TECHNICAL REPORT:

A Net Zero Transition Plan for the UK Food System

November 2024

WRAP | IGD

Scope of the report

Project origination

In mid-2024, EY, IGD and WRAP agreed to collaborate on a UK Food System Transition Plan report. The aim was to create a robust evidence base to show what it would take for the sector to reach net zero, facilitating a system-wide focus on key actions and highlighting gaps and dependencies that need to be collectively addressed.

By incorporating many of the requirements of the Transition Plan Taskforce for companies to disclose their detailed decarbonisation plans, it is hoped this report will also function as a useful reference and framework for sector and individual company planning.

This report is a basis from which to stimulate collaboration, focus and acceleration towards net zero, leveraging the deep expertise and capability across the system to build upon and enrich this initial thinking and move opportunities into scale implementation together.

What this report does aim to do

- ✓ Set out a high-level pathway for the UK food system to reduce Greenhouse Gas emissions in line with a 1.5-degree SBTi outcome and to meet the UK's legally binding national decarbonisation goal.
- ✓ Provide an independent, rigorous evidence base for which types of actions at what scale are likely to be required for sector decarbonisation. Individual companies should be able to compare their own transition plans to this model to ensure they will meet or exceed all relevant levers.
- ✓ Focus on actions which are assessed to be technically feasible and economically viable, based on current technologies and those where innovation is likely to offer further opportunities.
- ✓ Indicate overall system costs potentially associated with the transition and point towards sources of funding.
- ✓ Indicate important dependencies, in particular assessing technology readiness and the sufficiency of the policy environment to incentivise key actions.
- ✓ Indicate areas where pursuing net zero may imply trade-offs or impacts on other dimensions such as nature, nutrition and land use.

What this report has not tried to do

- ✗ Incorporate abatement options which are not yet scientifically proven. As science evolves (e.g., relating to soil carbon), it may be that there are further opportunities for improved supply-side outcomes, which can be incorporated in updated plans.
- ✗ Incorporate abatement from carbon removals related to land-use change, as rules regarding their inclusion in company inventories are to be finalised next year, following which their implications should be reviewed.
- ✗ Present a picture of the best imaginable case wherein every company moves as fast on every dimension as the best in class. It is recognised that many individual companies are more ambitious on some dimensions than the pathway set out here.
- ✗ Offer a complete analysis of dependencies and impacts of decarbonisation actions on related dimensions such as nature, nutrition and land use; further work is proposed here.
- ✗ Offer a complete analysis of the financial implications for separate parts of the supply chain over time, for example where significant upfront capital may be required to unlock cost efficiencies over a number of years. For any individual company, the cost outlook may be very different to the macro aggregate presented here.
- ✗ Propose a target or roadmap for delivering the emissions reduction potential of consumers shifting towards lower-GHG dietary choices.

Foreword from Sarah Bradbury, Chief Executive, IGD

This is the start of a journey, together.

In recent years we have seen first-hand the vulnerabilities in the food system and the increasing risks to its resilience, as here in the UK we have seen temperatures reach record highs of 40ºC and some of the wettest months on record last year and this year.

It highlights that climate adaptation planning will need to be central to ensuring food security in the future.

Food production is responsible for around a third of global GHG emissions, so we must play our part in the transition to net zero, the targets we have committed to for 2030 and 2050 are stretching so collective action is what's needed. Decarbonisation is a challenge for any sector and this is compounded for the food system by its enormous complexity and the competitive nature of the industry

Commitments to WRAP's 2030 Courtauld Agreement have helped deliver a significant reduction in food retailers' scope 1 and 2 emissions. The development of a measure by WWF brought together leading food retailers with a commitment to halving the environmental impact of the shopping basket by 2030. Recognising that achieving net zero can't happen in isolation – there is also a nature emergency, so we must prevent further biodiversity loss

This plan shows the challenge that several 2030 targets are at risk of not being met, but that doesn't mean without co-ordination we can't still achieve net zero by 2050. We need a different approach, one that involves the whole end-to-end supply chain, a more aligned dialogue across Industry and with government. A more widely shared view of where we are now, how extensively we can reduce emissions and what will be needed in terms of capabilities, financing and policy support to do this.

That is why we commissioned this Food System Net Zero Transition Plan as an independent, evidence-based review built from the broadest, most robust and proven data available, to align the conversations and progress. The analysis has been conducted by an expert consultancy team at EY with the support of specialists at the Scottish Rural Agricultural College and the support of our partner, global environmental NGO, WRAP.

Our thanks to those who have been involved in delivery of this report and for the engagement we have had through its development – from industry stakeholders including trade associations, from farming sector bodies, and from officials in central government and the devolved administrations.

The report sets out what it will take from now to achieve net zero, facilitating a system-wide focus on the levers and actions, highlighting gaps and dependencies. It makes clear that we need to go further, faster, together. It also makes clear that investing in abatement opportunities now is more affordable than paying for offsetting costs later.

It is important to recognise some of the limitations of this work. By virtue of it taking a whole system approach it does not take into account the diversity of progress across subsectors. Nor does it reflect that some businesses are moving faster by investing sooner or with the benefit of shorter, simpler supply chains. We know that the conclusions drawn from this work will not be universally agreed upon. Indeed, reaching consensus on every element is not practical or realistic.

Our aim is for it to be the basis for collaboration and accelerated progress, providing an aligned framework and measurement, with the same methodology as used by government and the Climate Change Committee to develop carbon budgets . From this we can use our collective expertise and capabilities to align around opportunities to implement solutions at scale.

My ask of you reading this is to ensure we don't use all our energy debating the elements on which we might disagree.

I invite you to join us, to enrich this analysis, and to use it is a catalyst for us to work in partnership – because we will go further, faster, together.

Foreword from Catherine David, Executive Director of Behaviour Change and Business Programmes, WRAP

This report is a clear call to action to achieve our shared goal of a net zero food system by 2050.

We have worked together with stakeholders from across the value chain to synthesize several complex data sets regarding the UK food system, creating and quantifying a strategic plan for the sector to meet its net zero obligations.

We are up against the clock now, which is why this plan lays out both the supply and the demand side actions needed if we are to cross the net zero line in time.

We can only achieve our net zero, and nature, goals by investing in our farmers. We recognise the many pressures bearing down on farmers, and we share a dependence on a resilient UK food and farming sector, providing affordable nutritious food for all, whilst protecting and restoring nature. Without fairness, security, and sufficient financial rewards for net zero changes reaching our farmers, there can be no meaningful climate action in the food sector.

This report lays out the key actions that need to take place on farms, and at scale. To achieve the pace of change needed, we must see significant increases in investments as well as a step change in the nature of collaboration with farmers, and across the value chain.

On the supply side, the pathway to net zero depends on the rapid decarbonization of electricity, heat, and transport infrastructure, whilst on the demand side, we must ensure that the food we do produce is not wasted and provides people with a healthy, environmentally sustainable diet.

We have made great progress on food loss and waste through WRAP's Courtauld Commitment[1].

This report highlights how eliminating food waste can help achieve net zero goals and presents unambiguous evidence that this should be a core pillar of net zero planning in the food sector. With the average family throwing away approximately £1000 worth of edible food each year, there is a huge opportunity for change, and the need for a national collective mission to accelerate action on household food waste prevention.

At WRAP, we do not shy away from challenging issues and for the food sector, no issue is more charged than diet change. WRAP has published a 2030 pathway[2] for delivering a 50% reduction in the GHG footprint of UK food and drink that includes significant mitigation from shifting diets towards the Eatwell Guide.

This report restates that need for urgent action on diets, whilst modelling a 2050 scenario that is more conservative than the current recommendation of the Committee for Climate Change. We believe urgent action is needed by industry and government to establish a pathway for diets, with clear targets for 2030 that are rooted in the best current evidence and a range of expert perspectives, including from a nutrition and nature viewpoint.

We call on the sector to come together, work through such differences, and focus UK Food's incredible strengths and talents on solving the greatest challenges of our generation.

As an organisation committed to evidence-based action to drive system change, WRAP stands ready to work with the sector, with flexibility, humility, and determination,

to drive that change and ensure that UK Food leads the way and delivers on its commitments to a net zero future.

1 Courtauld Commitment – WRAP
2 UK Food System GHG Emissions – WRAP, 2021

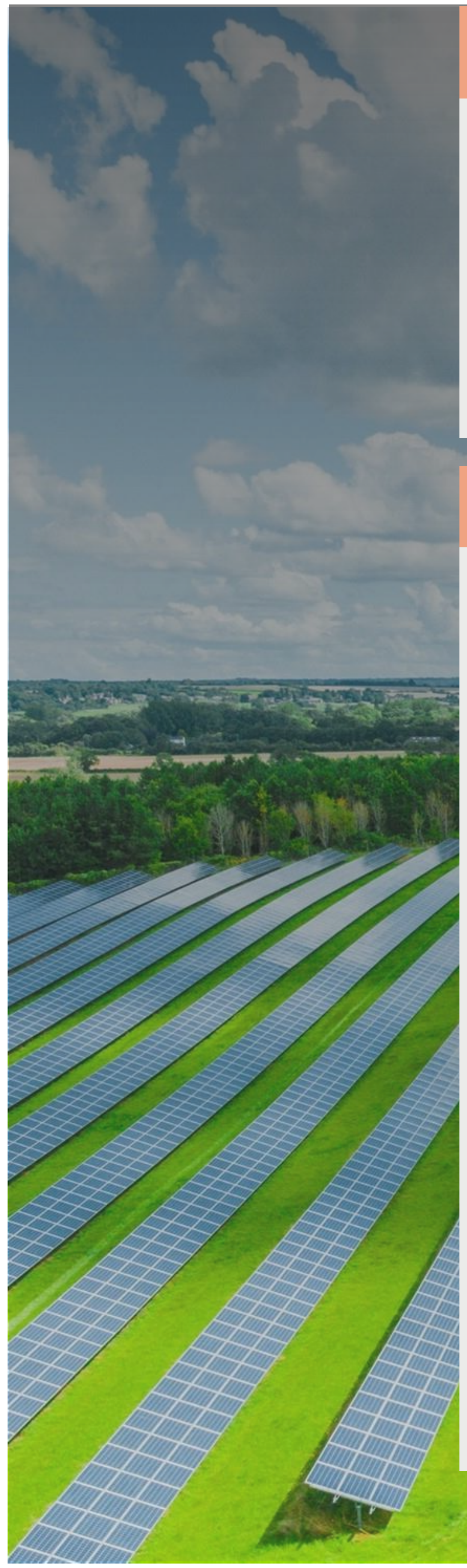
Approach and methodology

The approach of the report

1. This report starts with the **UK food system carbon footprint** and the WRAP estimate of the food system carbon footprint in 2021, which includes net imports. Emissions related to citizens transporting and using products were removed, some estimates are updated to use alternative sources, and some are recategorized to align with intervention levers.
2. Next, **levers to reduce emissions are assessed** for each part of the footprint, based on bottom-up analysis of feasibility and cost-effectiveness. These levers relate both to the supply-side (production) and demand-side (consumption). The evidence base includes government and Climate Change Committee (CCC) analysis; industry intelligence from interviews with and materials provided by farming representatives, protein processors, manufacturers, retailers, plus logistics, chemicals, science and commodities companies.
3. The **agriculture analysis** uses a Marginal Abatement Cost Curve (MACC) model developed by Scotland's Rural College (SRUC). This is used by the CCC, including for its forthcoming advice on the Seventh Carbon Budget. **Therefore, it is consistent with what will be required from agriculture to meet carbon budgets and the net zero target,** and is used by both government and the private sector. The MACC has been tested through review by independent experts. Abatement potential relative to a baseline is drawn from a longlist of over 300 mitigation measures and an evidence base that has been developed over the last fifteen years by SRUC, from primary and secondary sources. Based on this assessment, a MACC is constructed, showing those options which are applicable to UK conditions, where there is a degree of confidence, they are feasible and do not have negative impacts for other environmental objectives. For measures that meet these criteria, the MACC maps their abatement potential and related cost, the latter including a full assessment of costs (e.g. capital, operating, income foregone). Pathways for agriculture emissions reductions are developed, accounting for barriers to uptake. The focus is on a High Ambition scenario, with very high rates of uptake for key measures by 2035, given the need for ambitious action to meet climate commitments and targets.
4. The **potential opportunities to meet SBTi commitments** are identified for 2030 and 2050 through a mix of supply-side and demand-side interventions from bottom-up analysis, and the conditions that would have to be in place to make these options commercially viable. System emissions pathways are developed with different levels of ambition and delivery-confidence and compared with commitments that the industry has made for 2030 and 2050.
5. The **annual costs** associated with emissions reductions are estimated as being the difference between costs associated with low-carbon technologies and a business-as-usual scenario.
6. Significant **uncertainties and dependencies** are identified with recommendations on how these should be managed.

The approach is consistent with guidance from the Transition Plan Taskforce (TPT). In particular, it sets out quantified ambition, identifies key drivers and actions to deliver emissions reductions including action owners, associated costs, dependencies, and some aspects of just transition (inclusiveness, affordability impacts). Further work will be needed as the plan is developed and implemented, e.g. on nature and the just transition, and by sector. Other aspects of transition planning guidance should be covered in company plans (e.g. financing plans, company governance and incentives).

Importance of a net zero food system and key findings



Context and importance

The UK food system is inextricably linked to the climate crisis. It is both a significant contributor to greenhouse gas (GHG) emissions and other environmental impacts, and completely dependent upon healthy ecosystems to nourish and protect crops.

Food emissions are a large share of total global and UK GHG emissions and **deep cuts will be required to meet climate objectives**. The industry has faced this challenge through wide adoption of net zero targets. Recognising that unilateral action is difficult in a context of intense competition and interdependent supply-chains, the industry has agreed that a **system approach to net zero is required**, while respecting boundaries placed by competition legislation.

This report sets out a system approach with a focus on decarbonisation whilst acknowledging the need to avoid negative consequences for related imperatives like nature, nutrition and livelihoods.

Key findings

1. Achieving sector net zero targets by 2030 and 2050 will be extremely stretching, but is possible with urgent focus and partnership throughout the system.
2. Major transformation is called for in all aspects of the food system’s supply side, most notably:
    - Very high uptake of lower carbon farming practices in UK and overseas agriculture.
    - Effective regulation and processes to eliminate deforestation from supply chains.
    - Major infrastructure and capacity provision for renewable energy, zero emission logistics and low carbon heating and cooling.
3. Demand-side change will be key to reaching targets, specifically:
    - Significant reductions in household food waste could deliver major benefits.
    - Shifting dietary choices towards lower carbon foods that are equally nutrient rich and/or the Eatwell Guide represents a significant GHG abatement opportunity.
4. Innovation is a key driver of emissions reductions in the plan, offering opportunities in agriculture, low-carbon heat and logistics, and production of green fertiliser.
5. Common methodologies for carbon footprinting, more reliable data and integrated systems are required to support emissions reductions and improve accuracy of reporting.
6. Action is required by government to strengthen policies and incentives for: agriculture in England and the devolved administrations (DAs); investment in low-carbon heat and logistics; power sector decarbonisation; and development of the hydrogen economy. A land-use strategy is urgently needed, with a request that a draft for consultation be published in the first quarter of 2025.
7. Industry collectively can accelerate progress by supporting farmers on their net zero journey, developing approaches for overseas sourcing, and supporting consumers with changes to their food waste and diet behaviours. Individual companies can drive decarbonisation of energy, transport and refrigerants.
8. Analysis in the report suggests significant costs to 2030 of the agriculture transition, together with reducing land-use change emissions and making packaging more sustainable. There will be further significant costs associated with decarbonisation of heat, logistics and fertiliser production in the period 2030 – 2050. Throughout, there will be significant financing requirements for energy efficiency improvements, replacement of old refrigeration equipment, and over time, for investment in relatively capital-intense low-carbon technologies.

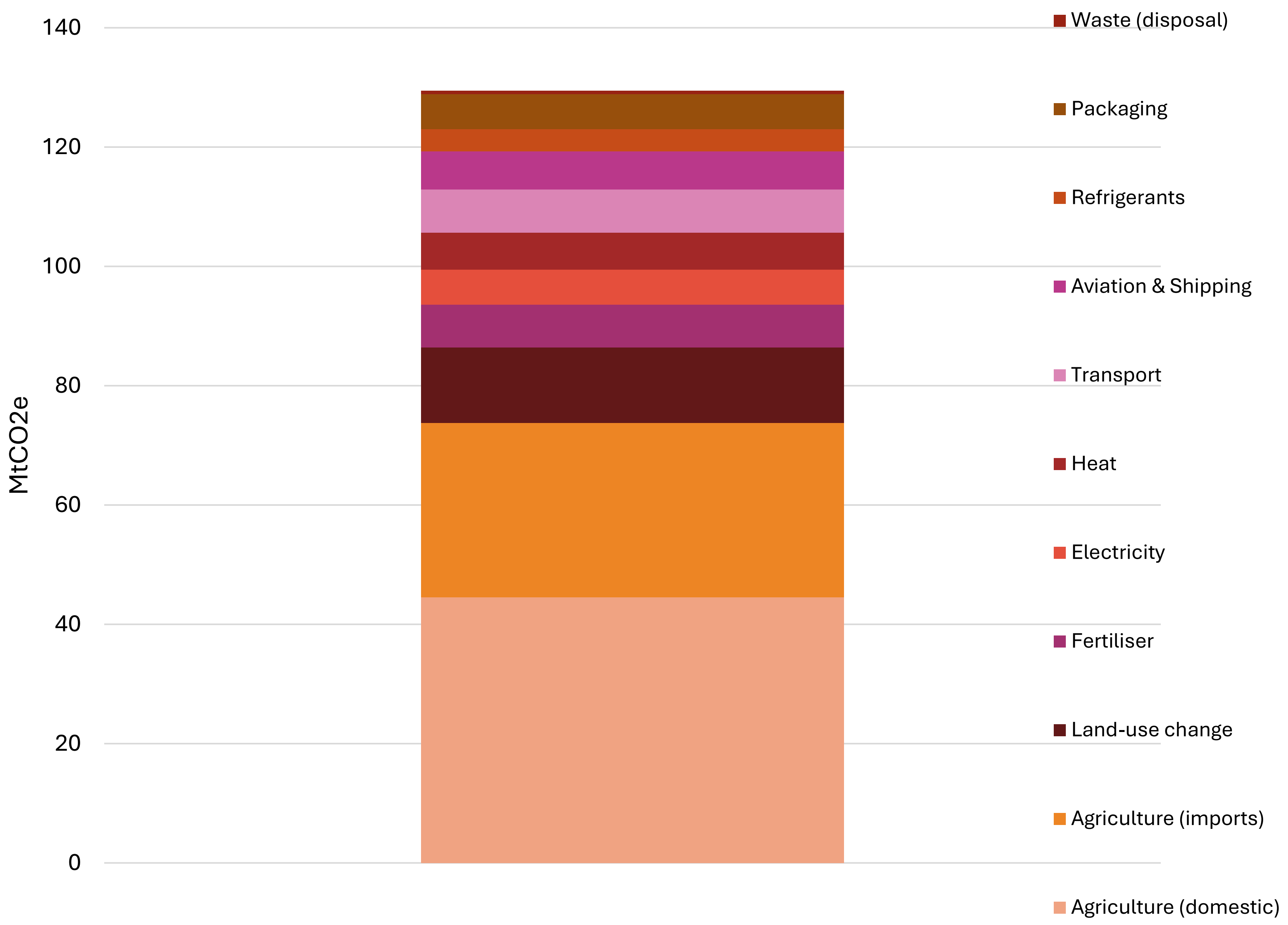
Contents

Executive summary

There are huge opportunities to reduce the carbon footprint of the UK food system.

The UK's food system carbon footprint is 129.5 MtCO2e, equivalent to around 30% of territorial emissions. As at the global level, the UK system footprint is dominated by agriculture and land-use change, with fertiliser production, energy and transport being significant components.

Breakdown of emissions baseline (2021)*



Supply-side abatement opportunities

- **Agriculture:** change farming practice, end land-use change for imported commodities, green fertiliser
- **Energy:** grid decarbonisation, energy efficiency improvements, low-carbon heat
- **Refrigerants:** fridges and freezers with minimal F-gas emissions
- **Transport:** fuel efficiency improvements, logistics efficiency improvements, low-carbon vehicles
- **Packaging:** increase recycling, alternative materials, reuse

Demand-side abatement opportunities

- **Food reduction:** opportunities throughout supply chain, but particularly at household level
- **Diet change:** eating less of the most carbon intense foods and replacing these with low-carbon alternatives, while maintaining nutrition, accessibility and affordability

*The scope of this footprint excludes emissions associated with household energy and consumer transportation. As a result, it is different to that presented by WRAP in its report 'Tracking UK Food System Greenhouse Gas Emissions: 2015-2021'. Aside from this, the footprints are consistent subject to small adjustments relating to agriculture emissions based on new SRUC analysis and recategorising some data (e.g. fertiliser use for imported goods).

Executive summary

Deep cuts in emissions are required to meet SBTi targets and carbon budgets.

Industry has made ambitious commitments under SBTi, comprising targets for Forest Land and Agriculture (FLAG) and non-FLAG emission sources. Deep cuts in food system emissions will be needed to meet legislated carbon budgets.

SBTi non-FLAG targets (energy, transport, heat, food waste, packaging, refrigerants)

- **2030:** deep cuts required
- **2050:** net zero (100% reduction)

SBTi FLAG targets (agriculture practices, LUC associated with imported commodities, fertiliser production)

- **2030:** 30%+ reduction
- **2050:** 70% reduction

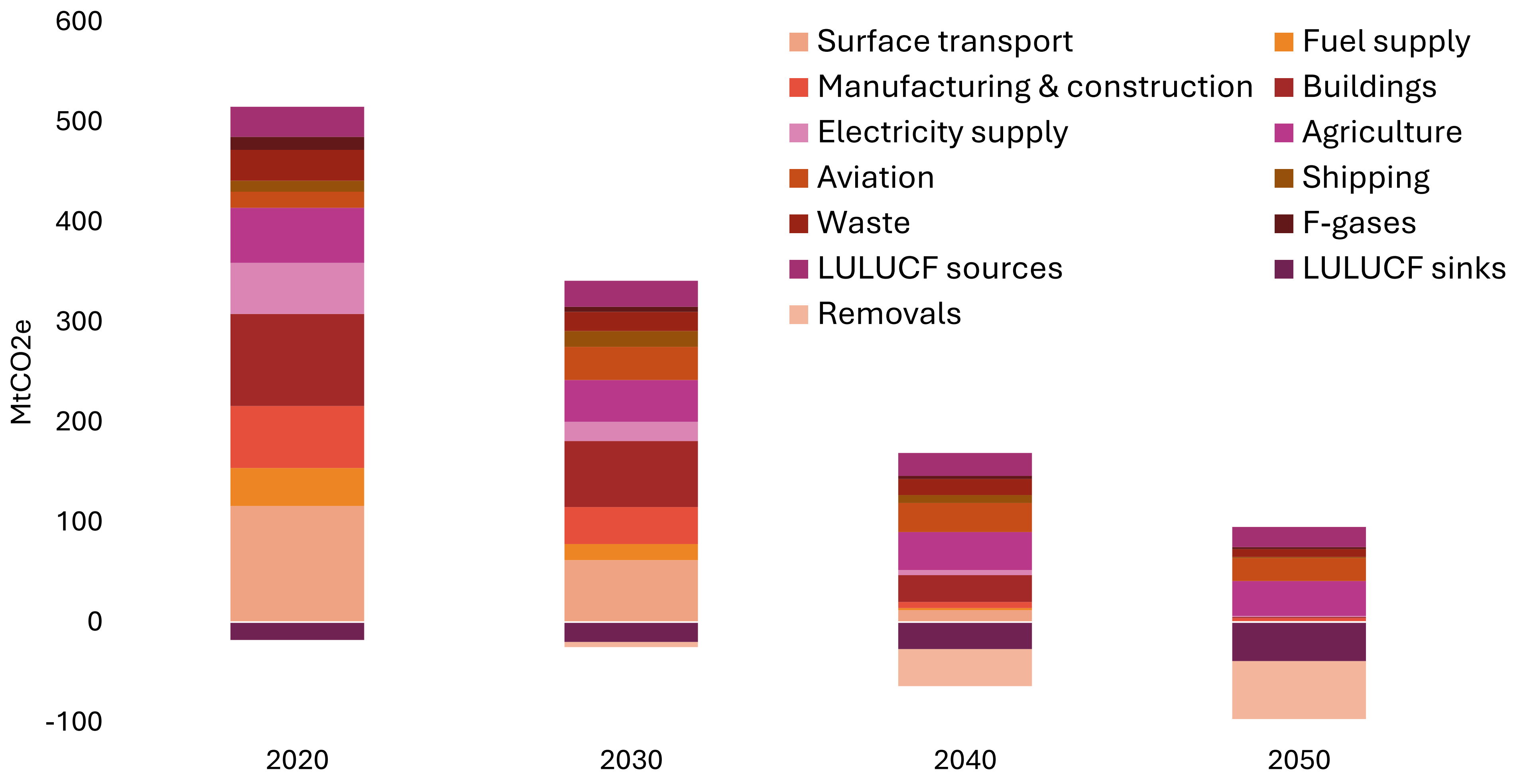
Population growth

- The Office for National Statistics (ONS) projects population growth from 67m in 2021 to 77m in 2046 (extrapolated in the modelling to 78m in 2050)
- Food demand is assumed to increase with population growth
- This implies the need for further emissions reductions in order to meet absolute reduction targets

Carbon budgets

Carbon budgets are designed based on sector pathways for emissions reductions. The food system should at least keep pace with these pathways. Over time, emissions from electricity, heat and transport fall to zero in pathways underpinning budgets. The agriculture pathway assumes widespread adoption of low-carbon practices, together with food waste reduction and diet change – though with flexibility of the balance of effort across levers, which are considered in this report.

UK economy emissions by source towards net zero[1]



1 The Sixth Carbon Budget – Climate Change Committee, 2020

Executive summary

There are significant supply-side opportunities to cut emissions close to zero for non-FLAG and to make deep cuts for FLAG.

Agriculture: 40 – 55% cut against 2021 baseline by 2050

- 40% reduction requires:
  - Widespread adoption of low-carbon farm practices
  - Land-use change emissions reduced to zero through sustainable growing
  - Fertiliser emissions reduced to zero through use of hydrogen

- 55% reduction requires the deployment of the above, alongside less mature and more challenging approaches:
  - Feed additives for grazing animals
  - Biostimulants
  - Low-carbon feed
  - Inter-cropping

Electricity: close to zero emissions by 2035 or earlier

- Grid decarbonisation through investment in renewables and nuclear
  - Government to clarify ambition and drive the decarbonisation
- Grid expansion, including to support electrification of heat and transport

Heat: close to zero emissions by 2050

- To 2030, focus on energy efficiency and trialling of renewable heat
- From 2030, electrification through electric technologies, predominantly heat pumps and electric ovens

Transport: close to zero emissions by 2050

- To 2030, focus on fuel efficiency of HGVs and electric delivery vehicles for retail
- From 2030, deployment of low-carbon HGVs, most likely to be battery HGVs

Packaging: emissions cut by at least 50% by 2050

- Reductions through the period to 2050, based on increased recycling, alternative materials and reuse

Refrigerants: emissions cut by at least 83% by 2050

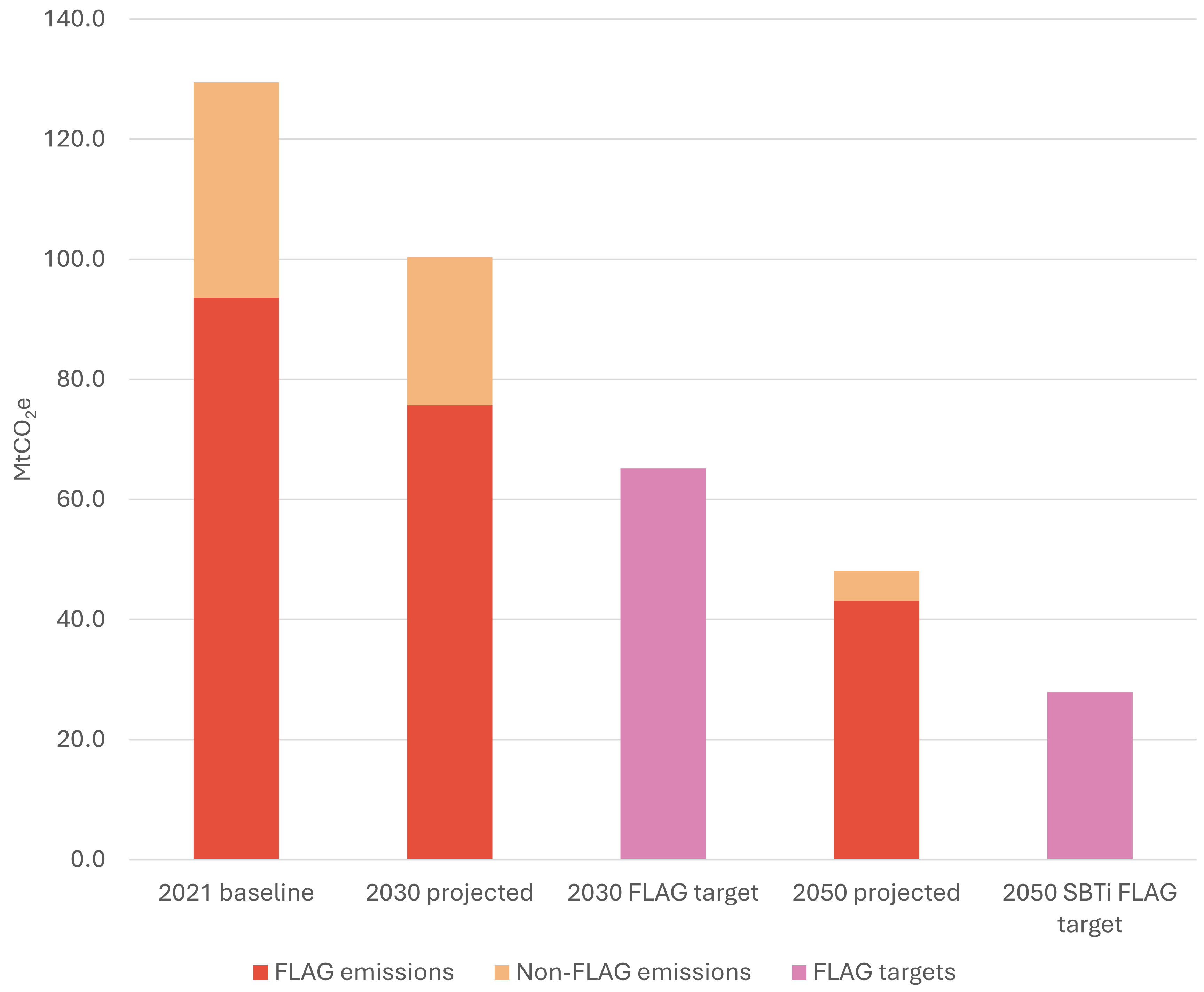
- Replacement of old, polluting refrigerators and freezers with modern technologies that have lower F-gas emissions

1 The Sixth Carbon Budget – Climate Change Committee, 2020

Executive summary

Supply-side opportunities are sufficient to meet non-FLAG commitments and to make important contributions to meeting FLAG targets and carbon budgets – but demand side action will also be needed.

FLAG and non-FLAG emissions projections against FLAG targets



Demand-side action

The chart shows maximum potential from supply-side action, which makes significant contributions to SBTi FLAG targets – but demand side action will be required to meet these and to contribute to carbon budgets. There are important demand-side opportunities relating to food waste reduction and diet change.

Food waste reduction

- Currently around 25% of food is wasted[1], with the biggest single contributor being household food waste.
- The Courtauld Commitment aims for a 50% per capita reduction in food waste by 2030 vs the UK 2007 baseline.
- The industry should aim to deliver the Courtauld Commitment and go beyond it, reducing food waste to very low levels by 2050.
- The lever for this is collective industry action working in partnership with government.
- Food waste reduction would make an important contribution to meeting SBTi FLAG, but would still leave a gap.

Diet change

- The Climate Change Committee has developed scenarios for diet change to help meet carbon budgets. Without diet change, the food system would not be able to make its contribution here, and would not meet SBTi FLAG targets.
- Given the assessment of supply-side opportunities and scope for food waste reduction, moderate diet change away from the most carbon intense foods – red meat and dairy - could be sufficient, e.g. equivalent to a 20% reduction across these categories, but with no set balance of effort.
- Diet change also has important health considerations, which are beyond the scope of this report.
- The food industry should work urgently to develop an approach to diet that balances net zero and health objectives; the absence of a position stands in the way of progress and leaves the industry vulnerable to having policies imposed upon it.

1 UK Food Waste & Food Surplus – UK Key Facts – WRAP, 2023

Executive summary

Costs of decarbonisation: Funding of at least £500 mn annually will be required to support low-carbon agriculture measures – without this, key measures will not be adopted by farmers.

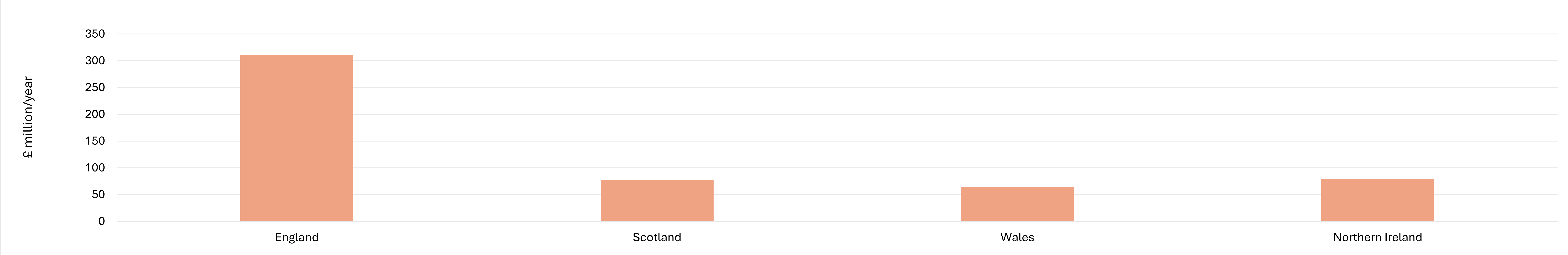
There are two categories of measures for agriculture abatement: those that save money and those that cost money on a net basis.

Even for the former, farmers will need to be supported in their net zero transition. For example, it is recommended that funding should be made available for farm-level carbon audits, benchmarking and planning; in Northern Ireland, these are funded in effect through direct payments, for which they are a qualifying condition. There are some measures where there is lag between investments and payoffs. Again, these will have to be funded.

Measures which cost money will have to be funded or they are highly unlikely to be adopted. While a net cost, these pass a value-for-money (VfM [return on public investment]) test: abatement costs are well within the UK Government's carbon values, and there are significant nature co-benefits. Annual costs are estimated of the order £500 mn, which are distributed across England and the DAs as shown in the chart below. These are funded in England under ELM, and it is recommended that these should similarly be funded in the DAs. Funding would typically be in the form of ongoing payments, given the vast majority of costs are operating. For the fewer measures where there are significant capital outlays, these should be funded through grants; for example, grants are available for slurry investment in England and Scotland. Over time, grants for low-carbon mobile machinery are likely to be needed.

There are much higher costs associated with supporting the broader farming transition and meeting national environmental objectives, which requires a more extensive scope of changed farming practice together with taking land out of production (e.g., for forestry, peatland restoration and nature recovery). For example, a recent NFU report estimated this cost to be over £4 bn annually[1].

Positive abatement cost per DA in 2050 (Section 3.4)



1 An agricultural budget that delivers for the environment – NFU asks of government – NFUonline, 2024

Executive summary

Costs of decarbonisation: There are significant costs of decarbonisation currently facing the food system. These relate to imported agriculture, sustainable feed and commodities procurement, and sustainable packaging.

Net cost and capital cost are differentiated: the former reflects any operating cost savings associated with the latter. Costs of low-carbon options are compared with business-as-usual alternatives. Costs are assessed on an annual basis to allow comparison with system revenues and consequently infer potential price impacts, as is the convention in effective transition planning.

To 2030:

Net costs:

In addition to domestic agriculture, there are three significant areas of cost related to decarbonisation facing the food system:

- **Imported agriculture:** Where the recommendation is that farming costs in the UK should be funded by government, there is not an equivalent mechanism for imported products. It is recommended that an industry programme should be considered to reduce emissions from imported products. While this would be costed as part of scoping work, based on UK costs and a comparison of farming products in the UK and foreign supply chains, funding of several hundred million pounds annually could be required.
- **Commodities caught by deforestation regulations:** There will be a premium associated with sustainable soy and commodities. This is currently uncertain, with a wide range of estimates in the market related to cost premia for EUDR. However, across the range of commodities, this could be in the hundreds of millions of pounds at the system level. It should only be temporary, because costs associated with establishing new supply chains and traceability systems are non-recurring.
- **Sustainable packaging:** There are a range of policies to drive sustainable packaging (e.g., EPR, plastics tax, PRNs), which together would add around £2.5 billion annually according to industry estimates.

Capital cost:

There are significant capital costs in the near term related to energy efficiency improvement. While related investments should have short payback periods, they still need to be funded (e.g., for waste heat recovery). Replacing ageing cold storage also requires large investments. These have typically been costed at the company level and included in financing plans. For purposes of illustration, the CCC estimates an annual investment requirement of £300 million across all industry for energy efficiency improvement. Costs associated with Anaerobic Digestion (AD) and renewable heat will need to be funded if they are to happen.

Executive summary

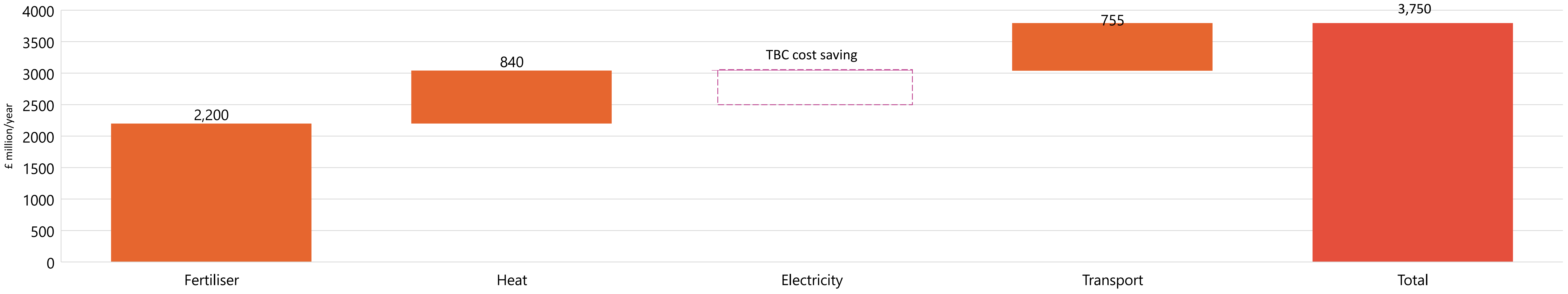
Costs of decarbonisation: Beyond 2030, there will be further costs equivalent to 1-2% of system revenues, related to heat, transport and fertiliser decarbonisation. There will be significant capital requirements throughout the period for low-carbon investments.

To 2050:

Net costs (additional to 2030):
Net costs will be added to the system through renewable heat, low carbon-HGVs and green fertiliser. For full abatement approaching 2050 across these three categories, the associated costs are estimated to be around £3.5 bn annually, which is equivalent to around £1.5 bn in present value terms, i.e. 1-2% of annual food expenditure of £140 bn. New policies will be required, with these costs to be funded by government (e.g., grants) and/or consumers (e.g., carbon pricing impacting food prices).

Capital cost:
There will also be significant capital outlays required for these technologies. For example, heat pump capital costs are around 4-8 times those of gas boilers, and battery HGVs are currently 3.5 times the capital costs of conventional alternatives, with further investment required for charging infrastructure. This raises a question about how investments can be financed within capital constraints. Opportunities to be considered further here are the roles for sustainable finance from banks (i.e. finance dedicated to support sustainability) and for government finance, to complement commercial finance.

Annual cost of decarbonisation 2050*



* Refer to pages 139 (fertiliser), 125 (heat), 121 (electricity), 144 (transport) for more detail

Executive summary

Strengthening of government policy and support will be required to deliver emissions reductions across the food system.

Agriculture area	Specific ask
Farming budget	Confirm farming budget to support net zero and wider sustainable farming practices; and publish a land-use framework, including ambition and funding.
Farm-level carbon planning	Strengthen incentives for farm-level agri-environment practices through funded carbon audits, benchmarking and plans for farmers, to buttress their engagement with sustainable farming and related schemes.
Sustainable Farming Incentive uptake	Assess impact on uptake from uplifting payment rates in the Sustainable Farming Incentive scheme and consider the case for a further increase to improve uptake across farming types.
Feed additives	Extend farming support schemes to include full or partial payment for use of feed additives to support rollout.
Anaerobic digestion (AD)	To commit a new round of funding to support farm AD for farm waste (not crops).
Stacking of benefits / framework for accessing private finance	Develop a framework for farmers to access private finance, namely through generating revenue from carbon and nature markets and selling of ecosystem services, over and above what they are paid for through ELM, in order to monetise benefits of sustainable farming. This should take into account any new industry schemes.
Farm regulation	Undertake a regulatory review with respect to three objectives for farming: food production, net zero, nature.
Deforestation legislation	Introduce a regulation that prevents land use change from imports of soy and tropical commodities consistent with the EUDR, while managing risks related to land conversion.
Farm data	Standardise carbon calculations, data and reporting through agreeing common methodologies and standards. These should differentiate between different types of farming practice and, as a matter of urgency, reflect improvements due to SFI participation. With more confidence in data, reporting should be mandated, to support consumer decision making.
Trade policy	Ensure a level playing field between domestic produce and imports through common environmental standards, border tariffs for carbon-intense products, and trade preferences in Free Trade Agreements related to environmental standards and animal health/welfare; export promotion and trade facilitation for British products.
Agriculture – Welsh Government	Ensure that net zero measures are funded under the new Welsh framework, by testing them against the key net zero measures identified in this report to ensure that there are no gaps.
Agriculture – Northern Ireland Government	Provide financial incentives for the key measures identified in this report to drive down emissions from dairy and beef farming, which dominate Northern Ireland’s farming carbon footprint.
Agriculture – Scottish Government	Provide financial incentives for the key measures identified in this report to drive down emissions from dairy and beef farming, which dominate the carbon footprint of farming in Scotland.

Executive summary

Strengthening of government policy and support will be required to deliver emissions reductions across the food system (cont.).

Supply-chain area	Specific ask
Grid decarbonisation	Clarify target date for grid decarbonisation (2030 vs 2035) and disclose credible plans to achieve this. Change regulatory guidance to support running of freezers at 15 degrees, to unlock energy efficiency savings.
Heat	Incentivise decarbonisation of heat processes in the food system by extending the Industrial Energy Transformation Fund (IETF) to support interim investment in low-carbon heat technologies. Rebalance gas and electricity prices, adding carbon costs to the gas price and removing policy cost uplifts from the electricity price.
Grid connection	Food companies and logistics companies should be prioritised for grid connection from the 2030s, which is when electrification becomes an important part of food system decarbonisation.
Transport decarbonisation and hydrogen economy	Building on participation of food companies in current programmes for transport decarbonisation (vehicles and infrastructure) and development of the hydrogen economy, ensure continued uptake as efforts are scaled up.
Packaging	There is an ongoing policy dialogue between the industry and government with the objective of a joined-up and streamlined approach across England and the DAs. This is detailed and technical in nature and therefore out of scope of the report.
Demand-side area	**Specific ask**
Food waste reduction	To be developed by industry group, but will include mandatory food waste reporting and addressing date labelling and pre-packaging of fresh produce.
Diet change	To be developed by industry group, but will include information provision, education, and revision of the Eatwell Guide including updating for latest evidence on consumption patterns.

Executive summary
Implementing the System Plan: Areas for Action

Asks of government

What: In this strategic plan there are 19 asks of government (see previous pages), which are key to supporting a level playing field and providing incentives for action to net zero.

Action: Industry to engage with government on policy asks at the earliest opportunity.

How: Structured discussions between industry and government convened by IGD.

Collective industry action

What: The areas for collective action are many, but prioritisation is needed in those which will generate faster progress to net zero and model ways of driving system change, taking account of the nature emergency and human health. There are a set of proposed areas, which have been under discussion with representative sector organisations from across industry since April this year.

Action:

Supply

1. Supporting farmers to join schemes through facilitation and incentives, in order to boost adoption of low-carbon practices (reduced fertiliser use, feed additives, etc.).
2. Convening on soil carbon, to understand the evolving evidence base and draw out implications for transition planning in the sector, including potential opportunities for farmers.
3. Aligning and further driving detailed design of regulation for deforestation-free soy and its implementation, to minimise costs while achieving policy objectives.
4. Consultation on establishing an import standard platform and programme for adoption of low-carbon practices in foreign supply chains.

Demand

5. Recommitting to reducing household food waste with greater adoption of all proven tactics across businesses.
6. Aligning industry to a position on diet change that balances net zero and health objectives, including an action plan.

How: IGD in partnership with WRAP to convene working groups to identify approaches for developing strategies and action plans in each of the above areas. These should be done on the basis of clear mapping of existing forums/initiatives/working groups to avoid duplication and ensure efficiency.

Sector and company transition plans

What: Sector and company transition plans should be aligned with – or go beyond – the strategic plan.

Action: Review sector and company plans against the strategic plan and update as appropriate, and be open to sharing learnings.

How: IGD to support this process and to facilitate greater sharing of learnings through lifting outputs into progress reporting (see below).

