-£17	0.6	£80	3.0

Source: Vivid Economics and CEH (2019) *Economic impacts of Land use scenarios* published alongside this report.

Across the UK, the measures with the highest social benefit-cost ratio based on the assumptions outlined in Table 3.2 are the planting of conifers and broadleaf forests and the restoration of peatlands, as well as cost-saving measures in agriculture. The cost of land acquisition also affects the overall cost-effectiveness of each measure. Areas of the UK which have the largest proportion of these measures and the cheapest land costs will therefore experience higher benefit-cost ratios overall.

Overall, the set of measures to reduce emissions from agriculture and land use in our Further Ambition scenario deliver a higher ratio of benefits to costs in each of Scotland, Wales, and Northern Ireland when compared to England. The following sub-sections cover the variation in costs and benefits by devolved administration in more detail.

England

England has the lowest social benefit-cost ratio (2.5) in the Further Ambition scenario of all of the four nations that make up the UK:

- This is partly because a relatively low proportion of the required land use change in England consists of forest planting and peatland restoration (44% of private costs), compared to the Scotland, Wales and Northern Ireland.
- Land acquisition costs are higher in England than in Scotland, Wales and Northern Ireland, increasing the costs of several measures including forestry.

Scotland

With a social benefit-cost ratio of 3.9 for the Further Ambition scenario, Scotland has the second highest benefit-cost ratio across the UK:

- The further ambition scenario for Scotland has a high proportion of expenditure on forestry (51%) and peatland restoration (11%), both of which have very high social benefit-cost ratios.

- Land acquisition costs are lower in Scotland than in England and Wales, meaning the benefit-cost ratios are higher for forestry than in other areas (7.4 for conifers and 5.2 for broadleaves).
- Hedgerows are one of the measures with an extremely low social benefit-cost ratio (partly due to issues with valuing biodiversity) of 0.2. Compared to England, Wales and Northern Ireland, our scenario for Scotland has an extremely low proportion of expenditure on hedgerow expansion (1%).

Wales

Wales has the second lowest social benefit-cost ratio of 3.3 for the Further Ambition scenario across the UK:

- A relatively high proportion of expenditure in Wales in the scenario is on forestry (55%). Land acquisition costs are higher in Wales than in Scotland, but lower than England, resulting in a benefit-cost ratio for forestry here of 5.3 for conifers and 3.8 for broadleaf forests.
- Wales has the lowest proportion of expenditure on peatland restoration across the UK, which reflects its low share of total peatland area (less than 5%).

Northern Ireland

Northern Ireland has the highest social benefit-cost ratio of 4.1 across the UK in our Further Ambition scenario:

- Many of the livestock low-carbon farming measures are cost saving. Compared to the rest of the UK, the agricultural sector in Northern Ireland is more heavily focused on livestock.[58] Meat and dairy contributed to 83% of gross farming output in Northern Ireland in 2018, compared to half (49%) for the whole of the UK. Lifetime cost savings from implementing these measures alone represent £1 billion of private benefits in Northern Ireland.
- Only 25% of private expenditure in our Further Ambition scenario for Northern Ireland is spent on forest planting and peatland restoration. However, the land acquisition costs in Northern Ireland are joint lowest with Scotland across the UK, leading to extremely high social benefit-cost ratios for the forestry that is planted (7.4 for conifers and 5.2 for broadleaves).
- The Further Ambition scenario for Northern Ireland has a significant proportion of expenditure on hedgerow expansion (16%) and short rotation forestry (11%), which both have an extremely low social benefit-cost ratio of 0.2.

The following chapter will consider how these changes can be implemented, and explore the best ways to fund the transition.

[58] DAERA (2018) *Statistical review of Northern Ireland Agriculture.*

Chapter 4: Policies to deliver land-based emissions reduction and carbon sequestration

Introduction and key messages

This chapter sets out an assessment of the policy mechanisms to deliver the emissions reduction and CO_2 removals in the agriculture, land use, land use change and forestry (LULUCF) sectors set out in our Net Zero report. Our assessment includes policies to transition to different uses of land and the adoption of low-carbon farming practices. Policies needed to deliver diet change and reductions in food waste are set out in Chapter 5.

The key messages are:

- **Current policies are not driving the required changes.** Substantial change in the use of land is necessary to achieve net-zero in the UK, but the scale of change required is not yet supported by policy. There are gaps in current policy, voluntary initiatives are not delivering and there is a patchy framework of support for farmers and land owners, which will not deliver improvements at the pace required to meet the net-zero goal.
- **There is an opportunity now to implement a new policy framework** for land use in the UK that will give long-term clarity and priority to climate change. The legislative opportunities for real change are available and should progress immediately. Early action is essential to enable the transition to lower carbon uses of land given the time required for some measures to deliver emissions reduction and removals. Interim policies should be implemented to avoid a hiatus in action before the new framework is fully in place (e.g. the national roll-out of the Environmental Land Management Scheme (ELMS) in 2024).
- **Farmers and land managers must be well supported in the move to a net-zero economy.** Our estimates in Chapter 3 indicate that there are overall benefits to society, but added net private costs for farmers and land managers of £1.4 billion annually to 2050. The new policy framework will need to ensure these private costs are funded.
- **A coherent mix of regulation, financial incentives and enabling policies is required** to overcome the range of barriers that are preventing change. An effective framework will have a strong regulatory baseline requiring the adoption of low-cost low-carbon practices, funding mechanisms for carbon sequestration through tree planting, peatland restoration and energy crops, subsidies for low-carbon farming practices and a complete package of enabling policies to break down barriers to action. We set out a policy framework which can be delivered alongside a strong sustainable agriculture sector (Box 4.1).
- **A strong monitoring, reporting and verification framework is also essential.** This can in part be based on the delivery of outcomes (e.g. emissions reduction) and partly through the take-up of measures (e.g. planting trees). The strengthening of bodies responsible for enforcing regulation and standards, such as the Forestry Commission, Natural England, the Environment Agency (and their equivalents in Scotland, Wales and Northern Ireland) and the farm inspection regime is critical.

We set out the analysis in the following sections:

1. Background and context
2. A new policy framework for land
3. Policies to deliver the net-zero ambition in agriculture and land use
4. Summary and conclusions

Box 4.1. The policy framework to deliver the UK's net-zero ambition

The new policy framework is designed to support the measures in our Net Zero advice: a high up-take of low-carbon farming practices and land uses that reduce emissions and increase carbon sequestration (see Chapter 2). We identify a policy framework that requires a mix of regulation, financial incentives and enabling policies to deliver the measures that can drive emissions reduction in the agriculture and land use sectors:

1. Low-carbon farming practices

- Adopt existing environmental stewardship rules that have benefited mitigation in UK legislation (e.g. the Nitrates Directive) and new legislation (e.g. the Clean Air Strategy) to capture additional sources of emissions (e.g. enteric emissions from livestock).
- Public money should be provided to incentivise the adoption of practices that go beyond the new regulatory baseline. There is also scope to pay for any additional measures required by new regulation for a limited period of time.
- Government should address barriers relating to skills and training, and support market commercialisation of more innovative options (e.g. livestock breeding and low-carbon fertilisers).

2. Forestry and agro-forestry

- The key mechanism should be a carbon trading scheme or auctioned contracts (e.g. similar to those offered for renewable electricity) to attract private sector investment. Either of these could be funded through a levy on greenhouse gas-emitting industries (e.g. fossil fuel providers or airlines). These schemes must explicitly avoid double counting of credits. The Woodland Carbon Code, which complies with the UK Forestry Standard already exists to monitor, report and verify carbon savings.
- Alongside this, public funding should be used to encourage the non-carbon benefits of afforestation (e.g. alleviating flood risk, recreation). Public funding may also be needed for planting trees on farms where it would not occur through the main mechanism above (e.g. because costs are higher than the price established through the market or where there are non-financial barriers).
- Enabling measures include a streamlining of the application process for afforestation, resolving tenancy constraints to facilitate tree planting, reviewing the tax treatment of woodlands (and, if necessary, amendment to ensure there is no disadvantage to farmers from changing their use of land to forestry) and the provision of policy certainty to enable a scaling-up in capacity of the domestic forestry supply chain from nurseries to sawmills and wood processors.

3. Peatland restoration

- Ban damaging practices such as rotational burning and peat extraction, which should be accompanied by a ban on the sale of peat for horticultural use.
- Mandate water companies to restore upland peat that is under their ownership, and owners of peatland within a Site of Special Scientific Interest. Pending on-going work by Defra, internal drainage boards should be required to maintain optimal water table levels that can reduce emissions on lowland peat, while allowing agricultural production to continue.
- Make public funding available for restoration and sustainable management practices on lowland peat that remains in agricultural production. The carbon benefits could eventually be paid for by the private sector following on-going development of the carbon verification mechanism, the Peatland Code.
- Where farmers continue to farm on lowland peatland, raising awareness and the provision of training and incentives on the adoption of sustainable management practices is crucial.

Box 4.1. The policy framework to deliver the UK's net-zero ambition

4. Bioenergy crops

- Use existing demand-side instruments to develop and strengthen the market for energy crops. There is a role for policy to provide greater certainty through carbon pricing, for example, underpinned by a guarantee of long-term supply contracts.
- Combustion processes that exclusively use biomass do not currently have to buy allowances from the EU Emissions Trading System (ETS). This should continue to be the case in any UK scheme linked to the EU ETS or in a separate UK ETS.
- Place an obligation on biomass combustion facilities to source a fixed proportion of their biomass feedstock from the UK. That proportion should rise over time in line with a realistic scale up of sustainable UK supply.
- Support market commercialisation of lower-cost planting mediums, and encourage the development of private sector intermediaries that can raise awareness of the financial benefits of crop diversification and arrange long-term contracts between farmers and end-users.
- Fast growing energy crops can provide a rapid and therefore important source of biomass feedstock for fuel use. During this decade, Government policies should assist a transition towards use of biomass (including energy crops) as a fuel with Carbon, Capture and Storage (CCS), and away from use for heating buildings and generating power without CCS.

1. Background and context

(a) The current policy landscape

Land use in the UK has been highly influenced by a complex set of sub-national, national, EU and international policies. These have, to date, rewarded food production over other services that land can provide including climate change mitigation and adaptation and wider environmental benefits.

The UK is subject to EU environmental regulations, which impact the management and use of land. Within the UK, agricultural and land use policies are fully devolved. There are no national or UK-wide policies that directly target the reduction of greenhouse gas (GHG) emissions in the agriculture sector beyond the provision of information and advice. There have been limited amounts of grant funding available for tree planting and peat restoration for climate mitigation purposes:

- The provision of information and advice to farmers is the main mechanism to incentivise emissions reductions in agriculture. These voluntary approaches include the industry-led Greenhouse Gas Action Plan in England and the Farming for a Better Climate initiative in Scotland.
- England's Woodland Carbon Fund launched in 2016 is providing £19 million for woodland planting and on-going maintenance. A £10 million Peatland Grant is being shared across four projects to restore over 6,000 hectares of lowland and upland peat in England, delivering an estimated annual saving of 23,000 tCO_2e. The Peatland ACTION project, funded by the Scottish Government has awarded £8 million to restoration projects since 2012.

There are a number of EU policies that, through the provision of funding and regulation, encourage the adoption of better farming practices, afforestation and peatland restoration:

- Under Pillar I of the Common Agricultural Policy (CAP), farmers must adhere to additional standards for animal health and welfare, plant health and the environment if in receipt of the direct subsidy (i.e. the Basic Payment Scheme). In England, some of these cross-compliance rules[59] can benefit climate change mitigation, for example by avoiding soil carbon losses from measures to minimise soil erosion (GAEC 5) and increasing carbon sequestration by protecting hedgerows (GAEC 7a).
- Under Pillar II of the CAP, additional co-funding by the EU and each member state is provided by the Rural Development Programmes for farmers, land managers, woodland owners, and foresters. [60] Under England's RDP, £3 billion is available for environmentally friendly practices, woodland creation and the restoration of priority habitats (e.g. including peatland) under the Agri-Environment schemes for the 2014-2020 period. The Countryside Productivity Scheme, which targets productivity improvements in agriculture and forestry is providing an additional £141 million over the same period. Similar RDP schemes exist in Scotland, Wales and Northern Ireland.
- EU environmental legislation to address non-GHG pollutants has indirectly reduced agriculture GHG emissions through changes in farming practices:[61]
  - The Nitrates Directive restricts when and how fertilisers can be applied in designated Nitrate Vulnerable Zones (NVZs) to minimise nitrate run-off from soils into water courses, for drinking water standards. These practices have reduced excess application of fertiliser and as a result lowered N_2O emissions. NVZ designation covers all of Northern Ireland, some parts of Wales, 14% of Scotland and around 55% of England, mainly in the east of the country.
  - The Water Framework Directive aims to improve the quality of water bodies to a good ecological status in the UK. To reduce diffuse water pollution from agricultural activities, the Farming Rules for Water for England were implemented in 2018. Under these rules, all farmers are required to meet a basic standard of good practice, underpinned by new legal requirements. This includes having a nutrient management plan, and preventing the application of fertiliser if soils have not been tested for pH and nutrients in the last five years. The rules are designed to capture all farmers irrespective of whether they are in an NVZ.

Smaller amounts of private sector investment in tree planting and peat restoration are being delivered through voluntary carbon markets, with verification of carbon savings provided by the Woodland Carbon Code and UK Peatland Code (Box 4.2).

[59] Cross-compliance rules comprise the Statutory Management Requirements and standards for Good Agricultural and Environmental Conditions (GAEC).
[60] The RDP provides funding for schemes to improve the environment, increase the productivity of farming and forestry and to grow the rural economy.
[61] Defra (2012) *Review of progress in reducing greenhouse gas emissions from English agriculture.*

Box 4.2. The UK Woodland Carbon Code and UK Peatland Code

The Woodland Carbon Code and Peatland Code offer companies that invest in afforestation and peat restoration assurance and clarity on the quantity and quality of the carbon savings being delivered:

- Since its launch in 2011, the Woodland Carbon Code, which is administered by the Forestry Commission, has validated 187 projects by March 2019 covering almost 8,300 hectares of new woodland. It is estimated that these projects will sequester 3.4 $MtCO_2e$ in the project lifetime (up to 100 years). It is accredited by the UK Accreditation Service (UKAS) and requires compliance with the UK Forestry Standard, making it a robust mechanism with which to report and verify the carbon savings of new woodland projects.
- The UK Peatland Code, administered by the International Union for Conservation of Nature UK (IUCN UK), is a more recent initiative. To date, it has validated one restoration project covering 77 hectares in Scotland, with a further nine projects under development. The Peatland Code is currently restricted to restoring certain types of upland peat (e.g. eroded and drained peatland), but it is working with Defra to widen eligibility to other peatland habitats such as upland modified bog and lowland peat. It is also working on gaining UK Accreditation Service accreditation this year, which is crucial to attract private sector investment.