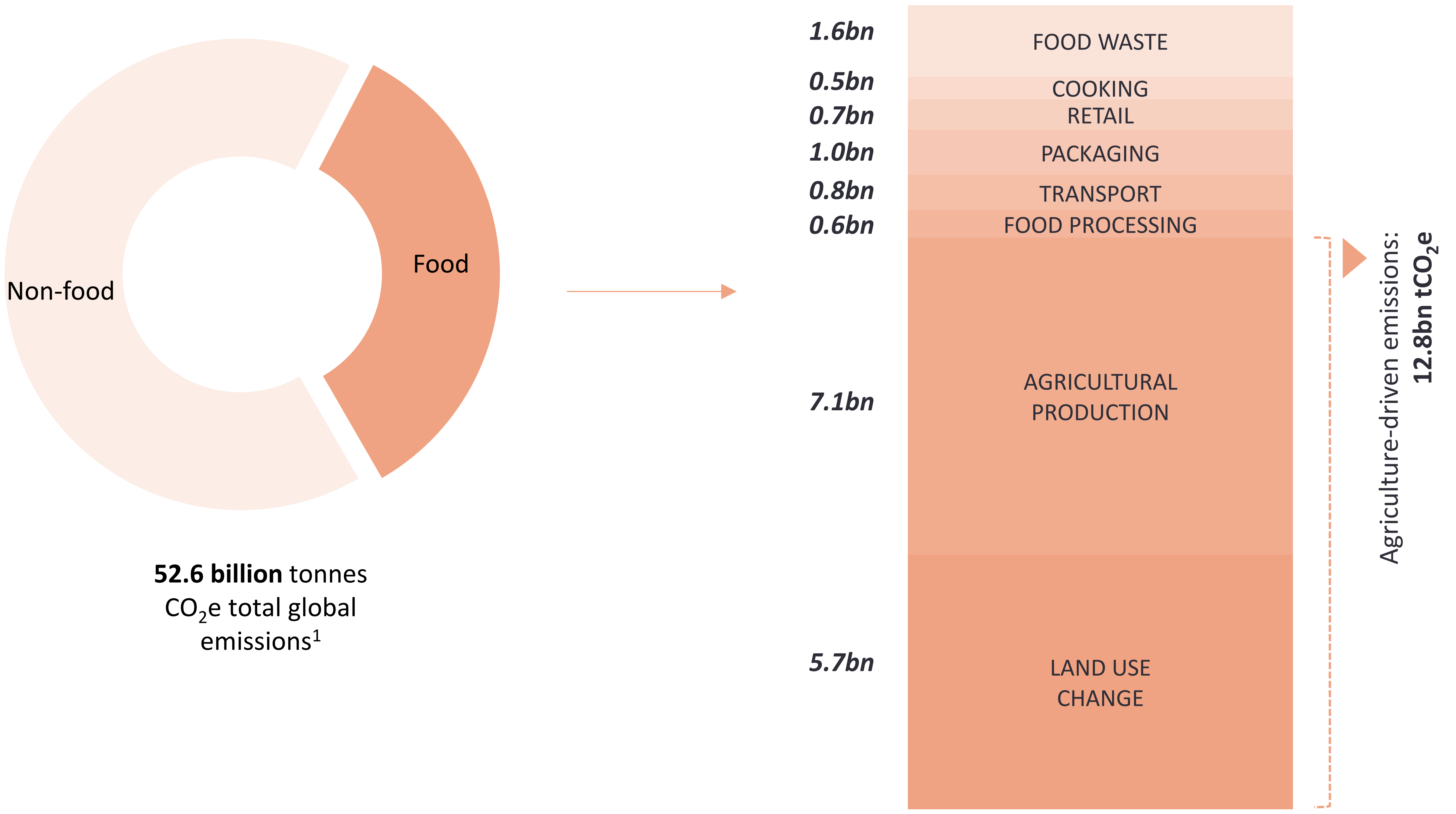
Review of progress

A first overall review of progress from the plan and the areas for action above will be publicly shared via a Webinar and Food System Net Zero Transition Plan Progress Report in June 2025, then bi-annually with a focus on the progress of actions.

01 Overview: emissions reductions opportunities and levers

Globally, the food industry is responsible for around a third of GHG emissions – it is increasingly the focus of international efforts to tackle climate change, and deep cuts will be required to meet global climate objectives.

Food system emissions make up 17.9 billion tonnes (34%) of global GHG emissions[1]



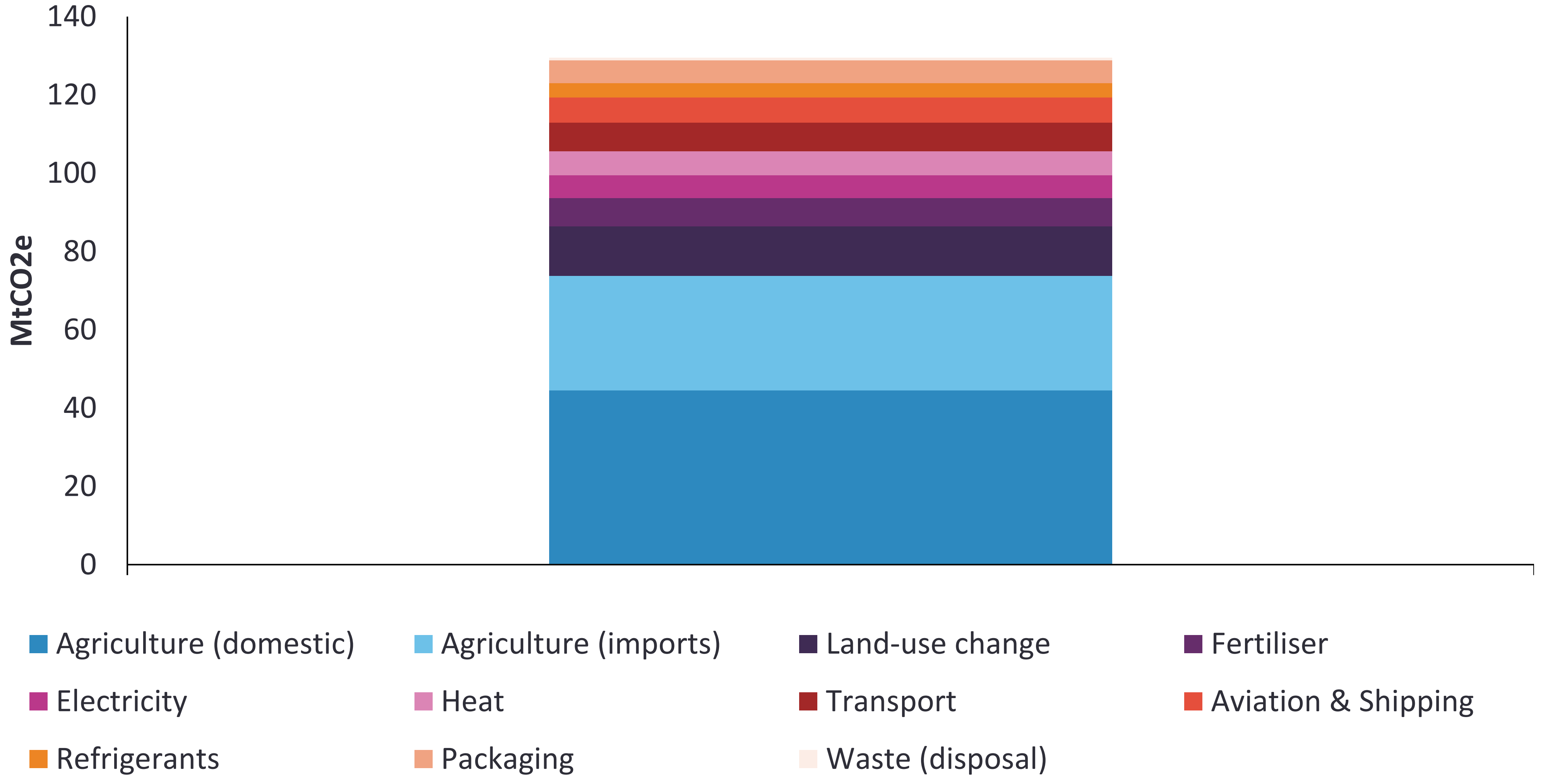
1. The global food system carbon footprint is dominated by agriculture and land-use change emissions, with downstream emissions in energy, transport and food waste.
2. Abatement opportunities across the industry can be split between supply (from food production to sale) and demand (consumer choices). These are deeply interconnected, with purchasing behaviours directly impacting upstream emissions sources.
3. Food was a focus of COP 28 in UAE, where there was agreement for each country to integrate agriculture and food systems in nationally determined contributions, strategies and action plans for COP 30 in Brazil. **This report contains the first national food system plan to be produced.**

1 Food systems are responsible for a third of global anthropogenic GHG emissions – Nature Food, 2021

In the UK, deep cuts in food system emissions will be required to meet legislated carbon budgets and industry targets under SBTi.

The UK's food system carbon footprint is 129.5 $MtCO_2e$, equivalent to around 30% of territorial emissions. As at the global level, the UK system footprint is dominated by agriculture and land-use change, with fertiliser production, energy and transport being significant components.

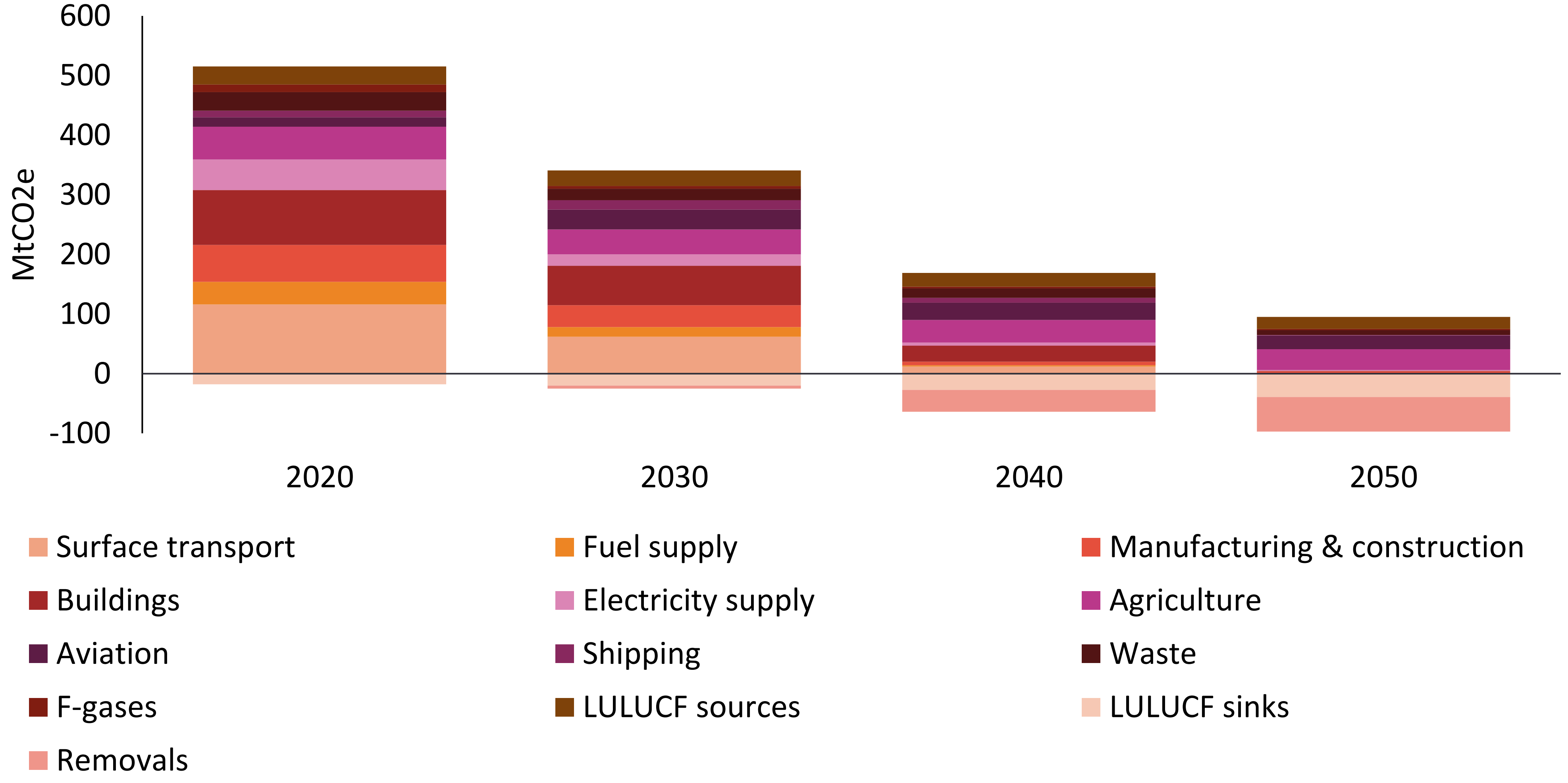
Breakdown of emissions baseline (2021)*



**The scope of this footprint excludes emissions associated with household energy and transportation. As a result, it is different to that presented by WRAP in its report 'Tracking UK Food System Greenhouse Gas Emissions: 2015-2021', Aside from this, the footprints are consistent subject to small adjustments relating to agriculture emissions based on new SRUC analysis.*

Legislated carbon budgets require a 36% emissions reduction from 2020 to 2030 on the path to net zero in 2050. Deep cuts will be required across the economy, including those sectors in the food system carbon footprint. Food system decarbonisation should move in tandem with the wider economy: an early focus on energy efficiency, electricity decarbonisation and agriculture, extending to the electrification of heat and transport.

UK economy emissions by source towards net zero[1]



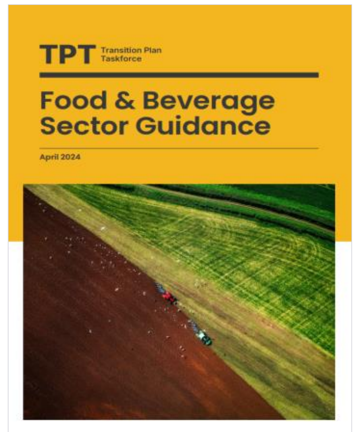
Most companies in the food industry have also made voluntary commitments in line with SBTi, which require achieving net zero by 2050 at the latest. Many have committed to an earlier date for net zero.

1 The Sixth Carbon Budget, The UK's Path To Net Zero – Climate Change Committee, 2020

Transition planning is the bridge between carbon budgets and corporate action. It is an opportunity to set out credible decarbonisation approaches which balance ambitious emissions reductions with commercial objectives, driving value in a changing world. Transition plans are increasingly being scrutinised by a range of stakeholders, including financial institutions and consumers.

There are forthcoming regulatory requirements in the UK for large companies to publish net zero plans in line with the Transition Planning Taskforce (TPT) framework. The TPT recommends that organisations should take a strategic and rounded approach to their transition planning, through decarbonising their own entity, responding to climate-related risks and opportunities and contributing to an economy-wide transition.

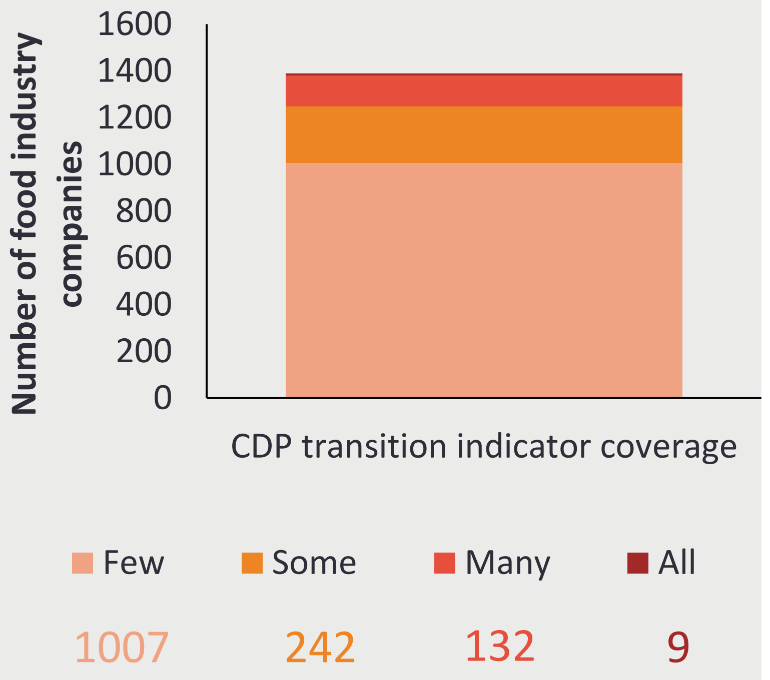
Principles	**Ambition**	**Action**		**Accountability**	
Disclosure elements	**1. Foundations**	**2. Implementation strategy**	**3. Engagement strategy**	**4. Metrics and targets**	**5. Governance**
Disclosure sub-elements	1.1 Strategic ambition	2.1 Business operations	3.1 Engagement with value chain	4.1 Governance, engagement, business and operational metrics and targets	5.1 Board oversight and reporting
	1.2 Business model and value chain	2.2 Products and services	3.2 Engagement with industry	4.2 Financial metrics and targets	5.2 Management roles, responsibilities and accountability
	1.3 Key assumptions and external factors	2.3 Policies and conditions	3.3 Engagement with government, public sector, communities and civil society	4.3 GHG metrics and targets	5.3 Culture
		2.4 Financial planning		4.4 Carbon credits	5.4 Incentives and remuneration
					5.5 Skills, competencies and training



Key

Transition plan sub-elements further expanded on in the TPT Food & Beverage guidance

CDP recently released their global study on Climate Transition Plan Disclosures in 2023, which highlights the Food, Beverage, & Agriculture companies as lagging behind other key sectors (such as Energy and Financial Services) on disclosure of "key transition indicators" – as defined by the CDP transition plan questionnaire.



Financial institutions (FIs) have commitments to decrease portfolio emissions, and the UK food system plays a major role in this. FIs are working with farmers directly to improve agricultural practices, and with food companies on their operations and supply chains. A system approach could underpin activity by FIs and align this with the industry approach.

Many major financial institutions have set targets to reduce financed greenhouse gas emissions in their loan portfolios to zero by 2050. They join a growing movement of companies throughout the food supply chain to set ambitious targets to reach net zero by 2050.

Given their unique position in the economy, banks will play an important role in the sector's climate transition, particularly on agriculture. Many banks have already signed onto the Net Zero Banking Alliance (NZBA) and have committed to setting emissions targets for high-emitting sectors, including agriculture.

Banks are developing bespoke approaches to the use of transition plans

Rabobank

- Despite the nascent data landscape, Rabobank was able to establish an initial baseline that provides a valuable starting point to both improve measurement tools and begin to identify strategies to support farmers in reducing emissions
- As it looks to decarbonise its portfolio it will explore target setting and weigh two interconnected dynamics: portfolio optimization, and client engagement.

Lloyds Banking Group

- Working in partnership with the Soil Association Exchange, Lloyd's is piloting consultancy visits to farms to assist with measurement of baselines, identification of areas for improvement, and development of action plans to implement best practices.
- The bank aims to build up a database of financed emissions across approximately half their lending book, allowing them to extrapolate data across their portfolio

Santander

- To start measuring its agricultural emissions, Santander focused on the farm gate considering physical activity data captured at the origination of the loan such as property location, livestock farming by type and number of animals, commodity production by type, crop area financed by commodity in hectares, or quantity produced by commodity, in tons. Establishing an emissions baseline highlighted the level of complexity of the agribusiness industry

FIs are also developing transition planning approaches, although **food & agriculture is lagging other industries** where there is a clear decarbonisation pathway (e.g. energy, automotive).

Transition finance on favourable terms and conditions is yet to flow to food & agriculture – which reflects the **lack of a clear pathway and drivers**, lack of high quality company transition plans (see previous page) and data limitations.

The food system accounts for

1/3 *of global emissions*[2]

but currently only receives

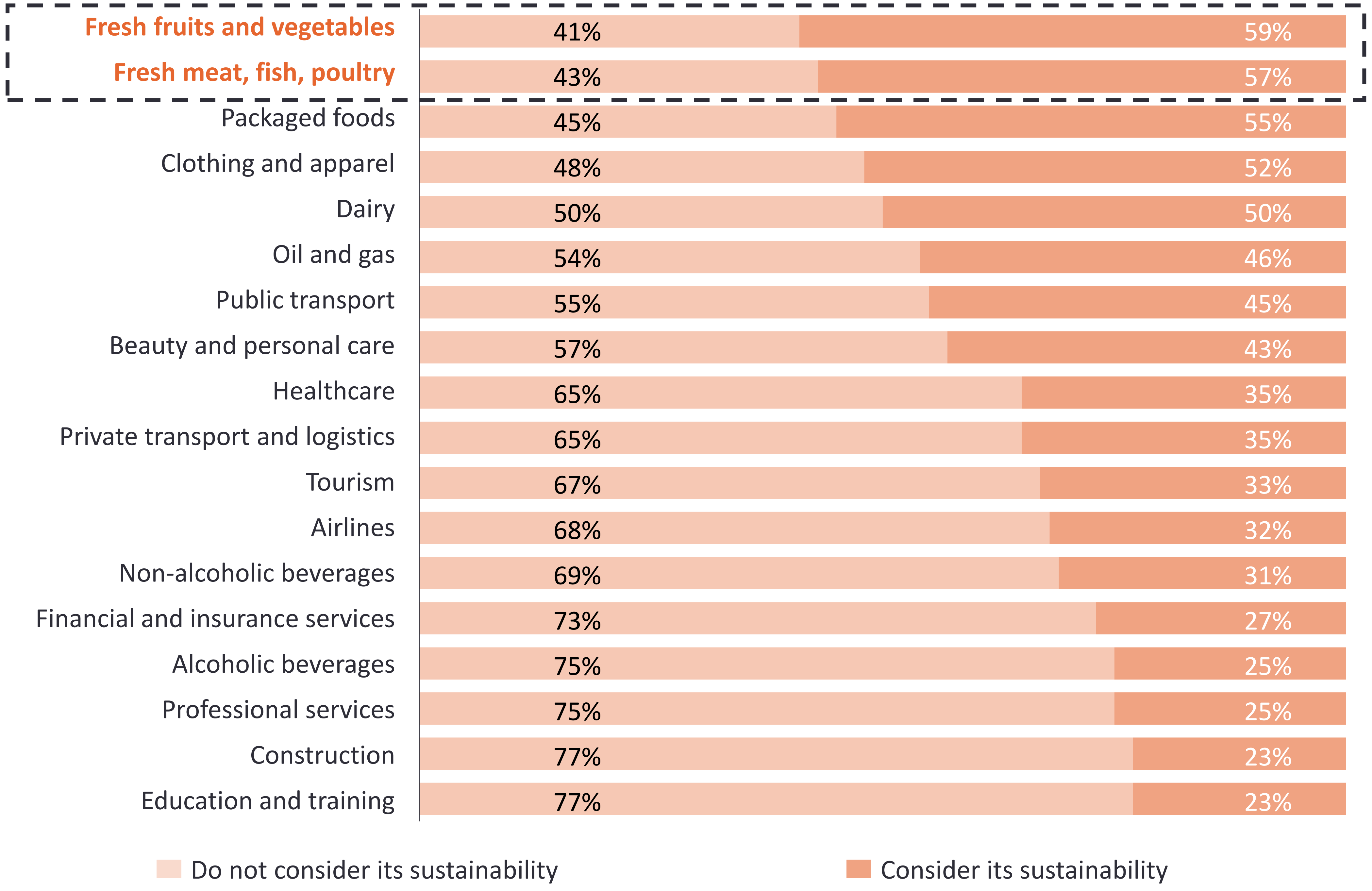
<4% *of climate finance*[3]

$600 billion (approx. climate finance budget)

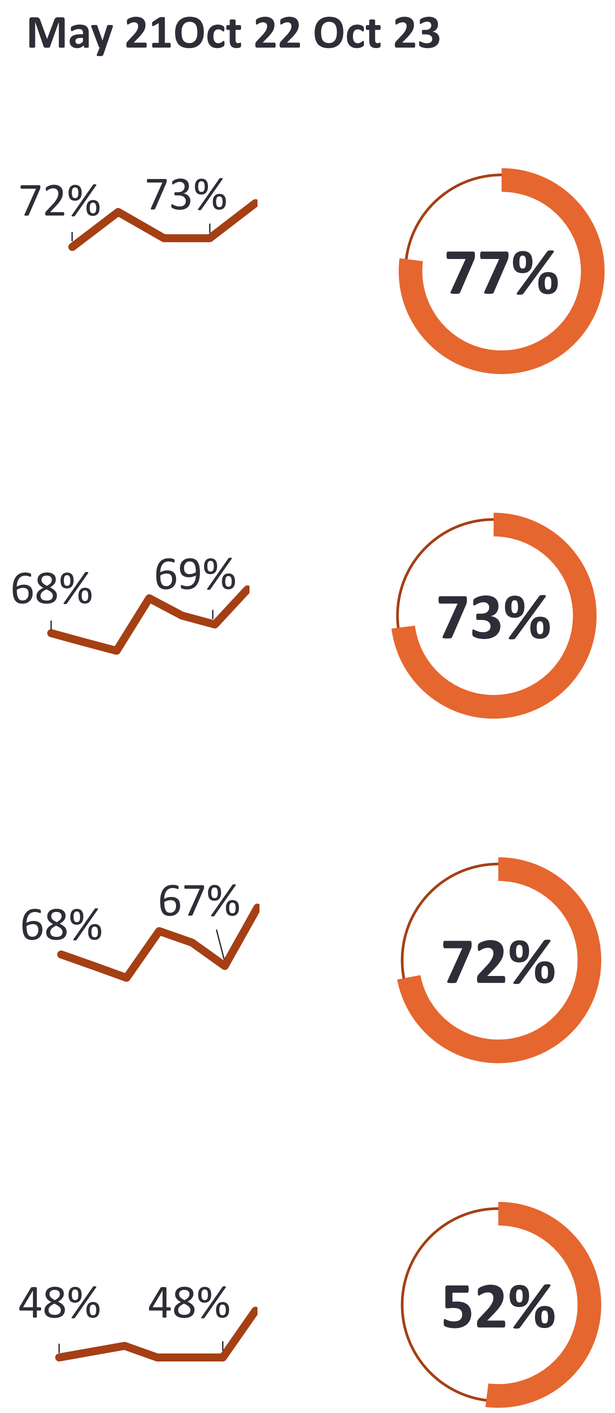
Agreement on a system-level transition plan between financial institutions and food companies would drive action and unlock climate finance.

Consumers are increasingly aware of product and company sustainability. While this is yet to translate into large scale purchasing behaviour, particularly in a cost-of-living crisis, consumers expect industry and government to drive change on their behalf within the food system.

Based on EY market research[1], consumers prioritise sustainability most when they buy fresh food…



….and increasingly expect companies (and governments) to drive change



feel governments need to act as leaders in driving positive social and environmental outcomes

feel companies should drive positive social and environmental outcomes

feel businesses must ensure suppliers comply with high sustainable standards of practice

believe products would be banned if they were bad for society or the environment

1 EY Future Consumer Index, Oct 2023, UK respondents

We are facing threats to resilience of the food system, nature and health – moving to net zero can help manage the risks.

Climate crisis

The most recent Climate Change Committee Risk Assessment highlights risks to agriculture production from climate change:

- Soil health is at risk due to increased flooding and droughts, for example, flooding causes soil erosion and compaction
- Climate change poses a direct risk to crops and livestock, including through increased exposure to heat stress, drought risk, waterlogging, flooding, fire, pest, diseases, and non-invasive species

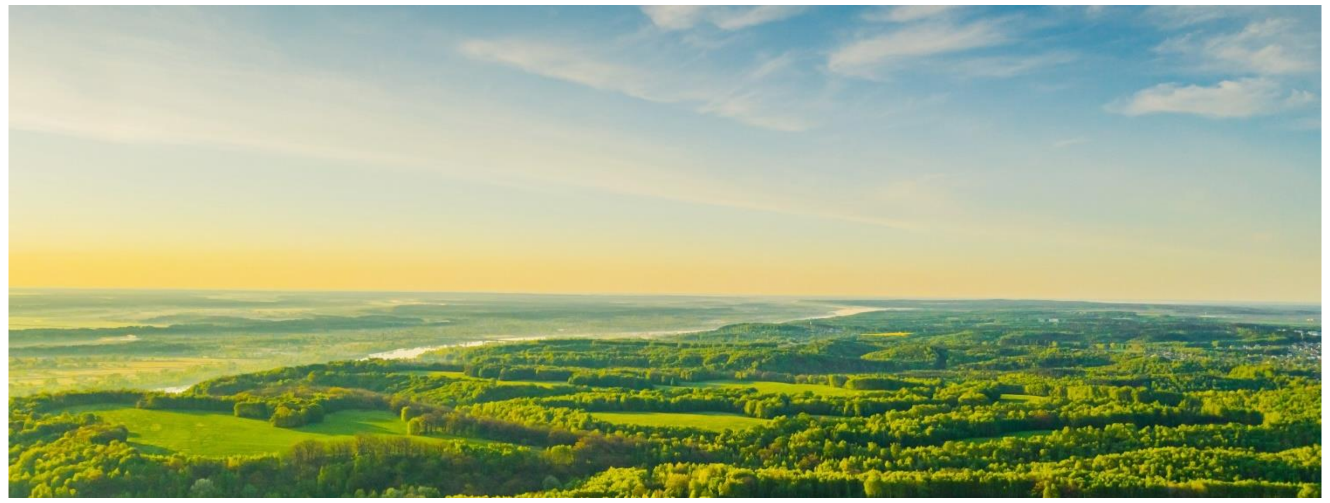
It recommends the need for more widespread adoption of farming practices for managing water and nutrient inputs and improving soil health

Obesity crisis

The Dimbleby review of the food system highlighted the obesity crisis currently facing the UK:

- One in three people in the UK is clinically obese, because of the low price and high availability of unhealthy foods
- Obesity costs the NHS £18 billion annually, is responsible for 1.5 million hospital admissions a year, and reduces life expectancy by 2.7 years

It recommends diet change and refers to the Government's "Eatwell Guide" as the closest available reference diet based on obesity and other important health outcomes.



Nature crisis

The Dasgupta review of the economics of biodiversity highlights risks to agriculture from nature loss:

- While nature is fundamental to the food system, we have degraded nature as an asset: biodiversity is declining faster than at any time in human history because it is not being properly valued and invested in
- This is putting future food production at risk, among other things

The review recommends the adoption of sustainable food systems, including reducing the use of environmentally damaging inputs, the use of precision agriculture, and integrated pest management.

Moving to net zero has wider benefits e.g.: improving soil quality can boost resilience of production, increase biodiversity, reduce run-off of water and chemicals; agroforestry boosts biodiversity and can manage flood risk; less-carbon intense diets can be more healthy.

A system approach to reducing food emissions is needed. This should address abatement opportunities through the supply chain and from demand-side changes in emissions.

Action is required at the system level

Decarbonisation of the food industry requires a systemic approach.

No single company or segment of the food system can achieve the change alone.

There is benefit in collective action.

The industry should work together to capitalise on shared knowledge, set common standards, enjoy economies of scale and engage with government.

Supply-side abatement opportunities

- **Agriculture:** Change farming practice, end land-use change, green fertiliser
- **Energy:** Grid decarbonisation, energy efficiency improvements, low-carbon heat
- **Refrigerants:** Fridges and freezers with minimal F gas emissions
- **Transport:** Fuel efficiency improvements, logistics efficiency improvements, low-carbon vehicles
- **Packaging:** Increase recycling, alternative materials, reuse

Demand-side abatement opportunities

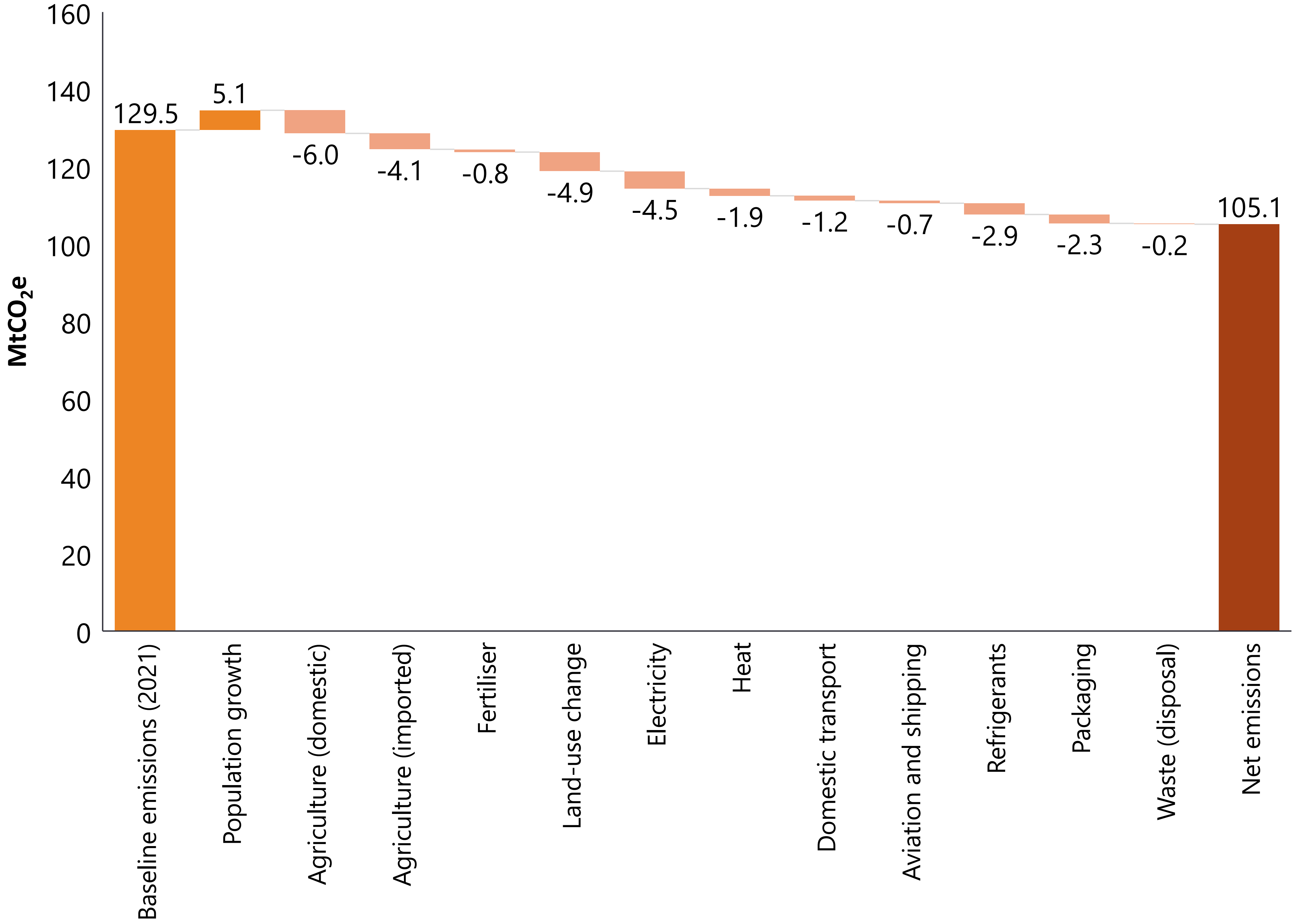
- Food waste reduction: opportunities throughout supply chain, but particularly at household level
- Diet change: eating less of the most carbon intense foods and replacing these with low-carbon alternatives

Note: in this analysis, the geographical footprint of the food system has been kept constant, however, change may be desirable given climate, nature and geopolitical risk, and a further assessment is required to test this, see page 49.

The analysis in this report suggests that there is scope for a 19% emissions cut in 2030 vs the 2021 baseline through supply-side abatement options – with opportunities to go to 25% through pushing hard on agriculture, electricity and transport. This is slightly slower than planned economy-wide decarbonisation to 2030, reflecting the dominance of (hard-to-decarbonise) agriculture in the system footprint.

Key abatement drivers for the 19% reduction are energy and fuel efficiency improvements, electricity sector decarbonisation, and reductions in agriculture and land-use change (LUC) emissions.

Supply side emissions reduction potential across the UK food system by 2030



Opportunities to go further in 2030

There is potential for a system level reduction of 25% in 2030 through system actions, with further reductions at the company level.

Agriculture

- *System:* Accelerate uptake of farming measures in the UK
- *Company:* Substitute green for conventional fertiliser; insect-based feed

Electricity

- *System:* Accelerate pace of grid decarbonisation / sign PPAs for renewable generation

Heat

- *Company:* Deployment of renewable heat (e.g. electric, biomass, waste valorisation), subject to availability of grants

Domestic transport

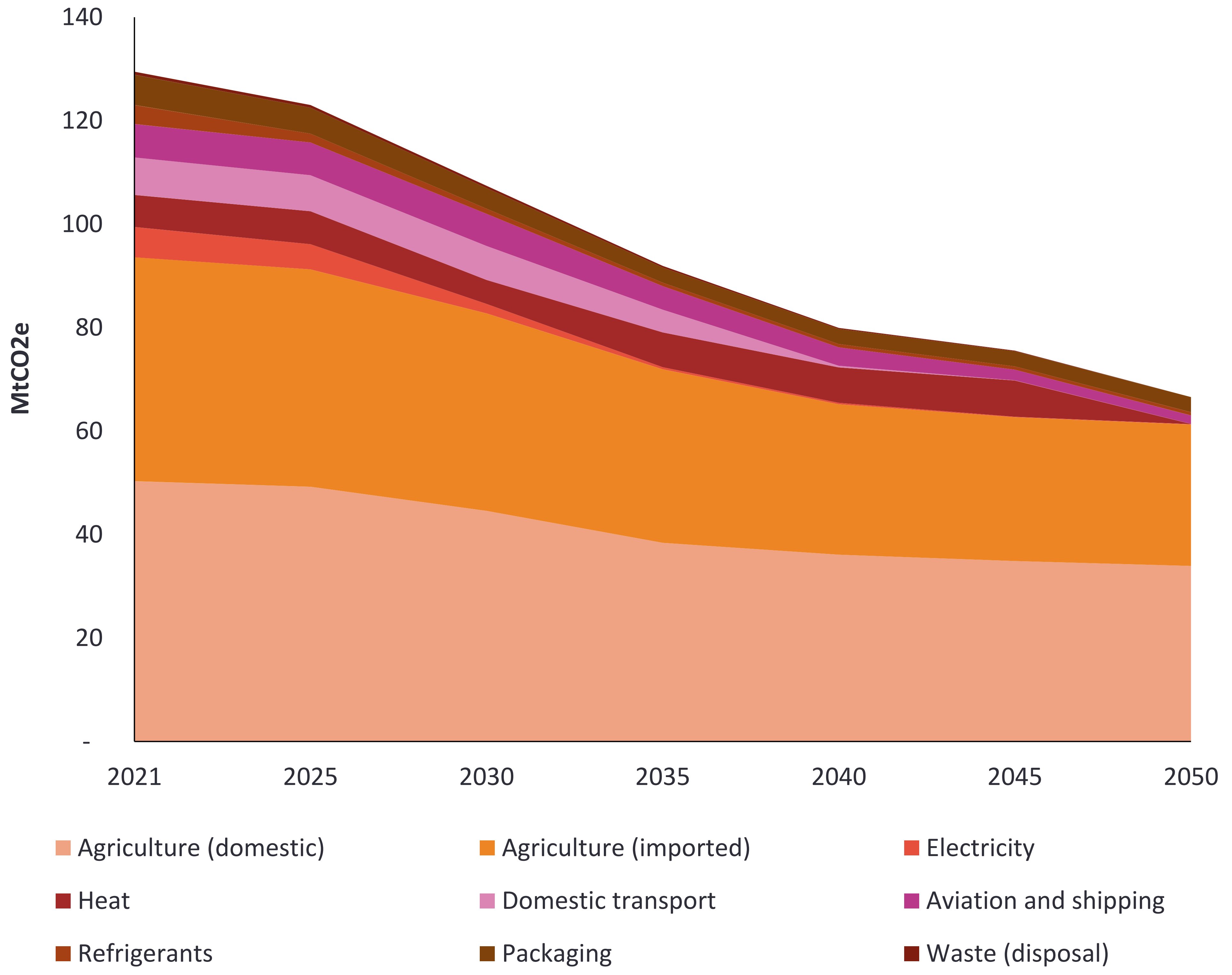
- *System:* Reduce empty running rates of HGVs; switch from road to rail
- *Company:* Use of biofuels, e.g. from waste valorisation and waste vegetable oil

The system-level opportunities offer around a further 7.5 MtCO2e abatement. Company-level trialing in areas above could help meet individual targets, but with limited scope for system scaling given feedstock constraints.

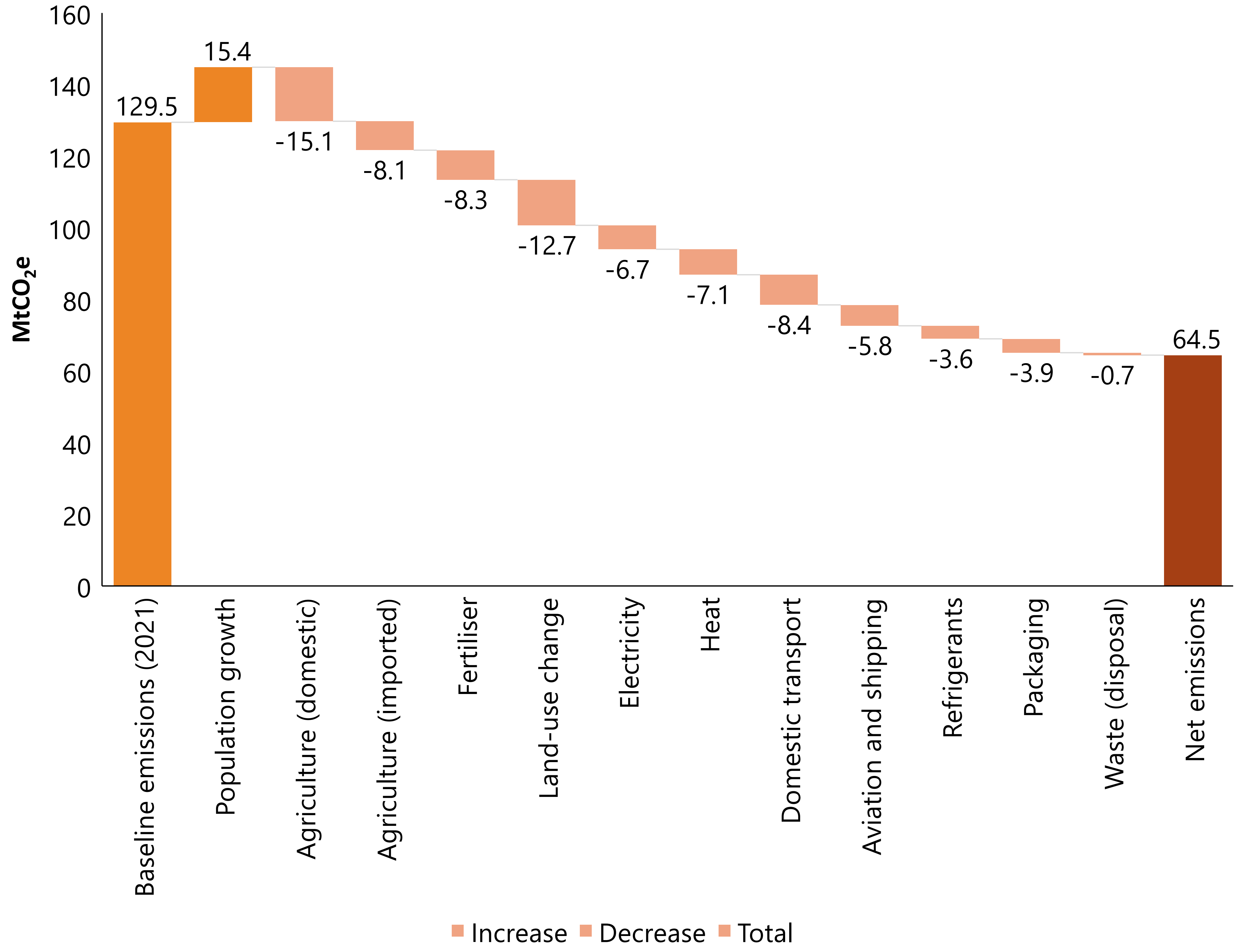
There would be further opportunities for insetting, if this were allowed to be counted against industry commitments, with a decision due on this soon by the GHG Protocol.

The analysis for this report suggests that by 2050 a 50% emissions reduction against the 2021 baseline is possible through supply-side abatement options. This includes deep cuts in agriculture emissions and full decarbonisation of fertiliser, land-use change, electricity, heat, and transport.

UK food system supply side emissions pathway by category



Supply side emissions reduction potential across the UK food system by 2050



The deep cuts in agriculture emissions reflect modelled abatement from the range of measures related to soils and livestock, together with greening of fertiliser and sustainable land-use. Less mature or more challenging measures are also accounted for.