Current policies to incentivise the planting of energy crops and to integrate more trees within existing agricultural systems are limited:

- In 2017, perennial energy crops made up just 0.2% of UK arable areas, while short rotation forestry[62] (SRF) for bioenergy is non-existent. This reflects historic low levels of confidence in the market for these products despite the presence of demand-pull instruments such as the Renewable Heat Incentive.
- Incentives to plant trees on farms vary across the UK. Scotland, Wales and Northern Ireland fund agro-forestry on grassland through their respective RDPs, while currently, there is no similar funding available in England.

The existing policy framework has been insufficient to meet the emissions reduction set out in our first five legislated carbon budgets. A new set of policies is urgently required to deliver the higher ambition of the net-zero target.

(b) The current direction of new policies

Defra's draft Agriculture Bill sets out provisions to transition by 2028 from the current subsidy support and funding arrangements of the Basic Payment Scheme (BPS) and RDPs to payments for the delivery of public goods. The main body of the Bill applies to England only, with some provisions extending to the whole of the UK (Box 4.3).

The Scottish Government intends to create new policy through its own Bill, although no long-term plans have yet been published. As we stated in the recent progress report for Scotland,[63] the Scottish Government needs to set out the future direction of its rural support policy, and make provisions for Ministers to create new policy or reform existing policy.

[62] SRF is similar to conventional forestry (a single stem tree species), but grown on a much shorter rotation of typically 8 - 20 years. Typical species include poplar, ash and sycamore (Forest Research).
[63] CCC (2019) *Progress Report to Scottish Parliament.*

Whatever the UK's future relationship with the EU, a shift in the subsidy system towards the delivery of environmental benefits is needed. The EU is currently negotiating the direction of the next CAP budget (2021-2027) and the European Commission has already stated that two of its nine objectives for the CAP beyond 2020 will be climate change and environmental care.[64] Final sign-off on the CAP budget is expected in June this year.

Box 4.3. Current proposals for the replacement of the Common Agricultural Policy

The implementation of a domestic agricultural policy to replace the Common Agricultural Policy (CAP) in each country of the UK represents the largest opportunity to redirect public funding towards emissions reductions and removals and the delivery of other public goods.

Defra's proposals for the new Future Farming and Countryside Programme, which will replace the CAP in England, comprises three elements:

- The development of a new regulatory baseline reflecting the 'polluter pays' principle.
- A new Environmental Land Management Scheme (ELMS) will replace direct payments (which is largely based on the amount of land farmed) with public money, which will be awarded for the delivery of public goods in agriculture and the other land use sectors, over and above any actions set out in the regulatory baseline:
  - The six qualifying public goods are climate change mitigation and adaptation; thriving plants and wildlife; clean and plentiful water; clean air; protection from and mitigation of hazards; and beauty, heritage and engagement.
  - ELMS payments will be phased in and the direct subsidy phased out over a seven year transition period (2021-2027). The new scheme will take full effect in 2028, by which time Defra estimates 82,500 farmers and land managers will be participating in the scheme. This is close to the 85,000 that received the direct subsidy in England in 2017.
  - Payments are expected to be based on the delivery of outcomes, and where that may be difficult to quantify, the uptake of actions, which will serve as a proxy for a particular outcome (e.g. planting trees along water courses to improve water quality). The findings from a three-year pilot using a 'payment by results' approach in North Yorkshire and East Anglia to deliver certain biodiversity objectives, will along with other evidence sources be used inform the development of the ELMS.
- In addition to ELMS, farmers and land managers will receive funding for improving soils, animal health and welfare and farm productivity. This is expected to support innovation, investment in farming equipment, technology and infrastructure.

In England, funds will still be available under the Countryside Stewardship to fill the void between CAP funding ending in March 2021 and the national roll-out of the ELMS in 2024. Defra is intending to fund these schemes using Treasury money from March 2021. Elsewhere in the UK, progress has been mixed. Scotland is yet to publish detailed plans, and the absence of an Executive in Northern Ireland until its recent return has hindered the development of new policy:

- **Wales.** The current proposal is for a new single scheme to support farmers and land managers, comprising two elements:
  - The Sustainable Farming Payment. This will provide an annual income for the delivery of environmental outcomes.

[64] European Commission (2018) *Future of the Common Agricultural Policy.*

– Business Support. Payments to develop farm businesses, with the focus on advice, capital investment and developing skills.

- **Scotland.** The Government introduced a Rural Support Bill in 2019, which is designed to maintain and simplify the existing CAP scheme in the three to five years after leaving the EU. It does not set out the future direction of Scottish rural support policy, nor does it make provisions for Ministers to create new policy or reform existing policy. The Scottish Government has expressed a desire to do so in a future Scottish Agriculture Bill rather than accept the inclusion of a Scottish schedule in the UK Agricultural Bill.

Source: Natural England (2019) *Pilot Results-Based Payment Approaches for Agri-environment schemes in arable and upland grassland systems in England.* Welsh Government (2019) *Sustainable farming and our land.*

Defra and the Scottish and Welsh Governments are also developing policies to reduce emissions in agriculture and land use. This is complemented by three strategies to improve the environment (the 25 Year Environment Plan), air quality (the proposed Clean Air Strategy) and food production (the Industrial Strategy), all of which will have a bearing on the agriculture and land use sectors (Box 4.4).

Now is the time, therefore, to redesign agricultural support systems across the UK to deliver better on climate change mitigation and other objectives, including climate change adaptation.

Box 4.4. Government strategies covering the agriculture and land use sectors

There is a range of strategies that will have an impact on the agriculture and land use sectors:

1. The Clean Growth Strategy. Work is on-going by Defra and the Scottish and Welsh Governments to develop policies to reduce emissions in agriculture and land use towards the net-zero target:

- Defra's two year 'Delivering Clean Growth through Sustainable Intensification project' (2018-2020) for agriculture will identify abatement savings from over 30 mitigation measures, understand better the social factors governing uptake amongst farmers and assess a range of potential policy options. This work will inform Defra's *Farm Emissions Reduction Plan* for reducing emissions in agriculture, which is expected later this year. Ambition for reducing emissions from peatland and increasing carbon removals through tree planting are expected to be set out in the forthcoming publications, the Peatland Strategy and Tree Strategy.
- The Scottish Government published the Climate Change Plan: third report on proposals and policies 2018-2032 (RPP3) in 2018. The Scottish Government has committed to publishing an update to this plan by May 2020 following its adoption of a net-zero target by 2045. The Plan will cover all areas of the economy, including the agriculture and land use sectors.
- The Welsh Government is working on plans for meeting its ambition for agriculture by 2030. This report pre-dates our Net Zero advice.

2. Complementary strategies:

- **The 25 Year Environment Plan.** The Plan sets out an aim to "be the first generation to leave the environment in a better state than we inherited it". The plan contains commitments to recognise good practices that build up and bolster natural assets, such as soil, water and biodiversity, while also taking account of the negative effects of a range of current land uses and activities. The Plan makes provision for targets, plans and policies for improving the natural environment.

Box 4.4. Government strategies covering the agriculture and land use sectors

Climate change mitigation and adaptation are one of the ten goals set out in the Plan. The main body of this Bill applies to England, but similar powers extended to Wales and Northern Ireland.

- **The Clean Air Strategy.** The Strategy is targeting the reduction of ammonia alongside other damaging air pollutants to improve air quality. Agriculture accounts for 88% of ammonia emissions, which comes from three main sources; livestock manure and urine and the use of nitrogen fertiliser. The three main proposals will require the adoption of low-emissions farming equipment and measures. While these proposals are targeting a reduction in ammonia, the associated benefits for non-CO_2 emissions will be variable, with the proposal to extend environmental permitting to the dairy and intensive beef sectors offering the largest opportunity to reduce non-CO_2 emissions:
  - **Covering of slurry and digestate stores from 2027.** It is estimated that while fixed slurry covers can reduce ammonia emissions by 72% to 95% depending on the type of cover, there is a weak beneficial impact on non-CO_2 emissions, as reductions in N_2O are partly offset by an increase in methane due to the storage of slurry in anaerobic conditions.
  - **The spreading of slurries and digestate using low-emission spreading equipment from 2025.** While shallow injection techniques can reduce ammonia emissions by up to around 70% compared with surface broadcast application, there could be a corresponding increase in N_2O emissions due to an increase in the readily available nitrogen in the soil as a consequence of less ammonia loss.
  - **Extending environmental permitting to the dairy and intensive beef sectors from 2025.** This would go beyond the Industrial Emissions Directive, which only requires the regulation of intensive pig and poultry sectors. Farmers will have the flexibility to select measures (e.g. best available technologies) to meet emissions limits, which have yet to be determined. These measures are expected to also deliver non-CO_2 emissions reductions given the target will cover a wide number of pollutants, not just ammonia.
  - As part of the Clean Air Strategy, Defra is planning to develop a tool in 2020 that will quantify the changes in GHG emissions savings from the first two proposals. Quantifying the impact of environmental permitting will depend on which best available technologies are selected.
- **The Industrial Strategy.** As part of the Strategy, BEIS is allocating £90m worth of investment to transform food and farming ('Transforming Food Production Challenge'). On the technology side, the fund will focus on measures such as artificial intelligence, robotics, remote monitoring and data science, and will be allocated in tranches between 2018 and 2022. Reducing GHG emissions and improving resilience will be two of the criteria that will be used in the evaluation process. The first tranche of funding (£22m) was awarded last year, while a second tranche will allocate up to a further £20m in 2020 to projects that develop amongst other things, new and efficient low-emission food production systems (e.g. indoor growing systems).

Source: Welsh Government (2019) *Prosperity for All: A Low Carbon Wales.*

2. A new policy framework for land

In this section we set out a policy framework that delivers land's contribution to net-zero. The pathway we identify maintains a strong agriculture sector and also aims to support the delivery of a wide range of co-benefits, including climate change adaptation.

Our assessment of appropriate policies is informed by work we commissioned from Vivid Economics and ADAS, which included a UK and international literature review.[65] We held extensive stakeholder engagement, which included a specially convened external advisory group,[66] and we drew on work undertaken for the Committee's 2018 Biomass Review.[67]

The required policy framework has three broad elements:

- **Regulation.** Establishing a strong regulatory baseline through existing and new legislation.
- **Financial support.** The provision of public and private sources of funding to address financial barriers.
- **Non-financial support**. Key enabling policies to address non-financial barriers.

For each of the measures in our net-zero scenario, we assessed the range of financial and non-financial barriers that need to be overcome and how these can be addressed. The criteria used to assess policies are set out in Table 4.1.

[65] Vivid Economics and ADAS (2019) *Policy framework for deep emissions reduction and carbon removals in agriculture and land use in the UK.*

[66] Professor Allan Buckwell (2019) *Summary report, CCC land use advisory group.*

[67] CEH (2018) *Steps to scaling up UK sustainable bioenergy supply.*

Table 4.1. Assessment criteria for policies

Criteria	Description
Track record	Has the policy been implemented successfully in the past in the UK or elsewhere?
Value for money	Is the measure cost-effective for the agriculture sector and UK as a whole?
Incentives to innovate	Does the measure provide incentives for farmers to innovate and reduce costs over time? Does it give farmers flexibility to find their own solutions?
Easy for farmers to understand and implement	Is it easy for all types of farmers to comply with and does it limit potential distortions between types of farmers?
Does it assist farmers through change?	Does it provide an effective transition between the current payments system for farmers and the future?
Political acceptability	Is the policy expected to receive broad support and does it limit the costs to the Exchequer?
Administrative complexity	Is the policy feasible to implement, monitor and verify over time?

Source: Vivid Economics and ADAS.

It is important that a hiatus in the take-up of measures required for delivering net-zero is avoided while awaiting the implementation of new policies (e.g. the roll-out of ELMS in 2024). It is critical therefore that on-going public funding should continue, and where necessary be increased. In addition, the terms of funding available under existing programmes (e.g. Agri-Environment schemes) should be amended to incorporate measures that directly reduce emissions.

Monitoring, reporting and verification (MRV) are key parts of the new policy framework. Monitoring of farm activity can be done through remote review of data, farm inspections (e.g. to ensure specific actions have been undertaken) or through sampling based on risk assessments, while land use change can be monitored through field surveys and remote sensing. New modelling techniques and tools can help in this process (e.g. remote sensing or spatial decision making tools).[68] Government should ensure the right MRV is in place as part of the policy design process to ensure it provides evidence to support effective evaluation of new policies.

[68] For example, landscape-scale remote sensing to create a map showing vegetation cover as a proxy for peat restoration, and the Outdoor Recreation Valuation tool (ORVal) produced by the University of Exeter to model where new woodland could be sited to increase recreational value.

3. Policies to deliver the net-zero ambition in agriculture and land use

In this section we set out new policies needed to change the way land is used and managed in order to deliver our net-zero ambition for the agriculture and LULUCF sectors. This covers four key areas:

(a) Low-carbon farming practices
(b) Afforestation, agro-forestry and woodland management
(c) Peatland restoration and management
(d) Bioenergy crops

Policies to reduce food waste and diet change are set out in Chapter 5.

(a) Low-carbon farming practices

Low-carbon farm practices reduce soil, livestock and manure management emissions and include established options (e.g. avoiding soil compaction, using a manure planning tool and improving livestock health) and more innovative measures (e.g. use of breeding and methane inhibitors for cattle and low-carbon fertilisers). We estimate that these practices combined with measures to reduce energy use could deliver annual GHG savings of around 10 $MtCO_2e$ compared with a business as usual scenario by 2050.[69]

As we set out in Chapter 3, we estimate that implementing low-carbon farming practices in line with our Further Ambition scenario would deliver net benefits to farmers of £0.4 billion per year to 2050.[70]

To encourage the take-up of these practices a range of social, economic and behavioural barriers will need to be overcome. These include inertia; difficulty for newcomers with the right skills to enter the market; lack of knowledge, experience and skills in applying farming techniques and practices; contractual arrangements that may constrain uptake amongst farms that are tenanted or designated as common land. For those options that represent technological solutions (e.g. livestock breeding measures) there is also often a disconnect in translating R&D into market commercialisation that would allow for wide-scale adoption.

Overcoming these barriers will need a mix of policies comprising a strengthening of regulation, financial incentives and measures to overcome non-financial barriers.

Strengthen the regulatory baseline

Farmers have to date adopted farming practices that have indirectly reduced emissions in agriculture in response to UK and EU regulations and to comply with cross-compliance standards if in receipt of direct subsidy payments under CAP. These standards and regulations must be maintained. At the same time, the baseline needs to be strengthened through additional compliance rules, use of existing legislation (e.g. the Nitrates Directives) and the introduction of new legislation (e.g. the Clean Air Strategy).

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[69] This report does not cover policies to reduce GHG emissions from use of stationary and mobile machinery in agriculture.
[70] This is based on an assessment of the private costs and private revenues.

Key measures needed are:

- **Maintaining existing standards.** Proposals for the new public payment scheme to replace CAP (e.g. ELMS in England) allow farmers to opt in or out. This voluntary approach risks a reversal in good farming practices for those who opt out, which could prove detrimental to emissions, and wider environmental goals.[71] To avoid this, measures under existing cross-compliance rules that have benefited climate change mitigation (e.g. measures to minimise soil erosion and establishing buffer strips along watercourses) should be mandated irrespective of whether farmers are in receipt of public money.
- **Fertilisers.** Extend coverage of the Nitrates Vulnerable Zones (NVZ) to all of the UK. Currently all of Northern Ireland, some parts of Wales, 14% of Scotland and around 55% of England, mainly in the east of the country, are designated as NVZs. Extending coverage could provide significant incentives to reduce N_2O emissions from manure management and fertiliser use. For example, it would benefit large areas of the west, which experiences higher rainfall and where soil conditions make the release of N_2O more likely.[72]
- **Waste management.** The proposal for all slurry and digestate stores to have a cover from 2027 under the Clean Air Strategy could deliver additional N_2O savings not captured in our Further Ambition scenario. A Defra study found that slurry covers can reduce N_2O by up to 91% compared to uncovered stores.[73] In addition, as covers increase the overall nitrogen use efficiency of the manure when spread, this could reduce the need for inorganic fertilisers. The N_2O savings are partly offset however, by an increase in methane due to the storage of slurry in anaerobic conditions.[74]
- **Improvements in livestock diets, health and breeding** can be incentivised through the Clean Air Strategy and by placing an obligation on compound feed manufacturers.
  - The Clean Air Strategy offers an opportunity to target emissions from enteric fermentation, which is not covered by existing regulation. Of the proposals being considered, extending environmental permitting to the dairy and intensive beef sectors from 2025 offers the widest scope to reduce agricultural GHG emissions. It is expected to target several pollutants, including non-CO_2 emissions. In developing a list of best available techniques to meet appropriate emissions limits from the sector, we recommend that the Environment Agency and the relevant environmental bodies in Scotland, Wales and Northern Ireland include measures covering waste management, livestock diets, livestock health and breeding, which can address both non-CO_2 and ammonia emissions.
  - Feed additives can reduce enteric emissions by inhibiting the production of methane in the rumen. Mandate compound feed manufacturers and providers of mineral supplements to include a minimum percentage of additives that are fed to ruminant livestock:

[71] National Audit Office (2019) *Early review of the new farming programme.*
[72] CCC (2018) *Technical Annexe: The Smart Agriculture Inventory.*
[73] Defra (2010) *Science & research project - WQ0106.*
[74] See Chapter 2 for a discussion of relative lifetimes of methane and N_2O and judging trade-offs between these gases.

- Our net-zero Further Ambition scenario includes abatement from nitrates additives and probiotics. The latter could save money for the farmer through resource efficiency as well as reducing emissions.[75]
- As compound feed is produced entirely in the UK, placing the requirement on the few producers rather on livestock farmers is likely to make verification easier to administer.
- The obligation should also extend to providers of mineral (major and trace minerals) additives to cover ruminant livestock not captured by the Clean Air Strategy and where compound feed is a small share of the diet (e.g. extensive sheep and cattle).

A strengthened regulatory baseline needs to be accompanied by a strong enforcement regime to ensure compliance. The Environment Agency in England and corresponding environmental bodies in Scotland, Wales and Northern Ireland are responsible for enforcing many of the regulations but lack of resources has weakened their ability to undertake this role to a satisfactory standard. These bodies need to be fully resourced to ensure effective enforcement of existing and future regulations.

Financial incentives for measures above the regulatory baseline

We recommend that actions beyond those required to meet the new regulatory standards should be publicly funded. There is also scope to pay for any additional measures required by new regulation for a limited period of time. The proposed ELMS scheme in England could become the largest source of public funding of environmental public goods in the future. To ensure that farmers are incentivised to reduce on-farm non-CO_2 emissions in the intervening period, public money needs to be available as soon as possible. This could be delivered through the existing Rural Development Programmes or new schemes and grants.

Costlier measures should be incentivised through such programmes. This includes controlled release fertilisers, slurry acidification and 3NOP, the methane inhibitor. We estimate that these three measures will require £140 million per year to fund and with high take-up rates could deliver annual savings of around 1.9 $MtCO_2e$ by 2050.

Opportunities for private sector finance to be blended with public money should also be explored. Water companies have been actively engaged with farmers to reduce water pollution at source. For example, Wessex Water's EnTrade initiative to reduce nitrogen run-off into Poole Harbour by 40 tonnes each year by 2020 is being delivered through a series of reverse auctions, with farmers bidding for funds to plant cover crops over winter or revert arable land back to grassland. With over 60 farmers involved covering almost 3,000 hectares, the scheme has removed the need to build costlier assets to remove the nitrogen at its local sewage works.

Policies to address non-financial barriers

Successful uptake of low-carbon farming practices will require a range of non-financial barriers to be addressed:

- **Partnership working.** This is critical for farmers who are time poor and not fully aware of best practice to reduce emissions**.** For example, the recent tests and trials for ELMS saw a wide representation of stakeholders including NGOs (e.g. RSBP and the local Wildlife Trusts), public organisations (e.g. universities and national parks) and industry bodies (e.g. utility

[75] CCC (2015) *Sectoral scenarios for the fifth carbon budget.*

companies and food processors) leading the projects, with an established networks of farmers and landowners.

- **Provision of independent advice, skills training and demonstration.** Sustainable farming is knowledge-intensive and in order to make the right decision, farmers rely on a supply of advisory services. Government should work with the private and voluntary sectors and through agricultural colleges and universities to consider how this is best delivered.
- **Research and development** of nitrogen-efficient and resilient crops, low-carbon fertilisers and breeding of lower-methane emitting livestock is needed, as well as accelerating their implementation on farms. In the Netherlands, the approach is one of close collaboration between the research institutes (e.g. Wageningen University & Research), the Government and businesses to developing a more sustainable agricultural sector.
- **Resolving barriers arising from tenancy** (including common land) is a key issue that cuts across agriculture and alternative uses of land (Box 4.5).

Box 4.5. Tenancy and common land

Around 28% of the land area in England, 22% in Wales, and 24% in Scotland is tenanted. The length of the tenancy (an average of 2.9 years in England and Wales in 2018) may dissuade famers from investing in technologies and innovative practices that have a long payback, while the terms of the tenancy contract may prohibit switching land to alternative uses. At the same time, a landowner willing to support changes for the benefit of emissions reduction may be constrained if it is common land:

- Tenants may be prevented from planting trees either because the terms stipulate that the land can only be used for agricultural purposes or there is a specific ban on tree planting; and in the event that tree planting is allowed, ownership and the benefits that accrue may reside with the landowners rather than the tenants.
- There is also the additional complexity of common land, which is used mainly for grazing. Under this type of tenure, the commoners rather than the landowner controls the use and management of land, which could prohibit a willing landowner from making sustainable changes.

Resolving tenancy constraints should allow and encourage tenanted farmers to undertake long-term investment decisions. This could include, and is not limited to:

- A review of the taxation system where it may be acting as a barrier to alternative uses of agricultural land.
- Aligning incentives between the tenant and landowner could include firmer guidance on compensation (e.g. for improvements made during the tenancy) to encourage tenants to make longer term investments to the holding so that both parties can benefit.
- When renewing leases, landowners could look to appoint forward-thinking tenants who are open to farming in a more sustainable manner. This is the approach that National Trust are adopting when selecting new tenants.
- There are examples of landowners working with commoners to increase sustainable land use. For example, the National Trust which owns 66,000 hectares of common grazing is working with commoners on upland peat to adopt low-carbon management such as reducing grazing intensity.

The Government should work with the agriculture sector including landowners and tenants on how best to take this work forward. This could include a review of current tenancy legislation to ensure it is 'fit for purpose' to meeting the net-zero target, a review of the tax system, and ensuring that tenants and commoners are able to participate in the new system of public payments.

Role of the supply chain

There is a range of actors in the food supply chain that can exert influence on farmers to adopt low-carbon farming practices. These comprise the suppliers and providers of animal feed and inorganic fertilisers, and downstream of the farm-gate, food processors and the food retail sector:

- **Input providers and distributors:** There is scope to widen the training implemented by the GHG Action Plan to include all providers and distributors of animal feed and inorganic fertilisers. One way of delivering this would be to require these groups to use accredited personnel when advising farmers on nutrient use and animal nutrition. For example, fertiliser advisors under the FACT's (Fertiliser Adviser Certification) scheme are required to undertake on-going training on emissions abatement in order to retain their professional status. The comparable accreditation scheme for livestock feed advisors is the Feed Adviser Register.
- **Food processors** have been instrumental in encouraging sustainable farming practices, for reasons that extend beyond corporate social responsibility. In some cases they have invested in large processing plants co-located to the source of key inputs. As a consequence, there is a vested interest in sourcing quality inputs, and securing future supplies by minimising their exposure to climate change risks (Box 4.6)
- While the **food retail sector** has introduced a number of initiatives and programmes as part of their corporate social responsibility strategies, engagement with farmers has been patchy. This in part reflects their ability to hedge against risks and switch suppliers, which means for some, there is less of a vested interest to pursue a long-term commitment to reducing on-farm emissions. With many retailers sharing the same suppliers there is an opportunity for more action, which could deliver a sector level commitment.

To encourage greater accountability for businesses, government should facilitate the development of clear and robust metrics and standards for reporting emissions from food. This could be the first step to the development of more stringent obligations on the food supply chain to reduce their scope 3 emissions over time (i.e. the emissions from their supply chain). We cover this in more detail in Chapter 5.

Box 4.6. Food processors and work with farmers

Example of progressive action by food processors include:

- Arla Food UK, the country's largest dairy producer comprising around 2,400 dairy farms in the Arla cooperative has set a target to be carbon neutral by 2050. This new commitment follows the 2018 launch of 'Arla 360 UK', a new standard to improve the sustainability of the co-op's dairy farms across six key areas, including the environment. Under the programme, farmers are required to undertake carbon footprint assessments and monitoring. Farmers are paid a premium to cover the additional compliance costs. The programme is also investing in new technology. For example, 3D imagery systems is being trialled by cattle farmers to help identify changes - earlier than would be possible using the naked eye - to the physical wellbeing, mobility and weight of each animal, which could support improvements in emissions intensity.
- PepsiCo UK, a large buyer and processor of potatoes, is working with farmers to reduce their emissions footprint as part of its wider Sustainable Farming Programme. For example, the iCrop technology is being used to relay real time data back to the farmers to inform their decisions on fertiliser use, while the 'Cool Farm Tool', has allowed farmers to identify, measure and reduce

Box 4.6. Food processors and work with farmers

emissions in growing potatoes. The company is also providing on-going support to ensure the technology is being adopted in the correct manner.

- Operations at Nestlé UK's milk processing plant in Cumbria - which has undergone a multi-million pound upgrade - are reliant on being able to source a stable and sustainable supply (around 65 million litres a year) of milk from local farmers. This reliance means that Nestlé works closely with local farmers to enhance yields, improve animal welfare and reduce the environmental impact, while sustainability measures covering soil and water quality can earn a price premium for the farmer. Last year, Nestlé pledged to reduce GHG emissions to net-zero by 2050 across its international supply chain and operations.

(b) Afforestation, agro-forestry and woodland management

Our net-zero scenarios imply the area of woodland cover in the UK increasing from the current 13% to around 17-19% by 2050. This is based on annual tree planting levels reaching at least 30,000 hectares from 2024, possibly up to 50,000 hectares.[76]

We also include agro-forestry on 10% of agricultural land and a 40% increase in hedge length by 2050. Our scenario also includes an increase in the management of existing broadleaf woodlands that complies with the UK Forestry Standard, from 20% currently to 80% by 2030.

We estimate that net additional funding of £0.5 billion per year will be required to meet the planting of 30,000 hectares of trees in our Further Ambition scenario, and £0.2 billion for growing trees on farms.

Although managing existing broadleaf woodlands would deliver a net annual benefit of £0.1 billion, the presence of non-financial barriers probably explains the current low rate of management.

It is crucial that afforestation continues to conform to the UK Forestry Standard. In particular, decisions on where and what tree species to plant must take account of the need to adapt to the current and future impacts of climate change.

Main policy instrument

An effective policy mechanism for afforestation and some agro-forestry needs to provide a secure income stream, long-term certainty and deliver value for money. This can be funded through a Feed-in-Tariff or trading scheme:

- **Feed-in-tariff.** The UK awards long-term contracts ('Contracts for Difference' (CfDs) - a type of feed-in tariff) to support new low-carbon electricity generation via a reverse auction mechanism. It is funded by a statutory levy on all UK electricity suppliers. This style of policy could be adapted to support investment in afforestation. This would confer additional benefits:
  - The auction mechanism allows for price discovery. Long-term costs of new generation in the power sector have fallen over time and could represent a more

[76] This is equivalent to 0.9million hectares planted by 2050 in the Further Ambition scenario and 1.5 million hectares in the Speculative scenario.

efficient option than an emissions trading scheme particularly if there is a wide variation in costs, as is likely for afforestation.

- The guarantee of a fixed payment (the 'strike' price set at auction) offers an insurance against a variable market price that will reduce risks given that most of the costs of afforestation are occurred upfront.
- The mechanism could be funded by an additional obligation on a polluting industry (e.g. fossil fuel suppliers or aviation).