The High Scenario (see Agriculture section) for agriculture abatement includes extensive uptake across the set of measures below by 2035:

Sub-sector	Beef	Dairy	Sheep	Pork	Poultry	Arable	Horticulture	Cross-cutting
Main decarbonisation measures	• Grass-legume mix • Feed additives • Faster LWG • Improved health • Anaerobic digestion • Other manure management • Reducing feed crop emissions	• Grass-legume mix • Feed additives • Increased milking frequency • Anaerobic digestion • Other manure management • Reducing feed crop emissions	• Grass-legume mix • Feed additives • Improved health • Reducing feed crop emissions	• Improved health • Anaerobic digestion • Other manure management • Reducing feed crop emissions	• Reducing feed crop emissions • Poultry manure	• Soil pH • Nitrification inhibitor • Cover crops • Improved drainage • Reducing Nitrogen excess	• Soil pH • Nitrification inhibitor • Cover crops • Improved drainage • Reducing Nitrogen excess	• Decarbonising fertiliser production through use of hydrogen • Decarbonising mobile machinery • Agroforestry • Avoided land-use change

There are less mature / more challenging measures beyond the High Scenario, which together offer potential annual reductions of around 15 MtCO2e:

- Use of **feed additives for grazing livestock**, for which solutions are being developed, could save **3 MtC02e** annually in the UK.
- Use of **biostimulants to reduce use of fertiliser** and associated nitrous oxide emissions, which could save **1 MtCO2e** annually.
- Use of **low-carbon feed**, which could be available in the market at scale in the 2030s, offering a potential annual saving of around **3 MtCO2e**.
- **Inter-cropping** (i.e. intense agroforestry), which offers an annual saving of around **3 MtCO2e** across an area of 700 kHa.
- Application of the above to **imported agricultural products**, offering an annual saving of around 5 MtCO2e.

Soil carbon sequestration: the abatement potential includes soil carbon sequestration related to use of cover crops. The estimates used are specific to the UK and are relatively low compared to countries with better climate conditions (e.g., France). Should clear evidence emerge about higher potential, estimates should be updated. Soil carbon sequestration is also reflected in abatement from agroforestry.

Land use change: the analysis does not include sequestration due to land-use change, e.g., through tree-planting and peatland restoration. This could be regarded as additional, depending on the decision to be made early next year by SBTi. This would not attenuate the need for agriculture emissions reductions to meet carbon budgets, given that land-use change is already fully factored in here.

While the abatement opportunities identified could deliver very significant progress towards industry-wide targets, a gap remains to meet SBTi Forest Land and Agriculture (FLAG) targets – changes in demand-side (consumption) will also be required.

SBTi provides specific targets for Food, Land-use and Agriculture (FLAG) related emissions. In contrast to SBTi targets for non-FLAG emissions which require full decarbonisation, FLAG emissions are required to be reduced by 72% to 2050, reflecting that the agricultural sector cannot be fully decarbonised. This system plan embodies supply-side options to largely deliver on Scope 1 and 2 targets, but that only go part of the way to meeting FLAG targets. Therefore, demand-side changes in consumption and food waste will also be required.

Non-FLAG emissions: 95%+ reduction

In 2030, there is potential to reduce non-FLAG emissions by around 35% through a combination energy and fuel efficiency improvement, electricity sector decarbonisation, and reductions of emissions in refrigerant emissions.

Potential abatement options have been identified to reduce non-FLAG emissions close to zero by 2050. Specifically, there is potential for zero emissions in energy and transport, with very low residual emissions related to packaging and international aviation. Further abatement may be available in practice for these categories.

FLAG: ~40% reduction

Potential to reduce overall FLAG emissions by around 40% in 2050 compared to 2021 has been identified across domestic and imported agriculture; the carbon intensity reduction is much higher given 15% projected population growth across the period to 2050.

Further options for emissions reductions may be available beyond what is modelled – see previous page – which could drive an emissions reduction of around 55% in 2050 relative to 2021.

Even in a scenario where such options come through, this would still fall well short of achieving FLAG targets.

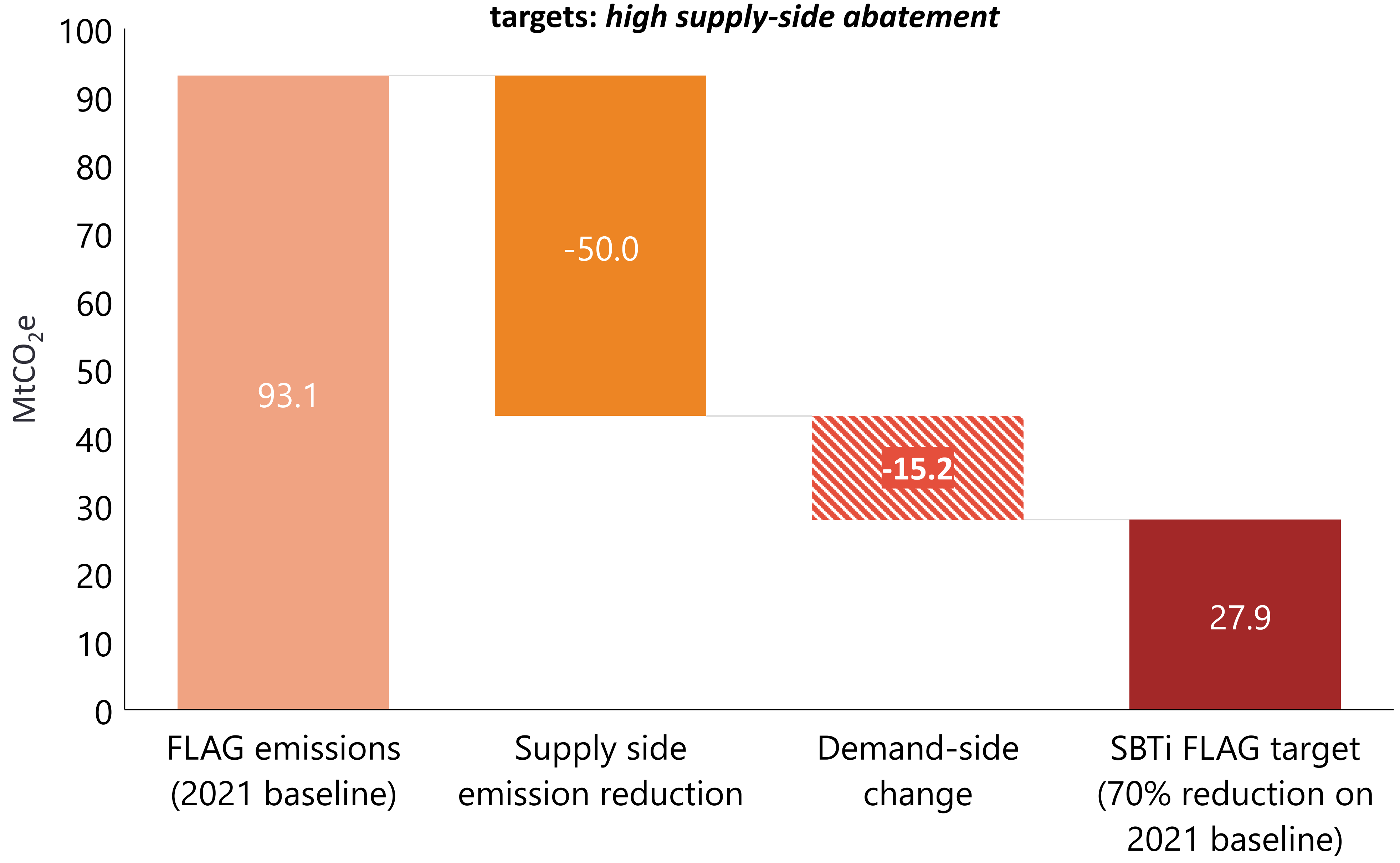
Therefore, demand-side (consumption) change will be required to reduce emissions to target alignment. The two key opportunities for demand-side change are food waste reduction and diet change.

The combination of supply-side reductions together with demand-side consumption change could lead to achievement of FLAG targets.

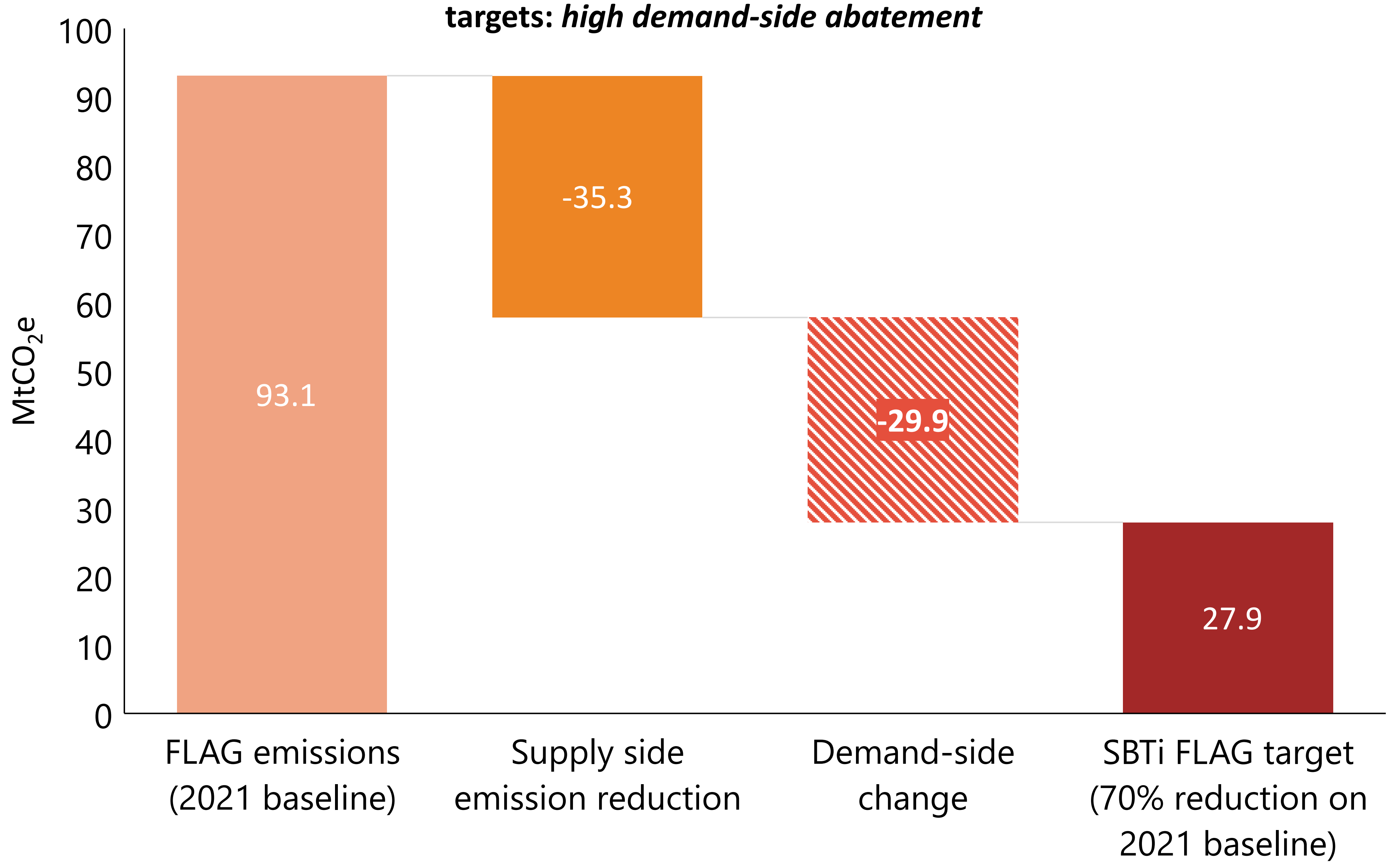
The chart on the left shows residual agriculture emissions in the high scenario plus less mature and very challenging abatement options. The former includes significant cuts from changed farming practice, with land-use change and fertiliser emissions having fallen to zero; the latter includes less mature and more challenging options from the previous page. Required emissions reductions from demand side measures to meet the 2050 SBTi FLAG are 15 $MtCO_2e$, around 23% of the total reduction on a 2021 baseline. Further supply-side reductions offset the impact of population growth.

The chart on the right shows residual agriculture emissions in the high scenario only (i.e. without abatement from less mature and very challenging measures). Required emissions reductions from demand side measures to meet the 2050 SBTi FLAG target are 30 $MtCO_2e$, around 46% of the total reduction on a 2021 baseline.

Illustrative contributions of supply-side and demand-side emissions reduction to meet FLAG targets: *high supply-side abatement*



Illustrative contributions of supply-side and demand-side emissions reduction to meet FLAG targets: *high demand-side abatement*



Demand-side: food waste reduction offers opportunities for significant emissions reductions because of its system effects – less food waste means less production required for a given demand, and consequently lower associated emissions.

Embodied food waste emissions are amongst the largest components of the food system's footprint

Around 25% of all food purchased is wasted in the UK.[1] Production emissions for food that is then wasted were estimated in 2021 by WRAP to be around 36 $MtCO_2e$. Reducing food waste has a significant impact on system emissions for this reason.

The majority of food waste occurs in households, with significant waste also occurring throughout the supply chain.

Meeting the Courtauld Commitment would significantly reduce these emissions

The Courtauld Commitment sets a target for the food industry to reduce food waste by 50% in 2030. This was based on the United Nations' Sustainable Development Goals (SDG) 12.3 (Food Loss and Waste).

WRAP estimates emissions reductions of up to 6.45 $MtCO_2e$ in 2030 through meeting the Courtauld Commitment. This would represent an additional food system emissions saving of around 5% in 2030 relative to 2021.

Progress has been made towards this target, particularly in manufacturing and retail; but much more remains to be done.

There is scope for emissions reductions linked to food waste beyond the Courtauld Commitment, which would make a very valuable contribution to FLAG targets

If the Courtauld Commitment could be achieved by 2030, there would remain a significant amount of food waste throughout the value chain. An additional ambitious reduction to 2050 has therefore been modelled, with this resulting in a further 10% FLAG emissions reduction, and very low levels of food waste in the home and through the supply chain.

This would leave a gap to 2050 FLAG target of between 4 and 20$MtCO_2e$ (4-21% of 2020 FLAG emissions) depending what can be achieved on the supply side.

1 Why we need to take action on food waste – WRAP

Demand-side: diet change towards low-carbon foods would reduce carbon emissions and can offer potential health benefits – but it should not be at the expense of health outcomes, which are complex and uncertain. Diet must remain nutritious, accessible and affordable.

Diet and net zero

Red meat and dairy foods are relatively carbon intense (see chart on the following page). WRAP has highlighted in prior publications the need for a shift in national diets to meet the greenhouse gas aspect of the Courtauld Commitment[1]. The CCC has modelled a central case ("balanced") 20% reduction in red meat and dairy by 2030, with red meat reduction of 35% by 2050; and "tailwinds" with 50% reductions in both red meat and dairy consumption in the UK by 2050.

A more conservative scenario than CCC's central case is modelled, with a 20% reduction in red meat and dairy by 2050, together with their tailwinds scenario; these result in further FLAG emissions reductions of 9% and 22% respectively, based on UK and imported abated agriculture emissions in this report[2]. These numbers assume that protein is instead gained from pulses; substitution to chicken or fish would slightly reduce emissions savings, e.g., doubling chicken and egg consumption would add around 1MtCO2e annually (less than 1% of FLAG emissions); doubling pork consumption would add around 2.5 $MtCO_2e$.

Diet and health

Nutrition impacts of diet are of paramount importance, diet change towards lower carbon foods would reduce emissions and can also offer potential health benefits but any diet change should maintain or improve nutritional balance, accessibility and affordability. This is recognised by consumers, with clear evidence that they prioritise health outcomes related to diet[3].

The Eatwell Guide is useful in this context, because it reflects consideration of health, nutrition and sustainability factors, and the benefits that can be achieved by moving more of the population's diet closer to what it recommends:

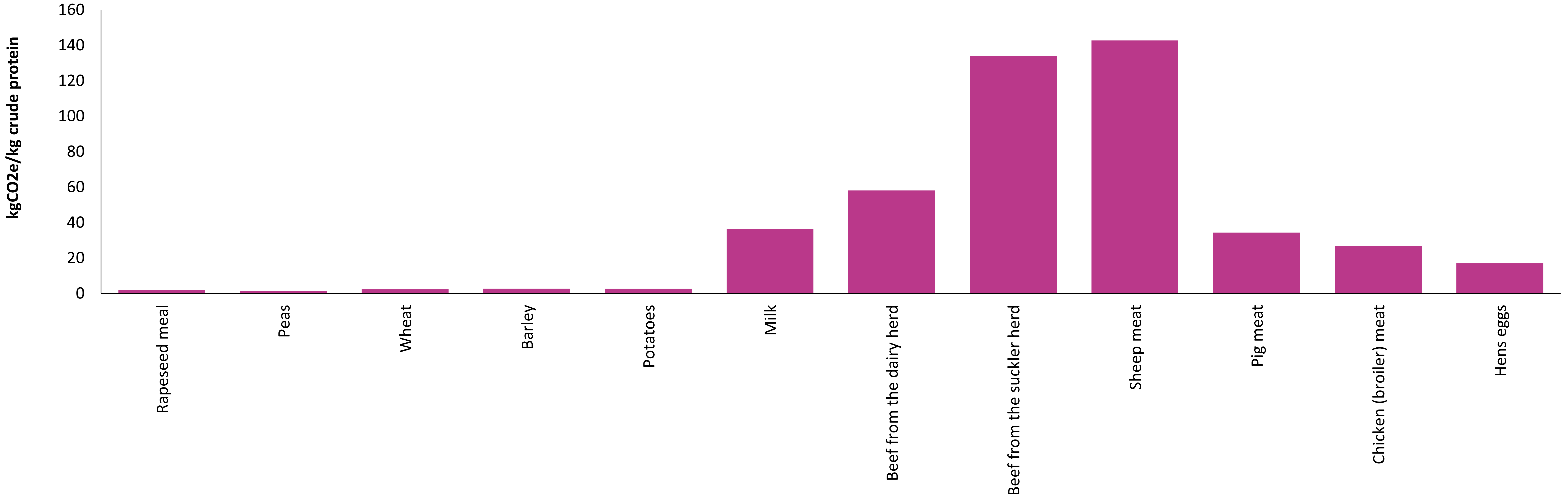
- More diverse proteins in the shopping basket, to help improve supply chain resilience and support a more nutrient dense diet;
- Grow/switch towards sales of healthier and more sustainable product choices;
- Change the balance of the basket towards more plant-rich choices.

A well-known study based on the Eatwell Guide suggests that a reduction in red meat and some dairy foods could improve health outcomes[4]. However, this should be heavily caveated: the study did not suggest lower consumption of semi-skimmed milk; consumption data upon which the study was based relates to 2008-11, since when there may have been significant changes in consumer behaviour. Therefore, dairy may be seen as an important part of a balanced diet at current levels of consumption, as per the Eatwell Guide and other international guidance[5]. Evidence from Food Standards Scotland[6] also suggests that reductions of red meat consumption could deprive people of essential nutrients, although these effects can be mitigated; a more nuanced approach is required (e.g. targeting high consumers of red meat or processed meat). More generally, the nation's diet varies greatly regionally and through different groups in society, and this should be fully allowed for when considering diet change.

1 UK Food System GHG Emissions: 2022-23 Update (Summary Report) – WRAP, 2023
2 SRUC
3 Consumer Insights Tracker February 2024 – Food Standards Agency
3 Consumer Insights Tracker February 2024 – Food Standards Agency
4 The cost of achieving the Eatwell Guide diet – University of Oxford, 2023
5 Nordic Nutrition Recommendations 2023 – Nordic Co-operation
6 Modelling the impact of reductions in meat and dairy consumption on nutrient intakes and disease risk – Food Standards Scotland, 2024

There is wide variation in carbon intensity of proteins – moving towards less carbon intense foods would reduce emissions – but this must not be at the expense of health considerations.

Carbon intensity of different foods per unit protein[1]



There is a high degree of variation in the carbon intensity of different foods, with red meat and dairy having relatively high carbon intensities by unit of protein compared to chicken and eggs. Vegetable sources of protein have a much lower carbon intensity than meat; the chart illustrates this for selected plant-based foods, chosen because they have a relatively high protein content.

1 UK Food System GHG Emissions: 2022-23 Update (summary report) – WRAP, 2023

Diet change will be needed, but to what extent will depend on how other abatement options are exercised. Health effects should be fully accounted for. Diet change does not imply the need for reduced production.

A modest change in diet could be sufficient to meet targets, depending on emissions reductions in agriculture and food waste, but greater dietary shifts can support deeper cuts in carbon emissions.

- If more challenging and less mature agriculture emissions reductions could be delivered, together with food waste reductions, a 20% reduction in red meat and dairy by 2050 would be sufficient to meet carbon targets. More would be needed if such measures are not successful.
- The 20% scenario should be regarded as illustrative. In practice, there could be more reduction in different categories of carbon intense food and less in others.
- Interventions to support dietary shift will need to be appropriately targeted to ensure the achievement of desired health outcomes. Greater alignment with the Eatwell Guide at a population level would be an appropriate direction of travel.
- **The key challenge to address is that the industry, working with government, should agree a position on diet change which balances net zero and health outcomes, fully accounting for impacts on nutrition.**

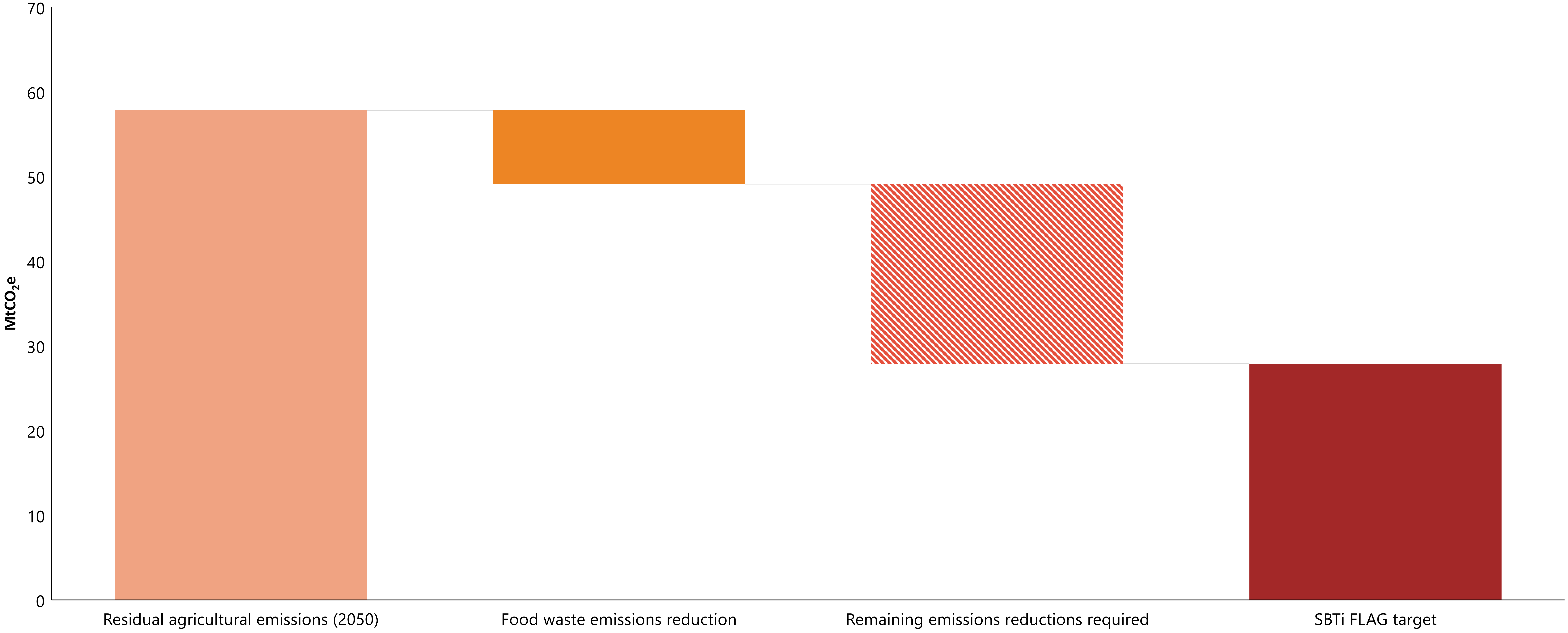
The modelling includes a 15% increase in population to 2050.

- With a proportionate increase in food demand, the consequence will be 15% growth in total food production.
- Diet change would reduce consumption per capita of certain products, and the two could broadly cancel out in terms of net impacts on production.

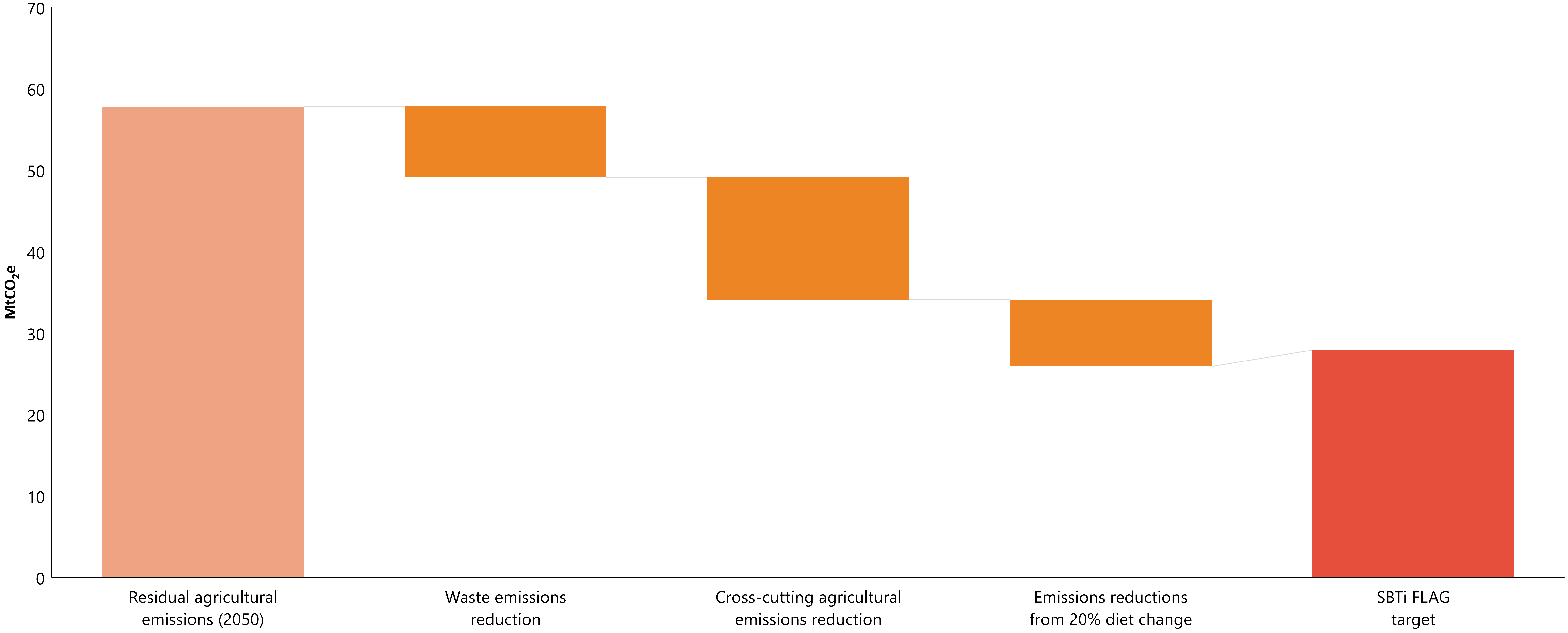
De-coupling production and consumption should be supported by trade policy

- Where there are further reductions in consumption (due to food waste reduction or diet change), this does not imply reduced production: there could be import substitution or increased exports. The rationale for this would be that the UK has relatively high environmental and animal health/welfare standards, and is comparatively climate resilient, and should therefore be supplying markets at home and growing markets abroad.
- For import substitution, this would be supported by environmental standards and carbon-based tariffs for imports and conditional trade preferences. For increased exports, trade promotion and facilitation would be the appropriate levers to build on the UK's unique selling points of high standards. Ways would have to be found to support such exports given the national carbon accounting convention based on territorial emissions, and the Government should consider this.
- It may be the case that there needs to be some land-sparing in order to achieve environmental objectives for carbon and nature; the Government should set out a draft land-use framework for consultation.

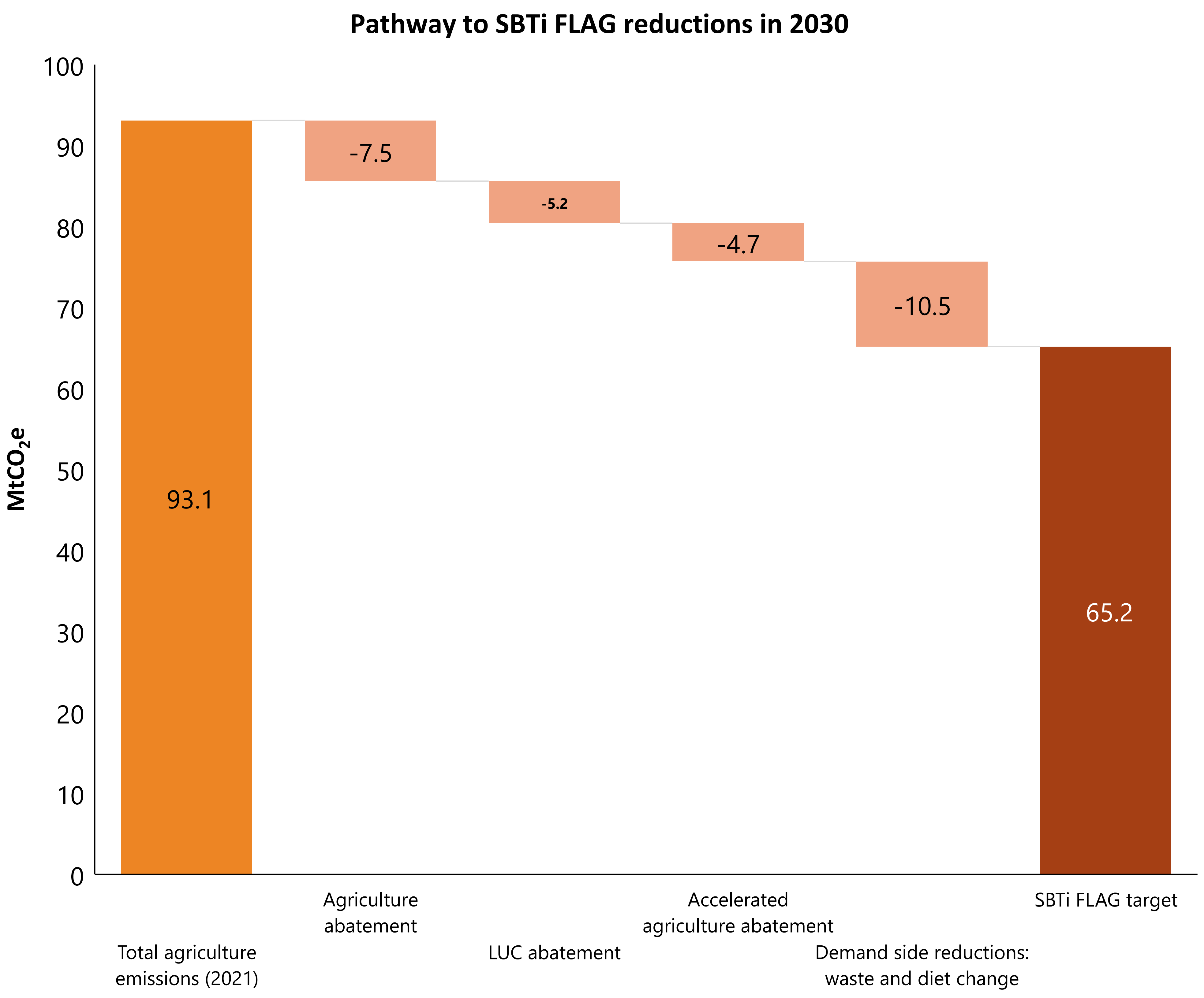
If food waste can be reduced to very low levels, in combination with the High Ambition scenario for agriculture, this would leave a gap of 20 $MTCO_2e$ to achieve SBTi FLAG targets.



In combination with the High Ambition scenario for agriculture and less mature or more challenging measures, this would leave a gap to the SBTi FLAG target which could be more than filled by a(n illustrative) 20% reduction in consumption of red meat and dairy.



SBTi FLAG 2030 targets of 30+% remain feasible but will be very challenging – they require urgent and concerted action to drive deep cuts on supply and demand sides - beyond the High Ambition agriculture scenario and / or involving diet change.



SBTi FLAG commitments to cut emissions in 2030 by 30% and above could be met but only if very ambitious emissions cuts were delivered:

Agriculture (up to 18 MtCO2e reductions)

- Emissions reductions through agriculture and avoided land-use change would be around 13 MtCO2 in 2030, compared to 27.9 MtCO2e required to deliver a 30% cut (and more to go beyond 30%).
- It is possible that further agricultural emissions reductions could be achieved by accelerating uptake of measures from 2035 to 2030 across the UK, which would result in additional savings of 4.7 MtCO2e in 2030. This would be very challenging, given incentives are not in place in DAs, and lead-times for farmer participation. **It reinforces the need for food companies to work in partnership with farmers and support their transition, within a framework of government incentives (pages 43 and 50).**

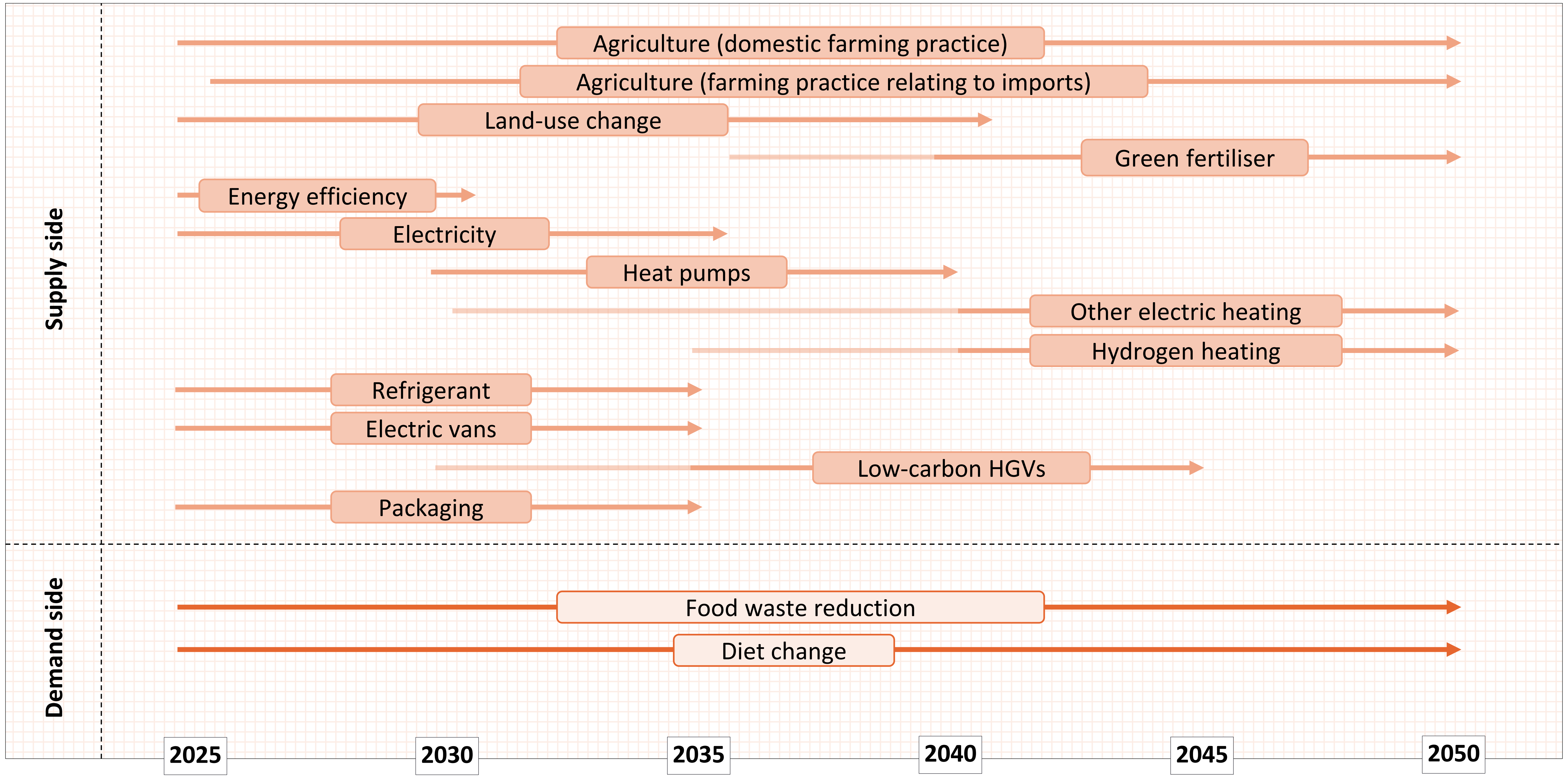
Demand-side measures (at least 10.5 MtCO2e reductions)

- Food waste reduction consistent with the Courtauld Commitment could reduce agriculture emissions by 5.6 MtCO2e in 2030; **this would require very significant change in consumer choices, supported proactively by industry and government (page 34).**
- Diet change could also contribute to agriculture emissions reduction in 2030, subject to previous caveats. **It may be the case that continuation of underlying trends could make a significant contribution here, This could be buttressed through early action by industry and government.**

The net zero transition plan for the food system to 2050 and its dependencies: technology innovation and policy development to support commercial viability.

Timing of key abatement measures

The figure shows a high-level view of the net zero transition plan for the UK food system, provided certain dependencies are met. Out to 2030, the plan is dominated by energy and fuel efficiency improvements, electricity sector decarbonisation, domestic and foreign agriculture practice and LUC. From 2030 to 2050, key areas of focus for FLAG emissions are further adoption of low-carbon practices and technologies, driving minimum emissions cuts of 40% and ideally more than 50%. For non-FLAG emissions, the focus should be completion of the transition to a low-carbon power system and electrification of heat and transport, with full decarbonisation of these sectors. Demand side requirements (food waste reduction and diet change) are a driver throughout.



Dependencies

- The plan has a number of dependencies, i.e. conditions that must be met in order for the plan to be implemented. The start dates shown opposite are consistent with what would ideally happen in the context of net zero strategy for the country.
- While there is good momentum already in many areas, these start dates will be particularly challenging for green fertiliser, electric heating, hydrogen-based heating and low-carbon HGVs. The dependencies here are new policies with very high carbon prices, and significant technology innovation. Should dependencies not be met, the pathway might entail delayed deployment of these technologies towards the end of the 2030s. Achieving net zero would then require accelerated deployment through the 2040s.
- The actual pathway will depend largely on policy implementation. Industry should engage with government on policies, make plans for low-carbon investment, monitor developments closely, and execute strategies when supporting conditions are in place. Where there is policy uncertainty, existing assets should be extended as long as possible.

Repeated from Executive Summary:

Costs of decarbonisation: Funding of at least £500 mn annually will be required to support low-carbon agriculture measures – without this, key measures will not be adopted by farmers.

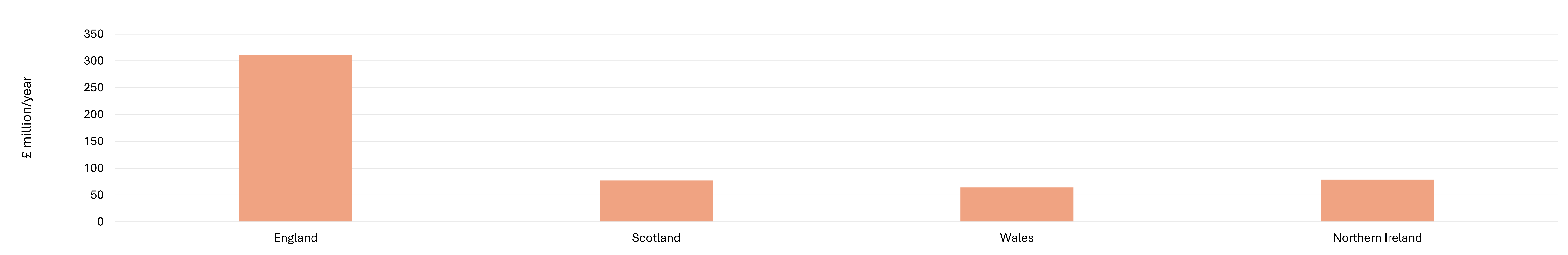
There are two categories of measures for agriculture abatement: those that save money and those that cost money on a net basis.

Even for the former, farmers will need to be supported in their net zero transition. For example, it is recommended that funding should be made available for farm-level carbon audits, benchmarking and planning; in Northern Ireland, these are funded in effect through direct payments, for which they are a qualifying condition. There are some measures where there is lag between investments and payoffs. Again, these will have to be funded.

Measures which cost money will have to be funded or they are highly unlikely to be adopted. While a net cost, these pass a value-for-money (VfM [return on public investment]) test: abatement costs are well within the UK Government's carbon values, and there are significant nature co-benefits. Annual costs are estimated of the order £500 mn, which are distributed across England and the DAs as shown in the chart below. These are funded in England under ELM, and it is recommended that these should similarly be funded in the DAs. Funding would typically be in the form of ongoing payments, given the vast majority of costs are operating. For the fewer measures where there are significant capital outlays, these should be funded through grants; for example, grants are available for slurry investment in England and Scotland. Over time, grants for low-carbon mobile machinery are likely to be needed.

There are much higher costs associated with supporting the broader farming transition and meeting national environmental objectives, which requires a more extensive scope of changed farming practice together with taking land out of production (e.g., for forestry, peatland restoration and nature recovery). For example, a recent NFU report estimated this cost to be over £4 bn annually[1].

Positive abatement cost per DA in 2050 (Section 3.4)



1 An agricultural budget that delivers for the environment – NFU asks of government – NFUonline, May 2024

Repeated from Executive Summary:

Costs of decarbonisation: There are significant costs of decarbonisation currently facing the food system. These relate to imported agriculture, sustainable feed and commodities procurement, and sustainable packaging.

Net cost and capital cost are differentiated: the former reflects any operating cost savings associated with the latter. Costs of low-carbon options are compared with business-as-usual alternatives. Costs are assessed on an annual basis to allow comparison with system revenues and consequently infer potential price impacts, as is the convention in effective transition planning.

To 2030:

Net costs:

In addition to domestic agriculture, there are three significant areas of cost related to decarbonisation facing the food system:

- **Imported agriculture:** Where the recommendation is that farming costs in the UK should be funded by government, there is not an equivalent mechanism for imported products. It is recommended that an industry programme should be considered to reduce emissions from imported products. While this would be costed as part of scoping work, based on UK costs and a comparison of farming products in the UK and foreign supply chains, funding of several hundred million pounds annually could be required.
- **Commodities caught by deforestation regulations:** There will be a premium associated with sustainable soy and commodities. This is currently uncertain, with a wide range of estimates in the market related to cost premia for EUDR. However, across the range of commodities, this could be in the hundreds of millions of pounds at the system level. It should only be temporary, because costs associated with establishing new supply chains and traceability systems are non-recurring.
- **Sustainable packaging:** There are a range of policies to drive sustainable packaging (e.g., EPR, plastics tax, PRNs), which together would add around £2.5 billion annually according to industry estimates.

Capital cost:

There are significant capital costs in the near term related to energy efficiency improvement. While related investments should have short payback periods, they still need to be funded (e.g., for waste heat recovery). Replacing ageing cold storage also requires large investments. These have typically been costed at the company level and included in financing plans. For purposes of illustration, the CCC estimates an annual investment requirement of £300 million across all industry for energy efficiency improvement. Costs associated with Anaerobic Digestion (AD) and renewable heat will need to be funded if they are to happen.

Repeated from Executive Summary:

Costs of decarbonisation: Beyond 2030, there will be further costs equivalent to 1-2% of system revenues, related to heat, transport and fertiliser decarbonisation. There will be significant capital requirements throughout the period for low-carbon investments.

To 2050:

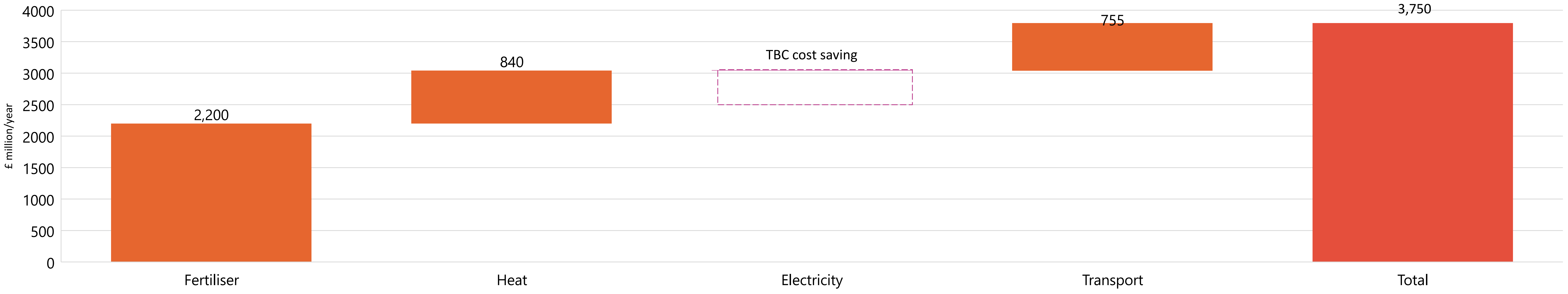
Net costs (additional to 2030):

Net costs will be added to the system through renewable heat, low carbon-HGVs and green fertiliser. For full abatement approaching 2050 across these three categories, the associated costs are estimated to be around £3.5 bn annually, which is equivalent to around £1.5 bn in present value terms, i.e. 1-2% of annual food expenditure of £140 bn. New policies will be required, with these costs to be funded by government (e.g., grants) and/or consumers (e.g., carbon pricing impacting food prices).

Capital cost:

There will also be significant capital outlays required for these technologies. For example, heat pump capital costs are around 4-8 times those of gas boilers, and battery HGVs are currently 3.5 times the capital costs of conventional alternatives, with further investment required for charging infrastructure. This raises a question about how investments can be financed within capital constraints. Opportunities to be considered further here are the roles for sustainable finance from banks (i.e. finance dedicated to support sustainability) and for government finance, to complement commercial finance.

Annual cost of decarbonisation 2050[1]

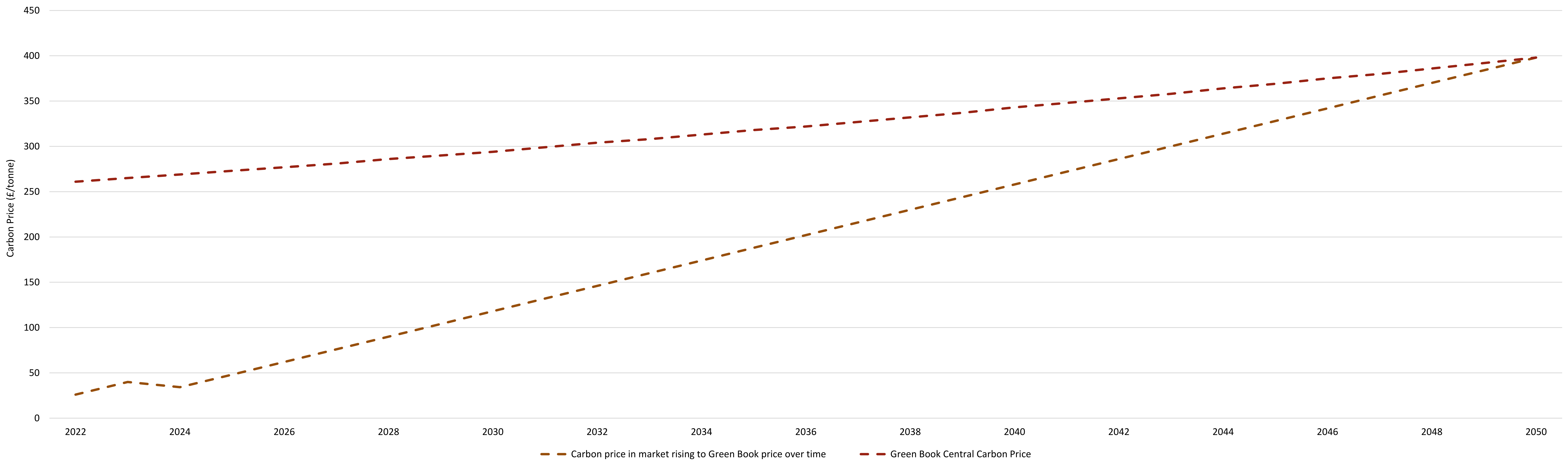


* Refer to pages 139 (fertiliser), 125 (heat), 121 (electricity), 144 (transport) for more detail

Costs of decarbonisation: Offsetting residual emissions through purchase of credits in the market would be very expensive compared to abatement measures – emphasising the need to unlock emissions cuts through this plan in order to manage costs.

If residual emissions of around 30 MtCO2e in 2050 were to be offset through the purchase of credits, this would be very expensive. For example, while the cost of credits in 2050 is highly uncertain, this is likely to be above £200/tCO2e (see graph below) implying a total cost of £6 billion annually (i.e., well exceeding the costs of industry-wide abatement outlined above). This highlights the importance of pulling policy levers for demand-side consumption change (food waste and diet change). It also highlights the benefits of early investment in insetting, as the value of related assets should grow very significantly over time. Determination of a carbon credit strategy does not need to be an immediate priority. However, there should not be an assumption that this will be used to get to net zero.

Carbon Price Projections



The food industry should embrace ambition consistent with SBTi targets for 2030 – and deliver this through driving action and managing dependencies.

Subsector	2030 ambition	Levers	Key players	Dependencies
UK agriculture	22% reduction versus 2021	• Very extensive uptake of key abatement measures across UK • Reduced LUC emissions	• Industry • UK and DA governments	• Overcoming financial and non-financial barriers to uptake of measures through policies and industry support • Deforestation regulation
Imported agriculture	15% reduction versus 2021	• Uptake of abatement measures in supply chains • Reduced LUC emissions	• Industry	• Successfully setting up a programme to support farmers outside the UK • Deforestation regulation
Power sector	70-100% reduction versus 2021	• Grid decarbonisation • Signing of PPAs	• Government • Industry	• Pace of grid decarbonisation
Energy efficiency improvement	20% reduction in energy consumption and emissions	• Investment in energy efficiency	• Companies	• Capital availability
Transport decarbonisation	10-30% emissions reduction versus 2021	• Electric vans • Fuel efficiency improvement • Reduction in empty running	• Companies	• Successful coordination across logistics companies to reduce empty running
Refrigerants	73% emissions reduction versus 2021	• New fridges with low fluorinated greenhouse gas (F-gas) emissions	• Companies	• Capital availability
Packaging	32% emissions reduction versus 2021	• Increased recycling and reuse • Alternative packaging	• Industry • Companies • Government	• Policies to support recycling and reuse • Recycling capacity
Food waste	Deliver Courtauld Commitment	• Build on efforts in supply-chain; develop approaches to reduce household food waste	• Industry • Government	• Consumer response to industry and government efforts
Diet change	TBC	• Moderate consumption of carbon-intense goods subject to nutrition objectives	• Industry • Government	• Agreement on approach • Consumer response to industry and government efforts

Detailed actions, metrics and leading indicators should be set following agreement on ambition and related levers.

Policy strengthening will be essential in order to align government and commercial objectives to deliver emissions reductions. The industry should engage with the UK Government on the areas outlined below.

	Problem to be solved	Policy/action	Alignment with government objectives	Budget
Farming budget	Current uncertainty over how the overall farming budget will be spent, particularly as regards land-sharing versus land-sparing.	Confirm farming budget to support net zero and wider sustainable farming practices; and publish a land-use framework, including ambition and funding.	Government has previously expressed commitment to focus on land-sharing, but has not published a land-use framework setting out the balance between land sharing and sparing.	The cost of funding all low-carbon measures in England is low relative to the farming budget (e.g. £310 mn versus £2.4 bn), much of which remains unallocated. However, it is important to recognise that this budget also needs to support broader environmental objectives.
Farm-level carbon planning	Need to boost uptake of the Sustainable Farm Incentive from current low levels.	Strengthen incentives for farm-level agri-environment practices through funded carbon audits, benchmarking and plans for farmers, to buttress their engagement with sustainable farming and related schemes.	Government wants to engage farmers and has previously acknowledged the benefit of farm planning to this end. Government needs a carbon baseline against which to assess scheme impacts.	To be determined by government as part of a review, noting there is a wide range of options currently in use, from light-touch tools to more extensive audits.
Sustainable Farming Incentive uptake	Current low levels of uptake for the Sustainable Farming Incentive (less than 25% of eligible farmers including recent EOIs) could reflect still low financial rewards, particularly for more productive farms who are penalised under the income-foregone approach.	Assess impact on uptake from uplifting payment rates in the Sustainable Farming Incentive scheme and consider the case for a further increase to improve uptake across farming types.	The Government is committed to increasing uptake of the Sustainable Farming Incentive and has previously increased payment rates to this end.	This could cost £10s of millions depending on the increase.
Feed additives	Feed additives are cost-effective from a societal but not a commercial perspective.	Extend farming support schemes to include full or partial payment for use of feed additives to support rollout.	The Government has previously recognised the importance of feed additives in its net zero strategy.	A cost of £65 million annually is estimated to support full rollout of feed additives for dairy, with lower costs for partial funding, lower levels of uptake, and falling prices as scale is reached; based on feed additive recently approved by the Food Standards Agency.

Policy strengthening will be essential in order to align government and commercial objectives to deliver emissions reductions. The industry should engage with the UK Government on the areas outlined below (cont.).

	Problem to be solved	Policy/action	Alignment with government objectives	Budget
Anaerobic digestion (AD)	Funding available for farm AD will end in 2028, such that socially desirable investment may not happen.	To commit a new round of funding to support farm AD for farm waste (not crops).	The Government recognises that AD is an important part of net zero strategy and that this requires funding.	It is currently funded; extending this beyond the current window would require the same fiscal space as now; annual funding across all sectors of the economy is £200 mn.
Stacking of benefits / framework for accessing private finance	Limited opportunities for farmers to monetise benefits of improved farming practice beyond government schemes.	Develop a framework for farmers to access private finance, namely through generating revenue from carbon and nature markets and selling of ecosystem services, over and above what they are paid for through ELM, in order to monetise benefits of sustainable farming. This should take into account any new industry schemes.	If the Government is to achieve its environmental objectives, it will need farmers to do more than can be paid for through schemes.	While the farming budget is sufficient to fund the net zero measures identified in this report, it is not sufficient to fund the full range of activities to achieve national environmental objectives, which will need to leverage private finance.
Farm regulation	Farm regulations are largely inherited from the EU Common Agricultural Policy (CAP) and were designed to achieve previous objectives. In some cases, they are at odds with net zero objectives (e.g. the Farming Rules for Water do not support the use of organic fertiliser).	Undertake a regulatory review with respect to three objectives for farming: food production, net zero, nature.	The government should support a review to ensure alignment of regulations with its own net zero and wider objectives.	A regulatory review has limited budget implications.
Deforestation legislation	Imports of soy and tropical commodities are associated with deforestation and land conversion, with significant adverse consequences for climate and nature.	Introduce a regulation that prevents land use change from imports of soy and tropical commodities consistent with the EUDR, while managing risks related to land conversion.	The Government is committed to tackling emissions associate with deforestation and land conversion.	Associated costs fall largely on industry rather than government.

Policy strengthening will be essential in order to align government and commercial objectives to deliver emissions reductions. The industry should engage with the UK Government on the areas outlined below (cont.).

	Problem to be solved	Policy/action	Alignment with government objectives	Budget
Farm data	There are many competing methodologies for calculating farm carbon footprints, leading to unnecessary administrative burdens for farmers and lack of confidence in data.	Standardise carbon calculations, data and reporting through agreeing common methodologies and standards. These should differentiate between different types of farming practice and, as a matter of urgency, reflect improvements due to SFI participation. With more confidence in data, reporting should be mandated, to support consumer decision making.	This is well aligned with the Government's Food Data Transparency Partnership (FDTP).	The value add of the Government is to act as a facilitator and to set standards. Budget implications are limited, although it is important to ensure that FDTP is adequately resourced.
Trade policy	There is a risk that domestic production held to high environmental standards could be displaced by imports produced to lower environmental standards.	Ensure a level playing field between domestic produce and imports through common environmental standards, border tariffs for carbon-intense products, and trade preferences in Free Trade Agreements related to environmental standards and animal health/welfare; export promotion and trade facilitation for British products.	The Government is committed to a level playing field to ensure protection of UK production.	Budget implications are limited for import measures; affordability impacts limited given small share of carbon costs in total household food expenditure; funding is already available for exports and should be continued.
Agriculture – Welsh Government	Incentives for uptake of net zero measures are currently limited.	Ensure that net zero measures are funded under the new Welsh framework, by testing them against the key net zero measures identified in this report to ensure that there are no gaps.	The Welsh Government is very committed to supporting farmers on their net zero and nature-positive transition; agriculture emissions are 15% of total greenhouse gas emissions in Wales.	The Welsh farming budget is being repurposed to support this transition; required funding for net zero measures is around £65 mn, relative to a farming budget of £420 mn.

Policy strengthening will be essential in order to align government and commercial objectives to deliver emissions reductions. The industry should engage with the UK Government on the areas outlined below (cont.).

	Problem to be solved	Policy/action	Alignment with government objectives	Budget
Agriculture – Northern Ireland Government	Financial incentives are very limited under current policies, and measures are unlikely to be taken up.	Provide financial incentives for the key measures identified in this report to drive down emissions from dairy and beef farming, which dominate Northern Ireland's farming carbon footprint.	The Northern Irish Government recognises the benefits of the key measures for driving down agriculture emissions.; agriculture emissions are 25% of total greenhouse gas emissions in Northern Ireland.	Funding of financial incentives would require repurposing of the farming budget, along the lines of what is being done in England and Wales; required funding for net zero measures is around £80 mn, relative to a farming budget of £550 mn.
Agriculture – Scottish Government	Financial incentives are very limited under current policies, and measures are unlikely to be taken up.	Provide financial incentives for the key measures identified in this report to drive down emissions from dairy and beef farming, which dominate the carbon footprint of farming in Scotland.	The Scottish Government recognises the benefits of the key measures for driving down agriculture emissions; agriculture emissions are around 15% ot total greenhouse gas emissions in Scotland.	Funding of financial incentives would require repurposing of the farming budget, along the lines of what is being done in England and Wales; required funding for net zero measures is around £80 mn, relative to a farming budget of £330 mn.
Grid decarbonisation	Uncertainty over the pace of grid decarbonisation and related contribution to carbon commitments for the industry.	Clarify target date for grid decarbonisation (2030 vs 2035) and disclose credible plans to achieve this. Change regulatory guidance to support running of freezers at 15 degrees, to unlock energy efficiency savings.	Power sector decarbonisation is one of the new Government's missions, and 2030 decarbonisation was a manifesto commitment.	Power sector decarbonisation is funded by consumers (at limited cost relative to a counterfactual of running the system on combined-cycle gas turbine) .

Policy strengthening will be essential in order to align government and commercial objectives to deliver emissions reductions. The industry should engage with the UK Government on the areas outlined below (cont.).

	Problem to be solved	Policy/action	Alignment with government objectives	Budget
Heat	Currently the relative prices of gas and electricity are imbalanced, given lack of a carbon price on the former and policy cost uplifts to the latter.	Incentivise decarbonisation of heat processes in the food system by extending the Industrial Energy Transformation Fund (IETF) to support interim investment in low-carbon heat technologies. Rebalance gas and electricity prices, adding carbon costs to the gas price and removing policy cost uplifts from the electricity price.	Heat decarbonisation is required to meet legislated carbon budgets.	This would be a continuation of current funding for the IETF.
Grid connection	While electrification of food manufacturing and logistics is an important part of food system decarbonisation, current grid connection timelines can be many years.	Food companies and logistics companies should be prioritised for grid connection from the 2030s, which is when electrification becomes an important part of food system decarbonisation.	Heat and logistics decarbonisation through electrification are an important pillar of the Government's decarbonisation strategy.	Grid connection costs would either be paid for by companies or socialised across electricity consumers.
Transport decarbonisation and hydrogen economy	Transport decarbonisation and use of hydrogen have an important contribution to make to sector decarbonisation.	Building on participation of food companies in current programmes for transport decarbonisation (vehicles and infrastructure) and development of the hydrogen economy, ensure continued uptake as efforts are scaled up.	Transport decarbonisation and development of a hydrogen economy are key pillars of the Government's decarbonisation strategy.	Programmes are funded in these areas.

Further work is required to assess system resilience and land-use, and to develop a program for driving down imported agriculture emissions.

System Resilience

As previously noted, the analysis for this plan assumes that the geographic footprint of the system remains constant. In practice, it is not clear whether the current footprint is optimal, in light of climate, nature and geo-political risks on the one hand, and the need to take land out of production in the UK on the other. This is further cast into doubt with potential impacts of trade deals on supply chains.

A next step from the current project would be to assess supply chains with respect to these factors in order to identify vulnerabilities and mitigating mechanisms, whether this be might land-use change in the UK, or invest in vertical farming, or for design of trade deals and border tariffs.

This a very live issue for Government, and an existential issue for the industry, on which it does not currently have a position.

Imported Agricultural Emissions

As previously noted, these form a major part of the system drive change. The optimal solution would be to establish a pan-industry programme and platform for supply-chains outside of England, which would function similarly to the Sustainable Farming Incentive (SFI) in England, except that this would be funded by industry. The benefit of a pan-industry approach would be to establish common standards and to benefit from economies of scale.

Repeated from Executive Summary:

Implementing the System Plan: Areas for Action

Asks of government

What: In this strategic plan there are 19 asks of government (see previous pages), which are key to supporting a level playing field and providing incentives for action to net zero.

Action: Industry to engage with government on policy asks at the earliest opportunity.

How: Structured discussions between industry and government convened by IGD.

Collective industry action

What: The areas for collective action are many, but prioritisation is needed in those which will generate faster progress to net zero and model ways of driving system change, taking account of the nature emergency and human health. There are a set of proposed areas, which have been under discussion with representative sector organisations from across industry since April this year.

Action:

Supply

1. Supporting farmers to join schemes through facilitation and incentives, in order to boost adoption of low-carbon practices (reduced fertiliser use, feed additives, etc.).
2. Convening on soil carbon, to understand the evolving evidence base and draw out implications for transition planning in the sector, including potential opportunities for farmers.
3. Aligning and further driving detailed design of regulation for deforestation-free soy and its implementation, to minimise costs while achieving policy objectives.
4. Consultation on establishing an import standard platform and programme for adoption of low-carbon practices in foreign supply chains.

Demand

5. Recommitting to reducing household food waste with greater adoption of all proven tactics across businesses.
6. Aligning industry to a position on diet change that balances net zero and health objectives, including an action plan.

How: IGD in partnership with WRAP to convene working groups to identify approaches for developing strategies and action plans in each of the above areas. These should be done on the basis of clear mapping of existing forums/initiatives/working groups to avoid duplication and ensure efficiency.

Sector and company transition plans

What: Sector and company transition plans should be aligned with – or go beyond – the strategic plan.

Action: Review sector and company plans against the strategic plan and update as appropriate, and be open to sharing learnings.

How: IGD to support this process and to facilitate greater sharing of learnings through lifting outputs into progress reporting (see below).

Review of progress

A first overall review of progress from the plan and the areas for action above will be publicly shared via a Webinar and Food System Net Zero Transition Plan Progress Report in June 2025, then bi-annually with a focus on the progress of actions.

02 Report methodology and key assumptions

Methodology: The criteria and assumptions informing the reduction pathways
The emissions reduction pathways build in abatement options which are assessed to be feasible and cost-effective.

Pathways have been developed based on assessment of feasible and cost-effective abatement opportunities for each component of the system footprint.

Feasibility of abatement options relates to technology readiness, ability to absorb technology into the capital stock given asset lifetime and turnover, and any barriers to uptake.

Cost effectiveness assessment compares the cost premium of low carbon options with the UK Government's carbon values and determines that options should be in scope where the former is less than the latter. It is important to note that this does not ensure commercial viability, which will require policies to be in place to mimic the effect of the carbon values, either in the form of carbon prices, grants or regulations.

Assumptions

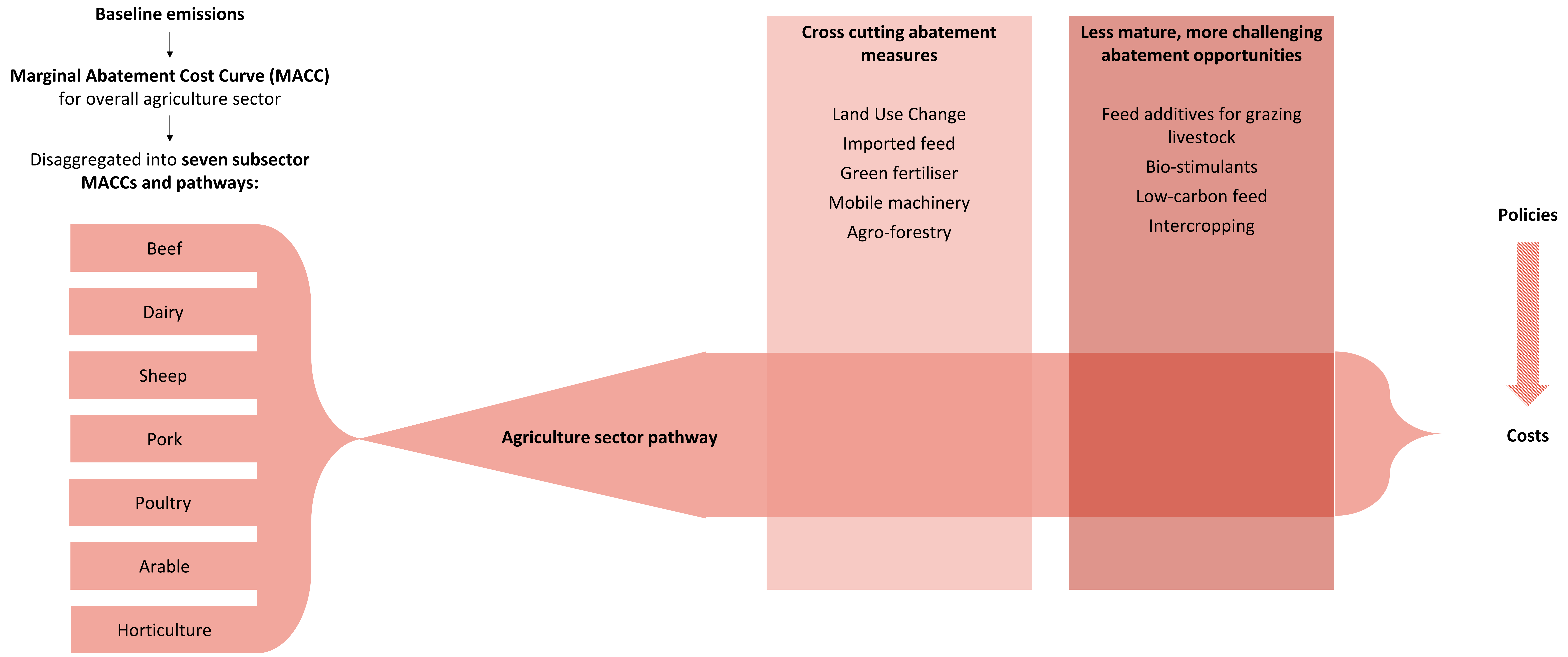
- UK population is assumed to grow in line with Office of National Statistics projections, reaching 78 million by 2050 (i.e. ~15% increase from 2021).
- Food demand is assumed to grow in line with the population, therefore making net zero more challenging.
- The geographical footprint of the food system is assumed to remain constant over time. There are important questions about whether this should change, on the one hand to strengthen resilience, and on the other to achieve domestic environmental objectives. A separate study is proposed to test how these factors should be balanced through industry resilience and land-use strategy.

Sources - sources are named and linked throughout the report where relevant.

- WRAP has contributed to the report and their estimate of the food system carbon footprint in 2021 was used as a basis.
- Scotland's Rural College (SRUC) has contributed to the report and their analysis of abatement opportunities in the UK is used; this is consistent with analysis used by the Climate Change Committee for its seventh carbon budget advice. SRUC have provided various scenarios; given the levels of abatement required across the food system, we have used the high ambition scenario.
- Climate Change Committee analysis is drawn on for various industries.
- Evidence and analysis published by the UK Government is used, alongside discussion with representatives from the DAs.
- Extensive discussions with stakeholders through the food supply chain and evidence that they have provided has been drawn on.

03 Reducing agriculture emissions at home and abroad

Reducing agriculture emissions in the UK and beyond: the approach



Reducing agriculture emissions in the UK and beyond: the approach (continued)

This table summarises the analytical approach to abatement opportunities in agriculture, both in the UK and relating to imported products. The aim is not to set out detailed agriculture sub-sector plans, which already exist (e.g., dairy and beef roadmaps). Rather, an evidence base is presented to further inform such plans in terms of ambition, key abatement levers, costs and supporting policies. The analysis is consistent with and complementary to these roadmaps, which should be reviewed in light of the evidence base presented.

Component	Approach
Baseline	The agriculture emissions baselines are from 2021 and based on the UK greenhouse gas inventory. The baseline is increased in line with population growth to 2050, with the assumption that demand for food increases proportionally. Productivity improvements for livestock are included in the baseline to 2030; these largely offset the impact of demand growth. After that, further productivity improvements are modelled as abatement options.
Marginal Abatement Cost Curve (MACC) for UK agriculture	From the baseline, abatement opportunities are netted as modelled in a Marginal Abatement Cost Curve (MACC) for UK farming developed over many years by Scotland's Rural College (SRUC). The MACC has been used widely by government, the Climate Change Committee and the private sector, and peer-reviewed by independent experts. For this report, the MACC was extended to cover the full carbon footprint of UK farming, by incorporating imported feed (including LUC emissions) and fertiliser production. The MACC was also cut on a sectoral basis, rather than the normal presentation in terms of gases (methane, nitrous oxide, carbon dioxide); sub-sectoral consideration reflects the organisation of the food industry in practice. As far as we know, it is the first of its kind in these respects. The MACC is the best estimate of emissions reduction opportunities based on current evidence. It includes measures around which there is a good degree of confidence relating to abatement potential and cost. SRUC regularly updates the MACC to reflect advances in science and innovations. Such updates should then be reflected in the decarbonisation approach that is recommended, with potential changes in the balance of effort between different abatement options (e.g. supply versus demand side). The MACC focuses on farming emissions and does not include LUC abatement measures such as afforestation or peatland restoration. These are highly valuable in the context of the UK's broader carbon strategy. To the extent that the Greenhouse Gas Protocol and SBTi approve the use of insetting in the context of meeting carbon targets, these may be seen as providing additional decarbonisation options. However, they should not be seen as alternatives to the farming emissions in this analysis. The MACC reflects the current scientific evidence on carbon sequestration. This is modelled as occurring through measures such as cover crops and agroforestry. If new evidence is found regarding sequestration, either from existing farming practices or new approaches (e.g. to change soil biology), these should be included as updates to the analysis, rather than built in at the current stage; given their uncertainties, they cannot currently be relied on. It is noted that at time of writing, a carbon removals taskforce is being established through the BRC Mondra coalition including expert organisations to answer questions around the inclusion of carbon removal mitigations in food business GHG inventories.

Reducing agriculture emissions in the UK and beyond: the approach (continued)

This table summarises the analytical approach to abatement opportunities in agriculture, both in the UK and relating to imported products. The aim is not to set out detailed agriculture sub-sector plans, which already exist (e.g., dairy and beef roadmaps). Rather, an evidence base is presented to further inform such plans in terms of ambition, key abatement levers, costs and supporting policies. The analysis is consistent with and complementary to these roadmaps, which should be reviewed in light of the evidence base presented.

Component	Approach
Subsector pathways	Seven subsector pathways are created: beef, dairy, sheep, pork, poultry, arable, horticulture. These reflect net emissions, i.e., baseline emissions minus abatement through the set of options in the MACC relevant to the subsector in question. Two pathways are developed for each subsector: Central and High Ambition. The latter reflects high rates of uptake of abatement measures. This report focuses on the High Ambition pathway, given the need for deep emissions cuts across agriculture to meet targets and carbon budgets. The pathways do not represent all abatement options relevant to subsectors: there are cross cutting options which are built into the overall emissions pathways but do not include in subsector pathways, given lack of data at the subsector level. The pathways should be seen as scenarios that could help inform development of sector plans, as outlined in the proposed next steps for industry action. They should not restrict ambition in individual or sector plans, should there be clear evidence that more is possible. It is possible to go beyond High Ambition through faster adoption of measures by farmers, and indeed it is recommended that this should be the aim, particularly to meet 2030 SBTi FLAG targets (page 37).
Cross-cutting abatement opportunities	Cross-cutting options include decarbonisation of mobile machinery and agroforestry. While reduction of land-use change emissions and green fertiliser are included in subsector pathways, these are considered as cross cutting issues, to provide more details on abatement approaches.
Less mature / more challenging abatement opportunities	There are a set of abatement options that are promising, but either less mature or more challenging: feed additives for grazing livestock, bio-stimulants, low-carbon feed, inter-cropping. Analysis of abatement potential is set out, and these are included as options for additional abatement in the modelling of overall food system abatement.
Costs of emissions reductions	Costs associated with abatement are calculated as the areas under the MACCs. Net costs (positive costs are offset by cost savings) are differentiated from positive costs which need to be funded.
Policies to support emissions reductions	Current policies in England and the DAs are considered, and it is recommended where these need to be strengthened in order for abatement measures to be adopted.

Reducing agriculture emissions in the UK and beyond: the approach (continued)

This table summarises the analytical approach to abatement opportunities in agriculture, both in the UK and relating to imported products. The aim is not to set out detailed agriculture sub-sector plans, which already exist (e.g., dairy and beef roadmaps). Rather, an evidence base is presented to further inform such plans in terms of ambition, key abatement levers, costs and supporting policies. The analysis is consistent with and complementary to these roadmaps, which should be reviewed in light of the evidence base presented.

Component	Approach
Food imports	Analysis is extended to food imports, using WRAP's carbon footprint model and the agriculture emissions reduction opportunities from the SRUC's MACC. Policy analysis is not undertaken for countries from which the UK imports products. However, we know that there has been very limited progress in moving away from general subsidies and income transfers to farmers, and that there are very few examples of new policies and financial incentives for uptake of abatement measures highlighted in this report. It is also unlikely that such policies will be developed at pace, for example, as part of the EU's Common Agricultural Policy (CAP). Therefore, if emissions are to be cut as required for imported products, industry will have to drive this – an industry approach is proposed in the overview section of this report.
Methane emissions	Global warming potential (GWP) 100 has been used in the accounting of methane emissions, as is the convention nationally and internationally. This metric underestimates near/medium term methane emissions and overestimates long term emissions. An alternative metric, GWP*, has been proposed as a way of addressing this. In essence, GWP* says that if new methane emissions are equal to the rate at which the stock of methane emissions in the atmosphere is decaying, then there is no net warming due to methane. However, given that methane is a highly potent greenhouse gas at a time when the world is approaching dangerous levels of warming, GWP* does not imply methane emissions from livestock should be de-rated, or that efforts to reduce methane emissions should be reduced, or that national and global emissions reduction targets should be relaxed. Rather, methane emissions reductions should be seen as being highly valuable in that they are one of the very few global cooling options we have; and the approach remains robust with respect to alternative metrics for methane emissions.

Reducing agriculture emissions in the UK and beyond: the approach

This analysis is set out over seven sections:

3.1 Overview of emissions from UK farming: footprint and abatement opportunities – overall, by nation, sub-sector and abatement measure

3.2 Emissions and abatement opportunities by subsector: beef, dairy, sheep, pork, poultry, arable, horticulture

3.3 Cross cutting emissions reduction opportunities: fertiliser, LUC, mobile machinery, agroforestry; more speculative and challenging options

3.4 Cost of reducing UK farming emissions

3.5 Assessment of farm policies

3.6 Emissions from fish, wild and farmed

3.7 Imported foods: carbon footprint and abatement opportunities

3.1 Overview of emissions from UK farming: footprint and abatement opportunities – overall, by nation, sub-sector and abatement measure

Overview of Scotland's Rural College (SRUC) Marginal Abatement Cost Curve (MACC) model

This chapter summarises calculations based on SRUC's MACC model; SRUC was part of the team preparing the analysis for this report.

The MACC model starts with baseline territorial emissions for agriculture in the UK, from the national Greenhouse Gas Inventory. The base year is 2021. The baseline footprint for 2021 is allocated across farming subsectors - beef, dairy, sheep, pork, poultry, crops - using production data and emissions factors. It is extended to include fertiliser production based on assumptions about fertiliser inputs and emissions factors; and imported feed, using trade data and emissions factors, and estimating Land Use Change emissions associated with soy imports using the PAS2050 method. The baseline is projected forward to 2050 based on assumptions about productivity and population / food growth (page 52).

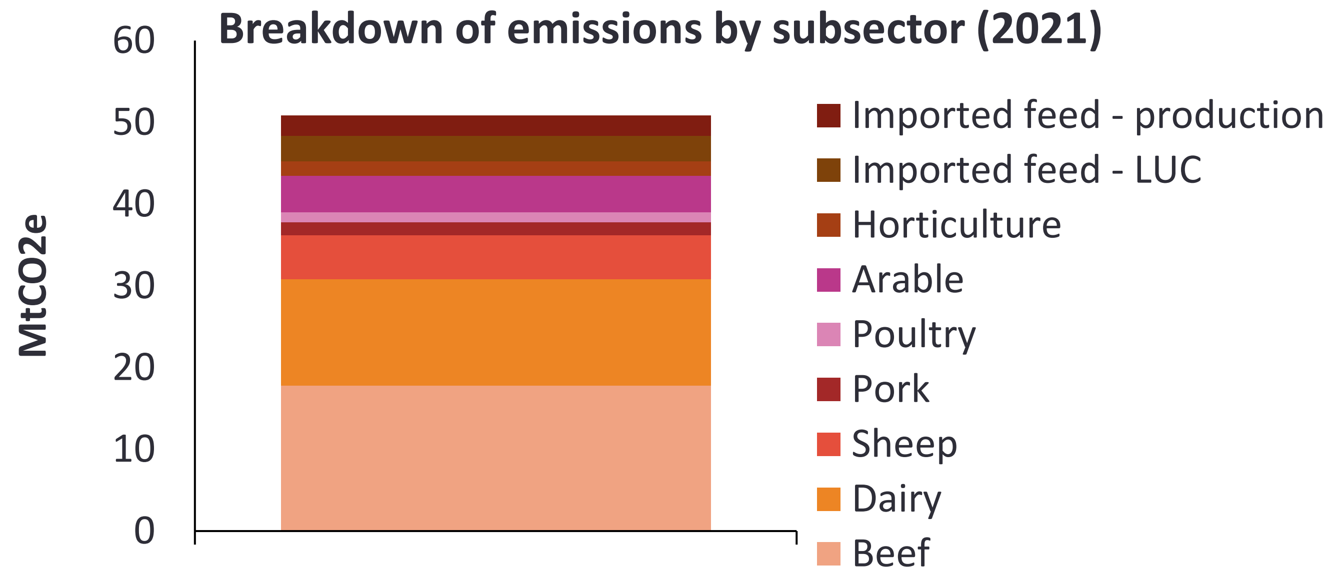
Abatement relative to a baseline is drawn from a longlist of over 300 mitigation measures, and an evidence base that has been developed over the last fifteen years by SRUC, from primary and secondary sources. These are assessed for (i) applicability to UK conditions (ii) confidence, feasibility, risk of negative inputs for other environmental objectives. Based on this assessment, a MACC is constructed, showing those options which are applicable, where there is a degree of confidence, they are feasible and do not have negative impacts for other environmental objectives. For measures that meet these criteria, the MACC maps their abatement potential and related cost, the latter including a full assessment of costs (e.g. capital, operating, income foregone). The MACC has been tested through review by independent experts.

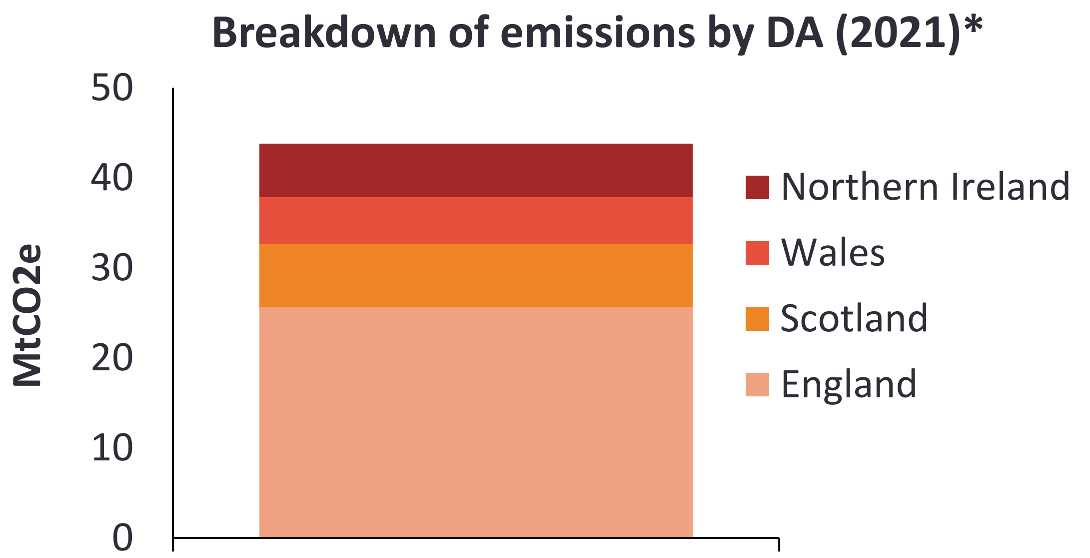
Barriers to uptake of abatement measures are assessed. Combining this assessment together with cost estimates for measures relative to projected carbon prices, two scenarios for uptake of abatement measures were developed: Central and High. The scenarios differ according to the extent and pace at which measures are adopted. For the purposes of this report, results are summarised from the High Scenario, given the need for ambitious action to meet climate commitments and targets. In this scenario, very high rates of uptake for the key measures are achieved by 2035.

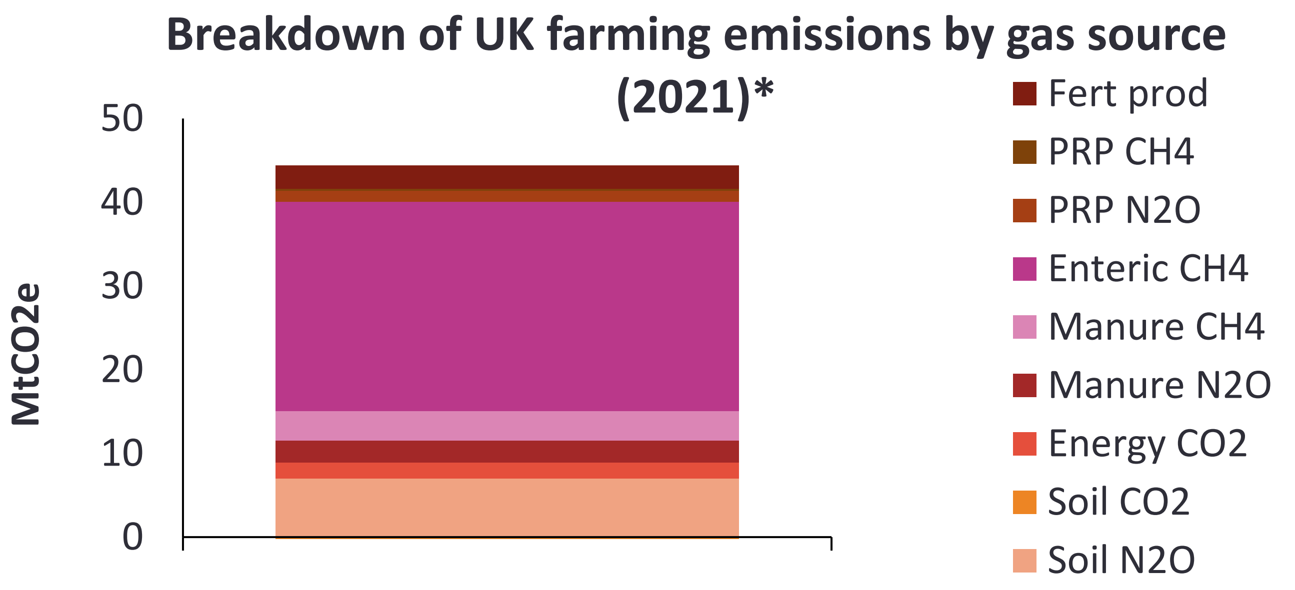
Some measures are considered that may be able to provide additional abatement relating to less mature technologies and more challenging measures. Abatement potential is quantified for these measures and include them in the system pathways as being additional to the High Scenario, and helping to close gaps with commitments and targets.

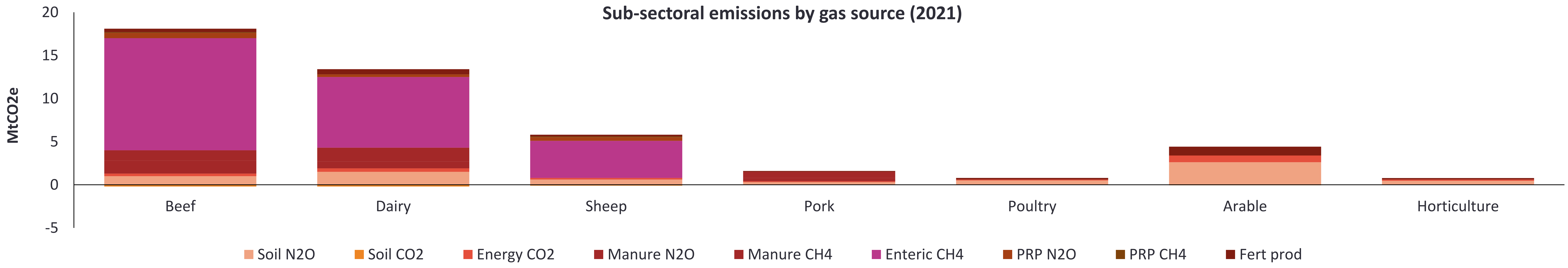
UK agriculture emissions account for around 39% of the total food system carbon footprint. Beef and dairy account for well over half of these emissions, reflected in high methane emissions relative to other gases.

Agriculture emissions in the UK were 50.3 $MtCO_2e$ in 2021, and comprise emissions relating to imported feed, fertiliser production and application, methane emissions from livestock, and CO_2e emissions from the fuels and power used for farm machinery. These emissions can be split into seven sub-sectors: beef, dairy, sheep, pork and poultry farming, as well as arable and horticulture farming. Of this, emissions from beef and dairy farming account for a significant portion (70%) of the total UK agriculture emissions. In what follows, emissions are considered by sub-sector and geography (England and the devolved administrations), as abatement options and policy levers will be different across these categories.









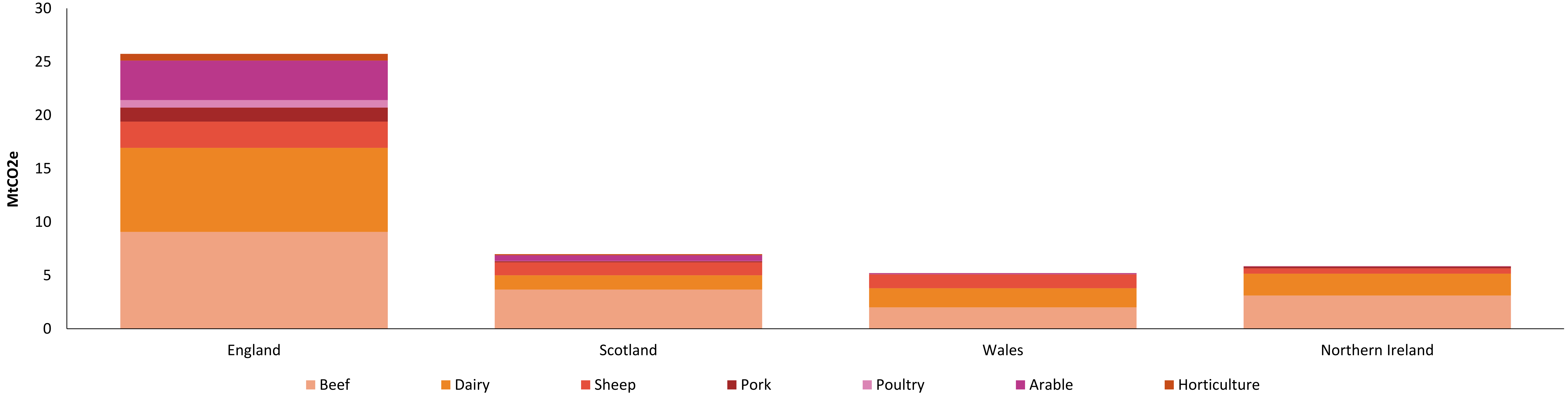
* Excludes imported feed

60% of the UK's agriculture related emissions are attributable to farming in England, with significant shares in each of the devolved administrations – where emissions are dominated by livestock farming.

Emissions across:

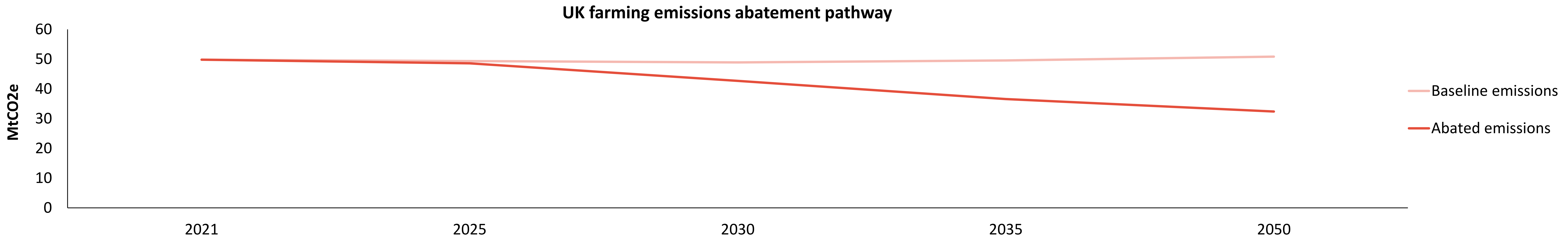
- England account for 59% of the total agricultural emissions in the UK, at 25.7 MtCO2e, including the majority of all sub-sector emissions.
- Scotland account for 16% of the total agricultural emissions in the UK, at 7 MtCO2e, with around half the emissions attributable to beef.
- Wales account for 12% of the total agricultural emissions in the UK, at 5.2 MtCO2e, where sheep makes up a relatively higher proportion of the footprint compared to other devolved administrations.
- Northern Ireland account for 13% of the total agricultural emissions in the UK, at 5.9 MtCO2e, where beef and dairy dominate.

Sub-sectoral emissions across the devolved administrations (2021)*



* Excludes emissions associated with land-use change and fertiliser production

Agriculture emissions can be reduced by 35% relative to the 2021 baseline, even with increased production to meet the needs of a growing population. Further improvements in farming productivity could yield additional emissions reductions but are uncertain and hard to quantify.