Defra has recognised the benefits that a reverse auction can deliver for afforestation with the launch of the Woodland Carbon Guarantee (Box 4.7)

- **A UK emissions trading scheme**. Forestry credits are not currently eligible for inclusion in the EU Emissions Trading System (ETS), though they have been included in other trading schemes around the world, for example in New Zealand (Box 4.8). However, the UK could develop a separate trading scheme for forestry or include it in a UK-wide ETS if the UK leaves the EU ETS.

  A trading scheme for forestry puts a price on carbon stored by woodland and provides an incentive to encourage landowners to establish and manage forests in a way that increases carbon storage.

  Owners of existing or new forests could apply to register their forest land into the ETS and would receive carbon credits (equivalent to EU Allowances, the permits traded in the ETS) for increases in carbon stocks issued by an administrative body. Credits could be held or traded. The level of carbon credits awarded for forestry owners would be determined by the existing Woodland Carbon Code (Box 4.2), which is compliant with the UK Forestry Standard (UKFS). The UKFS is the reference standard for sustainable forest management across the UK.[77]

  The scheme would need to ensure there are no incentives to deforest land once woodland is established.

  The scheme would have a maximum number of credits available to trade and would be funded through an obligation on emitting industry (e.g. fossil fuel suppliers or airlines). It could be underpinned by a floor price and have a maximum reserve price to be paid. If the UK withdraws from the current EU ETS and establishes its own emissions trading scheme, the forestry scheme could become part of that, with a separate cap on the level of forestry credits. To avoid undermining the need for emissions reduction elsewhere in the economy, a maximum volume for forestry credits should be set (e.g. in line with the Committee's net-zero scenarios), with the overall cap set correspondingly lower.

  It would be important to ensure that carbon-credits from land-based solutions are not allowed to reduce effort elsewhere in the economy. In the long run they should not be used to offset emissions that need to fall close to zero to meet net-zero across the economy (e.g. emissions from electricity generation, heating buildings, surface transport or most of industry).

  Over time, the scheme could be extended to other nature based solutions such as peatland restoration and other emissions removal technologies such as direct air capture. This would rely on the development of robust monitoring, reporting and verification mechanisms.

[77] The UKFS ensures that international agreements and conventions on areas such as sustainable forest management, climate change, biodiversity and the protection of water resources are applied in the UK.

There are advantages to having afforestation in a trading scheme:

- It provides long-term support for tree planting, and is consistent with the 'polluter pays' principle. A trading scheme allows for price discovery, and could be underpinned by a floor price to address price uncertainty and improve incentives to participate.
- In theory, inclusion in a wider trading scheme could reduce overall costs as the market would seek out the cheapest ways to reduce emissions in the capped sectors or to remove emissions through forestry. However, in the near-term it appears unlikely that any forestry allowances could be traded with the EU if a future UK ETS and EU ETS are linked.

To avoid undue delays to tree planting, it is imperative that the mechanism(s) to deliver private sector funding is established as soon as is practicable. In the meantime, public support (e.g. through grant funding) will be required to avoid delays in planting.

Box 4.7. The Woodland Carbon Guarantee

The Woodland Carbon Guarantee (WCG) was launched by Defra and the Forestry Commission at the end of 2019. The intent of the WCG is to boost afforestation rates in England by providing long-term certainty to investors in woodland creation. Every five or ten years up to 2055/56, participants will be able to sell the carbon credits at a guaranteed price (determined at a reverse auction) to Government. There is the option to sell on the open market should the market rate be higher. There will be biannual auctions between 2020 and 2025 with £50 million committed to the scheme. The first auction will be held at the end of January 2020 and funding of up to £10 million will be made available.

Box 4.8. Afforestation in the New Zealand carbon trading scheme

New Zealand has a trading scheme open to carbon credits from afforestation. Furthermore, it is the only example of a carbon trading scheme where afforestation is eligible for inclusion in its economy-wide ETS. In place since 2008, land managers and owners are able to annually claim for carbon credits equal to the amount of carbon stored by their trees each year. However, complexities associated with the scheme, and a fall in the price of carbon from around $20/tonne to $5/tonne in 2014 did not deliver the desired increase in afforestation. The delinking of the scheme to the global markets in 2015 has seen the price rise, reaching around $25/tonne in 2019. It is hoped that the rising price combined with amendments to streamline the process, and simplifications to the accounting for the carbon stored in the trees will help deliver the country's ambition to plant one billion trees by 2028. Meeting this ambition is being supported by grant funding, and the new forests will be able to register with the ETS if the forestry scheme meets the ETS criteria.

Public funding

Some public sources of funding would still be required for parts of this sector:

- **Non-carbon benefits of afforestation.** Tree planting costs may vary by location and there could be situations where it would be beneficial to plant trees where it is relatively costly to do so (i.e. where it delivers wider benefits such as amenity value or alleviating flood risk). In this case, top-up funding should be provided for delivering non-carbon benefits. Prioritisation may be required to determine the allocation of public money in order to maximise these non-carbon benefits.

- **Broadleaf management.** Bringing neglected broadleaf woodland back into sustainable management that is compliant with the UK Forestry Standard delivers a wide range of benefits including increased carbon sequestration, and improved resilience to potential threats that may increase with a warmer climate (e.g. pests and diseases, wind and fire). These benefits are recognised by public funding sources (e.g. the Countryside Stewardship's Woodland Management Plan Grant for England). Where possible, the costs of improved management could be part funded by the buyers of the harvested material (e.g. wood processing plant).
- **Agro-forestry.** A trading scheme or CfDs could be suitable for agro-forestry schemes that are low cost and deliver clear carbon sequestration benefits (e.g. when planted on cropland). Where costs are higher and/or the scheme delivers other environmental benefits, public funding should be provided.
- **Hedge creation.** Our analysis suggests that hedgerow creation is not cost-effective from a carbon perspective alone. However, hedgerows provide a large range of other environmental benefits that could justify public funding. These include reducing the effects of soil erosion from wind, shelter for livestock, biodiversity, and water quality, if planted by water courses. It has not been possible to quantify the extent of these public goods, but they could be significant. Hedgerows that are protected under existing cross-compliance rules,[78] should continue to be so to avoid the loss of this habitat. This should apply irrespective of whether in receipt of direct subsidy or future public payment. Additional funding should be provided where they deliver wider benefits.

Enabling policies

Despite the availability of public money under existing schemes for woodland creation (e.g. Rural Development Programme and the Woodland Carbon Fund), take-up has been modest as reflected by the low rates of afforestation which have been below the aspirational targets set by each country of the UK. This reflects the presence of a range of non-financial barriers that will need to be addressed:

- Streamline and simplify the application process and meet adequate deadlines for granting planting permission.
- Outreach to incentivise private sector investment as is the intended role for the Forestry Investment Zone (Box 4.9).
- Development of local markets is required for the harvested material from existing broadleaf woodland.
- The tax treatment of woodlands should be reviewed and, if necessary, amended to ensure there is no disadvantage to farmers from changing their use of land to forestry.
- Scaling up the supply chain from nurseries to sawmills and wood processors. Given the restrictions placed on importing nursery stock for phytosanitary reasons, the domestic nursery capacity will have to increase markedly to provide the quantity of planting stock needed to afforest 30,000 hectares each year. This will need to be accompanied by a rise in the skilled silviculture workforce to plant and manage the trees.[79] Providing advanced

[78] Defra (2018) *The guide to cross-compliance in England (GAEC 7a. Boundaries).*
[79] The Confederation of Forest Industries estimate that 800 people would be needed to plant 40,000 hectares annually.

market commitment to instil supply-chain confidence is critical, while the development of new planting technologies (e.g. seed planting drones) can support a scale-up in planting.

- Concessionary finance in the form of loans which have more generous terms than market loans (e.g. no interest or below-market interest rated) could be used to provide top-up funding.

Box 4.9. Forestry Investment Zones

Attracting more private investment also requires addressing non-financial barriers as reflected by the low afforestation rates in recent years despite the availability of public funding. Removing these barriers is the main aim behind the Forestry Investment Zones (FIZ), an enabling mechanism to attract more private investment into the planting of large-scale productive forestry. Launched in 2018 by Defra and the Forestry Commission, the two-year pilot in Cumbria is trialling the FIZ. It is looking to address some of the barriers associated with applying for large woodland creation schemes such as the application and approval process, which can lead to undue delay. The appointment of a FIZ officer to offer tailored advice to land owners and investors is expected to provide confidence in the application process, while a programme of whole farm audits is being finalised to seek opportunities to further integrate farming and forestry.

(c) Peatland restoration and management

Our Further Ambition scenario includes restoring 50% of upland peat, 25% of lowland peat, and the removal of trees on 25% of the area containing low-productive trees (less than yield class 8). In our Speculative scenario, we also included additional abatement savings from the adoption of sustainable management practices on 25% of lowland peat. Further restoration of peatlands may be needed as there is a risk that they could be destroyed altogether with climate impacts.

In Chapter 3, we estimated that £74 million per year would be required to restore the area of peat in our Further Ambition scenario.

Policy to increase the rate of peatland restoration should comprise three elements: stronger regulation; a mix of private and public funding; and overcoming non-financial barriers.

i) Upland peat

Extensive livestock grazing is the main use of upland peat. Upland restoration to date has been driven by Agri-environment schemes, with farmers mainly paid to reduce stocking rates. The other main mechanism has come from catchment-scale restoration to improve water quality by the water companies. It is estimated that the water companies invested around £45 million between 2005 and 2015 in upland restoration, often in partnership with conservation organisations.[80]

Strengthen the regulatory baseline

This should include a ban on blanket bog burning and a requirement on water companies to restore peatlands under ownership.

[80] ASC (2013) *Managing the land in a changing climate.*

- **Ban rotational burning in the UK in 2020**. This includes burning for grouse shooting. This practice was traditionally undertaken on mineral soils but over-time it has encroached onto peat soils. Burning heather promotes young shoots, which grouse feed on, but it is highly damaging to the peat, and to the range of environmental benefits that well-functioning peat can deliver (e.g. water quality, biodiversity and carbon sequestration). A voluntary cessation of this activity by landowners has not produced the desired outcome so the practice should be banned across the UK with immediate effect. The adoption of more sustainable practices to manage the vegetation (e.g. heather cutting) would still allow grouse shooting to continue on peat soils, while the burning of heather could continue on mineral soils. The ban could be implemented through an amendment to the Environment Bill.
- **Mnadate landowners to restore all peatland designated within a Site of Special Scientific Interest (SSSI).** Defra estimates that around 51% (158,000 hectares) of upland peat in England are within a SSSI reflecting their national importance for biodiversity. However, there is no specific duty set out in current legislation to bring a SSSI feature into favourable condition.[81] The area of upland blanket bog designated a SSSI in favourable condition was found to have declined from 19% to 12% between 2003 and 2018.[82]
- **Mandate water companies to restore peat under ownership.** Water companies are large land owners, which includes a lot of upland peat in the north and north-west of England, and smaller areas in the south-west. For example, United Utilities own 56,000 hectares of land, of which 34% is classified as moorland comprising blanket bog and heathland, while Yorkshire Water owns 27,553 hectares of catchment land, of which around 8,000 hectares is peat. Water companies including Scottish Water in Scotland have been actively engaged in peat restoration mainly driven by minimising water treatment costs (e.g. to remove dissolved organic carbon) for water quality standards on both owned and non-owned land. More recently, they have been factoring in the wider benefits that well-functioning peat can deliver (e.g. biodiversity). Water companies already have approval from the water regulator to recover the costs of restoration through customer bills, which helps offset the costs of treating water downstream of the catchment.

Funding

A mix of public and private sector funding could deliver further upland peat restoration.

- **Improve incentives for land-owners to invest in restoration.** Mandatory restoration of all upland peatland within a SSSI that is not owned by a water company and additional restoration above the regulatory baseline should be able to qualify for on-going and future public funding streams. This could pay for both the carbon and non-carbon benefits of restoration. Non-carbon benefits include improving water quality and enhanced biodiversity. Evidence suggests these are significant, but difficult to quantify at the UK wide level and are therefore not included in our overall estimate of benefits.
- Over time, it may be possible to attract more **private investment** to pay for the carbon benefits using the same mechanisms to incentivise afforestation, as set out in Section 3 (b). This is contingent however on the Peatland Code being developed to UKAS standards. Plans

[81] Natural England has powers through the Countryside and Rights of Way Act to seek recovery or restoration of feature condition.
[82] CCC (2019) *Progress in preparing for climate change.*

by Defra and the IUCN UK Peatland Programme to improve the Peatland Code should be taken forward as soon as is practicable (Box 4.2).

Enabling policies

- Raising awareness on the benefits of managing peatland in a more sustainable manner can help address cultural resistance to change. There is a place for local and trusted intermediaries to play a role in presenting a package to land managers that offers blended finance (e.g. public and private sources of funding), while making the Peatland Code accessible.
- Training staff and building up supply-chain expertise requires extra funding on top of the capital costs of restoration. This should be taken into consideration when allocating public money to restoration projects, as Scotland's Peatland ACTION scheme has successfully done.
- Natural England has the power to seek recovery or restoration of feature condition of SSSIs, while the Environment Agency takes the lead where there is pollution affecting a river in a SSSI. Both bodies should be sufficiently resourced to carry out their monitoring and enforcement duties.

ii) Lowland peat

In contrast to the uplands, lowland peat represents high-grade agricultural crop land. Over 40% of lowland peat area is graded with an Agricultural Land Classification (ALC) of 1 and 2, and thus the opportunity costs to restore are much higher compared to the uplands.

Our policy recommendations therefore cover both full restoration and sustainable management practices, which would allow agricultural production to continue. Under the Speculative scenario of our Net Zero advice we included additional abatement savings from management practices. The specific practice selected to demonstrate carbon savings was seasonal rewetting in the winter although there are other management options that could be deployed. Defra is currently undertaking a project to review a range of management practices comprising water table management, cover crops and paludiculture (wetland farming).[83]

More immediate policy instruments to preserve lowland peatland could include a ban on peat extraction and its sale and a regulatory requirement not to leave lowland peat soils bare for extended periods. There should also be a move to more sustainable management of peatland:

- **Ban the extraction of peat.** Less than 1% of peat area in England is commercially extracted, mainly for use in the horticulture sector.[84] Since 2012, no new licences for extraction have been granted**.** Nevertheless, some existing licences are not due to expire until the early 2040s. The extraction of peat for all uses in the UK should cease by 2023, and the Government should work with those licence holders to encourage a cessation of activity well before the expiration of their licence. This could include paying compensation, where not prohibitively expensive. The ban could be passed through an amendment to the Environment Bill.
- **Ban sales of peat for horticultural use.** There would need to be an accompanying ban on the sales of peat given that two-thirds are imported, mainly from Ireland.