The analysis of abatement potential is set out in the following pages; this is netted from a business-as-usual projection that incorporates assumptions about future production levels and emissions intensity; the chart above shows a modelled emissions reduction of 35% in 2050 compared to 2021.

On future production levels, it is assumed that these grow in line with the population; population growth is based on the ONS projection, reaching 78 mn by 2050 (i.e. ~15% increase from 2021) 1.

Future trends in baseline emissions intensity (EI) are hard to predict. For some sectors, changes in productivity may lead to reductions in EI, for example:

Dairy: We are likely to see increases in cow fertility and milk yield, which would lower the EI. However, changes in milk yield may necessitate other changes such as in housing and diet that have a more unpredictable effect on EI

Beef and sheep: Recent productivity gains have been modest but may continue (or even accelerate) if challenges such as increasing parasite resistance or antiparasitic treatments can be tackled. Further gains through dairy-beef integration will be limited by a likely reduction in the dairy herd through the 2030s as productivity increases.

Pork and poultry: Further productivity increases are possible, however, it may be that trade-offs between productivity and other goals (e.g. increasing animal welfare) slow reductions in EI.

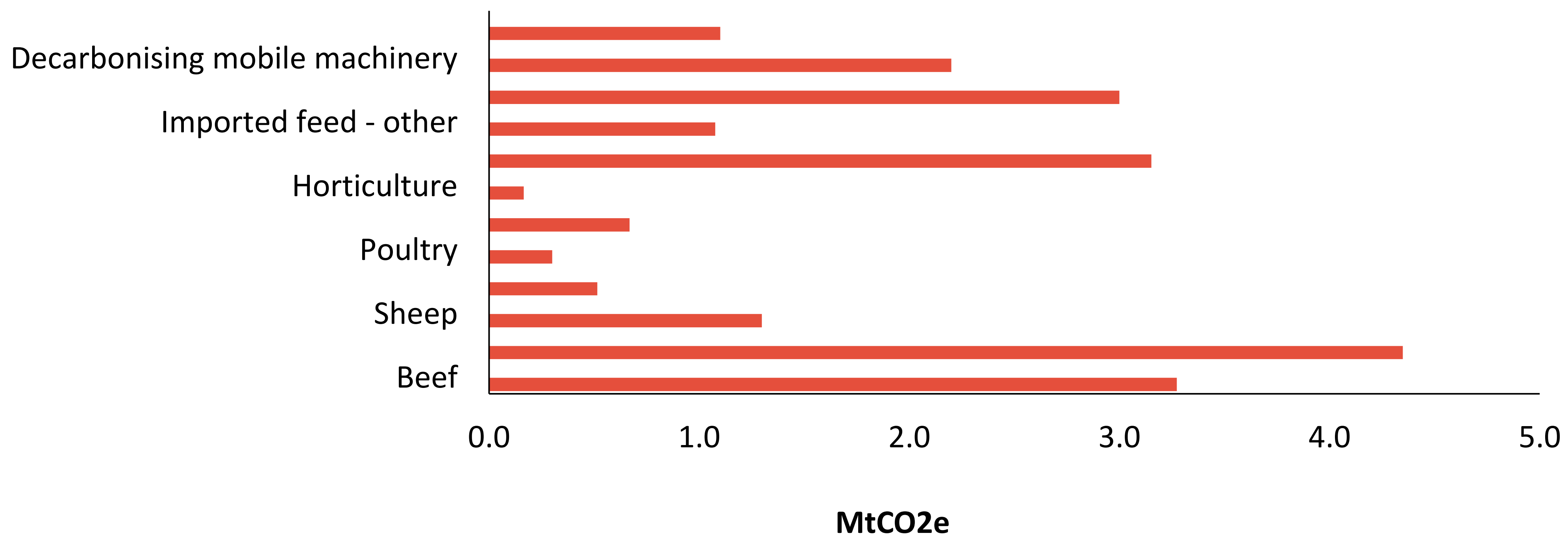
Arable: Improvements in nutrient-use efficiency may reduce the EI of crops, or pressures from changing weather patterns and pest/disease threats may shift the focus to resilience rather than yield.

Agriculture baseline emissions are assumed to be broadly constant through the 2020s, with EI reductions offsetting population growth; beyond this time, EI is assumed to be constant in the baseline, with further reductions modelled as abatement potential. To the extent that there are further improvements in productivity not captured in the baseline or abatement potential, these should be regarded as additional.

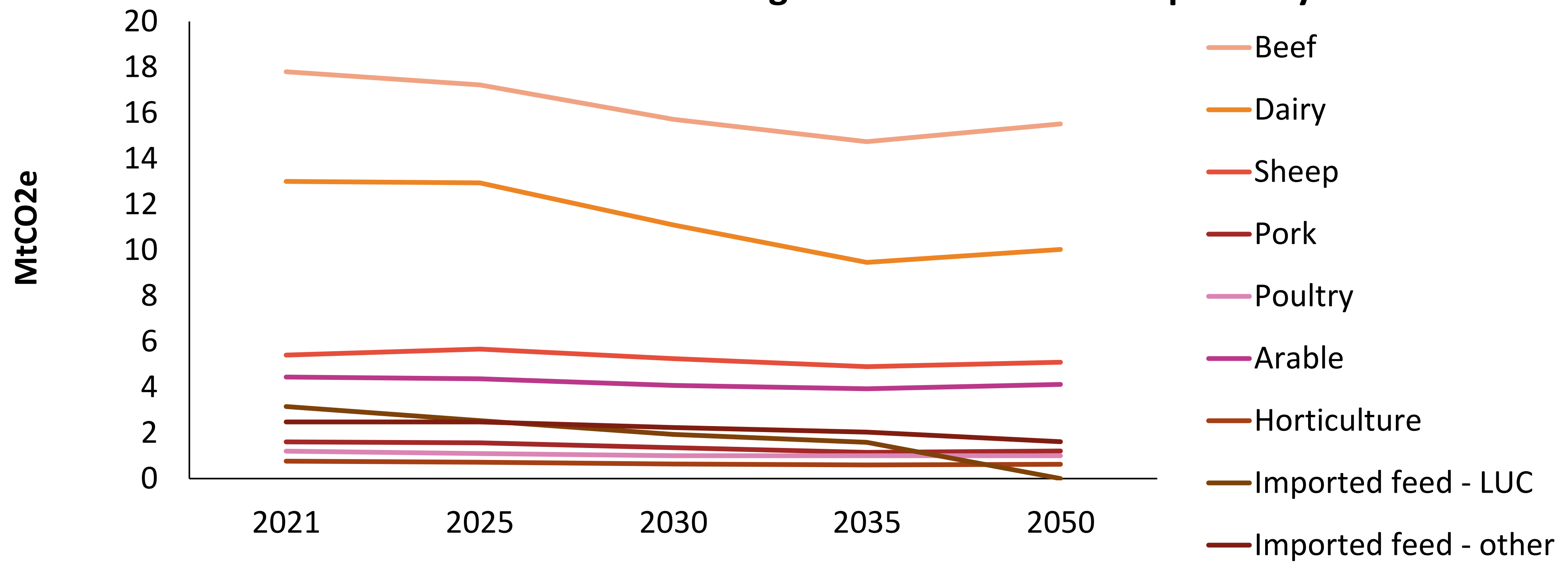
1 National Population Projections – Office for National Statistics, 2024

There is a possible 21.9 MtCO2e abatement in 2050 from both changed farming practices within the sub-sectors as well as cross-cutting measures, such as decarbonising fertiliser production and reducing land-use change, with varying potentials and timelines across the sub-sectors and devolved administrations.

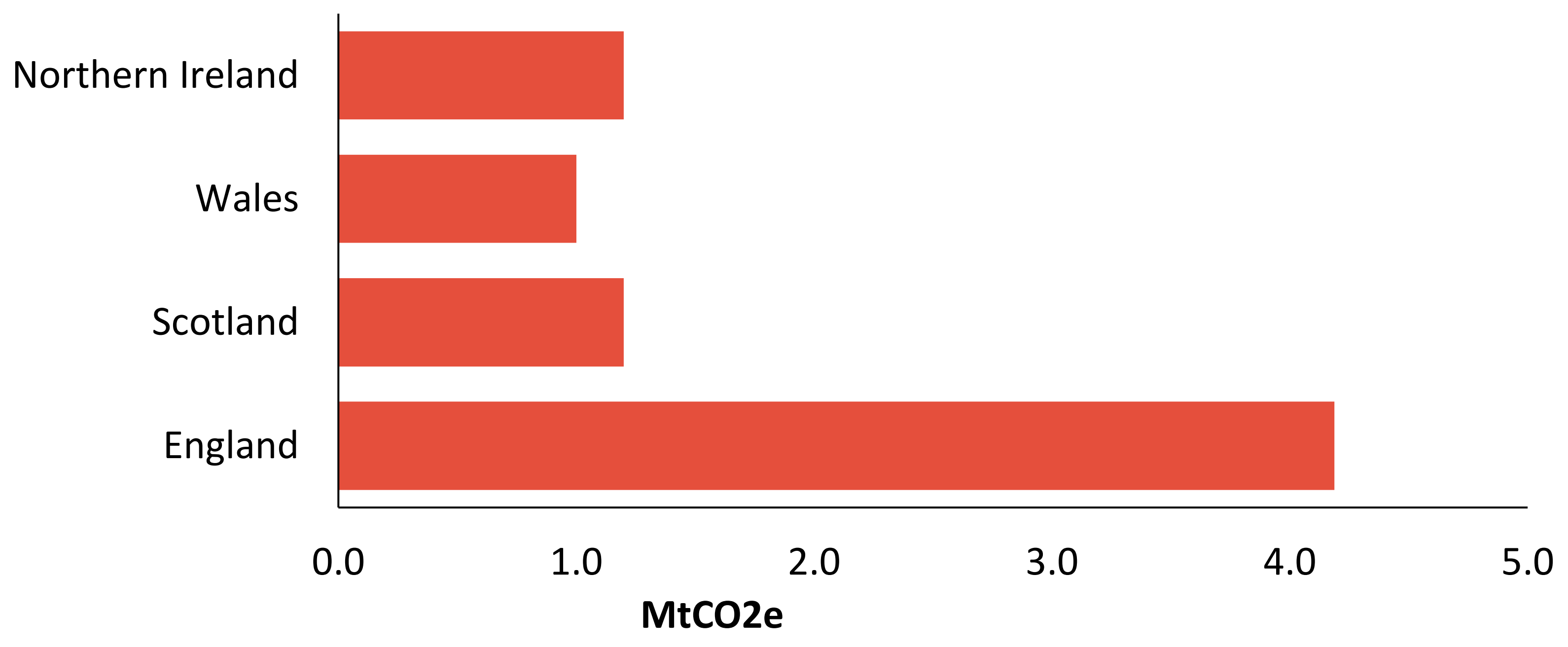
Sub-sectoral and cross-cutting abatement potential (2050)



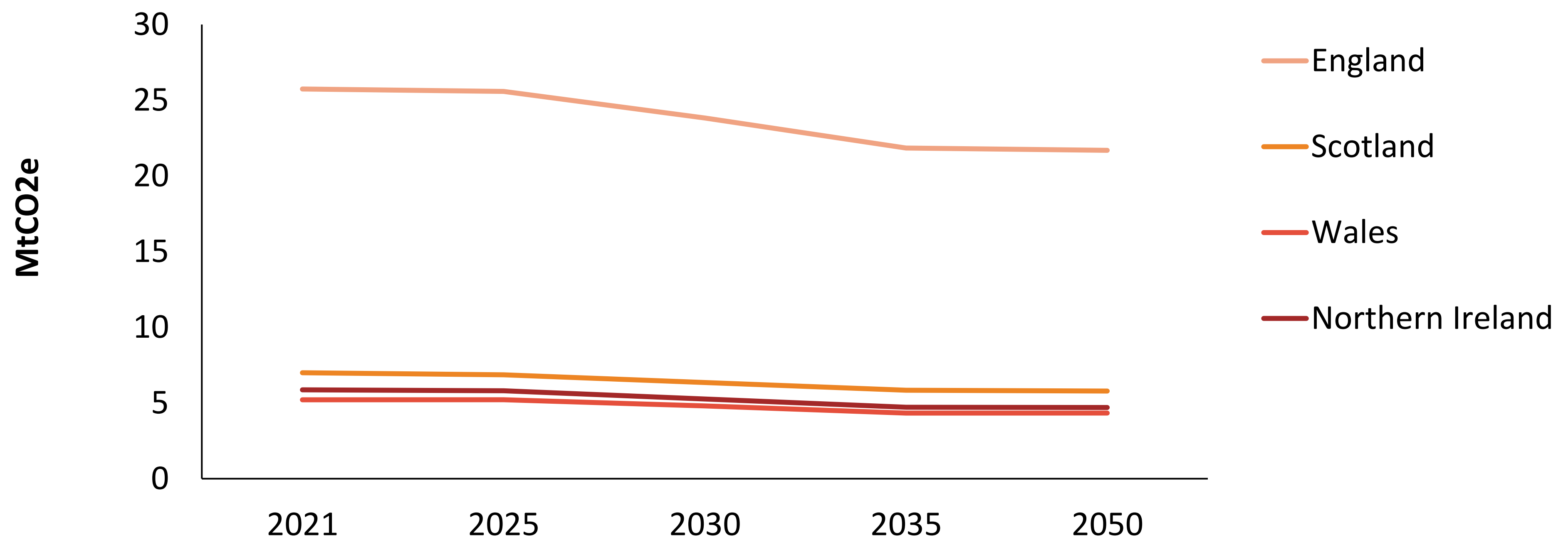
Sub-sectoral and cross-cutting emissions abatement pathways



Abatement potential (excluding cross cutting measures) by DA (2050)



DA emissions abatement pathways



Key measures in the MACC and uptake assumptions n.b, where assumed uptake is low, this reflects assumed high uptake in the baseline.

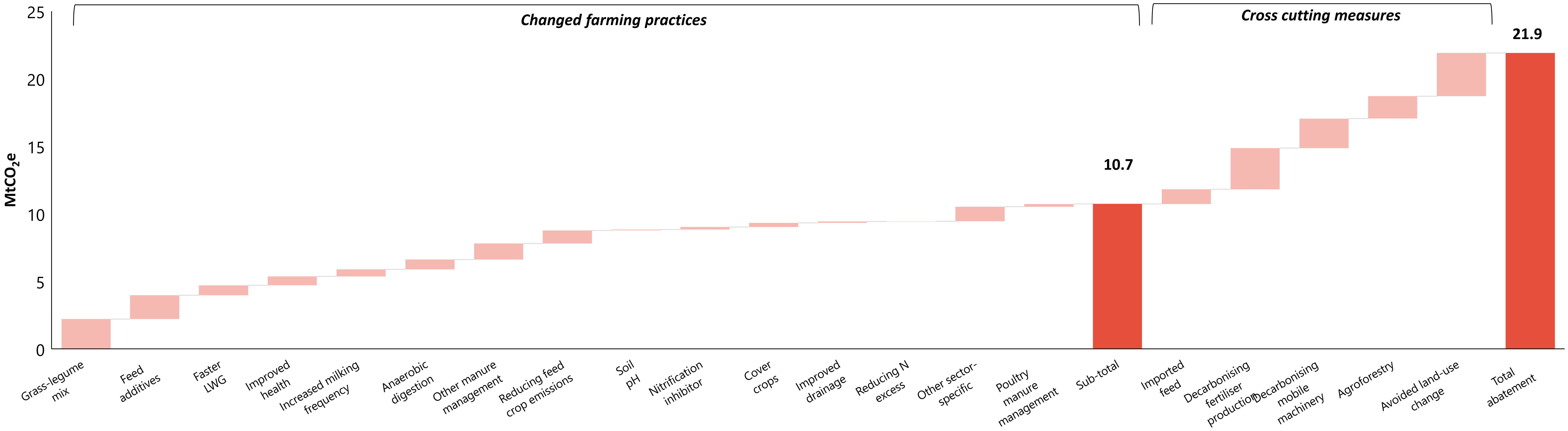
Measure	Comment	Uptake*
Grass-legume mix	Pure grass monocultures replaced by grass clover leys and clover content is increased on mixed swards to be up to 20-30% DM at an annual average. Reduces the rate of fertiliser application, and hence the N_2O emissions associated with fertiliser application, and the emissions from the manufacture of synthetic fertiliser.	62%
Feed additives	Additives to feed which reduce enteric methane production, specifically 3NOP and nitrate. 3NOP inhibits methyl-coenzyme M reductase, the final step of CH_4 synthesis by archaea (Duin et al. 2016).	92%
Faster LWG	Increasing cattle growth rates reduces the time taken to achieve target weights. This should, in theory at least, reduce the emissions per kg of beef produced as faster growing cattle require less energy for maintenance per kg of LWG. In practice, the change in emissions intensity also depends on how the increase in growth rate is achieved.	92%
Improved health	Improving animal health could in principle lead to significant reductions in emissions intensity by, for example, improving the feed conversion ratio of individual animals and reducing the herd breeding overhead (through improved fertility and reduced mortality).	85%
Increased milking frequency	Increasing the rate of dairy cow milk secretion without using hormones by moving from milking twice a day to three times a day. May require robotic milking parlours and changes to stock management (e.g. keeping cattle closer to the milking parlour).	92%
Anaerobic digestion	Capture of biogas, and use for generating electricity/heat. Requires additional feedstock (e.g. grass, maize) to ensure suitable C: N ratio. Reduces methane and NH3 emissions, end displaces fossil fuel use.	87%
Other manure management	Slurry acidification and impermeable slurry covers.	92%
Reducing feed crop emissions	Via the methods applied to the non-feed crops - see below.	Various
Soil pH	Carrying out soil analysis for pH and soil liming (if required) on arable and grassland. Sequesters C below ground through improved primary productivity and nutrient use efficiency.	92%
Nitrification inhibitor	NIs inhibit the oxidation of ammonium ions to nitrate with the aim of providing better synchrony between nitrate supply and crop uptake. By doing so there is less likelihood of nitrate being available in soils when they are wet and the denitrification potential and, consequently, N_2O emissions are high. Beyond reducing direct N_2O emissions, NIs can potentially lower emissions and improve emissions intensity also by reducing nitrate leaching and subsequent indirect N_2O emissions and increasing grass/crops yield.	92%
Cover crops	Cover crops are crops grown within a rotation to maintain soil cover during fallow periods, and are typically ploughed under as green manure, or killed with herbicides under no-till systems. Sequesters C below ground through increased primary productivity and maintenance of organic input throughout the rotation.	90%
Improved drainage	Improve/renovating current land drainage to improve yield and reduce N_2O emissions.	92%
Reducing N excess	Reducing the total amount of N applied without negative effects on the yield, by a combination of actions including nitrogen management planning, gathering information about the soil and manure nitrogen content, decreasing the error of margin in the applied amount and better application timing considering the weather	12%
Other sector-specific	Various other measures, including livestock genetic improvement and improved nutrition	Various

* Uptake is the additional % of farmers adopting the measure, above baseline adoption

The majority of emissions abatement could be achieved through the implementation of nine sub-sectoral specific farming practice changes and five key cross cutting measures. The decarbonisation potential is roughly equally distributed between these two areas of activity.

Abatement measure potentials have been calculated using a MACC developed over a number of years by SRUC in alignment with their analysis undertaken for the Climate Change Committee (CCC) advice for the seventh carbon budget. Given the levels of abatement required across the system, in the analysis SRUC's High Ambition scenario is used. The abatement measures have been split between sub-sector specific options, which relate to changed farming practices, and cross cutting measures such as decarbonising fertiliser production, low-carbon mobile machinery and more carbon-efficient imported feed, as well as investing in agroforestry and avoiding land-use change. Measure definitions and uptake assumptions are provided in Appendix A. Further cross cutting measures have been considered but not included in the modelling (see Page 58).

Total abatement potential by measure for the UK agricultural sector ($MtCO_2e$/year) in 2050



Farming is intrinsically linked with nature and biodiversity. Therefore, it is important to consider the wider impact of the various potential emissions abatement measures on the environment. These are broadly positive and where they are not, the negative impacts can be managed. A detailed assessment of nature impacts and pathways is required to substantiate this high-level analysis.

Abatement measure	Water quality	Air quality	Biodiversity	Comment
Grass-legume mix	+	+	+	Reduced nitrogen application rates reduce nitrogen losses and associated eutrophication and acidification; reduced impacts from fertiliser manufacture.
Feed additives	0	0	0	Feed additives reduce methane emissions, potentially increasing the utilisation of energy in the rumen; if other nitrogen sources are reduced it might not affect the nitrogen emissions from livestock. Assuming no significant impact from the production of additives.
Faster LWG	+/-	+/-	+/-	Improves feed conversion efficiency and reduces the amount of nitrogen excreted per kilogram of output, leading to reductions in ammonia from manure management and direct deposition of nitrogen. This may have trade-offs if it involves switching ration from grass to cereals.
Improved health	+	+	+/-	Measures that improve feed conversion efficiency will reduce the amount of nitrogen excreted per kg of output, leading to reductions in ammonia from manure management and direct deposition of nitrogen. There are potential negative impacts via control of wild animals/plants and habitat alteration to reduce vector/pathogen populations. There are further negative impacts of medication to dung invertebrates and indirect impacts further up the food chain.
Increased milking frequency	+/-	+/-	+/-	As with faster LWG, this should improve feed conversion efficiency and reduce the amount of nitrogen excreted per kg of output, leading to reductions in ammonia from manure management and direct deposition of nitrogen. This may have trade-offs if it involves increased housing and/or switching ration from grass to cereals.
Anaerobic digestion	+/-	-	0	Evidence on leaching rates from digestate is inconclusive. Effects on ammonia emissions are mixed. There is a risk of increased nitrogen oxides and particulates in biogas combustion.
Other manure management	+/-	+	0	Reduces ammonia emissions. There is a risk of increased nitrogen leaching, but this can be managed with rapid incorporation of manure.
Soil pH	+	0	+/-	Increasing soil pH is likely to increase nitrogen use efficiency, but higher pH can also lead to increases in ammonia volatilisation.
Nitrification inhibitor	+/-	+/-	+/-	The effects are multi-faceted, depending on fertiliser type, inhibitor type, soil, climate and crop. The synergies and trade-offs with reactive nitrogen emissions need to be carefully considered.
Cover crops	+	+	+/-	Less additional nitrogen will be needed as some is provided by the leguminous cover crops and/or reduced leaching; soil erosion is reduced; more herbicide might be needed.
Improved drainage	+/-	0	0	Better soil quality enables higher yield and surface run-off is reduced. Effects are likely to be location-specific and difficult to predict.
Reducing nitrogen excess	+	+	+	Reduced nitrogen application rates reduce nitrogen losses and associated eutrophication and acidification.

3.2 Emissions and abatement opportunities by subsector: beef, dairy, sheep, pork, poultry, arable, horticulture

Beef farming is the largest contributor to UK agriculture emissions, accounting for 40% of the total. Without abatement, it is projected that emissions from beef farming will grow to 18.8MtCO$_2$e in 2050. However, there is potential to decarbonise beef production by 15% compared to the 2021 baseline emissions.

The beef sector includes cattle raised for meat, meaning all suckler cattle and the surplus calves from dairy. It accounts for 40% of agriculture emissions inventory.

17.8 MtCO$_2$e
Beef related emissions in 2021

0 MtCO$_2$e
Additional emissions from land-use change

14%
Contribution to total food industry emissions in 2021

12%
Reduction in emissions: 2030 vs 2021

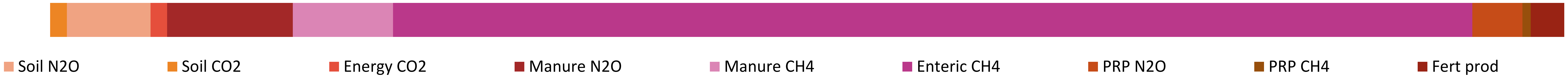
15%
Reduction in emission: 2050 vs 2021

21%
Reduction in carbon intensity in 2050

-£122 million
Expected cost of abatement in 2050 (i.e. cost saving)

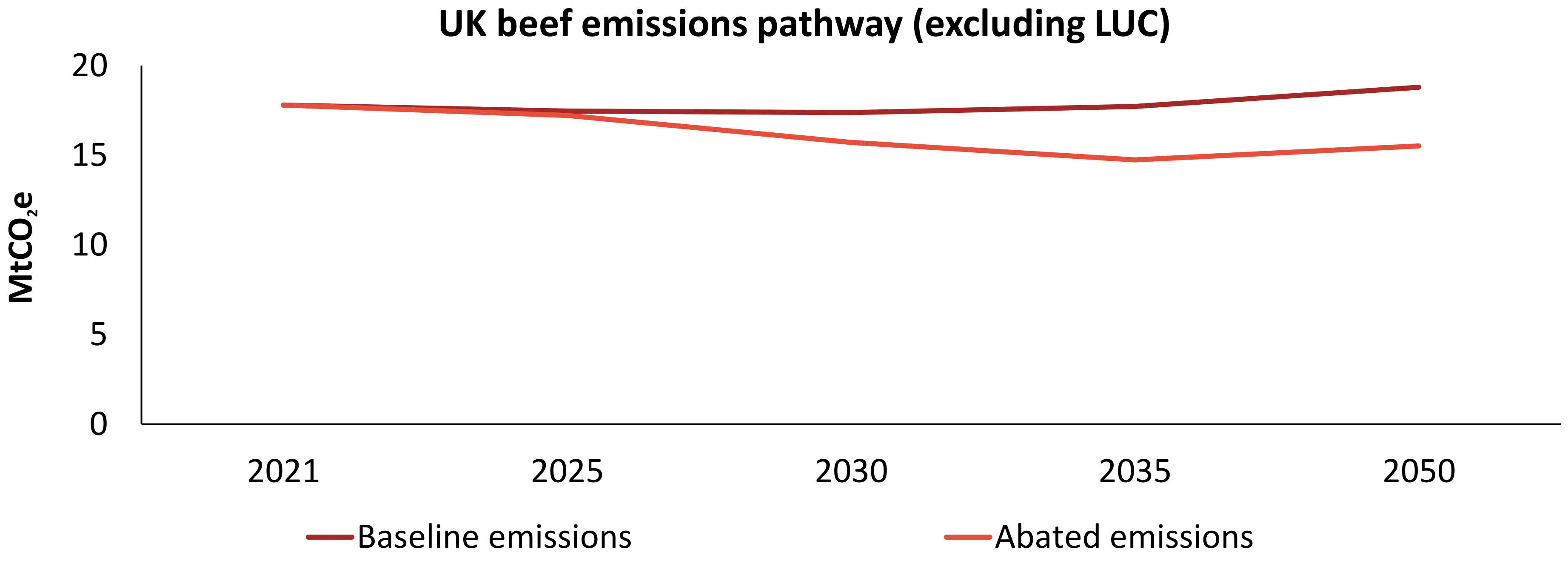
Emissions drivers

Beef sector emissions are mainly driven by methane (CH$_4$) from enteric fermentation and nitrous oxide (N$_2$O) from the application of (synthetic and organic) fertilisers to agricultural soils, including nitrogen deposited by grazing animals.

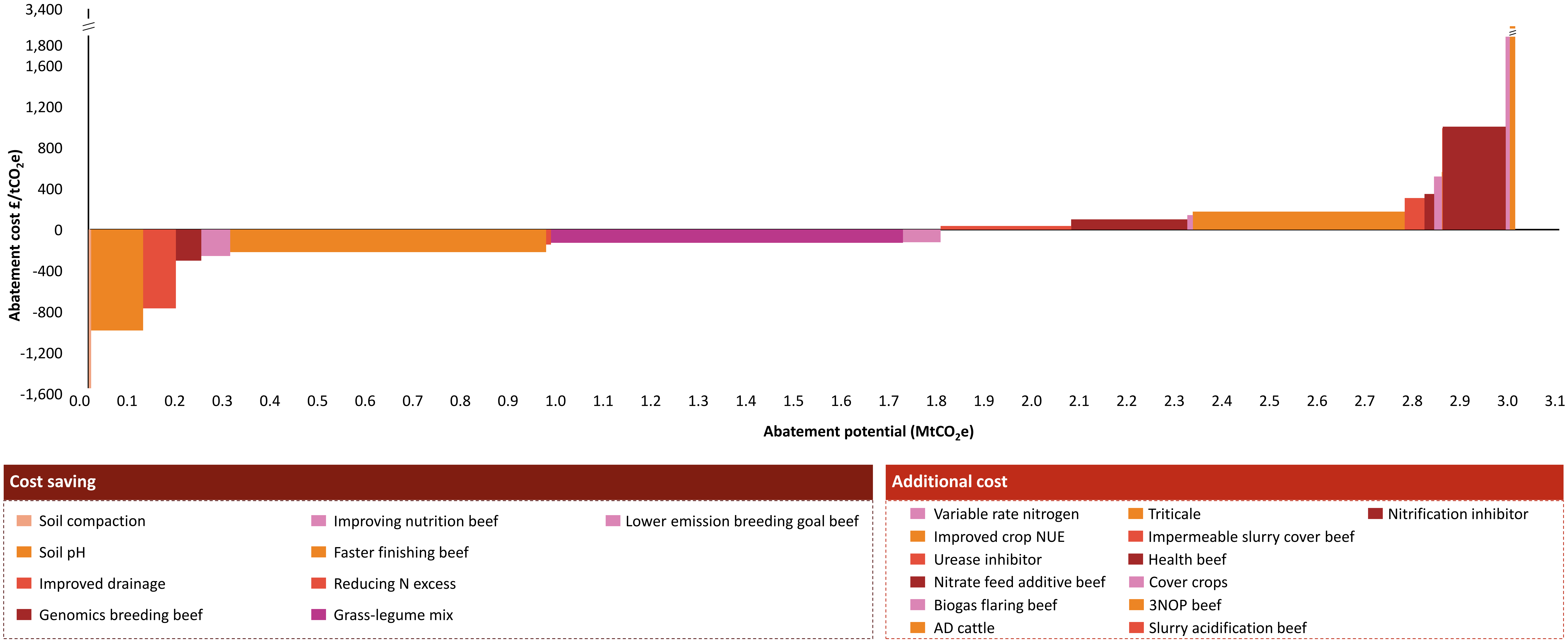


Abatement

There is the potential to reduce emissions by **13%** in 2050 relative to 2021 from **changed farming practices** (see graph opposite). In addition, there are some opportunities to reduce emissions from **green fertiliser, contributing a further potential 2% reduction;** these are limited given only small amounts of synthetic fertiliser are used in beef farming. Emissions reductions from avoided land-use change are limited given minimal use of soy in beef farming. Carbon intensity reductions of 21% in 2050 exceed emissions reductions relative to 2050, given significant population and demand growth over the period. There may be further significant opportunities to reduce emissions through low-carbon mobile machinery, agroforestry, feed additives for grazing animals, low-carbon feed and biostimulants (pages 91-93).

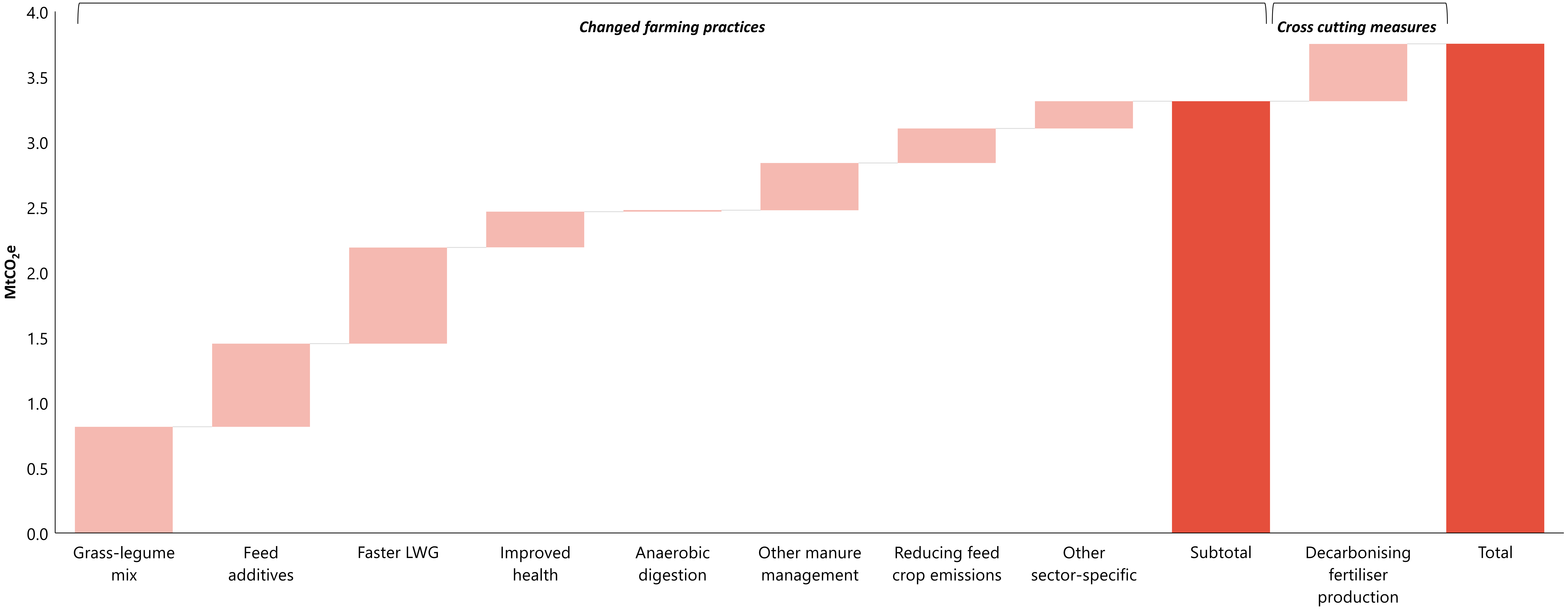


The total decarbonisation potential of changes in farming practices across the beef sector is more than 3 $MtCO_2e$ in 2050. SRUC's Marginal Abatement Cost Curve (MACC) analysis shows that around 1.8 $MtCO_2e$ of reduction can be delivered through measures that reduce cost to the sector, and 1.2 $MtCO_2e$ that would entail additional costs.



On top of changed farming practices, an additional 0.4 $MtCO_2e$ of emissions savings from green fertiliser and 0.3 $MtCO_2e$ from reducing feed crop emissions in 2050 is possible, bringing the total abatement potential for beef to 3.7 $MtCO_2e$ in 2050.

Total abatement potential for the UK beef sector ($MtCO_2e$/year) in 2050



Dairy farming is the second largest component of UK agriculture emissions, accounting for 30% of the total. Without abatement, it is projected that emissions from dairy farming will grow to 14.4 $MtCO_2e$ in 2050. However, there is potential to reduce emissions by 32% against the 2021 baseline.

The dairy sector includes all dairy cows and the calves/heifers reared to replace them. It accounts for 30% of the agriculture emission inventory.

13 $MtCO_2e$
Dairy related emissions in 2021

0.8 $MtCO_2e$
Additional emissions from land-use change

11%
Contribution to total food industry emissions in 2021

16%
Reduction in emissions: 2030 vs 2021

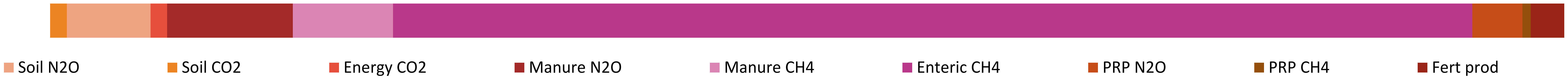
32%
Reduction in emissions: 2050 vs 2021

42%
Reduction in carbon intensity in 2050

-£61 million
Expected cost of abatement in 2050 (i.e. cost saving)

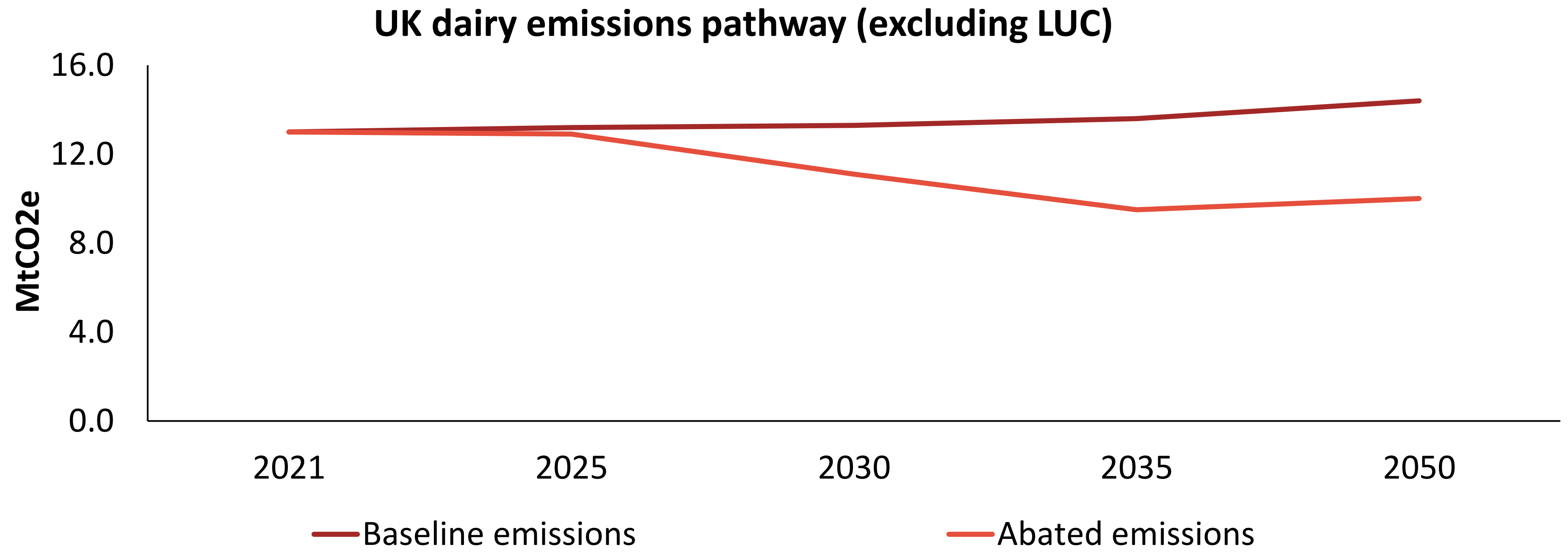
Emissions drivers

The dairy sector emissions are mainly driven by methane (CH_4) from enteric fermentation and nitrous oxide (N_2O) from the application of (synthetic and organic) fertilisers to agricultural soils, including N deposited by grazing animals.

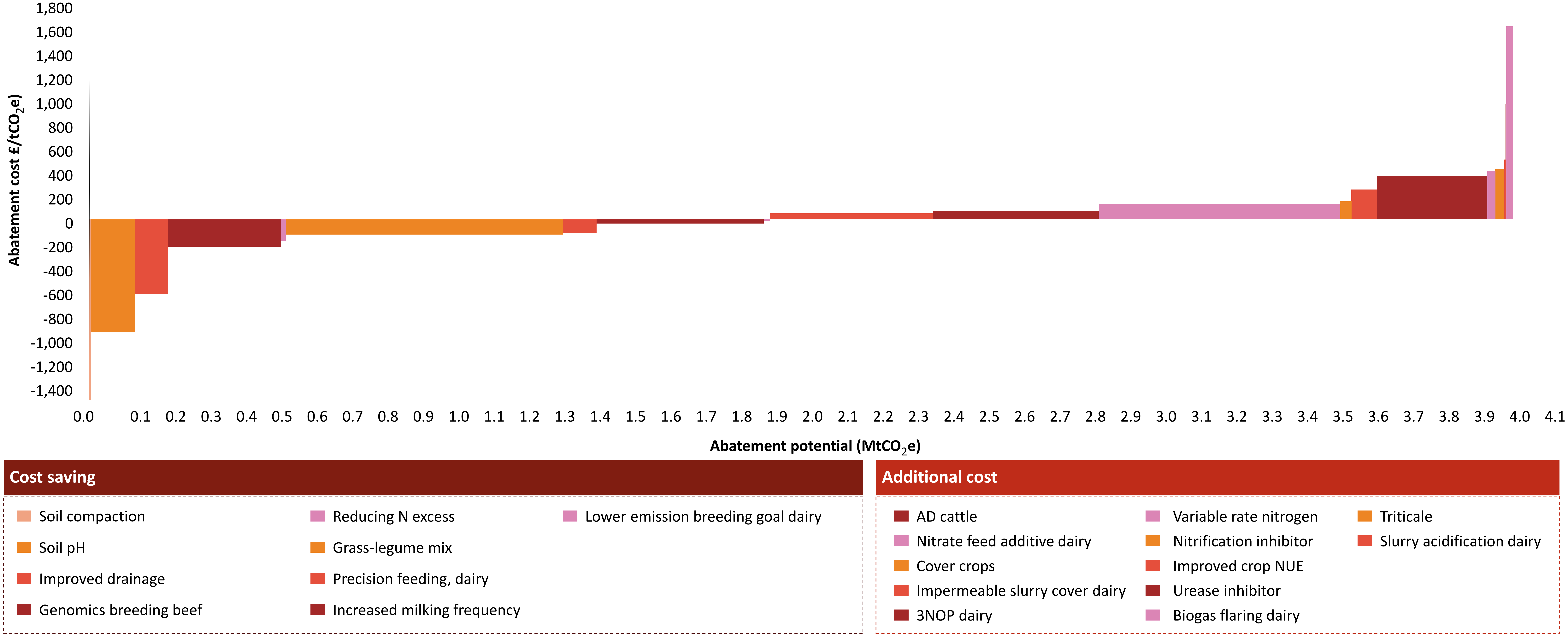


Abatement

There is the potential to reduce emissions by up to **23%** in 2050 relative to 2021 from **changed farming practices** (see graph opposite). In addition, there are opportunities to reduce emissions by an additional **9% from green fertiliser** and **from avoided land-use change**. Carbon intensity reductions of 42% in 2050 are greater than emissions reductions relative to 2021 because of significant population and demand growth over the period. There may also be further significant opportunities to reduce emissions through low-carbon mobile machinery, agroforestry. low-carbon feed and biostimulants (pages 91-93).

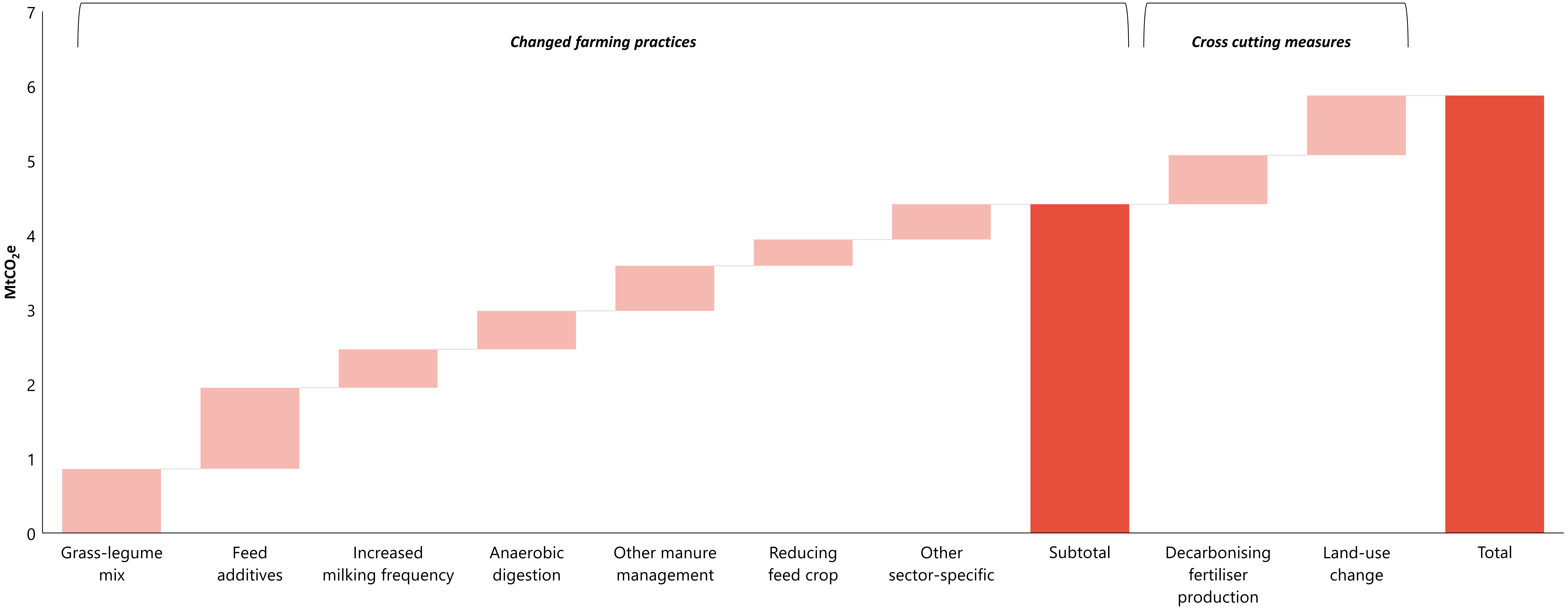


There is a total abatement potential of just over 4 $MtCO_2e$ from changed farming practices across the dairy sector. The MACC analysis shows that this comprises 1.9 $MtCO_2e$ from cost saving options, and 2.1 $MtCO_2e$ that would entail additional costs.



On top of changes in farming practices, there is the potential for an additional 1.5 $MtCO_2e$ of emissions savings from green fertiliser and avoided land-use change in 2050 within the dairy sector, bringing the total abatement potential for dairy to 5.9 $MtCO_2e$ in 2050.

Total abatement potential for the UK dairy sector ($MtCO_2e$/year) in 2050



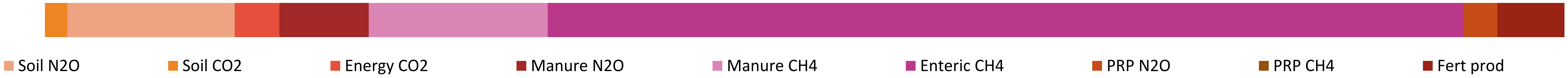
Sheep farming accounts for 13% of the total UK agriculture emissions, and is projected to grow to around 6.5 $MtCO_2e$ by 2050 without abatement. However, there is a decarbonisation potential of around 13% compared to the 2021 baseline.

The sheep sector includes sheep raised for meat. It accounts for 13% of agriculture emissions inventory.

5.4 $MtCO_2e$	Dairy related emissions in 2021
0.2 $MtCO_2e$	Additional emissions from land-use change
4%	Contribution to total food industry emissions in 2021
4%	Reduction in emissions: 2030 vs 2021
13%	Reduction in emissions: 2050 vs 2021
27%	Reduction in carbon intensity in 2050
-£209 million	Expected cost of abatement in 2050 (i.e. cost saving)

Emissions drivers

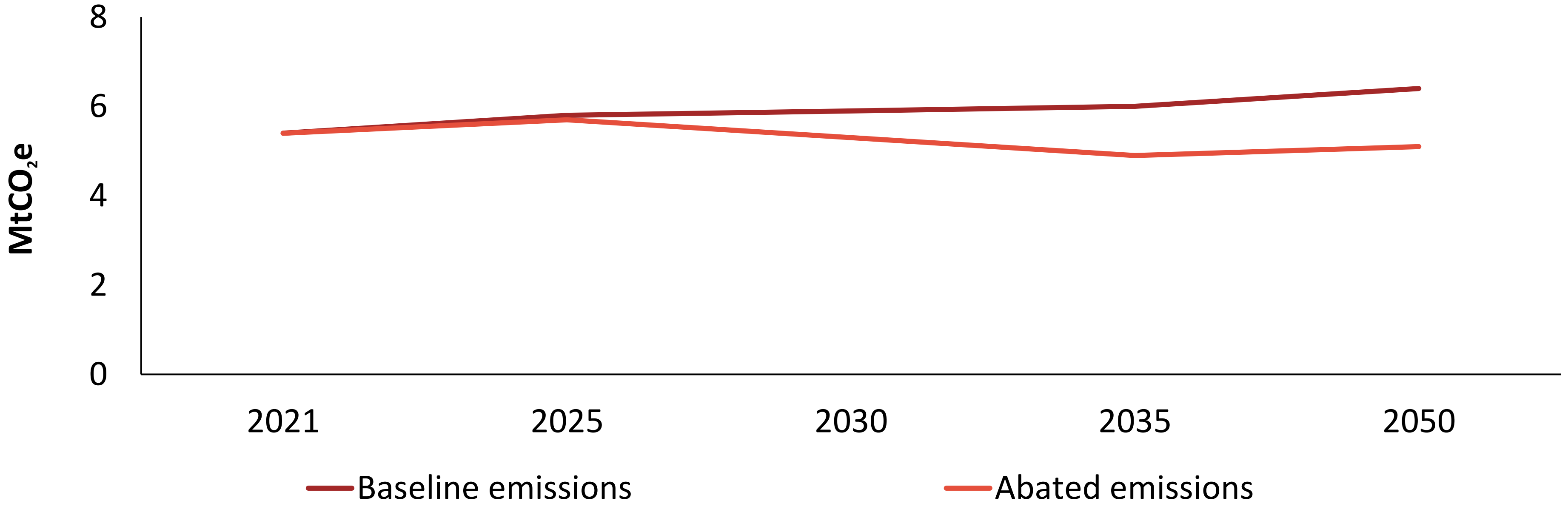
The sheep sector emissions are mainly driven by methane (CH_4) from enteric fermentation and nitrous oxide (N_2O) from the application of (synthetic and organic) fertilisers to agricultural soils, including N deposited by grazing animals.



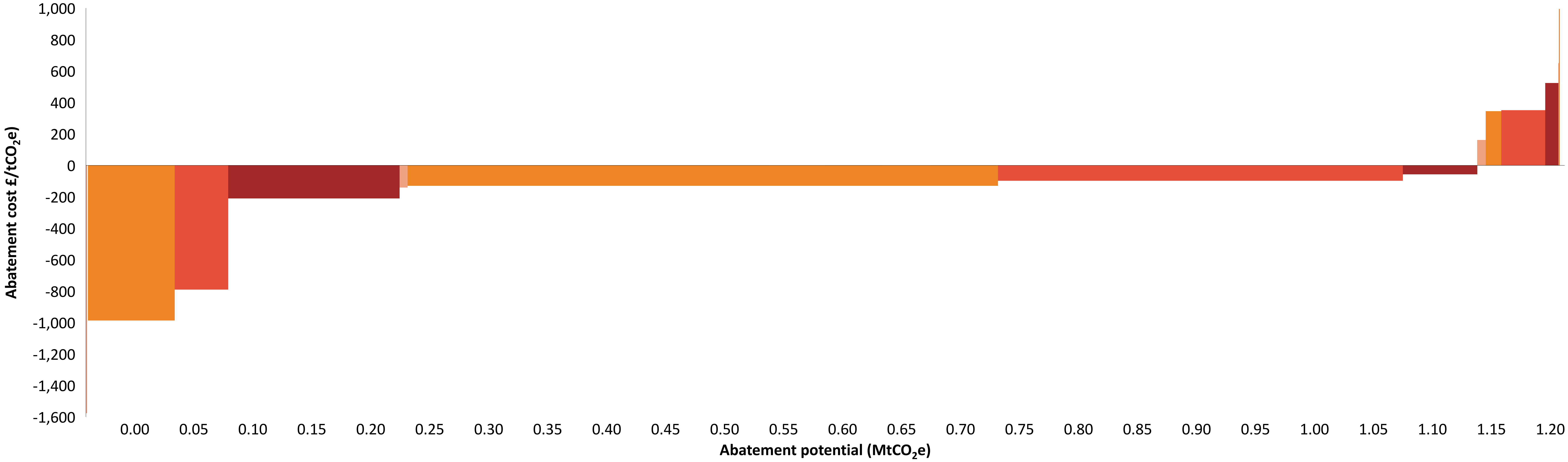
Abatement

There is the potential to reduce emissions by up to **6%** in 2050 relative to 2021 from **changed farming practices** (see graph opposite). In addition, there are opportunities to reduce emissions by an additional **7% from green fertilise**r and **avoided land-use change**. Carbon intensity reduction of 27% in 2050 exceeds emissions reductions relative to 2021, reflecting significant population and demand growth across the period. There may further significant opportunities to reduce emissions through agroforestry.

UK sheep emissions pathway (excluding LUC)



There is a total abatement potential of 1.2 $MtCO_2e$ from changed farming practices across the sheep sector. SRUC's MACC analysis shows that this comprises 1.1 $MtCO_2e$ from cost saving options, and 0.1 $MtCO_2e$ that would entail additional costs.



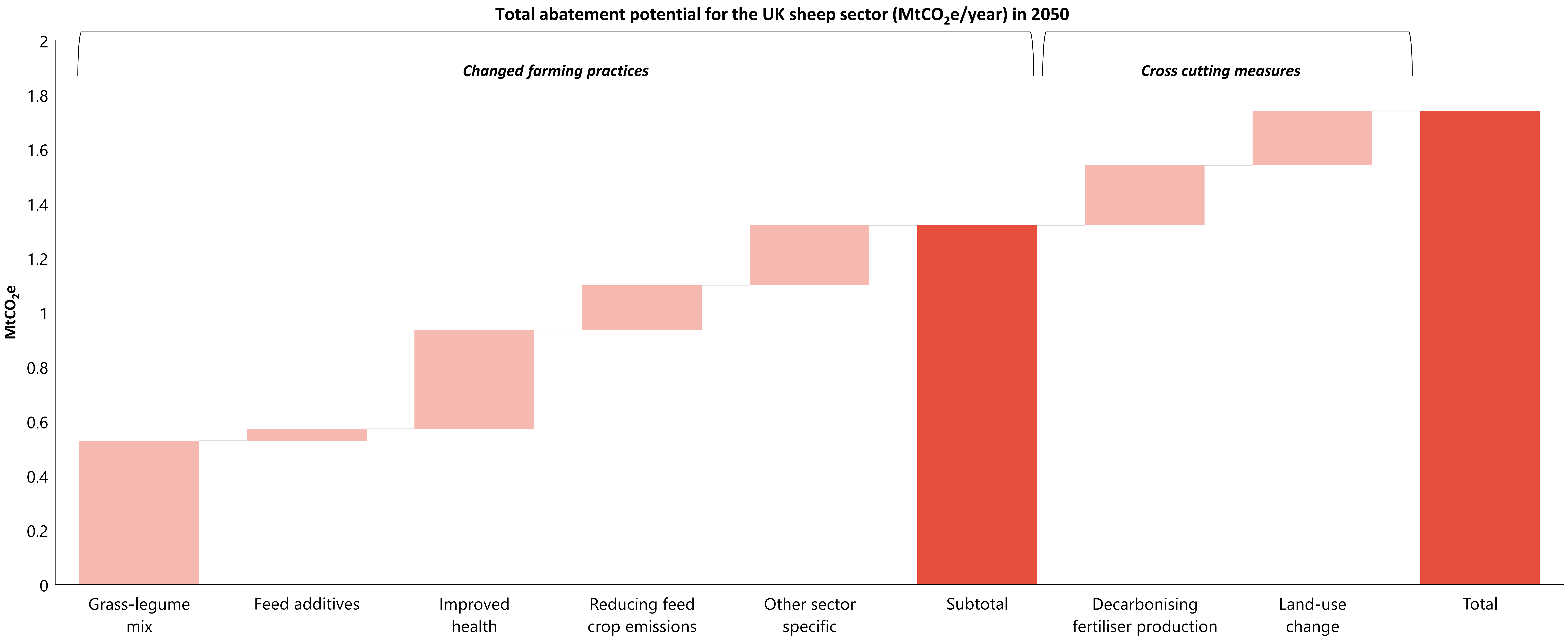
Cost saving

- Soil compaction
- Reducing N excess
- Soil pH
- Grass-legume mix
- Improved drainage
- Health sheep
- Current breeding goal in sheep

Additional cost

- Improving nutrition sheep
- Variable rate nitrogen
- Cover crops
- Improved crop NUE
- Nitrification inhibitor
- Urease inhibitor
- Nitrate feed additive sheep

On top of changed farming practices, there is the potential for an additional 0.4 $MtCO_2e$ of emissions savings from green fertiliser and avoided land-use change in 2050, bringing the total abatement potential for sheep to 1.7 $MtCO_2e$.



Pork farming accounts for 4% of the total UK agriculture emissions and are projected to grow to over 1.7 $MtCO_2e$ by 2050. There is potential to reduce pork emissions by 55% in 2050.

The pork sector includes pigs raised for meat. It accounts for 4% of the agriculture emissions inventory.

1.6 $MtCO_2e$
Pork related emissions in 2021

0.6 $MtCO_2e$
Additional emissions from land-use change

2%
Contribution to total food industry emissions in 2021

22%
Reduction in emissions: 2030 vs 2021

55%
Reduction in emissions: 2050 vs 2021

66%
Reduction in carbon intensity in 2050

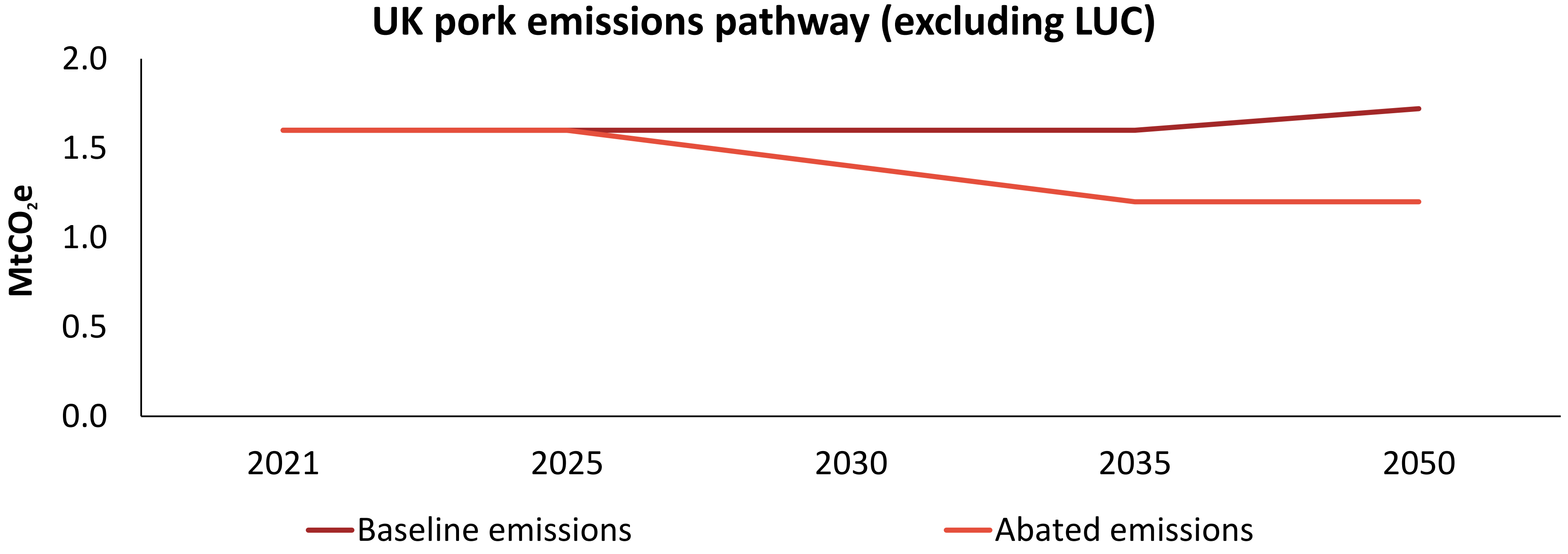
£29 million
Expected cost of abatement in 2050

Emissions drivers

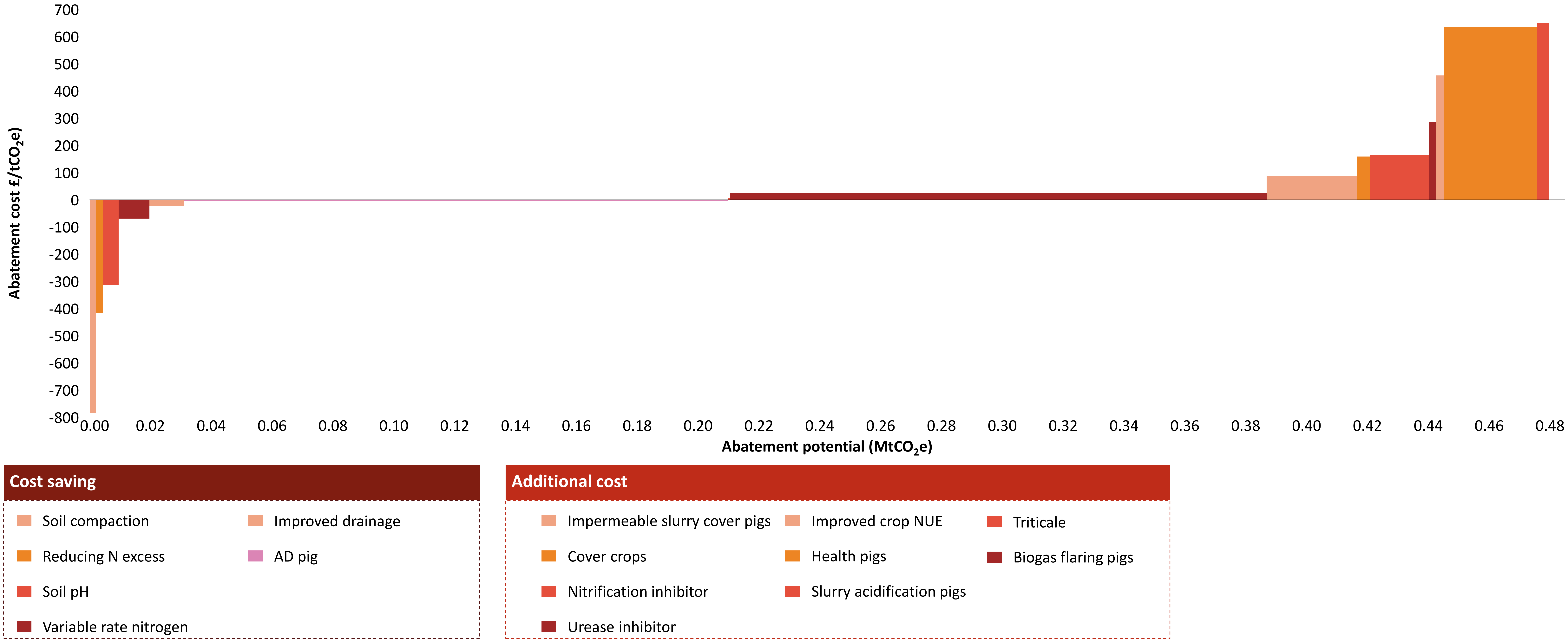
The pork sector emissions are mainly driven by nitrous oxide (N_2O) arising during feed production, including fertiliser application, and nitrous oxide (N_2O) and methane (CH_4) from manure management.

Abatement

There is the potential to reduce emissions by up to **25%** in 2050 relative to 2021 from **changed farming practices** (see graph opposite). In addition, there are opportunities to reduce emissions by an additional **30% from green fertiliser** and **avoided land-use change**. Carbon intensity reduction of 66% in 2050, exceeds emissions relative to 2021, reflecting significant population and demand growth through the period. There may also be some opportunities to reduce emissions through agroforestry, albeit these are likely to be limited.

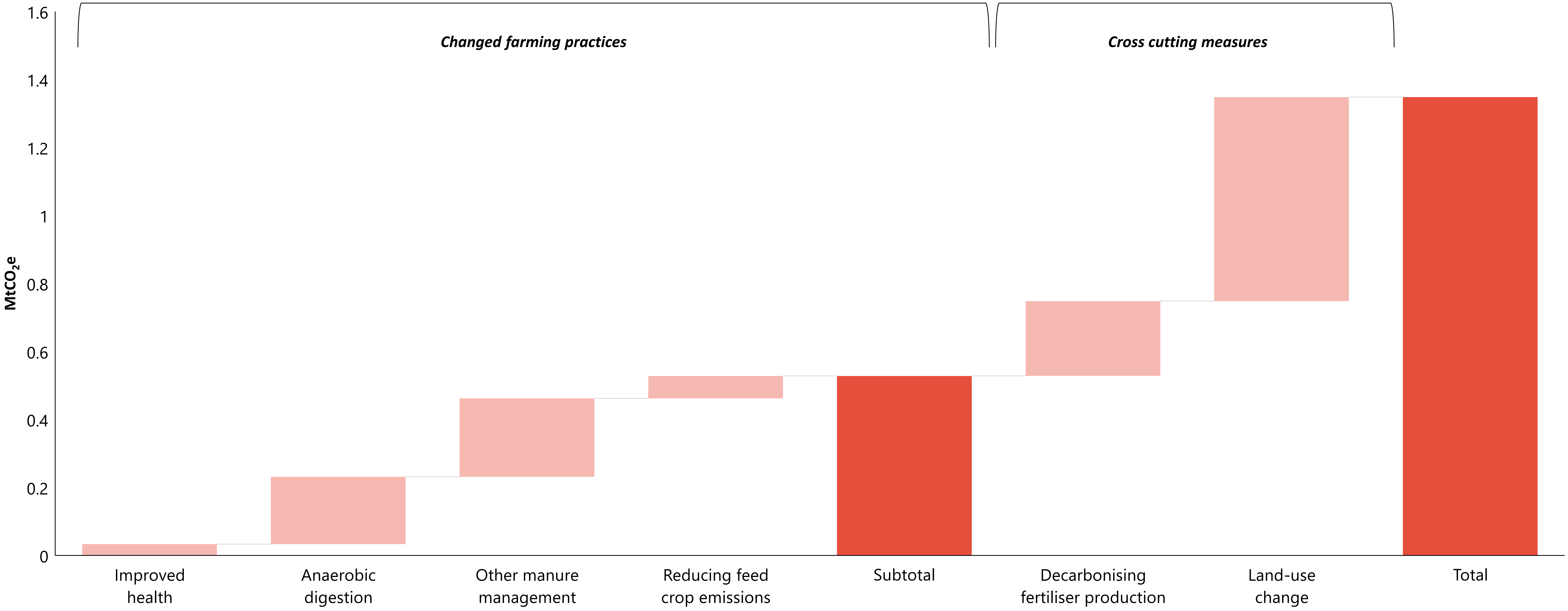


There is a total abatement potential of 0.5 $MtCO_2e$ from changed farming practices across the pork sector. The SRUC's MACC analysis shows this comprises 0.2 MtCO2e from cost saving options, and 0.3 MtCO2e that would entail additional costs.



On top of changed farming practices, there is the potential for an additional 0.8 $MtCO_2e$ of emissions savings from green fertiliser and avoided land-use change in 2050, bringing the total abatement potential for pork to 1.3 $MtCO_2e$.

Total abatement potential for the UK pork sector ($MtCO_2e$/year) in 2050



Poultry farming, including both meat and egg production, accounts for 2% of the total UK agriculture emissions, with the potential to reduce emissions by 72% in 2050.

The poultry sector includes chickens raised for meat and for eggs. It accounts for 2% of the agriculture emissions inventory.

1.6 $MtCO_2e$
Pork related emissions in 2021

0.6 $MtCO_2e$
Additional emissions from land-use change

2%
Contribution to total food industry emissions in 2021

22%
Reduction in emissions: 2030 vs 2021

55%
Reduction in emissions: 2050 vs 2021

66%
Reduction in carbon intensity in 2050

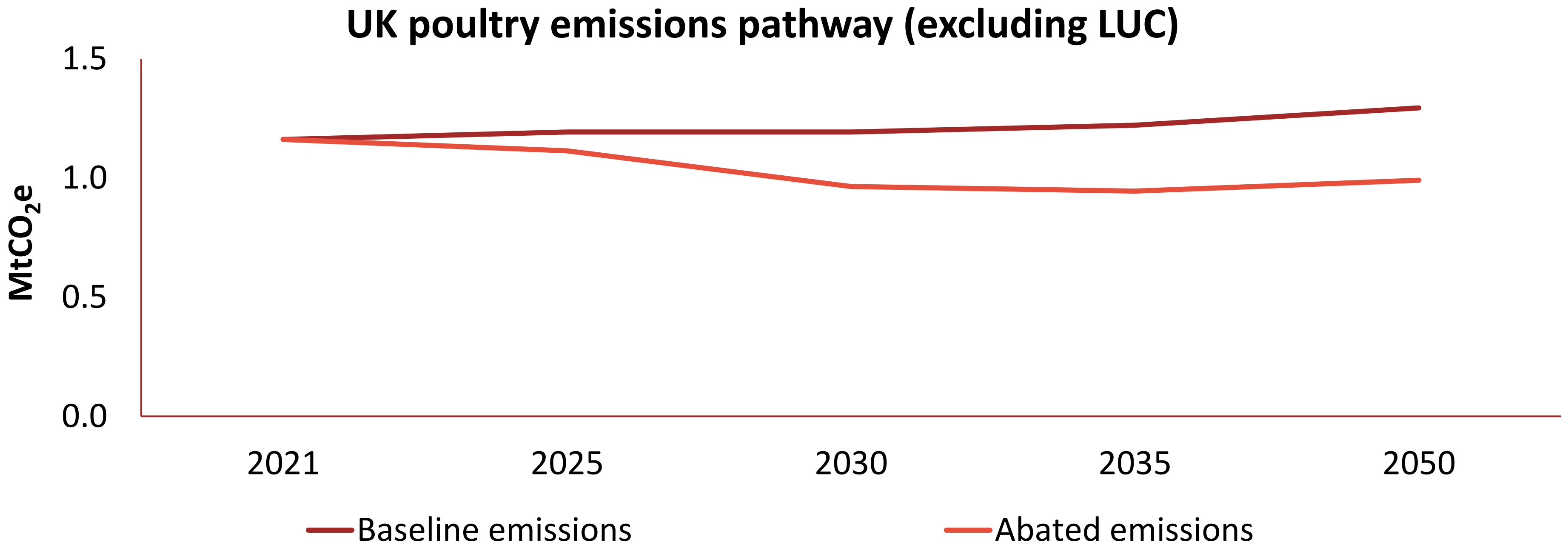
£29 million
Expected cost of abatement in 2050

Emissions drivers

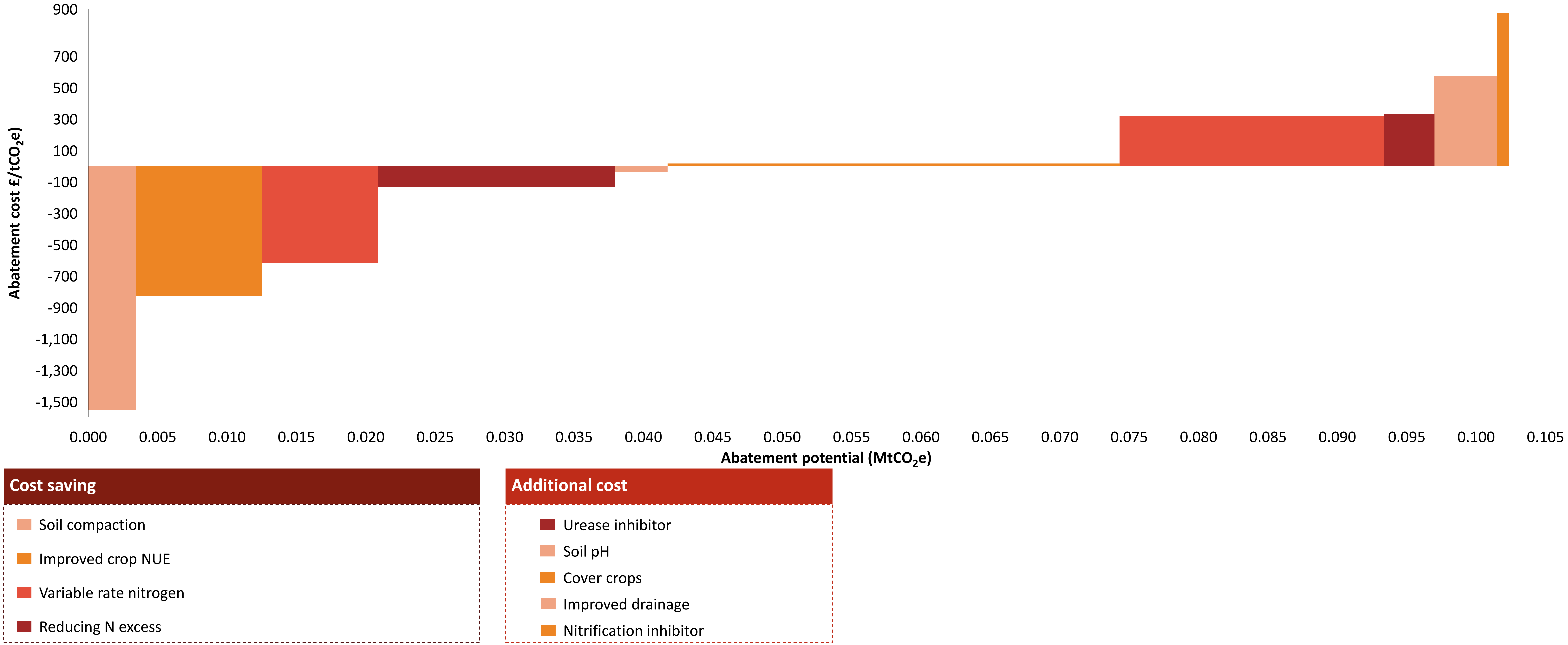
The poultry sub-sector emissions are mainly driven by nitrous oxide (N_2O) arising during feed production from the application of fertiliser, as well as from carbon dioxide (CO_2) in producing the fertiliser.

Abatement

There is the potential to reduce emissions by up **15%** in 2050 relative to 2021 from **changed farming practices** (see graph opposite). In addition, there are opportunities to reduce emissions by an additional **57% from green fertiliser and avoided land-use change.** The carbon intensity reduction of 83% in 2050 exceeds the emissions reduction relative to 2021, reflecting significant growth in population and demand over the period. There may also be some opportunities to reduce emissions through agroforestry. albeit these are likely to be limited.



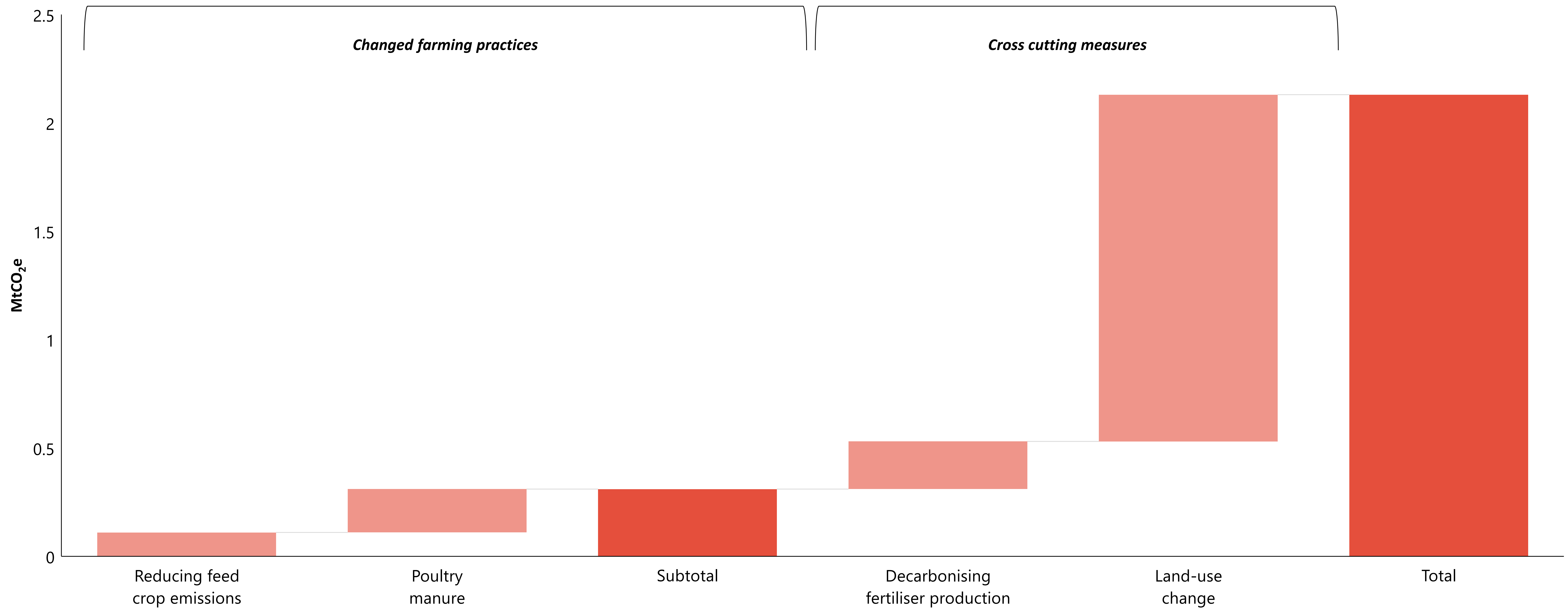
There is a total abatement potential of 100 $ktCO_2e$ from changed farming practices across the poultry sector. The SRUC's MACC analysis* shows that the emissions savings potential is comprises 40 $ktCO_2e$ from cost saving options, and 60 $ktCO_2e$ that would entail additional costs.



* MACC analysis excludes poultry manure emissions reductions

On top of changed farming practices and management of poultry manure, there is the potential for an additional 1.8 $MtCO_2e$ of emissions savings from green fertiliser and particularly from avoided land-use change in 2050, bringing the total abatement potential for poultry to 2.1 $MtCO_2e$.

Total abatement potential for the UK poultry sector ($MtCO_2e$/year) in 2050



Arable farming accounts for 10% of the total UK agriculture emissions, and is projected to grow to almost 5 $MtCO_2e$ by 2050. This sub-sector has a significant potential to reduce emissions by 32% compared to the 2021 baseline.

The arable sector includes the cultivation of grains or seeds, such as cereals. The emissions (and abatement) from crops used as feed are included in the relevant livestock subsectors consuming the feed. The sector accounts for 10% of the agriculture emissions inventory.

4.4 $MtCO_2e$
Arable related emissions in 2021

0 $MtCO_2e$
Additional emissions from land-use change

3%
Contribution to total food industry emissions in 2021

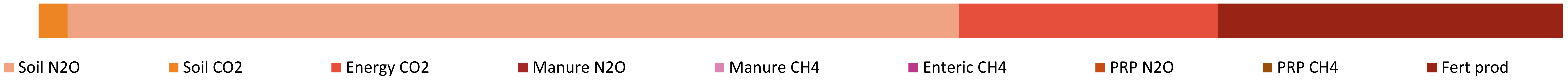
17%
Reduction in emissions: 2030 vs 2021

38%
Reduction in emissions: 2050 vs 2021

£37 million
Expected cost of abatement in 2050

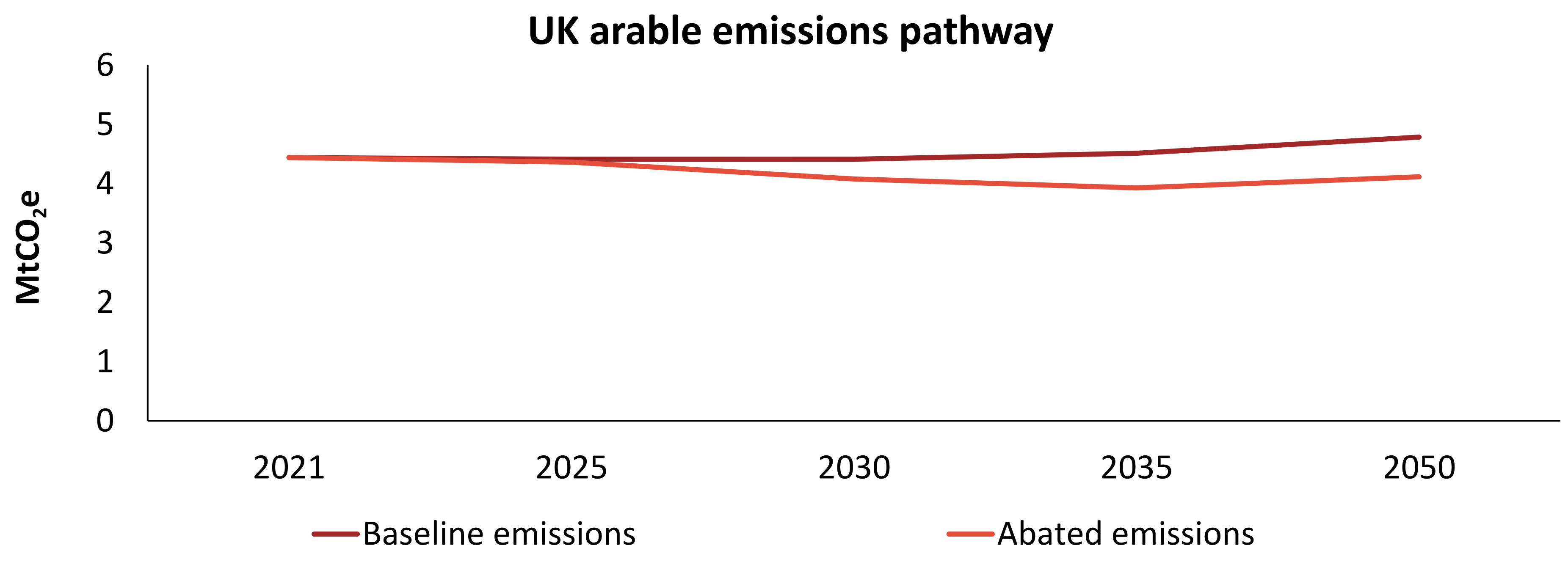
Emissions drivers

Arable farming emissions are mainly driven by nitrous oxide (N_2O), energy use on-farm for fieldwork and the emissions occurring during fertiliser production, though most of the latter occurs outside the UK.

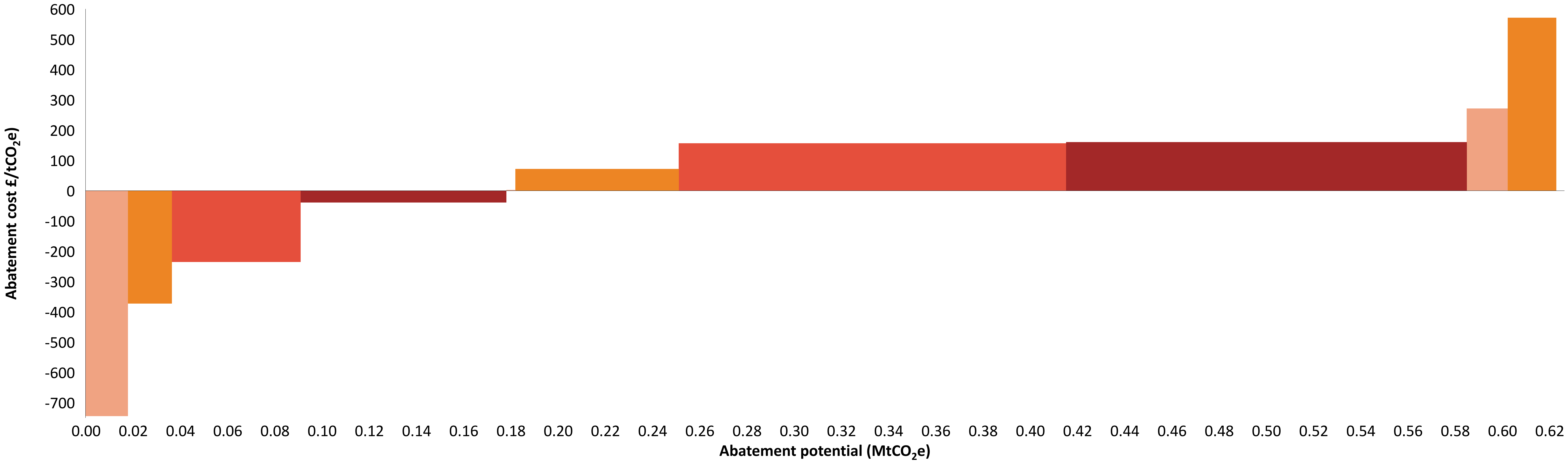


Abatement

There is the potential to reduce emissions by up to **7%** in 2050 relative to 2021 from **changed farming practices** (see graph opposite). In addition, there are opportunities to reduce emissions by an additional **25% from green fertiliser.** The carbon intensity reduction of 38% in 2050 exceeds the emissions reduction in relative to 2021, reflecting significant population and demand growth. There may also be significant further opportunities to reduce emissions through low-carbon mobile machinery, agroforestry and bio-stimulants (see pages 91-93).



There is a total abatement potential of 0.6 $MtCO_2e$ from changed farming practices across the arable sector. The SRUC's MACC analysis shows that this comprises 0.2 $MtCO_2e$ from cost saving options, including variable rate nitrogen, and 0.4 $MtCO_2e$ that would entail additional costs, including cover crops and nitrification inhibitor.



Cost saving

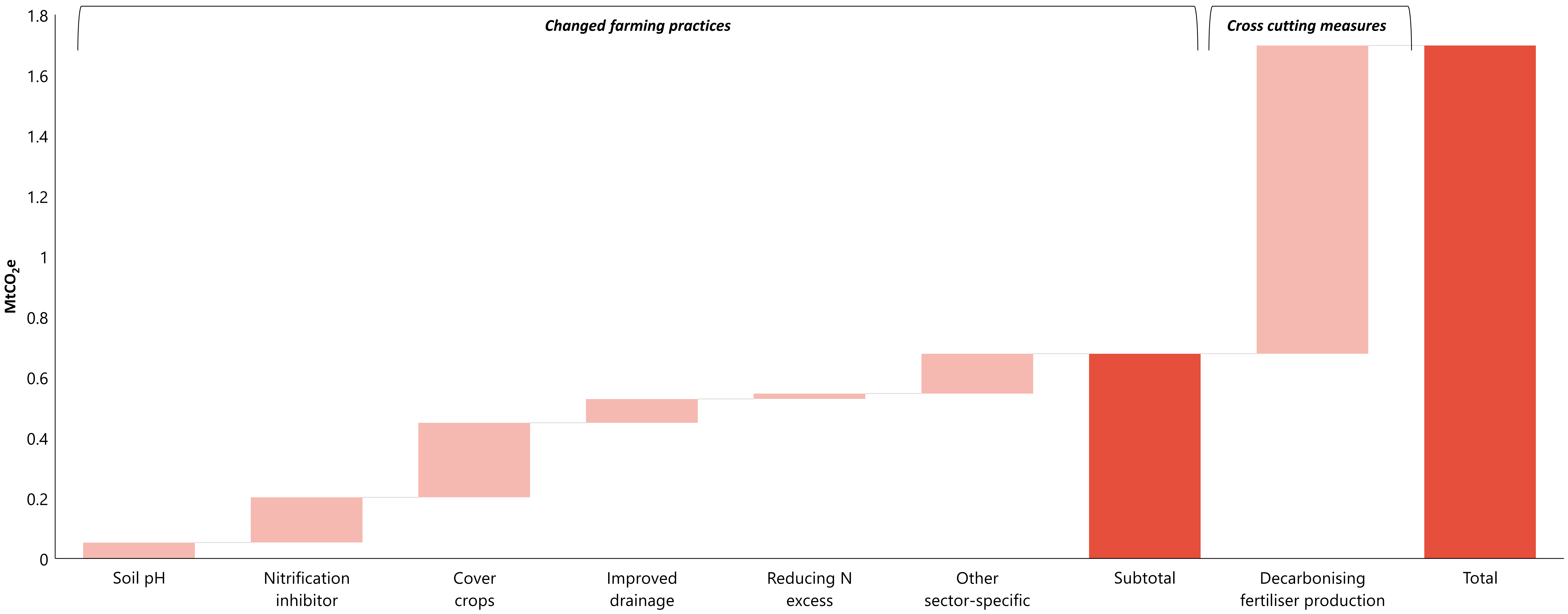
- Soil compaction
- Reducing N excess
- Soil pH
- Variable rate nitrogen
- Triticale

Additional cost

- Cover crops
- Urease inhibitor
- Improved crop NUE
- Improved drainage
- Nitrification inhibitor

On top of changed farming practices, there is the potential for an additional 1 $MtCO_2e$ of emissions savings from use of green fertiliser in 2050, bringing the total abatement potential for arable to 1.7 $MtCO_2e$.

Total abatement potential for the UK arable sector ($MtCO_2e$/year) in 2050



Horticulture farming accounts for 2% of the total UK agriculture emissions, and projected to remain at around 0.8 $MtCO_2e$ until 2050. There is a significant potential to reduce emissions by 46% against the 2021 baseline.

The horticulture sector includes the cultivation of nuts, fruits, vegetables and flowers. The emissions (and abatement) from crops used as feed are included in the relevant livestock subsectors consuming the feed. The sector accounts for 2% of the agriculture emissions inventory.

0.8 $MtCO_2e$
Horticulture related emissions in 2021

0 $MtCO_2e$
Additional emissions from land-use change

1%
Contribution to total food industry emissions in 2021

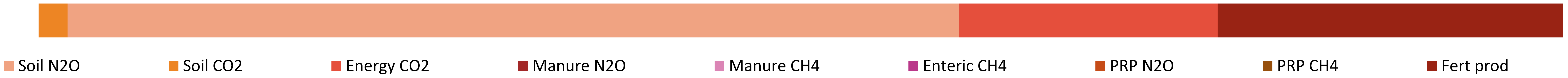
22%
Reduction in emissions: 2030 vs 2021

49%
Reduction in emissions: 2050 vs 2021

-£4 million
Expected cost of abatement in 2050 (i.e. cost saving)

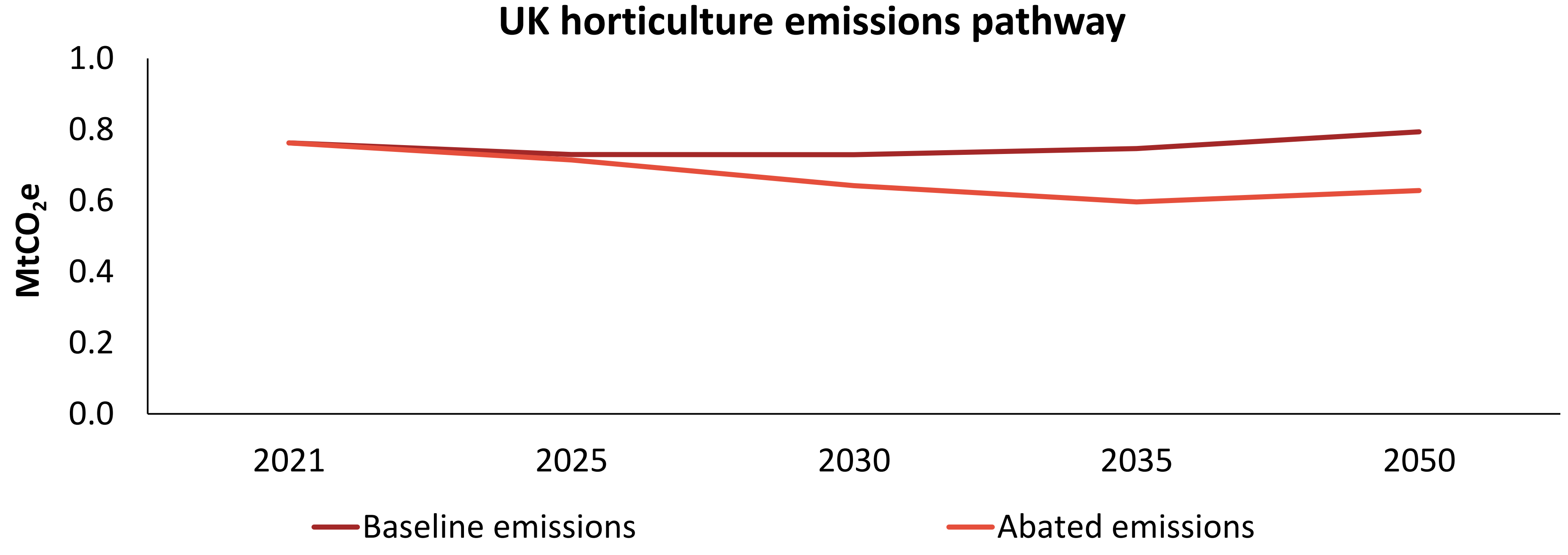
Emissions drivers

Horticulture farming emissions are mainly driven by nitrous oxide (N_2O) , energy use on-farm for fieldwork and the emissions occurring during fertiliser production, though most of the latter occurs outside the UK.