[83] Defra SP1218 (2018-2020) *Managing agricultural systems on lowland peat for reduced GHG emissions.*
[84] There are also small amounts that are extracted for use in the whisky-making process in Scotland.

In 2011, the Government introduced a voluntary phase out of peat for horticultural use in England (by 2020 for the amateur market and by 2030 for the professional market). However, this voluntary approach has not produced the desired decline in sales despite the availability of peat-free alternatives for compost and bedding. As primary legislation may be required to bring in the ban, this will provide sufficient time to scale-up the market for peat-free alternatives.

- **Mandate that lowland peat soils are not left bare.** This requirement would target cropland that is left bare (e.g. between crop rotations in the winter months). Bare soil makes the soil susceptible to wind erosion with resulting loss of carbon. The planting of cover crops would mitigate erosion, while helping to improve the health and condition of the soils. This could be delivered as a requirement for a short period if in receipt of public funding, before mandating this over the longer-term. To avoid any unintended consequences, it will be important for Defra to determine a list of suitable cover crops for peatland, as trials have shown that while rye is good for reducing emissions, the use of nitrogen fixing crops such as vetch increased N_2O emissions.[85]
- **Requirement to maintain the water table at an optimal level.** The overriding control on CO_2 emissions from lowland peat is mean water-table depth. It is estimated that for every 10 cm increase in the water table, there is a corresponding reduction in emissions of 3 tCO_2e/hectare. [86] There is evidence that in some areas, current levels are lower than may be needed for agricultural production and flood storage capacity. Defra is currently trialling different water-table depths in order to determine an optimal level that would allow on-going agricultural production, while still being able to manage flood risk. [87] Given that the hydrology of farms in some areas are inter-connected, it may not be possible for an individual farmer to manage the water table on their land without it impacting a neighbouring farm. Therefore, it would be easier to set the requirement on the internal drainage boards, who are responsible for managing the drainage system.

In Chapter 3, we estimated that net funding of £12 million would be required to restore 25% of lowland peat by 2050. The income forgone from taking land out of agricultural production represents the largest cost. There are additional costs of implementing sustainable management practices. Although we did not quantify this, we would expect these costs to be lower on a per hectare basis compared to full restoration as agricultural production would still continue.

As with upland peat, funding for sustainable management and restoration can come from both the public and private sectors:

- **Sustainable management.** Pending the outcome of the Defra project on sustainable management of lowland peat, there are a range of management options that could be supported by public funding that would go beyond the baseline. This includes switching to paludiculture, which is food and non-food crops that can grow in water (e.g. reeds, sphagnum and blueberries); seasonal management of the water table (raising the water table in the winter when there are no crops in the ground); and use of cover crops (e.g. rye) to avoid soil erosion.

[85] University of Bangor (2019) *Securing long-term ecosystem function in lowland organic soils (SEFLOS).*

[86] Defra (2016) *Lowland peatland systems in England and Wales – evaluating GHG fluxes and carbon balances (SP1210).*

[87] Defra (on-going) *Managing agricultural systems on lowland peat for reduced GHG emissions while maintaining agricultural productivity.*

- **Restoration.** Public funding can be used to restore agricultural land with lower opportunity costs such as grassland. In the Fens, 2% of peat area (2,000 hectares) is used for grazing livestock, as well as over 40% (4,250 hectares) of the Somerset peatland area. In the longer-term, restoration of more valuable cropland could be funded by the private sector through the purchase of carbon credits. The Peatland Code would have to be extended from its current upland focus, so that it could capture the different types of degradation and restoration methods in the lowlands.

Enabling policies

Where farmers want to continue to farm, raising awareness and the provision of training on the adoption of sustainable management practices is crucial. This can include the use of demonstration farms to showcase the different techniques and a communications campaign. Lowland peat area is a relatively small area located in specific regions (e.g. the Fens and Somerset Levels), so the logistics of running an information campaign and providing training may be relatively easy to implement.

(d) Bioenergy crops

In all scenarios for the achievement of net-zero, sustainably harvested biomass can play a significant role, provided it is prioritised for the most valuable end-uses. Our Further Ambition scenario includes the planting of around 0.7 million hectares of miscanthus, short-rotation coppice (SRC) and short-rotation forestry (SRF) by 2050 (around 23,000 hectares per year). Our more ambitious Speculative scenario could see that rise to around 1.2 million hectares. These are not prescriptive figures, but they demonstrate the importance of scaling up supply of sustainable biomass feedstock. Currently only 10,000 hectares of land is used to grow miscanthus and SRC in England,[88] while there is no SRF for bioenergy. In Chapter 3, we estimate the annual costs to fund this level of ambition to be £0.4 billion.

It is important to ensure that biomass feedstocks are sustainable. The Committee's 2018 Biomass report[89] set out recommendations to improve the UK and international governance of sustainability standards. Farmers will grow energy crops and supply biomass feedstocks if there is strong market demand. The main set of policies for energy crops builds on existing demand-side instruments and aim to develop and strengthen the market for energy crops.

There is a role for policy to provide that certainty through carbon pricing, for example, underpinned by a guarantee of long-term supply contracts:

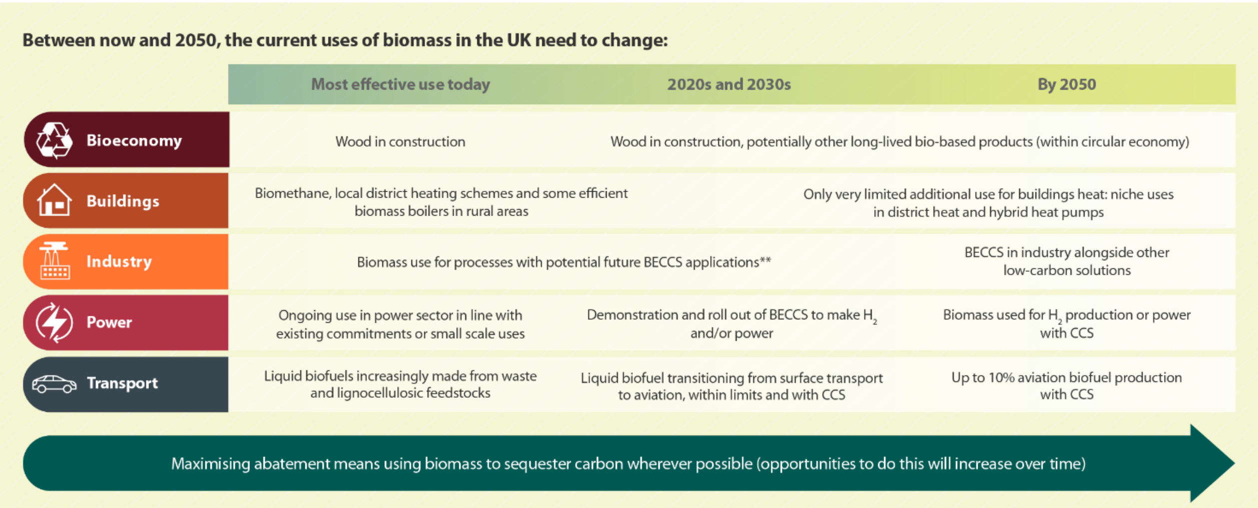
- Combustion processes that exclusively use biomass currently do not have to buy allowances from the EU ETS. This should continue to be the case in any UK scheme linked to the EU ETS or in a separate UK ETS. Additionally, the UK ETS should recognise and reward permanent removal of CO_2, for example through combining carbon capture and storage with biomass combustion ("BECCS").
- Biomass generation is currently eligible for financial support through CfDs and the RHI. This should continue in the short-term.

[88] DEFRA (2019) *Crops grown for bioenergy in England and the UK in 2017.*
[89] CCC (2018) Biomass in a low-carbon economy.

- An obligation could be placed on biomass combustion facilities to source a fixed proportion of their biomass feedstock (including energy crops) from the UK.[90] That proportion should rise over time in line with a realistic scale up of sustainable UK supply.
- Concessionary finance in the form of low-interest loans could provide top-up funding to cover the loss of annual income while the crop is being established.

In the longer term, support for biomass crops should reflect long-term best use. Over time, Government policies should assist a transition towards increased use of biomass in construction and BECCS, and away from using biomass for heating buildings and for generating power without CCS. The hierarchy of best uses for these biomass resources, drawn from the Committee's previous work, is shown in Figure 4.1.

Figure 4.1. Hierarchy of best use for sustainable biomass resources



Source: CCC (2018) *Biomass in a low-carbon economy.*

These should be accompanied by a set of enabling measures to overcome a range of non-financial barriers:

- The costs of establishing energy crops are relatively high due to the costs of propagating the planting material. For example, establishment costs for miscanthus average £2,300/hectare due to the cost of the rhizome.[91] Market commercialisation of cheaper alternatives such as hybrid seeds (which allows for faster upscaling of the planting rates) would reduce costs. This can be supported by industry, government and academia. BEIS is currently scoping out the potential for technical and biological innovations to reduce costs. The results will feed through to a potential innovation demonstration programme.[92]

[90] Currently, projects for new offshore generating capacity are encouraged to source at least half the value of the infrastructure within the UK, with the commitment rising to 60% by 2030.
[91] John Clifton-Brown et al (2018) *Breeding progress and preparedness for mass-scale deployment of perennial lignocellulosic biomass crops, switchgrass, miscanthus, willow and poplar.*
[92] Ricardo, CEH, Forest Research et al (2019-2021) *Increasing sustainable bioenergy feedstocks feasibility study for BEIS.*

- Concessionary finance in the form of low-interest loans could provide some top-up funding to cover the loss of annual income in the early years while the crop is being established.
- Intermediaries from the private sector could play a key role in instilling confidence in the energy crops sector through the provision of information and training, and raising awareness of the financial benefits that crop diversification can deliver. They can also act as an interface between the farmers and end users, which could extend to arranging long-term contracts. Terravesta (miscanthus) and Iggesund (SRC) are prime examples (Box 4.10).
- Publicly-supported provision of good agronomic advice and guidance on planting, management, and land suitability could raise the awareness of the benefits of bioenergy crops, particularly on low productive land and as a means to diversify income streams. There is currently no recommended list of appropriate species giving growers independent advice on yields and pest and disease resistance.

It is crucial that the transition is managed sustainably and avoids creating negative environmental effects.

Globally, a scale-up in bioenergy production is needed to meet the Paris Agreements goals, and the UK should be at the forefront of developing and demonstrating good governance practices.

Box 4.10. Case studies of farmers planting energy crops

Support and certainty of demand are crucial if farmers are to be convinced to plant what, for many, will be an unfamiliar crop. Three case studies developed by the Energy Technologies Institute showed that farmers were able to diversify their income and increase the productivity of their land by planting energy crops:[93]

- All three case studies demonstrated that planting energy crops could increase the profitability of the land over a 23-year lifetime. Initial investment costs were expected to be paid back within the first six to seven years.
- The farmers chose to grow energy crops for a variety of reasons – making better use of difficult or underutilised land, diversifying income and reducing workload.
- All farmers cited the importance of obtaining secure fixed-term contracts with buyers in their decision making. Long-term contracts were arranged by Terravesta (miscanthus) and Iggesund (SRC) who acted as the interface between the farmers and end users, which for SRC went to Iggesund's own paperboard mill.
- These two companies were also able to provide advice and support, arrange for haulage, and in the case of Iggesund undertook the harvesting, given the need for specialist equipment.

Source: Energy Technologies Institute (2016) *An ETI Perspective - Bioenergy crops in the UK. Case Studies of successful whole farm integration.*

4. Summary and conclusions

Table 4.2 sets out a summary of the policy framework required to deliver our emissions reductions and removals set out in our Net Zero advice.

Table 4.2. Key recommendations to deliver net-zero

Abatement measure	**Direct policies**	**Enabling policies**
Low-carbon farming practices	• Adopt existing environmental stewardship rules that have benefited mitigation in UK legislation. • Extend coverage of Nitrate Vulnerable Zones to all of the UK. • Include measures that reduce methane emissions in the Clean Air Strategy. • Include low-cost and low-regret measures in a future baseline regulation. • Mandate UK feed producers to incorporate methane inhibiting additives in compound feed & mineral additives. • Provide public money for more expensive measures above the baseline.	• Address skills and information barriers to take-up of low-carbon farming practices. • R&D and market commercialisation of low-carbon fertilisers and livestock breeding measures. • Address contractual arrangements that may constrain uptake among farms that are tenanted or designated as common land.

Table 4.2. Key recommendations to deliver net-zero		
Abatement measure	**Direct policies**	**Enabling policies**
Afforestation, agro-forestry, hedge creation and broadleaf management	• The main instrument should be a market mechanism (e.g. trading scheme or auctioned contracts), which could be funded by emitting sectors (e.g. fossil fuel suppliers or airlines). • Public money should fund the non-carbon benefits of afforestation, such as biodiversity and flood alleviation, which will also have benefits for climate change adaptation. • A market mechanism for agro-forestry schemes that are low cost and delivers clear carbon sequestration benefits, otherwise, public funding should be provided, and for the non-carbon benefits. • Public money for the carbon and non-carbon benefits of hedge creation and broadleaf management. • Adopt existing CAP cross-compliance rules on protecting hedgerows into UK legislation.	• Concessionary finance to provide top-up funding. • Streamline and simplify the application process for woodland creation. • Development of local markets for broadleaf harvested material. • Support scaling up of capacity of the domestic forestry supply chain from nurseries to sawmills and wood processors. • Review the tax treatment of woodlands and, if necessary, amend it to ensure there is no disadvantage to farmers from changing their use of land to forestry.
Upland peat restoration	• Ban rotational burning. • Mandate all peatland within a Site of Special Scientific Interest to be under restoration. • Mandate water companies to restore peatland under their ownership. • Public money to fund the carbon and non-carbon benefits of restoration. • In the longer-term, use of market mechanisms to pay for the carbon benefits.	• Develop the Peatland Code to obtain UK Accreditation Standard, and widen its eligibility to other upland types.