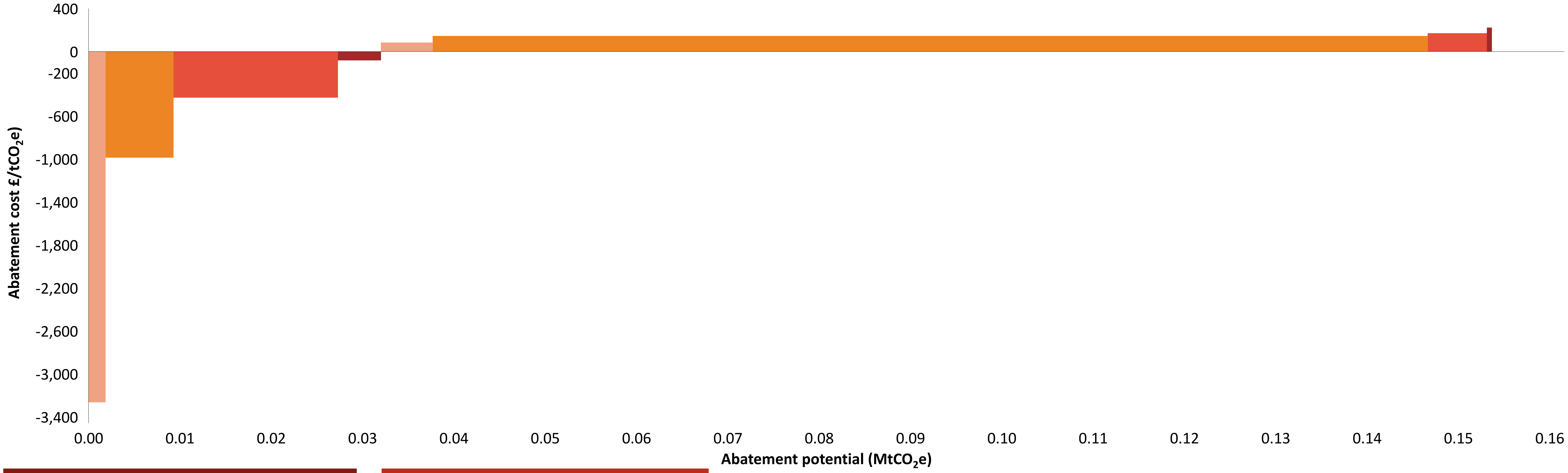


Abatement

There is the potential to reduce emissions by up to **18%** in 2050 compared to 2021 from **changed farming practices** (see graph opposite). There are opportunities to reduce emissions by an **additional 29% from green fertiliser.** The carbon intensity reduction of 49% in 2050 exceeds the emissions reduction compared to 2021, reflecting significant population and demand growth through the period. There may also be significant further opportunities to reduce emissions through low-carbon mobile machinery, bio-stimulants and agroforestry (see pages 91-93).



There is a total abatement potential of 150 ktCO_2e from changed farming practices across the horticulture sector. The SRUC's MAAC analysis shows this comprises 30 ktCO_2e from cost saving options, including improved drainage and soil pH, and 120 ktCO_2e that would entail additional costs, including cover crops and nitrification inhibitor.



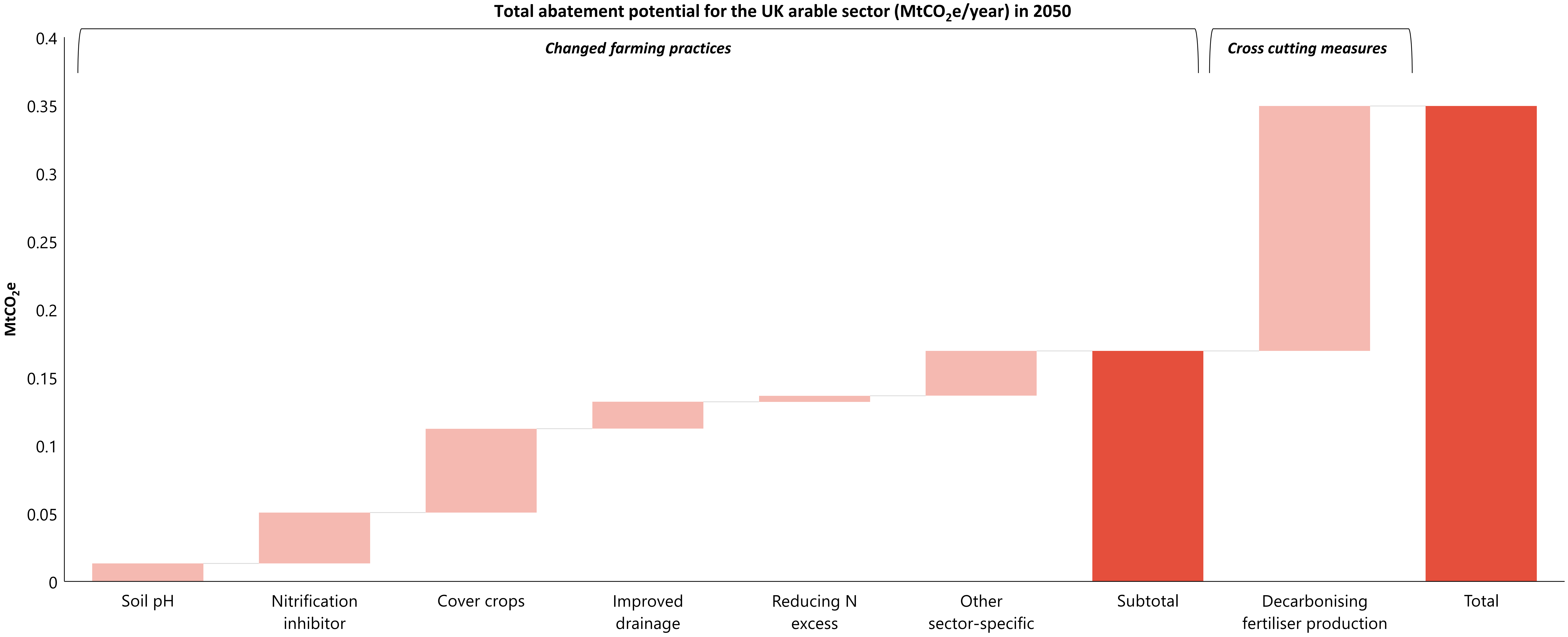
Cost saving

- Soil compaction
- Soil pH
- Improved drainage
- Reducing N excess

Additional cost

- Variable rate nitrogen
- Cover crops
- Nitrification inhibitor
- Urease inhibitor

On top of changed farming practices, there is the potential for an additional 180 ktCO_2e of emissions savings from use of green fertiliser, bringing the total abatement potential for horticulture to 350 ktCO_2e in 2050.



3.3 Cross cutting emissions reduction opportunities: fertiliser, LUC, mobile machinery, agroforestry; less mature and more challenging options

Taking a cross sectorial view, the total emission reduction potential through the use of green fertiliser is 3 $MtCO_2$ and a further 3 $MtCO_2$ through avoided land-use change related to soy production.

Green fertiliser

Current fertiliser production emissions related to UK farming are around 3 $MtCO_2e$ annually, largely related to the burning of methane in the production of ammonia. Fertiliser demand will be reduced through various measures considered in the previous section. There are limited opportunities to further reduce fertiliser production emissions, such as through the use of waste and through anaerobic digestion. Deep cuts in fertiliser production emissions will require green fertiliser to be produced from hydrogen. However, production at scale will depend on the cost and availability of hydrogen. Therefore, the earliest date green fertiliser can be rolled out at scale is 2035, but this may well be later, e.g. 2040. Using a cost of green hydrogen of £275/tCO_2e, the total cost for use of green fertiliser in UK farming is of the order £800 million annually.

Land-use change

UK emissions related to land-use change through feed-related deforestation and land conversion are estimated to be 3.2 $MtCO_2e$ in 2021. These emissions could be reduced over time through sustainable sourcing of feed. The EU's Deforestation Regulation (EUDR) requires that feed cannot be sourced from land that was deforested after 2021, with plans for the regulation to extend to cover land conversion (consultation due before Christmas 2024). Emissions could fall to zero by 2041 under an extended EUDR using the PAS2050 method of emissions accounting. This is used as a proxy for the UK, and modelled a back-ended trajectory, reflecting historic growth in land-use change. The costs associated with EUDR are highly uncertain and likely to fall beyond the initial period as new business models are established, noting that the cost of production on sustainable land is not significantly higher than on unsustainable land. The current premium being quoted is a minimum of 10% on soy imports of 2 Mt annually, which would equate to around £60 million – and could be much higher.

The UK's deforestation regulation was proposed to be introduced by the previous Government in summer 2024. The approach would have allowed legal deforestation, and included land conversion. Going further than EUDR in this latter respect would entail having separate supply-chains for the UK and could entail significant cost. It would also be burdensome for food companies subject to EUDR. This would be without environmental benefit, given conversion free feed already in the system would simply be diverted to the UK. A pragmatic approach would be to align UK policy with EUDR, while taking care to ensure that risks related to land conversion are managed.

Opportunities exist to reduce agriculture emissions through using low-carbon mobile machinery and investing in agroforestry – together these offer 3+ $MtCO_2e$ annual savings.

Mobile machinery

Emissions from mobile machinery on farms are currently around 2 $MtCO_2e$ annually, which equates to around 4% of total agriculture emissions. These occur due to the use of tractors, combine harvesters, etc.

Options to decarbonise these emissions are similar to those for surface transport more generally: electric vehicles, biofuels, hydrogen and hybrid vehicles. It is assumed that these are taken up through the 2030s / 2040s, such that emissions from mobile machinery fall to zero. To the extent that low carbon alternatives are relatively expensive, incentives will be needed for their uptake, for example, through capital grants to offset relatively high upfront costs of buying the machines.

Agroforestry

Agroforestry refers to the planting of trees around and inside fields in the context of producing food. This has net zero and wider benefits for nature.

The modelling above includes planting of trees in shelter belts and fence-lines, which could result in emissions reductions of 1.5 $MtCO_2e$ in 2050.

Agroforestry was included in the Sustainable Farming Incentive offer for 2024.

There are further options that could reduce emissions – although these are not yet proven and their potential is currently uncertain.

There are other abatement options in development that are less mature/more challenging, but which could have significant benefits if they fulfil their potential. These are not included in the MACC modelling, but could help to close the gap to meeting targets and/or change the balance of effort required – these are therefore accounted for in the system pathways. They should not be seen as a panacea; even if they were to fulfil their potential, a gap to meeting targets would still exist.

Enteric methane

As well as 3NOP and nitrate, other feed additives such as bromoform may be able to further reduce enteric methane. The abatement from feed additives would be increased significantly if they could be fed to grazing ruminants, with such delivery mechanisms currently being developed; this could offer savings of around 3 $MtCO_2e$ across the UK. In the meantime, reductions could be made by increasing the digestibility of forage by adjusting cutting time, choosing the right varieties and testing forage quality as well as breeding sheep for improved productivity and by capturing excreted methane from housed cattle using specialised air conditioning equipment.

Bio-stimulants

These can be applied to crops, resulting in a reduction of up to **20% in fertiliser use**. Bio-stimulants are currently uncertain in terms of performance and less reliable than use of nitrogen. If this could be overcome, then emissions of up to **1 $MtCO_2e$** (20% of 5 $mtCO_2e$ abated nitrous oxide emissions) could be available, equivalent to around **2% of base year emissions**.

Arable-livestock rotations

More fundamental changes could include (re-) integrating livestock into cropping systems or adopting regenerative farming. Such approaches seek to harness synergies, for example the diversification of crop rotations can reduce pest pressure and chemical inputs, close nutrient cycles, improve soil fertility and enhance biodiversity.

Insect-based or microbiotic feed

There could be opportunities to move away from conventional feed to insect-based feed or microbiotic feed. There are significant challenges with each of these, for example energy intensity of production, but if these technologies could be brought to market in a cost-effective way, the emissions saving would be of the order **3 $MtCO_2e$ annually** (remaining feed emissions after abatement), which is around **6% of base year agriculture emissions**.

Manure management

Better matching feed to livestock requirements should reduce nitrogen excretion and hence nitrous oxide from manure management. Lower protein feed can be used without negative effects on animal performance. Additives are being developed than can reduce methane and ammonia from slurry.

Carbon sequestration

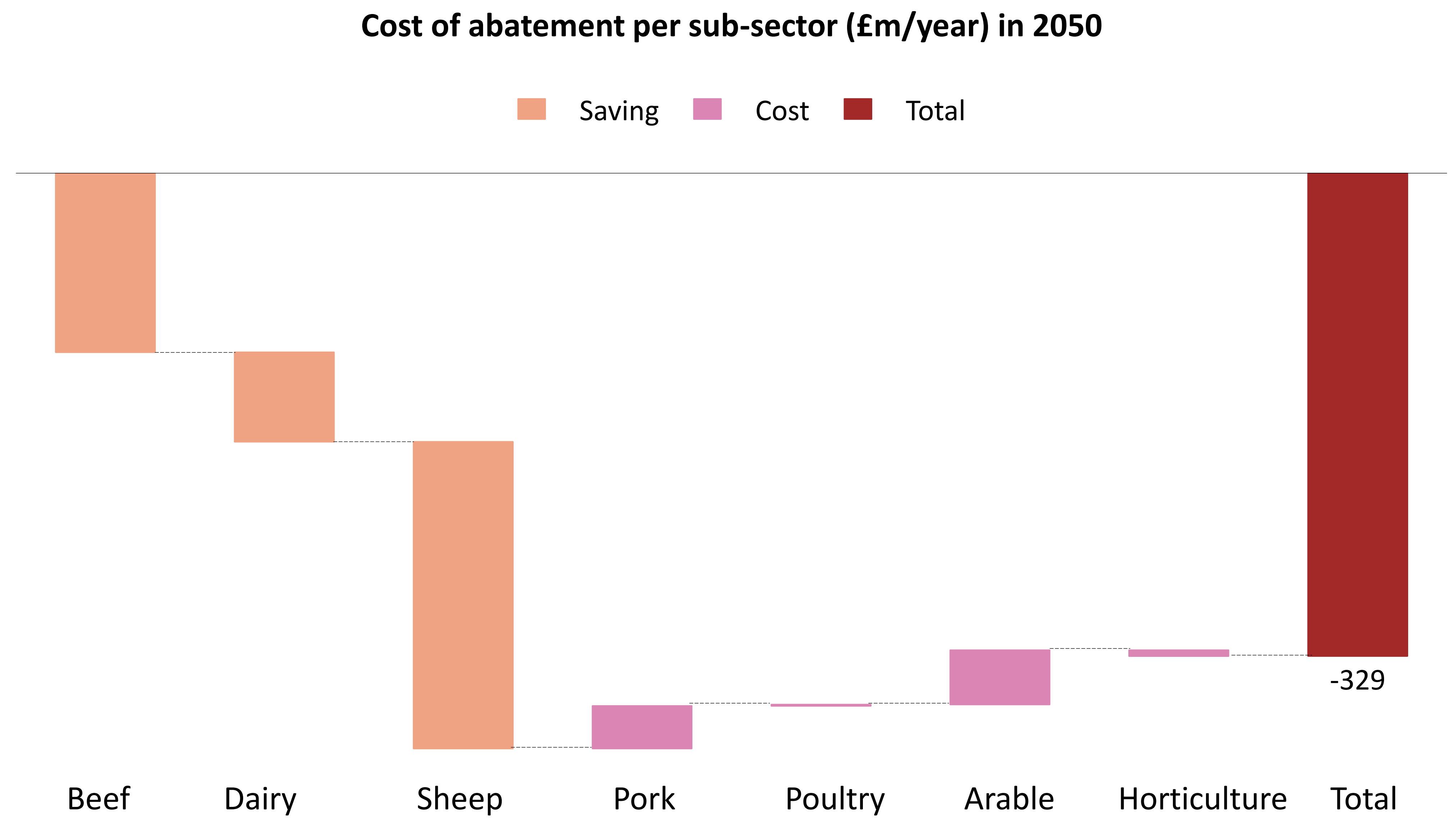
In addition to sequestration from agroforestry above, further sequestration could be achieved by integrating trees into livestock and crop production, e.g. SRUC estimated scope for an additional **3 $MtCO_2$ savings annually** in 2021 advice to Defra, through inter-cropping on 700 kHa of land.

However, barriers to uptake may be significant here, including potential impacts on productivity (this type of agroforestry is akin to forestry and can be viewed as land-use change). Therefore, we note this is an option where more may be possible in the overall assessment of system abatement opportunities. It would need to be done in a targeted way to avoid losses in production.

Soil carbon stocks could be increased by using biochar or through enhanced rock weathering.

3.4 Cost of reducing UK farming emissions

There is a net saving from abatement of £301 million in 2030 and £329 million in 2050. This saving is driven by beef, dairy and sheep subsectors, within which some measures have costs (e.g. feed additives); in pork, poultry and arable, there is a net cost of abatement.



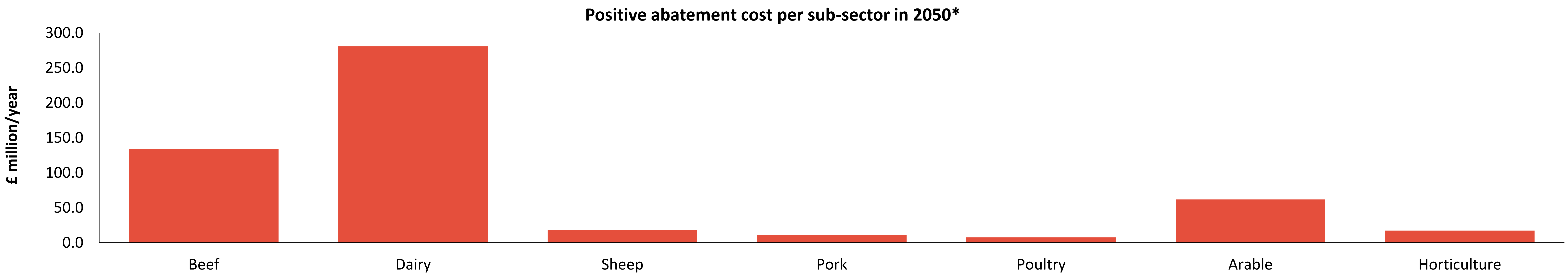
The sector MACCs show that some measures offer opportunities for cost savings or revenue generation, i.e., any initial investment is more than offset by operating cost reductions or yield increases.

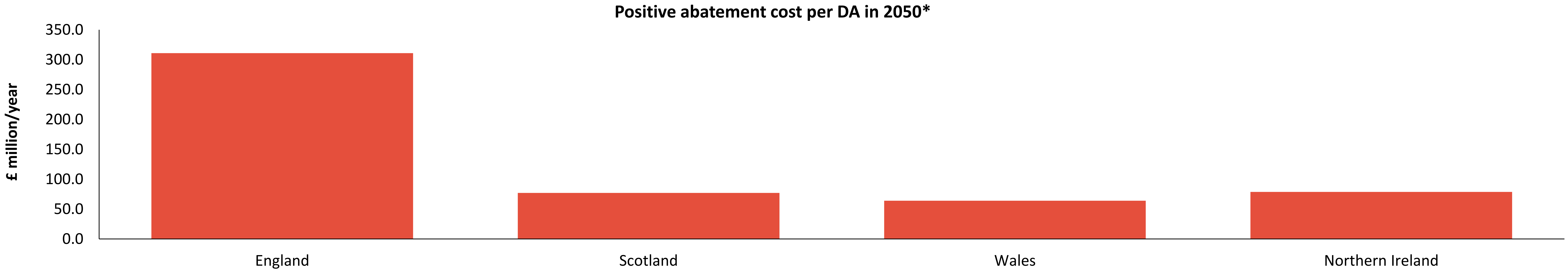
As a result, there are aggregate net cost savings across some sub-sectors, including beef, dairy and sheep, from measures such as improving the efficiency of fertiliser use and productivity.

Even where there are cost saving opportunities, funding will be required to support changed farm practice, and to bridge the gap between upfront costs and benefits over time.

The sector MACCs also show that there are important measures across all seven sectors which are costly rather than cost-saving, and will need to be funded. See the following page for estimated aggregate funding requirements.

For those measures that are costly, the total funding requirement is around £530 mn annually. The bulk of funding is required for beef and dairy farming, although funding is required across all subsectors. Across the nations of the UK, around 60% of funding needed is in England, with the remainder broadly equally distributed across the devolved administrations.





* Total includes positive abatement costs below £400/tCO2e only

3.5 Assessment of farm policies

Policy strengthening will be essential in England order to deliver emissions reductions.

Farming policy is a devolved matter. Farm policies in England and the DAs have been tested for alignment with government objectives, budget, targeting of abatement measures, and take-up of schemes.

Alignment with Government objectives

Reducing farming emissions is a key pillar of the UK's net zero strategy; territorial farm emissions account for around 10% of total UK greenhouse emissions.

Budget

The farm budget for England is £2.4 bn annually, compared to the estimated (positive) cost for net zero measures of around £300 mn, therefore there is sufficient budget to fund these measures. Much of the budget is currently not allocated. To the extent there are pressures on the farming budget, these could be managed through leveraging private finance for investment in forestry and peatland restoration; the Government is developing an approach for this.

Targeting of net zero measures

The relevant policies include ELM (including the Sustainable Farming Incentive), productivity grants, support for animal health improvement, the Food Data Transparency Partnership. These policies are well targeted to net zero measures by design (i.e. the Government has prioritised such measures in scheme design). The Government should commit to them and their funding.

Support should be extended to feed additives in dairy, which would cost up to £65 mn annually for fully funded rollout of Bovaer and 100% uptake; costs would (obviously) be lower for partial funding and lower uptake.

Support for AD is due to end and should be extended, given significant opportunities across farming sectors that are unlikely to be addressed without funding.

In due course, support should be provided for decarbonisation of mobile machinery from the productivity grants pot of money, when such measures become cost effective.

Farming regulations are inherited from the Common Agricultural Policy (CAP) and were designed for a different era with different objectives. They should be reviewed to see if they are designed to achieve the desirable balance between food production, net zero and nature. For example, the Farming Rules for Water do not support the use of organic fertiliser.

Policy strengthening will be essential in England to deliver emissions reductions (cont.).

Uptake of schemes

Government data shows that around half of the 80,000 farmers in the UK receiving direct payments are enrolled in agri-environment schemes, mostly Countryside Stewardship.

Enrolment in SFI is below 25% of eligible farmers including recent EOIs, reflecting financial and non-financial barriers.

Financial barriers reflect payment rates being based on income foregone, which makes schemes most attractive for unproductive land; payment rates should be reviewed in light of uptake in SFI23 and 24.

Non-financial barriers relate to lack of farmer knowledge of and engagement with schemes. This could be addressed by supporting farmers on their accounting, benchmarking and planning, linking this to SFI. The food industry has an important role to play, providing information to farmers in their supply chains, facilitating and encouraging them to enrol in schemes, including buttressing this through contract terms.

Emissions reductions from scheme participation are not currently reflected in carbon footprints: this undermines incentive to join schemes and undertake net zero activities. The Food Data Transparency Partnership (FDTP) seeks to address this through agreeing common methodologies and data process for carbon accounting, which could then be reflected in product and company level information. The Government should commit to the FDTP and ensure that it is adequately resourced to deliver its mandate. As a matter of urgency, ways should be found to reflect emissions reductions from farming policies in carbon footprints.

While emissions reductions paid for by the Government should not then be sold to the market, there are opportunities for farmers to stack benefits from agri-environment practices, including through going beyond measures in schemes and selling benefits. The Government should continue to develop approaches which would allow this through mobilising private finance.

Wales is making good progress with farm policies, much must ensure alignment with key carbon abatement measures as new schemes are finalised.

Alignment with Government objectives

Reducing agriculture emissions is a priority for the Welsh Government; agriculture emissions are around 15% of total greenhouse gas emissions.

Budget

The farming budget in Wales is around £420 mn, compared to (positive) cost for net zero measures of around £60mn, with further interim funding to support switching farm practice and to bridge the gap between timing of investments and flow of benefits.

Targeting of net zero measures

Enabling legislation has been passed, and a "Sustainable Farming Scheme" has been designed and consulted on. The scheme has three levels, including universal actions to be taken by all farmers, options which farmers can choose to undertake, and collaborative actions which work at the landscape level.

The scheme is well-targeted to key abatement measures, although it will be important to test these and ensure that no key levers are omitted from the final scheme design; this is due to be locked down in summer 2025 for implementation starting in 2026.

Uptake of schemes

The scheme has not been launched yet. However, the universal level scheme will – by definition – have full uptake. Uptake of options should be closely monitored, with payment rates adjusted as necessary.

The food industry has an important role to play supporting farmers to engage with schemes.

There has been some progress strengthening incentives for uptake of low-carbon measures in Northern Ireland – but much more is needed.

Alignment with Government objectives

Reduction of agriculture emissions is a key pillar of economy wide decarbonisation in Northern Ireland; agriculture emissions are over 25% of total emissions.

Budget

The farming budget in Northern Ireland is around £330 mn, compared to (positive) cost for net zero measures of £80 mn, with further interim funding to support switching farm practice and to bridge the gap between timing of investments and flow of benefits.

Targeting of net zero measures

Farmers are required to undertake carbon footprinting and planning.

Direct payments have requirements for beef age at slaughter, first calving and calving intervals.

While the Northern Ireland Government is considering support for other measures, financial incentives are currently lacking. Unless there are strong financial incentives, farmers will not adopt net zero measures. **Therefore a strong ask from the industry of the Norther Ireland Government is to fund net zero measures, as they are / will be funded in England and Wales.**

Uptake of schemes

Schemes are yet to be developed.

While reducing agriculture emissions is a priority for the Scottish Government, incentives for adoption of low-carbon farm practices remain weak.

Alignment with Government objectives

Reduction of agriculture emissions is a stated priority for the Scottish Government; agriculture emissions account for around 15% of total greenhouse gas emissions.

Budget

The Scottish farming budget is around £550 mn annually, compared to (positive) cost of net zero measures of around £80 mn, with further interim funding required to support switching of farm practice and to bridge the gap between timing of investments and the flow of benefits.

Targeting of net zero measures

Scotland has largely retained the CAP.

In order to get direct payments, there are conditions relating to carbon baselining and calving intervals.

Payments are available for investment in slurry management.

However, there are no financial incentives for most of the key abatement measures related to dairy and beef, which dominate Scottish farming – these will not be taken up unless this situation changes fundamentally. Therefore a strong ask from the industry of the Scottish Government is to fund net zero measures, as they are / will be funded in England and Wales.

Uptake of schemes

Schemes are yet to be developed.

3.6 Emissions from fish - wild and farmed

Fish is already a low-carbon source of protein, with scope for emissions reductions of wild-caught and farmed fish – although there are sustainability and welfare concerns which must be addressed.

Both domestic and imported fish contribute to the carbon footprint of the UK food system, including wild caught and farmed fish. Domestic fish emissions are estimated to be less than 0.5 $MtCO_2e$ and imported fish emissions are estimated to be around 2 $MtCO_2e$. Wild and farmed fish have a relatively low-carbon intensity (see top right) , with scope to reduce emissions.

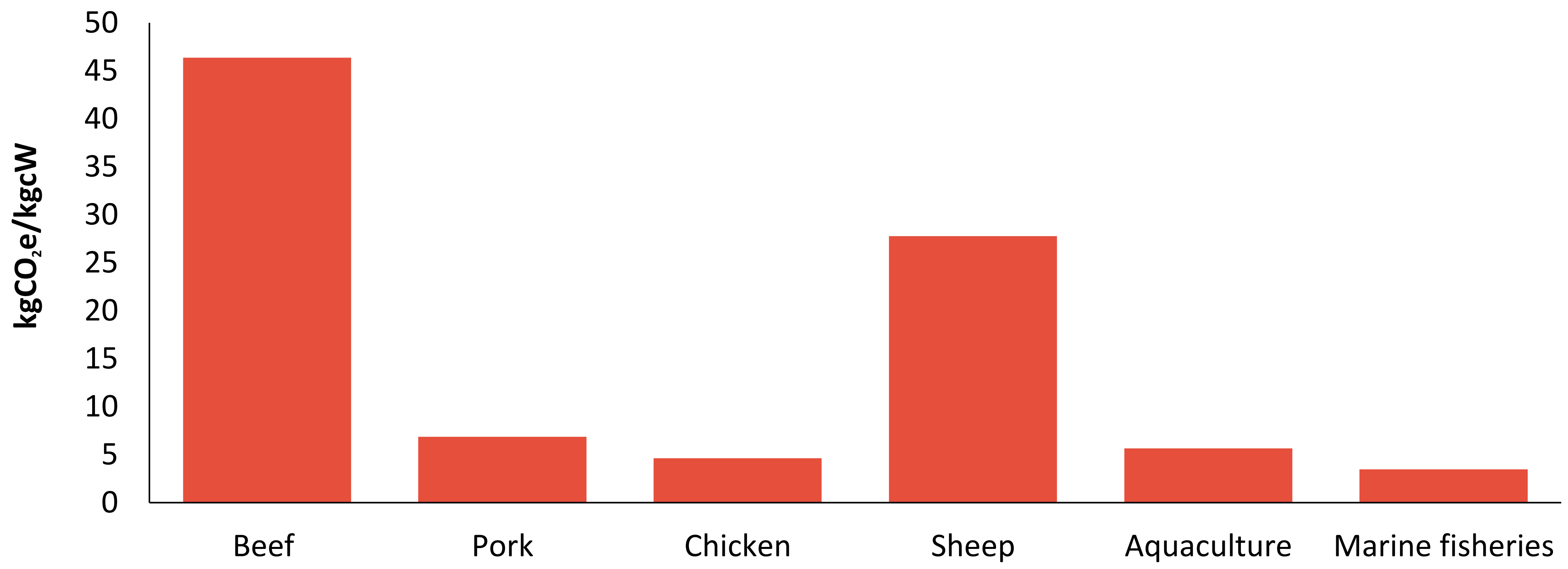
The emissions from wild caught fish are assumed to be driven by fishing fleet fuel use. Accordingly, it is assumed that these can be abated using the same levers as shipping and have adopted the assumptions from the CCC analysis (that shipping emissions can be reduced by 95% in 2050 from a 2021 baseline).

For farmed fish, there are opportunities for significant reductions in carbon intensity through the use of green fertiliser and avoiding land-use change emissions in feed production, and decarbonising energy use in aquaculture (see graph, bottom right, showing a breakdown of the farmed fish carbon footprint). It is assumed that emissions associated with farmed fish can be abated in line with domestic agriculture (for fertiliser and land-use change) and electricity (for aquaculture energy use). This results in approximately a 60% reduction out to 2050.

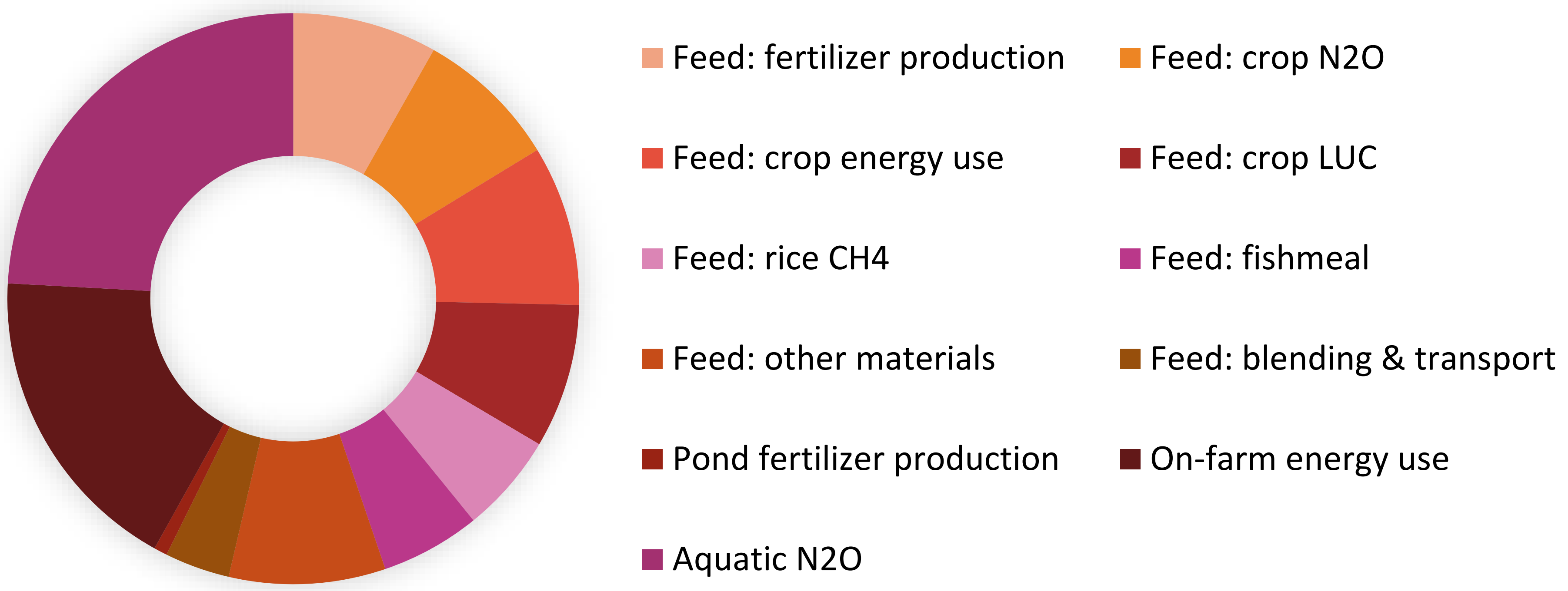
Wild caught and farmed fish offer opportunities for reduction of overall emissions when used as a substitute for more carbon intense forms of protein (see graph, top right, and page 116 on diet change). However, we note fish stock and environmental concerns with wild caught fishing, which are likely to limit its scope for expansion. For farmed fishing, while this can be done in a welfare sensitive way, this is not always practiced; any expansion should be consistent with high standards of welfare. Schemes are in place to support sustainable fishing.

We note that WRAP's carbon footprint – the baseline for this report – includes farmed fish imports, but does not include domestically farmed fish; this is an area for further work.

Emissions intensity of various protein sources[1]



Global average emissions intensity breakdown of farmed fish & seafood[1]



1 Quantifying greenhouse gas emissions from global aquaculture – Food Nature, 2020

3.7 Imported foods: carbon footprint and abatement

WRAP IGD

Approach to imported farming emissions

Approach

- This section extends the analysis of UK farming to imported products. It considers different categories of imports, starting with their carbon footprint and applying the abatement factors from the SRUC model.
- This is a first step in identifying abatement potential for imports, with further work needed to assess abatement potential in specific contexts where farming approaches and conditions may vary from those in the UK.
- The aim is not to consider whether there should be a rebalancing of domestic production and imports: a follow-on piece of work is recommended to do this, taking into account relative carbon intensity, risks related to climate, nature and geopolitics, and the UK's environmental targets.
- Whether or not the balance of production will change over time, it is clear that there will remain a very significant carbon footprint associated with imports, and this will have to be reduced if emissions targets are to be achieved. A higher level of savings for imported products compared to UK production is identified, given the relatively high share of LUC- and fertiliser-related emissions for imports, both of which can be reduced to zero.
- We do not consider policies to drive down emissions associated with imports, as this is beyond the scope of the report. However, there are very limited incentives in most countries outside the UK for emissions reduction. Therefore, it is recommended that the industry establishes a programme and platform to support changed farming practice in supply chains outside the UK to drive emissions down.
- Abatement costs are not estimated, because these are sensitive to the precise balance of abatement measures. However, if aggregate costs for UK abatement are adjusted to reflect the balance of types of farming and the abatement opportunity, this suggests a cost of the order several hundred million pounds for the opportunity to be realised.

Emissions associated with imported food are equal to around 85% of the domestic production footprint, totalling an additional 43.3 $MtCO_2e$. As such, they are a fundamental part of the decarbonisation effort of the whole UK food industry.

As well as producing food domestically, the UK has significant net imports. Emissions associated with food imported into the UK for consumption were 43.3 $MtCO_2e$ in 2021, which is broadly comparable to overall domestic agricultural emissions (50.3 $MtCO_2e$) but with a higher proportion of land-use change and fertiliser related emissions.

Imports have been categorized into three different product types, with fertiliser production and land-use change emissions also isolated:

Imports of products also grown domestically

- Beef
- Dairy
- sheep
- Pork
- Poultry
- Arable
- Horticulture

Imports of key tropical products

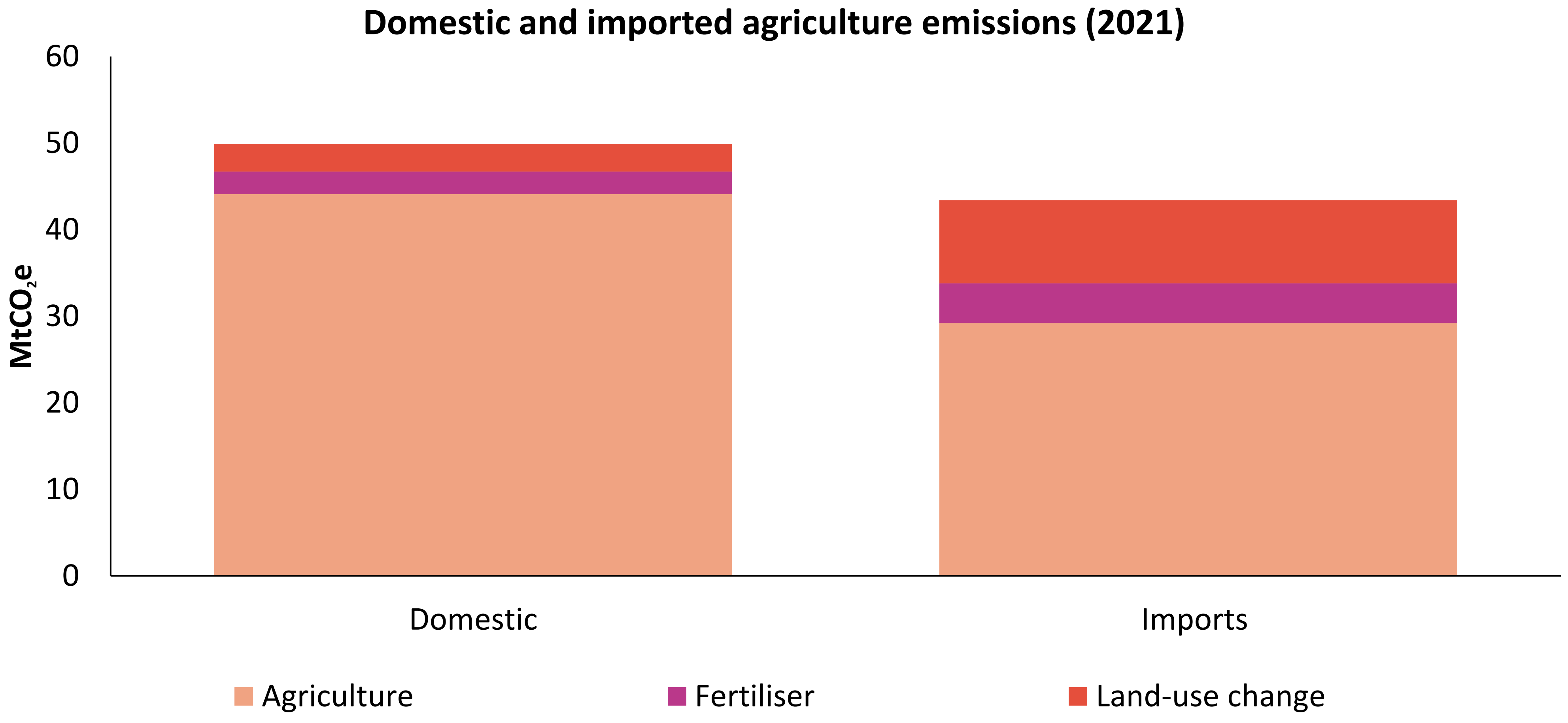
- Cocoa
- Rice
- Coffee
- Tea
- Palm Oil
- Soy
- Sugar

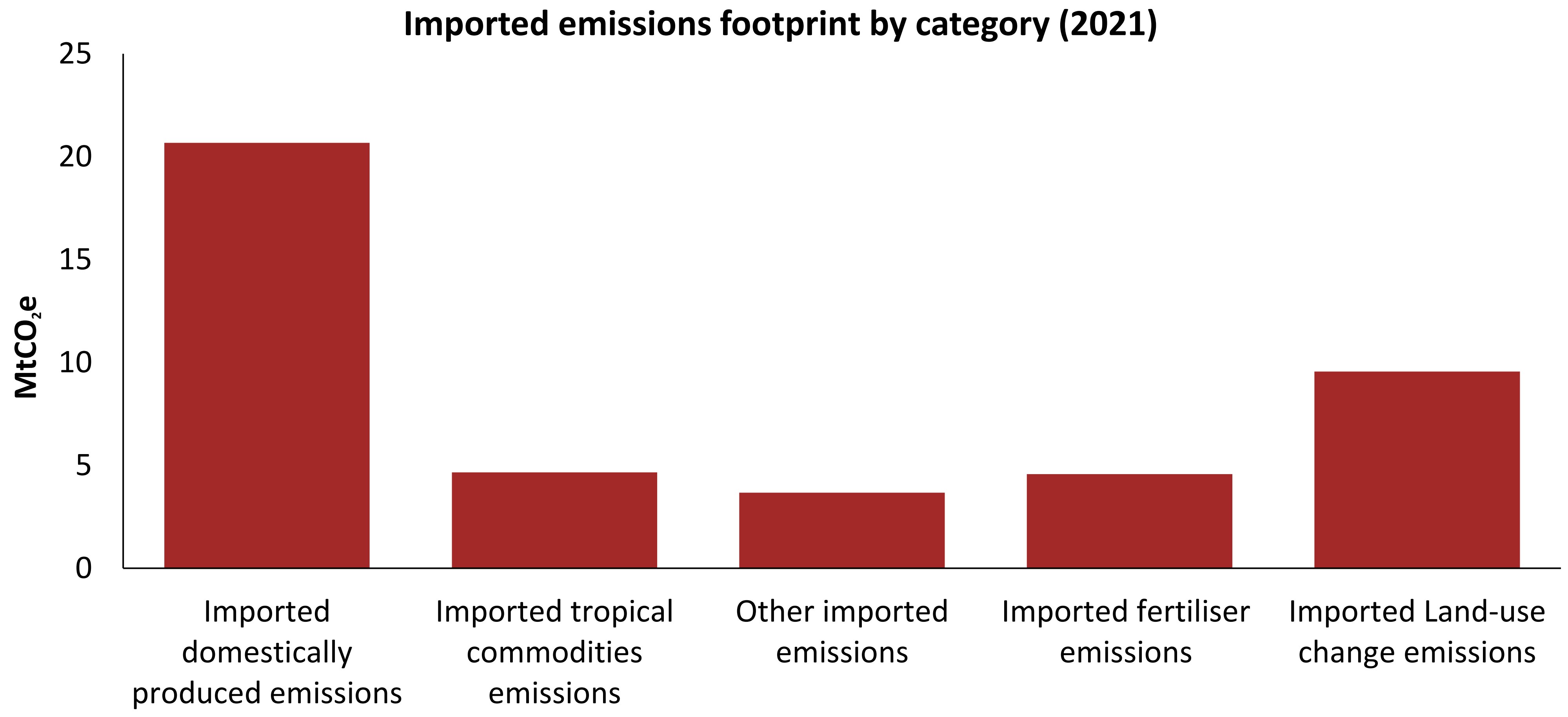
Other uncategorised imports*

- Alcohol
- Margarine
- Honey
- Sauces
- Condiments
- Soup
- Sweets
- Water

Land-use change

Fertiliser

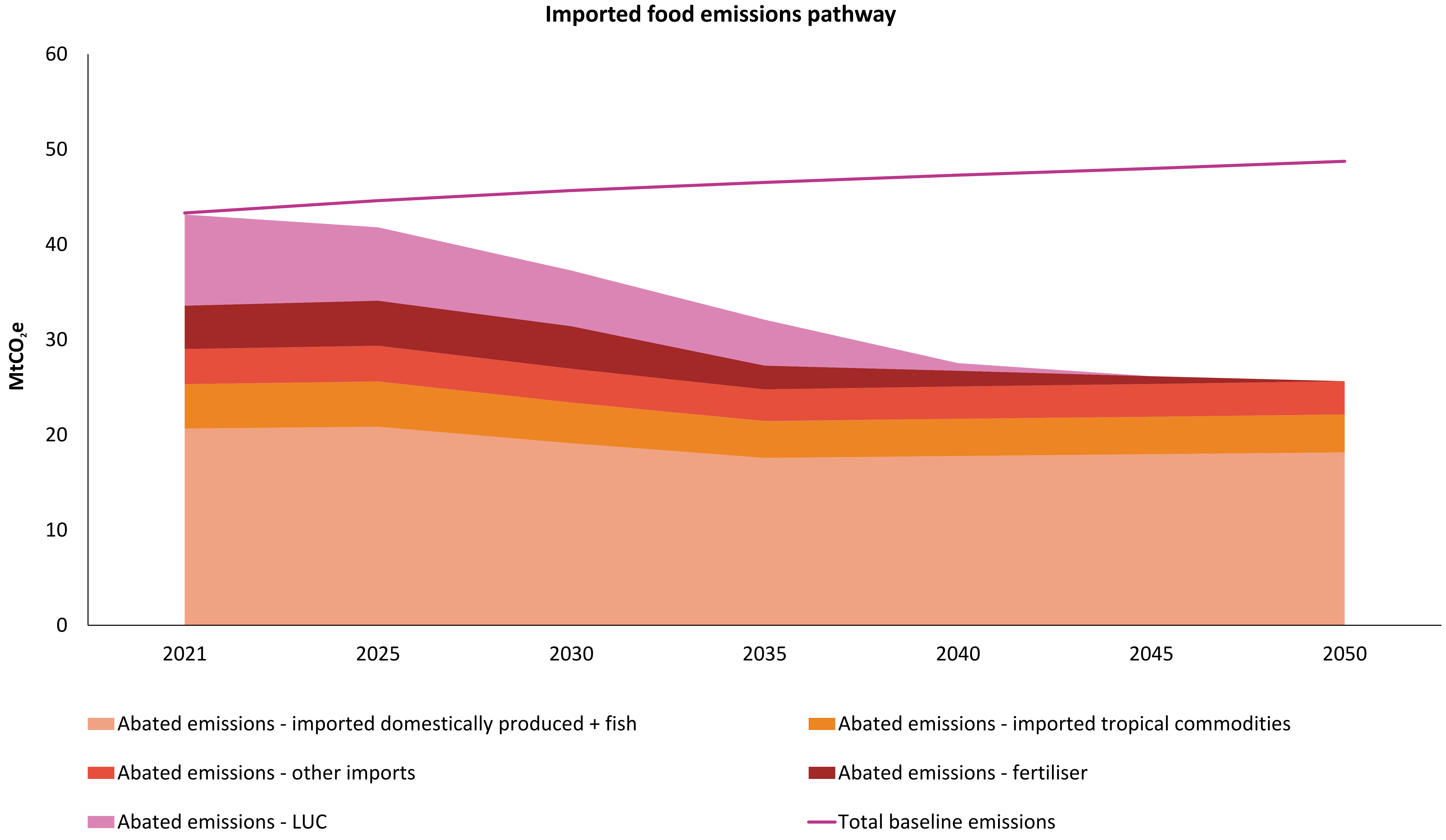




*Non-exhaustive list

Overall imported food emissions can be reduced by 45% in 2050.