Table 4.2. Key recommendations to deliver net-zero		
Abatement measure	**Direct policies**	**Enabling policies**
Lowland peat restoration and sustainable management	• Ban peat extraction and its sale, including for horticultural use. • Regulate that peat soils are not left bare. • Require internal drainage boards to maintain optimal water table levels. • Public funding for sustainable management practices, and restoration of low value land (e.g. grasslands). • Research to improve verification, and in the longer-term, use of market mechanisms to pay for carbon benefits.	• Raise awareness and provide training to support adoption of sustainable management practices on peatland. • Develop the Peatland Code to include lowland restoration projects.
Energy crops and biomass feedstocks	• Continue to exclude combustion processes that exclusively use biomass from the successor trading scheme to the EU ETS. • Continue to support biomass generation through existing market mechanisms in the short term. • Introduce a requirement for biomass combustion facilities to source a fixed proportion of their biomass feedstock from the UK. • During this decade, Government policies should assist a transition towards increased use of biomass (including energy crops) as a fuel with Carbon, Capture and Storage (CCS), and away from use for heating buildings and for generating power without CCS.	• Support for market commercialisation of cheaper planting material for miscanthus. • Role for more private sector engagement with farmers to raise awareness, training, crop advice, and the provision of long-term contracts. • Concessionary finance to top-up funding to cover the loss of annual income while the crop is being established.

Delivering the level of emissions reduction and CO_2 removals in our net-zero scenarios requires fundamental changes to the way land is used and managed. We have identified a mix of regulations and incentives that will provide land managers and farmers with the long-term clarity needed to deliver the changes set out. Our estimates in Chapter 3 indicate that there are overall benefits to society, but added net private costs for farmers and land managers of £1.4 billion annually to 2050. The new policy framework will need to ensure these private costs are funded.

This will require strong and effective leadership at all levels of government, supported by actions from people and businesses. Farmers and landowners will face many challenges over this transition, but the framework set out in this report can help to make it a fair one by creating new opportunities and revenue streams and a range of new enabling measures to overcome non-financial barriers. The UK Government and the devolved governments of Scotland, Wales, and Northern Ireland must work more closely and in a more strategic way to ensure that devolved and UK-wide policies are compatible and provide adequate support to land managers and farmers across all areas of the UK.

The actions we have identified are stepping stones to a long-term future use of land that is consistent with reaching net-zero. Continued delay is not an option. Each government of the UK needs to act now.

Chapter 5 - Measures to deliver changes in consumer behaviour

Introduction and key messages

In our 2019 Net Zero report we identified two key demand-side measures that could help reduce UK agricultural emissions, both based on behavioural change: a shift in diets away from the most greenhouse gas-intensive foods and a reduction in food waste across the supply chain.

In this chapter we present the latest evidence on the lifecycle greenhouse gas (GHG) emissions of different protein sources, to assess if the shift in diets we identify in our previous work remains valid. We also set out our assessment of the policy framework needed to deliver the changes in consumer behaviour. It draws on research and stakeholder engagement (Box 5.1).

The key messages are:

- **Animal -based protein sources generally have greater GHG footprints than plant-based sources.** Ruminant meat is generally found to have the most emissions associated with it. Studies also show wide variations in the GHG footprints within a particular type of food depending on the specifics of the production method and location of production. Operationalising standardised metrics for accurate lifecycle assessment across the food industry can help to understand the full climate impact of UK food supply chains.
- **Policy to shift** diets should focus on implementing low-cost, low-regret actions and an evidence-based base strategy as a first step followed by introducing stronger options to change behaviour, if needed:
  - Immediate actions should include all public-sector catering menus to offer a fully plant-based option every day.
  - Government should develop a strategy to shift diets that includes: the use of labelling; addressing skills gaps; promoting research and development of novel protein alternatives; exploiting synergies between health and environment; creating greater accountability for businesses by developing clear and robust metrics and introducing mandatory reporting if needed.
  - A second stage could focus on stronger options whether regulatory or pricing.
- **A strategy aimed at reducing food waste** should build on existing proven initiatives and incentivise action across the supply chain:
  - Immediate low-cost, low-regret measures in the public sector such as setting targets and monitoring impacts could set an example to other sectors. Businesses should make existing pledges mandatory and use their influencing role to 'nudge' consumers towards best practice (e.g. reducing portion size).
  - There should be universal separate food waste collection.

The rest of this chapter is set out in the following sections:

1. Climate impact of dietary choices
2. Measures to shift towards more sustainable diets
3. Measures to reduce food waste

Box 5.1 Key findings of the CCC Diets Expert Workshop

The CCC held a workshop to discuss policies that could drive changes in diets, drawing on expertise from academics, industry and non-governmental organisations. The chair's report is published alongside this report. The main findings are summarised below.

Changing diets and reducing waste have the potential to reduce GHG emissions substantially and free up land for other uses.

From a public health perspective there is a need for the UK to address diets, independently of sustainability concerns. Poor dietary health is increasingly driving health-care spend via non-communicable diseases like diabetes, heart disease and a range of dietary-related cancers.

However, there is no single answer and a national food strategy needs to align nutritional, trade and agricultural policy and address many barriers to change. While awareness and training or labelling can play a part, they are not enough and are often costly to implement. Instead there is a wide range of policy levers that can be applied to make 'better' food more available and cheaper and 'worse' food more expensive and less available. These include:

On food waste reduction:

- Regulations and taxes.
- Improving the shelf life of food.
- Circularising the economy to use waste to produce goods which substitute for raw materials.

On diet change:

- Changing food choice through nudge (nutrition/education/awareness campaigns), pricing, or money transfers.
- Changing subsidies/standards/regulations to promote healthier or more sustainably produced foods.
- Personalised nutrition advice and greater transparency of food's impact on health and the environment.
- Investment in disruptive technology to encourage a switch to food with a lower environmental footprint.
- Public procurement to stimulate new ways of producing food or different types of diet.

There is limited evidence in four areas, which need further research:

- Understanding of the interaction between diet change and its impact on the environment through supply chains.
- The potential for meat alternatives to scale up.
- The effectiveness of different interventions to drive change at scale.
- Transparency of the food system and how to measure the environmental impacts of food supply chains.

Notes: See Chapter 1 for a full list of workshop participants.

1. Climate impact of dietary choices

A healthy diet involves eating sufficient amounts of protein. This can be sourced from a wide-range of plant and animal sources, some of which have high GHG and other environmental footprints. This section summarises the latest evidence regarding the lifecycle emissions from protein production, and the mitigation opportunity from eating healthier diets at a global level.

(a) Evidence on the GHG impacts of protein sources

Lifecycle analysis (LCA) evaluates the environmental footprints of all aspects of the production, processing and transportation of food. LCA requires estimating GHG emissions from many different sources, several of which are more challenging for food than other sectors of the economy:

- **Land-use change**. Producing crops or rearing animals requires land. If this land is converted from another land use (particularly if converting high carbon content land such as rainforest) carbon lost from the land needs to be accounted for. This includes carbon stored above ground (e.g. in living biomass) and in the soil.
- **Crop and grass production**. Applying nitrogen fertiliser to boost crop or grass yields leads to some amount of N_2O emissions, depending on the type of crop, climate and soil conditions. Emissions from producing feed (e.g. crops and grass) for animals needs to be accounted for in the footprint of animal products.
- **Livestock**. Cows and sheep produce methane emissions from enteric fermentation and further non-CO_2 emissions are generated from the management of animal wastes and grazing returns.[93] Grazing practices can also affect the rate of N_2O emission from soil as well as helping to either reduce, or possibly restore, the amount of carbon stored in soils (Box 5.2).
- **Processing.** Energy used for processing food products will create emissions depending on the carbon intensity of the energy source.
- **Transportation**. Transporting food creates emissions depending on the carbon intensity of the mode of transport. Transportation by plane is more carbon intensive than by ship, road or rail.

Comparing LCAs of food production can be challenging due to different systems boundaries, assumptions regarding how emissions are allocated between multiple products from a single process, and whether the assessment is based on an equal mass of food or accounts for differing nutritional values between food types.[94]

[93] Urine and dung deposited on grasslands.

[94] For instance, human edible parts only make up around half of the weight of a slaughtered cow with the rest making up inputs for a wide range of processes and industry (e.g. gelatine). Co-products are often not considered in LCAs.

Box 5.2 Impacts of grazing ruminants on soil carbon

Grazing practices can affect the storage of carbon in the grassland soils. However, the effect of grazing ruminants on soil carbon can be difficult to measure, limited in scale, reversible and highly location specific:

- Ruminant grazing can affect how carbon and nitrogen are cycled through grassland ecosystems. Where soil carbon stocks are already depleted, low levels of properly managed grazing may be able to help increase soil carbon in some circumstances. Conversely, overgrazing can help deplete soil carbon stocks. In practice, the effects of any changes in grazing practice on soil carbon can be difficult to distinguish from ongoing changes due to previous land-use change.
- Results from a new BEIS research project suggest that grassland management activities (not all of which involve grazing ruminants) in the UK have only been a minor determiner of changes in non-organic grassland carbon stocks compared to climate and land-use history. The biggest opportunities for increasing grassland carbon stocks in the UK is through effective management of degraded grasslands, which have lost carbon due to previous poor management.
- Where changes in grazing practice does lead to enhanced soil carbon sequestration, soil carbon stocks will eventually reach a new equilibrium, meaning that initial sequestration rates will decrease to zero over time. If grazing practices change again in the future this carbon could be lost from the soil and re-emitted to the atmosphere.

Although there are many reasons to improve grazing practice and soil management on grasslands, soil carbon sequestration, where it can be robustly linked with improved grazing practices, does not offer a long-term way to offset ongoing methane and long-lived GHG emissions from livestock on that land.

Source: Garnett, T. et al. (2017) *Grazed and confused*; Smith, P. (2014) Do grasslands act as a perpetual sink for carbon? *Global Change Biology*, 20 (9), 2708-2711; Ricardo (2020) *Development of the impact of grassland management on the UK LULUCF Inventory.*

In the past few years efforts have been made to synthesise the rapidly expanding number of food LCA studies to allow like-for-like comparison between food types and production methods. The most comprehensive and up-to-date LCAs database identifies a number of robust conclusions regarding the GHG-intensities of different food types produced around the world (Figure 5.1):

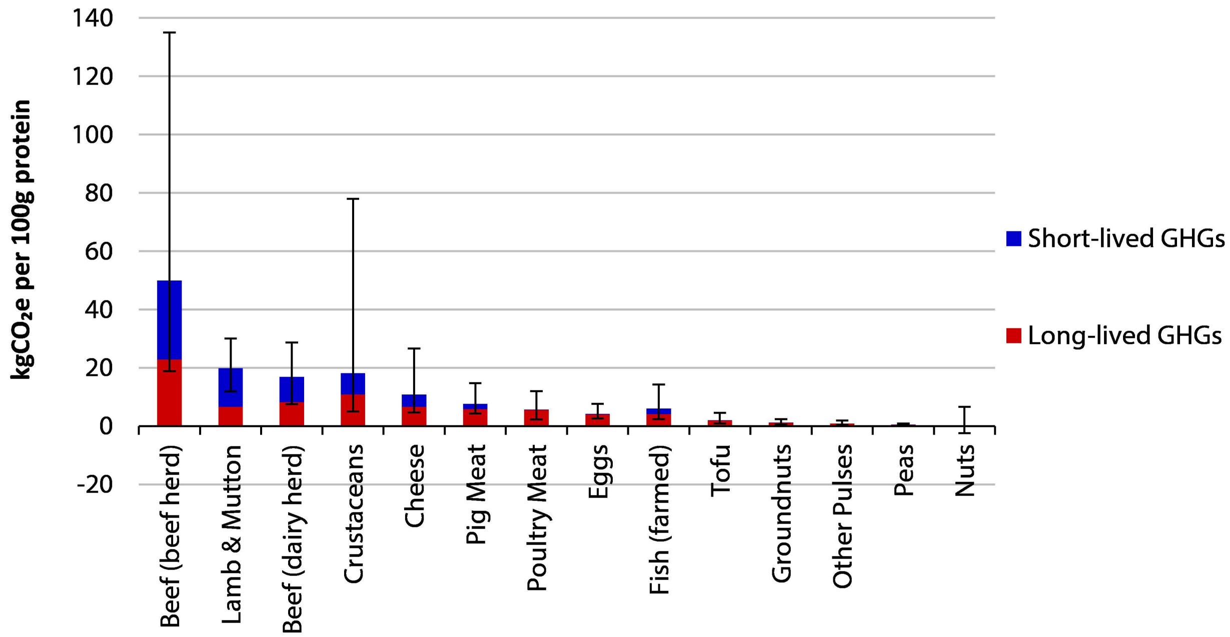
- **Plant-based protein sources** have significantly less GHG emissions than animal-sourced proteins when compared on a like-for-like basis. The most GHG-intensive production methods for plant-based proteins generally have less emissions than even the most GHG-efficient sources of animal-based protein.
- **Meat from non-ruminant sources** (e.g. pigs and poultry), farmed seafood and dairy products are generally more GHG-intensive than plant-based proteins, but less so than most methods of ruminant meat production. The amount of long-lived CO_2 and N_2O emissions (which determine long-term climate change) is more similar to some sources of ruminant meat (e.g. lamb), but generally less than that produced by beef from dedicated beef herds.[95]

[95] The amount of long-lived GHG emissions largely determines the level of long-term global warming created by food production. Many LCAs don't provide by-gas breakdowns of LCA GHG emissions, making difficult the identification of dietary changes where the total GHG emissions could decrease but long-lived GHG emissions increase.

- **Ruminant meat** is on-average the most GHG-intensive source of protein. Beef from dedicated beef herds generally has the highest level of total GHG emissions and of long-lived GHG emissions. Beef from the dairy herd is generally significantly less GHG-intensive, with a similar GHG-intensity to lamb. Good ruminant grazing practices can help to maintain and in some cases enhance carbon stocks in the soil, although the benefits are generally very location specific and limited in scale (Box 5.2). Conversely, overgrazing can lead to degradation of pastures and losses in soil carbon.

In recent years there has been growing interest in 'alternative' meats that aren't animal-based. Initial LCA studies suggests that these products can have significantly lower lifecycle emissions than animal-based meat, but the evidence base is still developing (Box 5.3).

Figure 5.1. Lifecycle GHG emissions associated with different protein sources



Source: Poore, J. & Nemecek, T. (2018) Reducing food's environmental impacts through producers and consumers. *Science*, 360 (6392), 987-992.

Notes: Solid bars indicate the production weighted global mean GHG-intensity of different food categories from studies looking at production across the world. Lifecycle emissions are expressed on the basis of equal protein content. Error bars indicate the 5th and 95th percentile of studies within the database. GHG emissions are aggregated using the GWP_{100} metric. Long-lived GHGs refer to CO_2 and N_2O and short-lived GHGs to methane.

Box 5.3. Plant-based substitutes, lab-grown meat, and other 'alternative' protein sources

There are a number of 'alternative' protein sources that have a less developed LCA literature than conventional animal- and plant-based sources:

- **Plant-based meat substitutes** (such as the Beyond Meat and Impossible burgers) have recently seen rapid increases in demand with high profile partnerships being launched between leading manufacturers and fast-food retailers.

  However, it still only makes up a small fraction of the total meat market. LCAs are still limited, but industry analysis indicates significantly lower environmental impacts than animal-based products (around 2 kgCO2e per 100 grams of protein).

- **Lab-grown meat** is produced from animal cells cultured in a lab and is a possible replacement for animal-based meat in the longer-term, but it is currently far from large commercial scales. If it can be made economically competitive at scale and achieve customer acceptability, it could offer significant environmental benefits with no non-CO_2 emissions and very small land footprints. Electricity requirements (and its carbon intensity) are the biggest uncertainty in assessments of GHG-intensity. Estimates in the literature range from 1.1 - 3.7 kgCO_2e per 100 grams of protein.

- **Insects** are efficient converters of their feed into edible calories and protein, and are consumed by humans in some parts of the world. If they could achieve widespread acceptability with consumers and lower production costs more insects may be eaten in western diets. Insects could also be used for animal feed. When fed on waste biomass insects can be a low GHG protein source (around 0.2 kgCO_2e per 100 grams of protein) and have minimal land-use impacts, but scale may be limited by the available waste resource. If fed with dedicated crop feedstocks, emissions and land-use impacts are higher.

We considered the potential for alternative proteins to enable greater shifts away from beef, lamb and dairy (up to 50% reductions in per person consumption) as 'Speculative' options in our Net Zero report. As the evidence on these protein sources develops we will continue to monitor the potential for these sources of protein to reduce emissions from UK food consumption.

Source: The Economist (2019) *Plant-based meat could create a radically different food chain*, SRUC and ADAS (2019) *Non-CO_2 abatement in the UK agricultural sector by 2050*.

Food production can require large amounts of land, particularly for animal-based sources. If it is possible to use this land for other purposes an additional 'carbon opportunity cost or benefit' exists for using the land to produce food:

- According to the current UK land-use GHG inventory, transitioning from grassland to forestland would increase the soil carbon stock by 25 tonnes of carbon per hectare (on average across England) once long-term equilibrium is established, although this may take many decades to be reached.[96] This is additional to the large amounts of carbon that would be stored in the biomass of the trees themselves.
- In contrast, land-use change from grassland to cropland would reduce the land's soil and biomass carbon stock by around 23 tonnes of carbon per hectare on average across England.

[96] Forest planting on grassland may lead to an initial temporary loss of soil carbon due to soil disturbances on planting, but this is recovered over time. The gains and losses of soil carbon per hectare are on average higher under the same transitions in Scotland and Northern Ireland than in England. Ricardo (2019) *UK Greenhouse Gas Inventory, 1990 to 2017: Annual Report for submission under the Framework Convention on Climate Change*.

If this is for planting of bioenergy crops, overall reductions in emissions may still be achieved via their use in the energy system.

These carbon impacts from alternative land-use is not considered within food LCAs but is an important element of the overall GHG impact of diet change. The costs and benefits of using agricultural land freed up by diet changes for carbon sequestration in our UK scenario is considered in Chapter 3.

(b) The potential for dietary changes to reduce global emissions

At a global level, large-scale shifts in diet could play an important role in reducing global GHG emissions and helping to achieve the long-term temperature goal of the Paris Agreement. This evidence was summarised in the recent IPCC Special Report on Climate Change and Land (SRCCL):[97]

- Currently, around 30% of global GHG emissions come from the food system,[98] of which around 50% are accounted for by livestock.[99] Around 50% of global habitable land is currently used for agriculture; nearly 80% of this is used to farm livestock, but provides less than 20%of total food calorific supply.[100]
- Different diets have been identified as having different global abatement potential (Figure 5.2). The upper end of the global technical abatement potential of dietary change is associated with a vegan diet (i.e. with no animal-sourced foods), which has been estimated at 8 $GtCO_2e$ per year by the IPCC.[101] This represents around 14% of current global emissions.[102] According to recent estimates, diet shifts could contribute up to a fifth of the mitigation needed to keep global temperature below 2°C.[103]

These dietary changes were also identified by the IPCC as having potential benefits for adapting to the risks of climate change and benefits for human health.

The overconsumption of meat and its impacts on the environment, health and society were also identified by the EAT-Lancet Commission in 2019.[104] This study provides the first scientific targets for a healthy diet from a sustainable global food production system. They found that a change to healthy diets by 2050 will require substantial dietary shifts, including a greater than 50% reduction in global consumption of unhealthy foods, such as red meat and sugar, and a greater than 100% increase in consumption of healthy foods, such as nuts, fruits, vegetables, and legumes. However, the changes needed differ greatly by region.

[97] IPCC (2019) *Special Report on Climate Change and Land.*

[98] The estimated percentage of global emissions coming from the food system is 21 - 37%. Estimates implicitly include emissions from food loss and waste which are estimated at 8-10% of total anthropogenic emissions.

[99] Total emissions from global livestock estimated are at 7.1 Gt CO2e per year, representing 14.5% of all anthropogenic GHG emissions, based on statistics from the Food and Agriculture Organisation of the United Nations (FAO).

[100] Based on 2011 data from the United Nations' Food and Agriculture Organization (FAO).

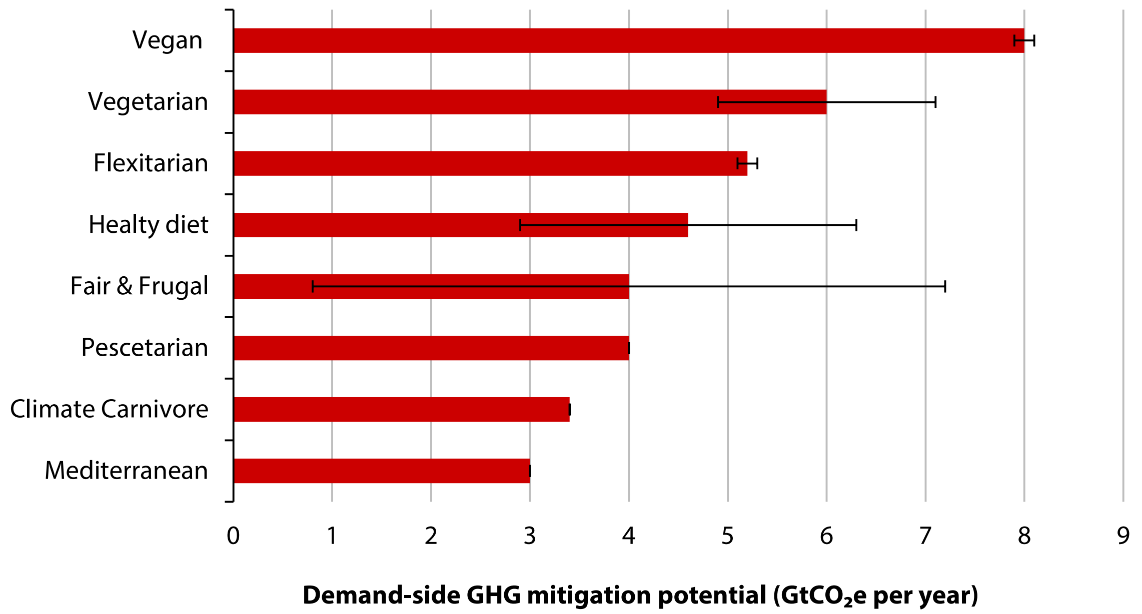
[101] Springmann. M. et. al. (2016) Analysis and valuation of the health and climate change cobenefits of dietary change. *Proceedings of the National Academy of Sciences, 113 (15), 4146-4151.*

[102] Olivier, J. & Peters, J. (2019) *Trends in global CO_2 and total greenhouse gas emissions*.

[103] Griscom, B. et al. (2017) Natural climate solutions. *Proceedings of the National Academy of Sciences, 114 (44), 11645-11650.*

[104] The EAT–Lancet Commission (2019) *Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems.*

Figure 5.2. Global GHG mitigation potential of different diets.



Source: IPCC (2019) *Special Report on Climate Change and Land.*
Notes: Technical mitigation potential of changing diets by 2050 according to a range of scenarios examined in the literature. Estimates are technical potential only, and include additional effects of carbon sequestration from land-sparing. Vegan: no animal source food; Vegetarian: meat/seafood once a month; Flexitarian: limited meat and dairy; Fair & Frugal: limited animal source food but rich in calories; Pescetarian: diet consisting of seafood; Climate Carnivore: limited ruminant meat and dairy; Mediterranean: moderate meat but rich in vegetables.

Summary

The most up-to-date evidence continues to support that protein sourced from animals (particularly from ruminants) generally has a larger GHG footprint than from plant-based sources. Reduced consumption of beef, lamb and dairy as in our scenarios (Chapter 2) therefore remains a valid measure to reduce the climate impact of food consumption. At a global level, shifting to diets with lower levels of animal products consumption could contribute an important 'wedge' of emissions reduction needed to move the world to a trajectory consistent with achieving the long-term temperature goal of the Paris Agreement.

The LCA evidence also highlights wide variations in GHG intensity within specific sources of protein (e.g. beef). These variations are especially large for animal-based products. This reflects the range of different production systems, land conditions and climates across the world. Within the food industry there is currently no standardised methodology for LCA assessment, meaning that detailed assessment of individual food supply chains by retailers and consumers is currently challenging. Efforts to operationalise and standardise LCA tools for use within the food industry could help actors throughout the supply chain make informed decisions regarding the climate impacts of purchasing choices, and could help to incentivise best-practice in low-GHG agricultural production methods.

In the next section we focus on policies needed to deliver shifts towards more sustainable diets.

2. Measures to shift towards more sustainable diets

(a) The UK context for dietary change

Current UK Government health guidelines (the Eatwell Guide) recommend a daily protein consumption of 55.5 grams per person for adult men and 45 grams per person for adult women. Particular individuals or groups may need to consume more or less than this, depending on age, lifestyle and medical conditions to remain healthy.

The consumption of protein in the UK is on average significantly in excess of these levels:

- Average daily protein intake was 75g per person per day in 2017/18.[105]
- 60% of this protein supply is derived from animal sources, with 40% from plant-based sources.
- Average daily consumption of beef and lamb is around 28g per person per day, over 80% higher than the Eatwell guideline of 5g per person per day.

In our Net Zero report, we identified at least a 20% shift away from beef, lamb and dairy to alternative protein sources per person by 2050, while a more ambitious reduction of 50% may be needed, depending on progress in other sectors.[106] Recent survey data does point to an increase in people adopting vegan or vegetarian diets and increased willingness to cut down on meat consumption. However, current trends are not likely to be sufficient to deliver the changes in our scenario by 2050:

- The average per person **meat** consumption decreased by 6% between 2000 and 2018. The consumption of fresh meat (i.e. beef, lamb and pork carcass) fell by 23%. However, the majority of the meat consumed (around 80%) is made up of processed meat, which has remained broadly constant.
- The consumption of **dairy products** has decreased by 16% between 2000 and 2018. This is largely due to reduced consumption of milk and milk products, with cheese consumption increasing by 14% over the period. The overall consumption of fruits and vegetables also decreased by 13% and fish by 4% over the same period, while the consumption of eggs increased by 23%.
- Official data suggest that the proportion of the UK population that is vegetarian or vegan has increased from 1.6% in 2009/10 to 2.5% in 2015/6.[107] However, more recent survey data suggests much higher figures and an increasing willingness to try alternative diets (Box 5.4).

The dietary changes we identify can have significant health co-benefits:

- Recent research on the links between the health and environmental impacts of food concluded that 'foods associated with the largest negative environmental impacts - unprocessed and processed red meat - are consistently associated with the largest increases in disease risk'.[108]

[105] Defra (2019) *Family Food Statistics.*

[106] The 20% cut was included in our 'Further Ambition' scenario, with a 50% cut in our 'Speculative' scenario.

[107] Public Health England (2019) *National Diet and Nutrition Survey.*

[108] Clark, M. et al. (2019) Multiple health and environmental impacts of foods. *Proceedings of the National Academy of Sciences*, 116 (46), 23357-23362.

- Reducing average per person meat consumption to two to three servings per week has been estimated to prevent 45,000 deaths a year and could save the NHS £1.2 billion per year.[109]

We have not included these benefits in our estimates of wider impacts.

Box 5.4. Trends in vegetarian diets in the UK

Several consumer surveys show an upward trend in the uptake of vegan and vegetarian diets:

- A 2019 YouGov Survey commissioned by the Eating Better Alliance showed that nearly 50% of people in the UK are willing or are already committed to cutting down or eliminating meat. Other surveys report 25% of UK shoppers plan to cut down meat in the next 12 months, though the figure is higher at 35% for 18 to 34-year-olds (Harris Interactive, 2018).
- A survey by comparethemarket.com in 2018 found 7% of respondents identified as vegan, 14% vegetarian and 31% as eating less meat.
- Sainsbury's reported year-on-year increase in customers searching for vegan products online (+82%) and in sales of plant-based products (+65%).
- Temporary surges in the consumption of plant-based products have been observed around January, probably due to the effect of campaigns such as 'Veganuary'.
- A survey for The Grocer magazine in 2018 found 12.5% of the population classed themselves as 'non-meat' eaters. This proportion was higher among women (14.6%), younger people (16.5% for 18-24 year olds) and for London (nearly 20%), but there was less variation by social class.

(b) Priorities for policy action

Evidence shows that shifting diets will not happen if left to the market or voluntary industry initiatives alone.[110] There is now a need for policy to support broader and faster changes. An evidence-based strategy should be developed to deliver the scale of change required, but there are a number of low-risk low-cost options that should be taken immediately.

The public sector and businesses

Government and other public bodies have a significant role in procuring food e.g. hospitals, schools and public sector canteens. However plant-based options are not routinely provided. Government should set the pace by acting as an example, requiring all public-sector catering menus to offer a fully plant-based option every day. This is already being done in other countries, and evidence suggests it can have a significant impact (Box 5.5). Government should also work with industry to set clear targets that can be successfully monitored, and provide training to address staff skills gaps:

- Various initiatives in other countries (e.g. Portugal) have been introduced aimed at rebalancing diets towards more plant-based protein.

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[109] Scarborough, P. et. al. (2010) *Modelling the health impacts of the diets described in 'Eating the Planet' published by Friends of the Earth and Compassion in World Farming.*

[110] Garnett et al. (2015) *Policies and actions to shift eating patterns. Food Climate Research Network.*

Similar initiatives have also been promoted by some organisations in the UK, such as the Vegan Society's 'Catering for Everyone' campaign.[111]

- Increasing plant-based menu options has been found to increase demand and reduce barriers to shifting to lower carbon-impact diets without restricting choice. It also has an important role in 'normalising' vegetarian options.
- Further action from Government should address the skills gap of public sector staff, including additional funding. Evidence suggests this can be an effective measure, and encourage staff to become promoters of plant-based alternatives.[112] [113]

In shifting towards diets with higher plant-based content, meat and dairy alternatives and blended products can play an important role, as well as deliver business opportunities. Government should support R&D and commercialisation of plant-based meat alternatives. There is also a role for private food manufacturers and retailers to influence food choices:

- Plant-based proteins and dairy replacements or analogues have an important role to play in shifting to sustainable diets. Similarly, plant-based milks can be used much like dairy milk. Costs are expected to reduce further due to economies of scale and moving along learning curves.
- The market in plant-based proteins could grow more than tenfold, from 1% of the global meat market to 10% ($140 billion) within the decade,[114] and the value of UK's plant-based alternatives market is predicted to reach £1.1 billion in value by 2023.[115] The UK has the biggest ready meal market in Europe, and 37% of beef consumed in the UK is minced, suggesting a significant opportunity for blending with plant-based minced beef analogues.
- Many supermarkets have extended the range of plant-based food in response to consumer demand, introducing a wide range of branded plant-based and blended products.
- Mintel research showed that about 16% of food products launched in 2018 had a vegan claim, up from 8% in 2015. Recently the UK took a leading position in the rise of vegan retail,[116] overtaking Germany in the launch of new vegan products (Box 5.5).[117]

[111] This campaign aims to encourage local institutions to improve their current plant-based offering, and guarantee a plant-based option on every public sector menu, including through legislative change.
[112] Harwatt, H. (2019) *Personal Communication, March 21, 2019.*
[113] For example, experience from the Humane Society International UK's Forward Food programme has shown that initial resistance from staff can be replaced by enthusiasm for gaining new skills in plant-based food catering.
[114] Barclays (2019) *I can't believe it's not meat.*
[115] Mintel Research (2018) *UK meat-free foods market report.*
[116] The Grocer (2019) *Vegan launches soar to one fifth of all retail food NPD.*
[117] Thomson Reuters Foundation (2019) *Sales of vegan products surging with UK consumers fuelling the rise.*

Box 5. 5. Private sector and international initiatives to encourage the uptake of plant-based alternatives

While examples of policies to shift diets are not widespread, there are some initiatives leading the way. In terms of public sector support:

- Since 2017, in Portugal it is deemed illegal not to offer vegan food options in public canteens (e.g. prisons, schools, hospitals).
- The Dutch Green Protein Alliance, established in 2017 is aiming to restore a healthy and sustainable balance in protein consumption. The current ratio of plant-based: animal protein in the Dutch diet is 37:63, and the target is for an equal share no later than 2025. The alliance of retailers, the catering industry and food producers is being supported by the Dutch Government and knowledge networks.
- The Netherlands Nutrition Centre, a government funded agency launched a campaign in 2018 to encourage men to consume less meat. Using the slogan 'There is more than meat alone', the awareness campaign is using posters in public places and social media to highlight the health benefits of replacing meat with vegetables, legumes and nuts.
- 14 global cities (including Barcelona, London, and Seoul) have signed up to the C40 Good Food Cities Declaration which commits them to achieve a 'Planetary Health Diet' for all by 2030.

A number of private sector companies have widened the availability of plant-based options in response to customer demand:

- Companies with an interest in food are increasing their portfolio in plant-based businesses, e.g. Unilever bought The Vegetarian Butcher.
- Virgin Trains was the first train operator in the country to offer a full vegan menu on all its services in 2018. This was in response to feedback from vegan customers requiring a consistency of vegan products across all services. In addition, they are improving food labelling to better identify vegan and vegetarian products. By the end of the year, seven UK train companies were offering plant-based menu options.
- PWC's Peas Please initiative with Baxter Storey, the hospitality provider, aims to increase the overall proportion of vegetables purchased in the PWC estate to 25% by mid-2020.
- The World Resources Institute (WRI), in an initiative with Sainsbury's, found a 70% increase in the demand for the some products sold in their cafés by using the term 'field grown' on labels.

Source: Netherlands Nutrition Centre (2018) *There is more than meat*; C40 (2019) *Good Food Cities: Achieving a Planetary Health Diet for All.*

To achieve change at a large enough scale, policy needs to develop the sector's accountability, and to incentivise a 'race to the top' through monitoring and reporting standards:

- The first step to this is to develop robust metrics and standards, underpinned by a clear methodology. This is already happening in places, for example in 2018 Tesco set up a partnership with the World Wildlife Fund to reduce the environmental impact of the average food basket by 50%. This is being underpinned by better assessment of the sustainability of its products.
- A second stage should follow with the introduction of mandatory reporting and monitoring standards covering GHG emissions across the food supply chain.

Creating an industry body could increase the influence of the plant-based food industry, which is currently highly fragmented compared to the meat and dairy industry.

The role of information and labelling

By raising awareness, information can be an effective enabler for change. It can help address non-financial barriers, including public acceptability, the idea that healthy diets are more expensive, and the effort of having to think about how to substitute meat and dairy.

Labelling can be used to improve the availability of information on health, GHG emissions and environmental impacts, and increase consumer awareness:

- Research finds awareness of the environmental footprints of foods is low and that a well-designed GHG emissions label has the potential to be an effective intervention.[119] Experience with electrical white goods indicates that eco-labelling can have far-reaching impacts, although in the case of food labelling there is a wider range of dimensions to consider (e.g. emissions, water, land footprint and biodiversity impact).
- As low GHG foods tend to be lower in saturated fat there is also the potential for environmental impact labelling and nutritional labelling to reinforce each other.[120]
- Language matters. For example, describing food as "field-grown" rather than "meat-free" makes people twice as likely to choose vegetarian options and reduce their environmental impact.[121]

In addition to the labelling of individual items, supermarkets could offer comprehensive feedback to shoppers on the nutrition and climate impact of their overall purchases:

- Survey research has demonstrated strong consumer interest in having this kind of whole basket feedback on till receipts indicating it could help inform healthier food purchases.[122]
- This would give consumers a clear, highly visible, picture of their overall shopping and eating patterns.

Pricing and regulation

If standard-setting and information provision is insufficient to change consumption patterns, a second stage of policy intervention could involve stronger action through changing prices or regulation. Financial incentives and price signals can be used to re-balance production and consumption away from the most GHG-intensive foods, and to stimulate product innovation. They could be applied through subsidies or taxes to ensure that the price of food reflects the climate impact of production. Regulations could influence the supply of lower GHG foods e.g. through application of environmental standards.

[119] Camallieri et al., (2019) Consumers underestimate the emissions associated with food but are aided by labels. *Nature Climate Change.*

[120] Note that the evidence on the effectiveness of nutritional labelling is mixed and is unlikely to be sufficient on its own. For instance an evidence review found nutritional labelling to have only a modest impact at best on purchasing behaviour (Robert Wood Johnson Foundation, 2009).

[121] Behavioural Insights Team and the WRI Better Buying Lab (2019) *It's all in the name. How to boost the sales of plant-based menu items.*

[122] *Cole et al., (2018)* UK consumer perceptions of a novel till-receipt 'traffic-light' nutrition system. *Health Promotion International, 1–12.*

Price signals and/or regulation could be the second part of a two-tier approach, with the first focused on increasing consumer choice and data availability, as set out above. Good information and food metrics would enable the design of a system that is effective and fair:

- Robust metrics on the LCA of different foods are needed to ensure that prices reflect their climate and other environmental impacts.
- Due to the wide range of farming methods and practices, producer-level data will need to be validated through industry-wide measurement standards. This will be needed to ensure the incentive system is fair and fully reflects differences among farming practices.

Evidence suggests that the public could be receptive to taxes especially when seen as being in the public interest.[123] A systematic review of 38 studies found that price signals (taxes and subsidies) are consistently effective at changing consumption patterns, especially when there are 'close untaxed substitutes'.[124] Price signals can change the perception of meat as a relatively cheap and 'essential' staple food purchase.

3. Measures to reduce food waste

(a) Context for reducing food waste

Worldwide, over one billion tonnes of food is wasted every year, one third of total food produced for human consumption.[125] This results in significant economic, environmental, and food security impacts, with the value of the loss estimated at $940 billion annually, and associated GHG emissions equal to 8% of global emissions. At the same time 1 in 9 people are under nourished.

In the UK each year around 13.6 million tonnes of food, is wasted in the UK, of which 3.6 million tonnes is on-farm, with the remainder post-farm gate.[126] The consumption stage within households is the most wasteful stage from farm to plate with approximately 14% of all food and drink taken home being discarded.

Reducing food waste across the supply chain reduces agriculture GHG emissions and allows agricultural land to be freed up for other uses. It could also deliver cost savings in waste collection and across the food supply chain, and reduce landfill emissions.

Fruit, vegetables, salads and drink accounted for almost 40% of the avoidable waste by weight. Reductions of these products results in a small impact on UK land area, given that most of the fruit consumed in the UK is imported, and that horticultural production accounts for only 3% of UK cropland area.[127]

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[123] See, for example, Chatham House (2015) *Changing Climate, Changing Diets Pathways to Lower Meat Consumption*; Department of Health and Social Care (2019) *Government Response to the House of Commons Health and Social Care Select Committee report on Childhood obesity: Time for action, Eighth Report of Session.*

[124] Thow et al. (2014) A systematic review of the effectiveness of food taxes and subsidies to improve diets: understanding the recent evidence. *Nutrition Reviews.* 72. 10.1111/nure.12123.

[125] Food and Agriculture Organisation of the UN.

[126] WRAP (2019) *Food waste in primary production in the UK.*

[127] CCC (2018) *Land use: Reducing emissions and preparing for climate change*. Imports accounted for 84% of UK fruit demand in 2017. Vegetables that are grown in the UK (and which supply 57% of UK demand) account for a small share of cropland (less than 0.5%), and overall horticultural production accounts for just 3% of current UK cropland area.

Our net-zero Further Ambition scenario assumed a 20% reduction in food waste by 2025 (with no improvement thereafter), but a more ambitious reduction, e.g. 50% by 2050 may be needed.

(b) Priorities for policy

Action on food waste should build on measures and commitments that have been shown to work in the UK and internationally. Government should also introduce mandatory separation of food waste for collection by 2023 so that food that is wasted can be used in other processes.

There are currently a number of actions and commitments at the international level, and in the UK by Defra, the Scottish and Welsh Governments, as well as the private sector. Evidence suggests that substantial reductions in food waste in the UK could be achieved through interventions with excellent cost-benefit ratios for local authorities businesses and households. (Box 5.6).

Box 5.6. Global and UK action on food waste

International initiatives aimed at reducing food waste include:

- UN Sustainable Development Goal 12.3 has the objective of cutting per capita global food waste at the retail and consumer level in half, and reducing food losses along production and supply chains (including post-harvest losses) by 2030. This target has been adopted by WRAP, in its *UK Food Waste Reduction Roadmap* (2018).
- "10x20x30" Food Loss and Waste Initiative, brings together ten of the world's biggest food retailers and providers to each engage with 20 of their priority suppliers with the aim to halve rates of food loss and waste by 2030. This is designed as a significant contributor to the above UN goal. Founding partners include Tesco, Carrefour and Walmart.

In the UK:

- In 2019, Defra and major food businesses (e.g. Tesco, Sainsbury's and Nestlé) signed the 'Step up to the Plate' initiative to halve food waste by 2030. This followed Defra's announcement of its £18 million Resource Action fund, which will be used to support resource efficiency projects, with the goal of diverting, reducing, and better managing waste, including food.
- Public Health England (PHE) has taken steps to cut people's excessive calorie intake as part of the government's strategy to cut childhood and adult obesity. This includes:
  - A challenge to the food industry to reduce calories in products consumed by families by 20% by 2024.
  - The launch of One You campaign, encouraging adults to consume 400 calories at breakfast, and 600 for lunch and dinner; this comes as adults consume 200 to 300 calories in excess each day.
- WRAP's 'love food hate waste' campaign aims to raise awareness and offer practical advice and solutions to help the public reduce their food waste. The campaign involves a wide range of partners, from community organisations, chefs, UK businesses, trade bodies and local authorities through to individuals.
- In Scotland 'Zero Waste Scotland' focuses on improving resource efficiency and the circular economy to create a society where resources are valued and nothing is wasted. Wales already has mandatory separate collection of food waste across all local authorities.

Source: CCC analysis.

A strategy on food waste should target low-cost, low-regret actions across the supply chain:

- **The public sector** could set and monitor its own targets and improve data collection to share best practice and set an example to the private sector. Government has a role in promoting waste avoidance more proactively and through education (e.g. schools).
- **Consumers** can be enabled to reduce waste through effective product date labelling; guidance on cooking, planning and storage; and having separate food waste collection. Financial measures could also play a role e.g. charge households for recycling depending on the quantity of food waste.
- **Businesses** should make current pledges mandatory (e.g. the 'Step up to the Plate' initiative), paired with measurement, monitoring and reporting. Reducing food loss along the supply chain could deliver cost savings for businesses. As an example, new research found that restaurants could earn $7 for every $1 spent in cutting waste.[128] Businesses could also play a role in influencing upstream businesses and 'nudging' consumers and investing in technological solutions:
  - A role for chefs, restaurants, TV programmes in promoting awareness and improving skills; and more and better communications on avoidance techniques.
  - Increasing availability of reduced portion sizes in supermarkets and catering.
  - Offers and incentives through loyalty rewards.
  - Promoting a shift to better quality vs quantity.
  - Use of technology to reduce food waste e.g. to help consumers plan, shop and cook; through optimising atmospheric packaging; and new sealing technology.
- **Farmers** should work with retailers to agree whole crop purchase standards so that crops that do not meet standards are not thrown out. Post-farm gate, more data is needed on ways to minimise losses at the packaging and distribution stage.

[128] Champions 12.3 (2019) *The business case for reducing food waste and loss: restaurants.*

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