- There is potential to reduce total imported emissions by 45% by 2050 from the 2021 baseline year (see graph opposite), through levers noted below.
- There is scope to cut land-use change emissions from 9.6MtCO_2e in 2021 to zero emissions in 2050. Land-use change emissions are higher than domestic agriculture due to the nature of land-use change related to tropical crops and land-clearing for cattle. It is assumed that this potential abatement is addressed by a UK corollary to the EU deforestation regulation.
- Fertiliser emissions can be reduced from 5.2 MtCO_2 in 2021 to 0 in 2050 through the use of green fertiliser.
- There is an opportunity to reduce imported agriculture emissions through changed farming practices abroad, with abatement of 8MtCO_2e (24%) in 2050.
- In estimating emissions reduction potentials for imports, it is assumed that the same opportunities exist in the same proportion as with domestic agriculture. To the extent that farming practices are less efficient than in the UK, there may be additional abatement potential, e.g. fertiliser use in production of tropical commodities.



*Includes costs for imports of products also grown domestically only

Imported products that can also be grown domestically account for just over half of the total imported emissions. The key measures for decarbonisation are farming practice changes and fertiliser use, resulting in a potential reduction of just over 36% compared to the baseline in 2021.

Imports of foods also grown domestically have emissions due to farming of 20.8 MtCO_2e of the footprint, with an additional 1.4 MtCO_2e of fertiliser production emissions. Around half of the emissions in this category are due to horticulture and arable, with significant contributions from dairy, beef and pork (see donut chart bottom right).

22 MtCO_2e
Imported domestically grown produce related emissions in 2021

17%
Contribution to total food industry emissions in 2021

14%
Reduction in emission: 2030 vs 2021

36%
Reduction in emissions: 2050 vs 2021

Emissions drivers

Emissions from imported food also domestically grown are mainly driven by horticulture and beef farming. Emissions reduction potential lies in both farming practice and green fertiliser production.

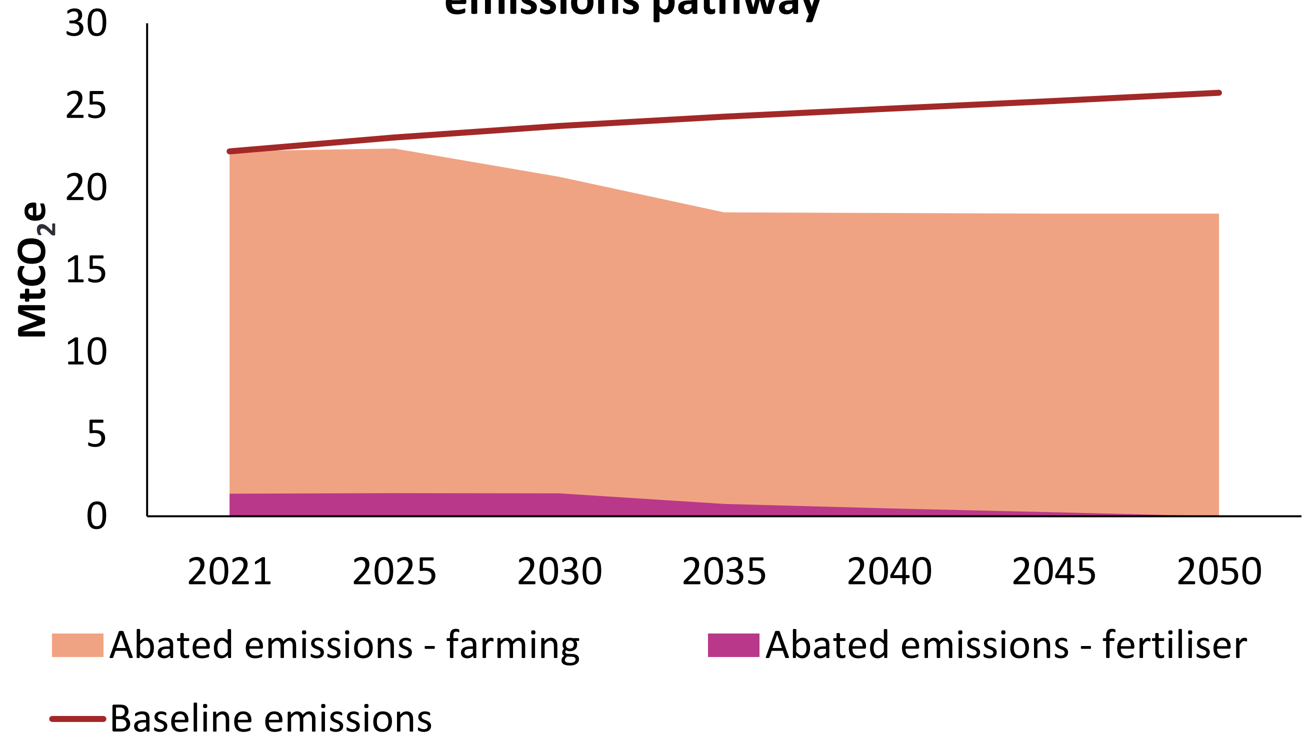
Abatement

Under a high abatement scenario, there is potential to reduce emissions by up to 36% in 2050 compared to 2021, through changed farming practice and use of green fertiliser (see graph to the right).

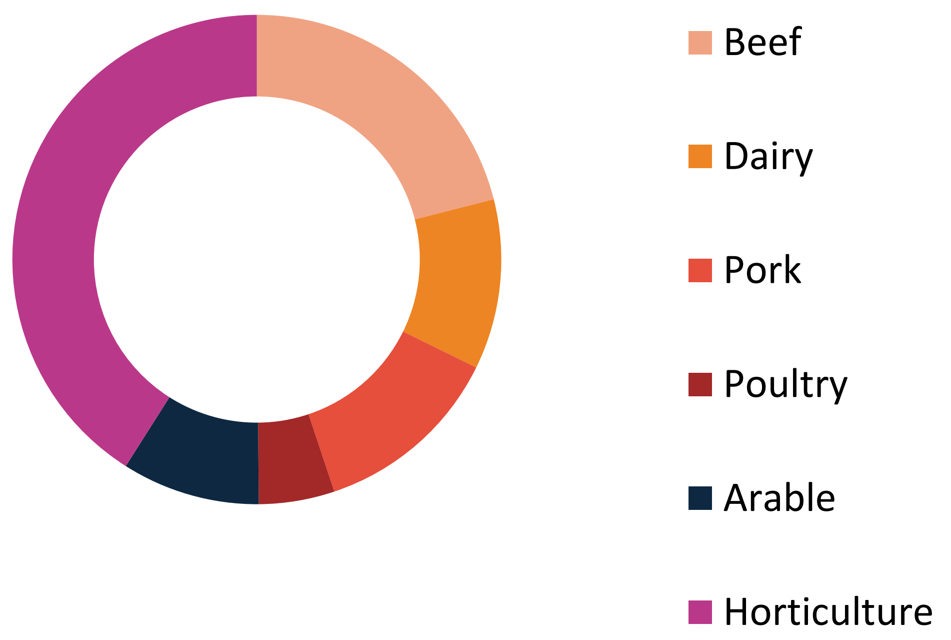
As noted previously, this is based on the assumption that foreign agriculture follows the same rate of decarbonisation as UK agriculture through similar abatement opportunities.

Avoided land-use change is very important for imported food and is included in the overall abatement potential (Page 108).

Imported products also grown domestically emissions pathway*



Imported products also grown domestically emissions footprint by category (2021)



*Does not include LUC emissions/abatement

Imports of tropical commodities not grown domestically account for 16% of total imported emissions. These products have a significant potential for decarbonisation, with a 49% reduction compared to 2021 baseline.

Imported tropical commodities have associated emissions of 4.7 $MtCO_2e$ from farming practice with a further 2.1 $MtCO_2e$ due to production of fertiliser. Emissions are distributed roughly equally across the seven commodities in this category (see donut chart below).

6.8 $MtCO_2e$
Imported food related emissions in 2021

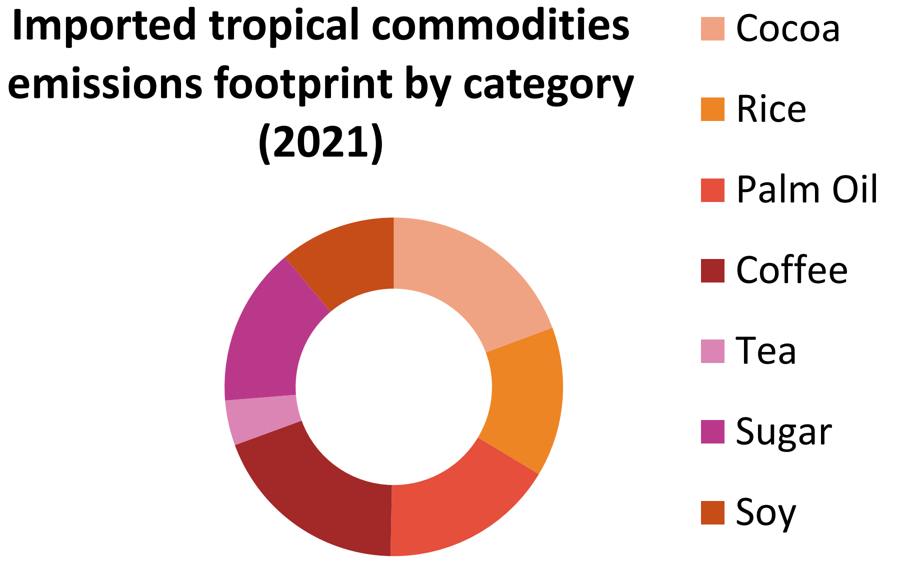
5%
Contribution to total food industry emissions in 2021

13%
Reduction in emissions: 2030 vs 2021

49%
Reduction in emission: 2050 vs 2021

Emissions drivers

Imported tropical commodities emissions are largely evenly split across cocoa, coffee, tea, rice, palm oil and sugar and soy. These emissions were estimated by WRAP to be ~6.8 $MtCO_2e$, with fertiliser production emissions making up around 2.1 $MtCO_2e$ (25%) of this total.

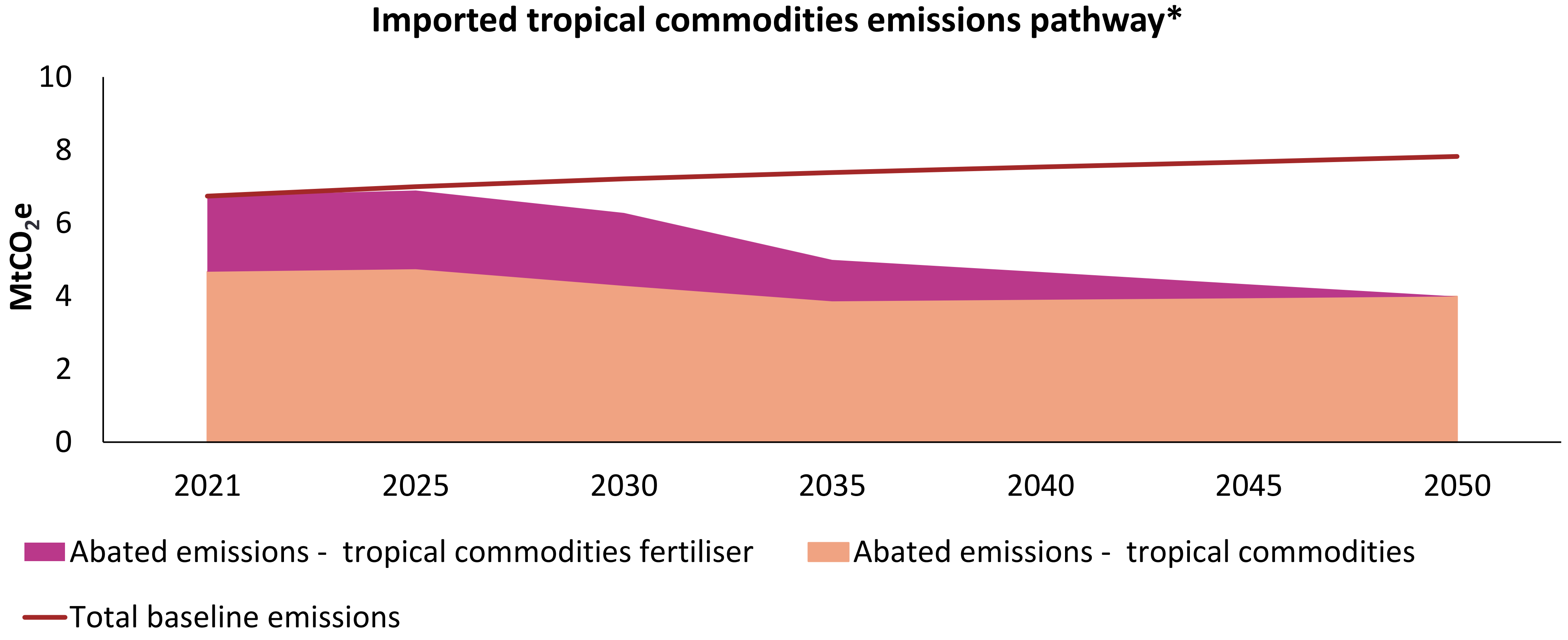


Abatement

Under a high abatement scenario, there is potential to reduce emissions by up to 49% in 2050 compared to 2021 (see graph to the right). Fertiliser is a relatively high share of total emissions for tropical commodities compared to animal products, implying relatively high abatement potential through use of green fertiliser. The remainder of the abatement is through changed farm practices.

As noted previously, the emissions pathway for imported tropical commodities is based on the assumption that foreign agriculture follows the same rate of decarbonisation as UK agriculture, through similar abatement opportunities. To the extent that the efficiency of fertiliser production and use is lower in countries producing tropical commodities, additional abatement would be available.

Avoided land-use change is important for tropical commodities and is included in the overall abatement potential (Page 108).



*Does not include LUC emissions/abatement

Modelling assumptions for imported foods

Imported food assumptions

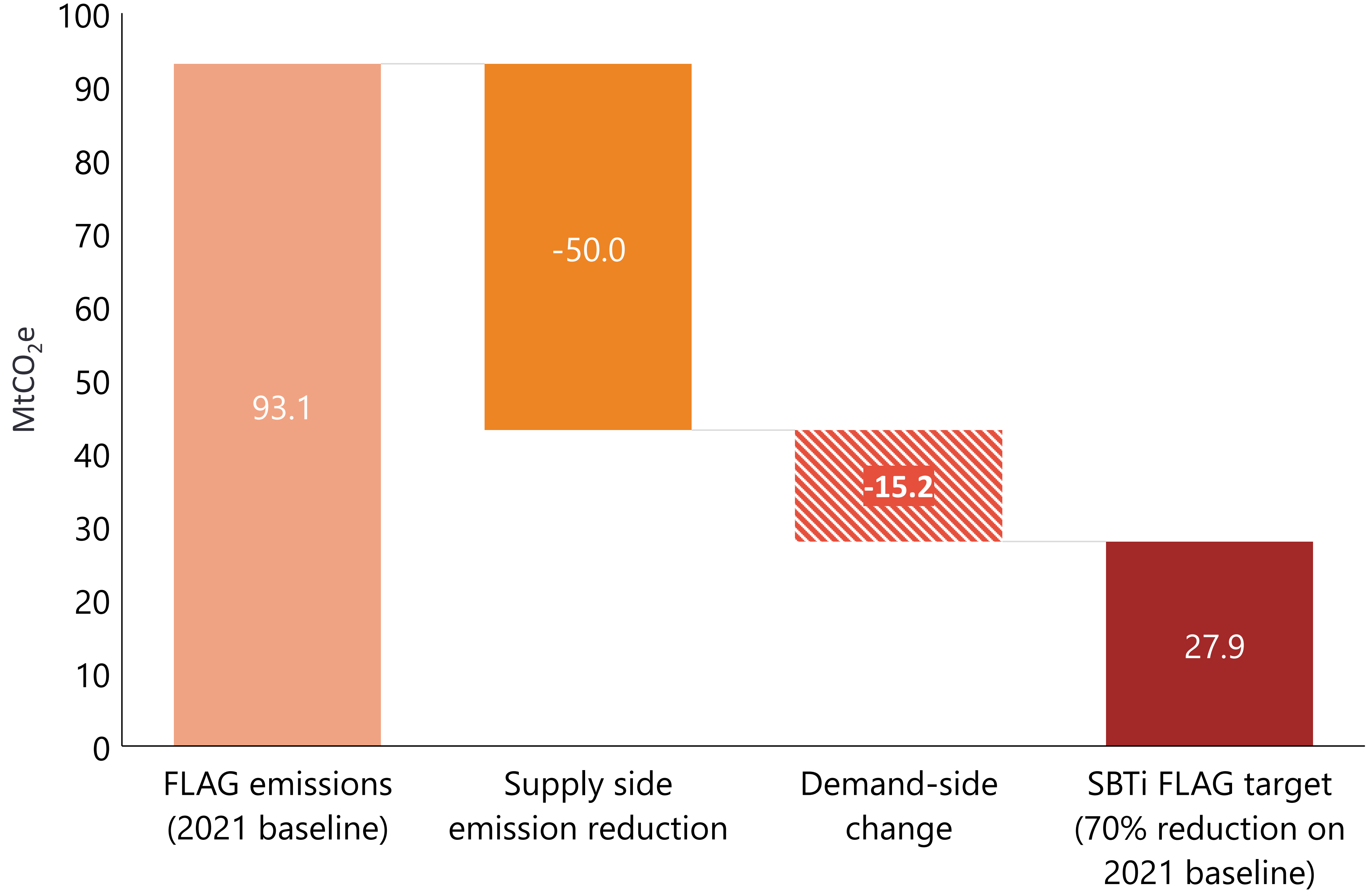
- **Imported products also grown domestically and tropical commodities:** carbon abatement is assumed to occur at an equal rate as for corresponding agricultural categories in UK. Tropical commodities are assumed to decarbonise in line with domestic arable abatement, with the same fertiliser proportion in the imported footprint as domestic.
- **Other uncategorised imported food:** this group is treated as domestic arable and therefore decarbonises in line with domestic arable abatement. This is a plausible starting point due to the product make-up of this category but requires further testing in the future. The emissions reduction of 2.1 MtCO_2 (including fertiliser) is important, but small relative to the whole system footprint, i.e. the assumption does not have a distorting effect on overall emissions as they are not material to overall emissions.
- **Land-use change:** land-use change emissions make up a relatively high proportion of the overall imported food carbon footprint, because of land-use change related to the production of beef and tropical commodities. It is assumed that LUC emissions are reduced to zero by 2041 under a UK corollary of the EUDR.
- **Fertiliser:** it is assumed that fertiliser is produced with the same carbon intensity and used at the same rate in foreign farming as for the corresponding category in the UK; where production intensity is higher, or use of fertiliser less efficient, there would be an additional abatement opportunity. Imported embodied fertiliser abatement has been included in the assessment of overall costs for use of green fertiliser. Imported-embodied fertiliser is assumed to decarbonise in line with that used in the UK, i.e. from 2035 at the earliest, with full decarbonisation by 2050. The associated cost of 5.2 MtCO_2 abatement is around £1.4 bn in 2050.
- **Less mature and more challenging measures:** These offer opportunities in foreign supply chain as they do domestically. Of particular relevance would be feed additives for grazing livestock, low-carbon feed and bio-stimulants. These are included in the system pathways as offering a further 4 MtCO_2e annual emissions reduction.
- **Energy:** The WRAP emissions model does not currently explicitly include embodied energy in food import emissions factors, e.g. related to drying of products, processing and manufacturing. This is an area where further work is required. This omission does not change where the food system decarbonisation potential in 2050, given scope for full decarbonisation of both electricity and heat production. It would, however, add to system decarbonisation costs, namely through the additional costs related to low-carbon heat.
- **Fish:** Fish emissions have been split into wild caught fish (fleet/ship related emissions) and aquaculture emissions, based on global data for current wild caught/aquaculture split from The World Bank. Fleet emissions have been decarbonised in line with shipping decarbonisation (95% reduction against 2021 baseline by 2050). Aquaculture emissions have split into components such as feed and energy use and decarbonised in line with relevant proxies (~60% by 2050, 2021 baseline).

04 Changing demand: food waste reduction and diet change

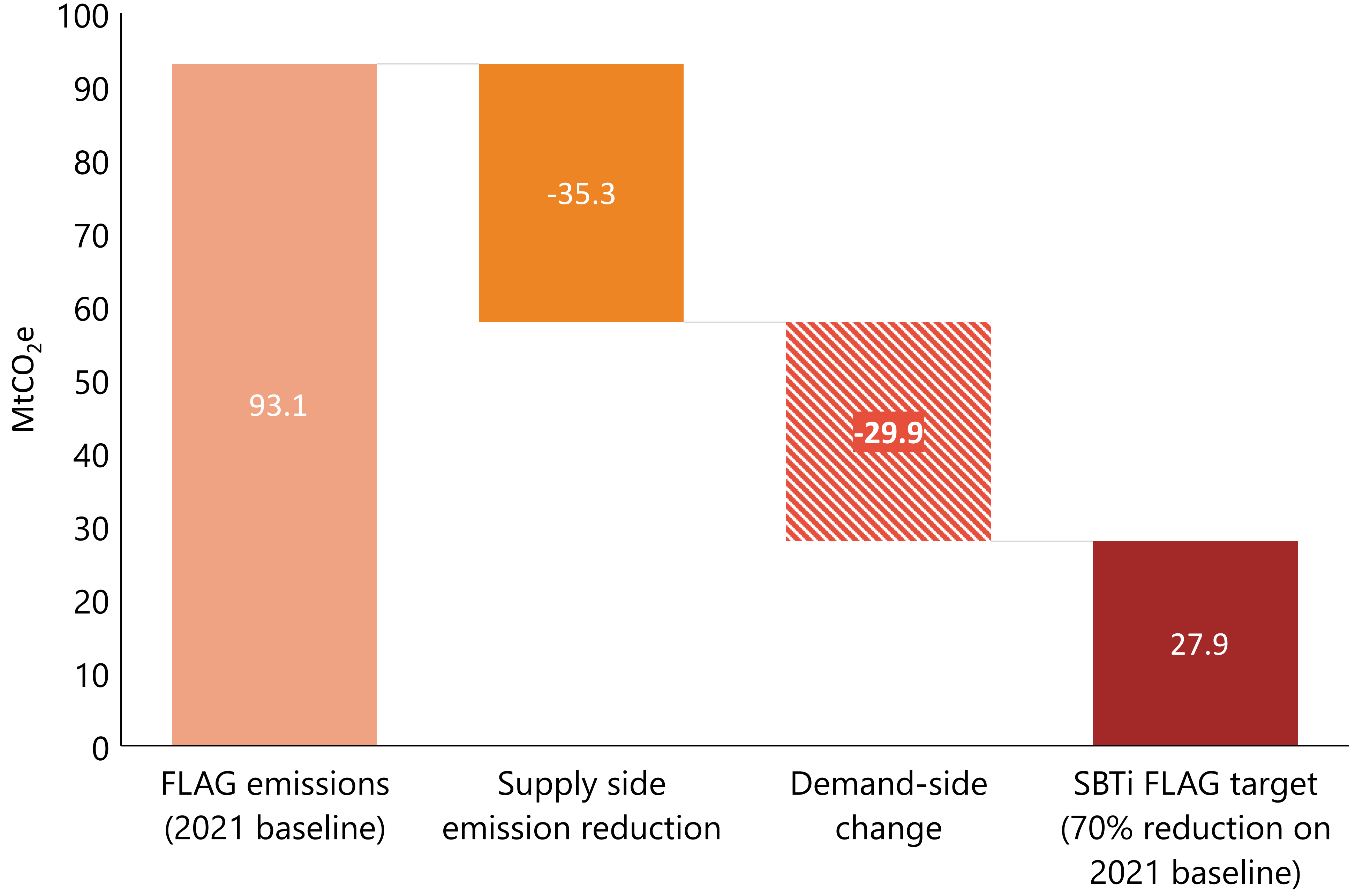
The combination of supply-side reductions together with demand-side consumption change could lead to achievement of FLAG targets.

The previous section showed how agriculture emissions could be reduced. This page shows in the left-hand chart demand side reductions required to meet SBTi FLAG if the High Ambition scenario for agriculture is delivered together with less mature and more challenging options. The right-hand chart shows demand side reductions required if the High Ambition scenario is delivered, but not the less mature or more challenging options.

Illustrative contributions of supply-side and demand-side emissions reduction to meet FLAG targets: *high supply-side abatement**



Illustrative contributions of supply-side and demand-side emissions reduction to meet FLAG targets: *high demand-side abatement**



25% of food is wasted and 60% of food waste emissions arise from households, with the remainder occurring throughout the supply chain. Cutting these in line with the Courtauld Commitment and going beyond this would make a significant contribution to meeting SBTi FLAG targets by reducing the amount of food produced to meet demand.

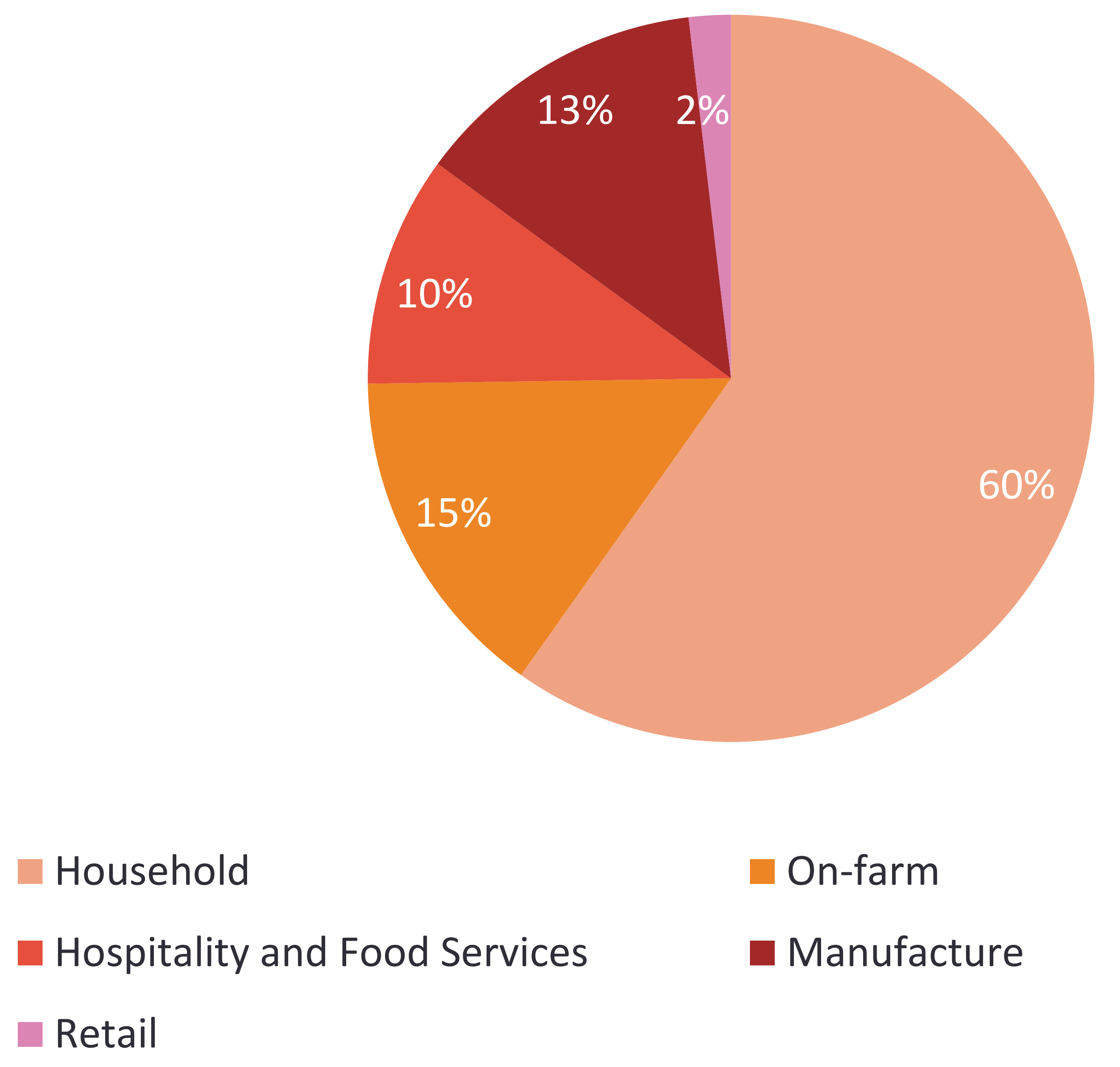
The starting point is that 25% of food is wasted[1]. Food waste is dominated by waste disposed at the household level, with significant contributions of embodied emissions throughout the supply chain (see chart on the right for breakdown of food waste by sector).

The modelling assumes the achievement of the Courtauld Commitment in 2030, resulting in embodied emissions reductions of 6.45 $MtCO_2e$ across the industry value chain, with much of this in agriculture[2]. If the Courtauld Commitment could be achieved, 12.5% of all food produced would still be wasted.

Beyond 2030, it is assumed further food waste reduction such that food demand (and therefore residual agriculture emissions) is reduced by 15% in 2050 compared to 2021, leaving food waste at very low levels. This has the effect of reducing residual agricultural emissions to 2050, noting that other parts of the system footprint are increasingly decarbonised.

Disposal emissions from food waste (i.e., methane from landfill) are relatively small, with opportunities to further reduce these to zero through diversion of food waste (e.g., from landfill to anaerobic digestion). Legislative requirements for local authorities to collect food waste separately have been introduced in England, complementing household and business food waste collections in the devolved administrations. Implementation of these requirements and engagement with households to encourage changes in consumption and food waste choices will drive the projected emissions reductions. The modelling conservatively shows these emissions going to zero by 2050, noting that ideally there will be significant progress by 2030.

Food waste in the UK by sector[2]



1 Food Surplus and Waste in the UK Key Facts –WRAP, 2023
2 Total UK Food & drink consumption footprint and pathway to 50% reduction by 2030 – WRAP, 2021

Demand-side: diet change towards low-carbon foods would reduce carbon emissions and can offer potential health benefits – but it should not be at the expense of health outcomes, which are complex and uncertain. Diet must remain nutritious, accessible and affordable.

Diet and net zero

Red meat and dairy foods are relatively carbon intense (see chart on the following page). WRAP has highlighted in prior publications the need for a shift in national diets to meet the greenhouse gas aspect of the Courtauld Commitment[1]. The CCC has modelled a central case ("balanced") 20% reduction in red meat and dairy by 2030, with red meat reduction of 35% by 2050; and "tailwinds" with 50% reductions in both red meat and dairy consumption in the UK by 2050.

A more conservative scenario than CCC's central case is modelled, with a 20% reduction in red meat and dairy by 2050, together with their tailwinds scenario; these result in further FLAG emissions reductions of 9% and 22% respectively, based on UK and imported abated agriculture emissions in this report[2]. These numbers assume that protein is instead gained from pulses; substitution to chicken or fish would slightly reduce emissions savings, e.g., doubling chicken and egg consumption would add around 1MtCO2e annually (less than 1% of FLAG emissions); doubling pork consumption would add around 2.5 MtCO_2e.

Diet and health

Nutrition impacts of diet are of paramount importance, diet change towards lower carbon foods would reduce emissions and can also offer potential health benefits but any diet change should maintain or improve nutritional balance, accessibility and affordability. This is recognised by consumers, with clear evidence that they prioritise health outcomes related to diet[3].

The Eatwell Guide is useful in this context, because it reflects consideration of health, nutrition and sustainability factors, and the benefits that can be achieved by moving more of the population's diet closer to what it recommends:

- More diverse proteins in the shopping basket, to help improve supply chain resilience and support a more nutrient dense diet;
- Grow/switch towards sales of healthier and more sustainable product choices;
- Change the balance of the basket towards more plant-rich choices.

A well-known study based on the Eatwell Guide suggests that a reduction in red meat and some dairy foods could improve health outcomes[4]. However, this should be heavily caveated: the study did not suggest lower consumption of semi-skimmed milk; consumption data upon which the study was based relates to 2008-11, since when there may have been significant changes in consumer behaviour. Therefore, dairy may be seen as an important part of a balanced diet at current levels of consumption, as per the Eatwell Guide and other international guidance[5]. Evidence from Food Standards Scotland[6] also suggests that reductions of red meat consumption could deprive people of essential nutrients, although these effects can be mitigated; a more nuanced approach is required (e.g. targeting high consumers of red meat or processed meat). More generally, the nation's diet varies greatly regionally and through different groups in society, and this should be fully allowed for when considering diet change.

*Page repeated from Overview

1 UK Food System GHG Emissions: 2022-23 Update (summary report) – WRAP, 2023

2 SRUC

3 Consumer Insights Tracker February 2024 – Food Standards Agency

3 Consumer Insights Tracker February 2024 – Food Standards Agency

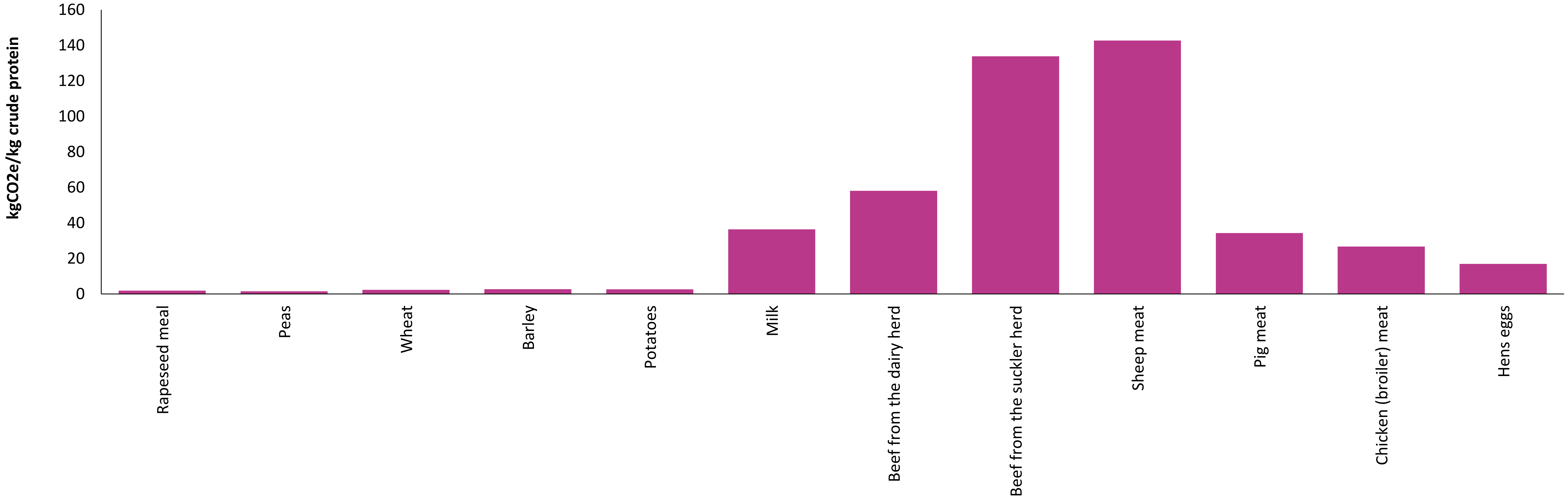
4 The cost of achieving the Eatwell Guide diet – University of Oxford, 2023

5 Nordic Nutrition Recommendations 2023 – Nordic Co-operation

6 Modelling the impact of reductions in meat and dairy consumption on nutrient intakes and disease risk – Food Standards Scotland, 2024

There is wide variation in carbon intensity of proteins – moving towards less caron intense foods would reduce emissions – but this must not be at the expense of health considerations.

Carbon intensity of different foods per unit protein[1]

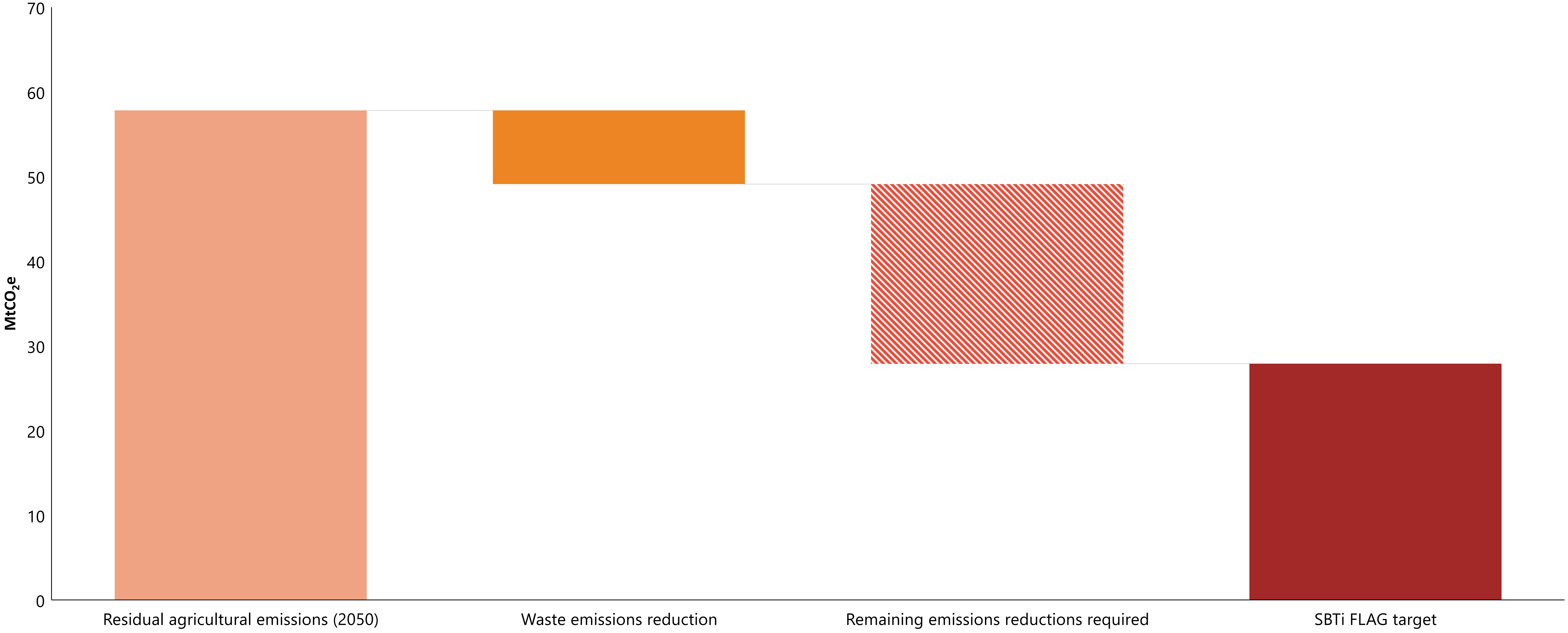


There is a high degree of variation in the carbon intensity of different foods, with red meat and dairy having relatively high carbon intensities by unit of protein compared to chicken and eggs. Vegetable sources of protein have a much lower carbon intensity than meat; the chart illustrates this for selected plant-based foods, chosen because they have a relatively high protein content.

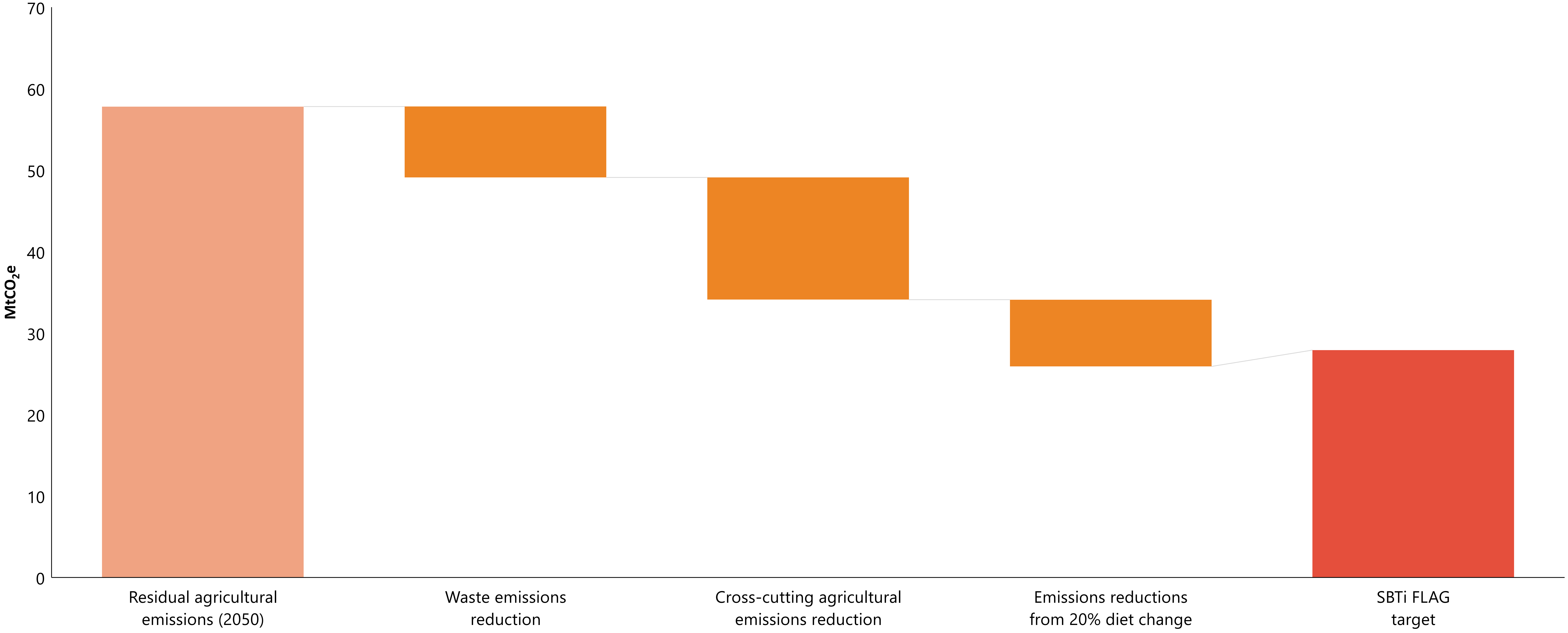
*Page repeated from Overview

1 UK Food System GHG Emissions: 2022-23 Update (summary report) – WRAP, 2023

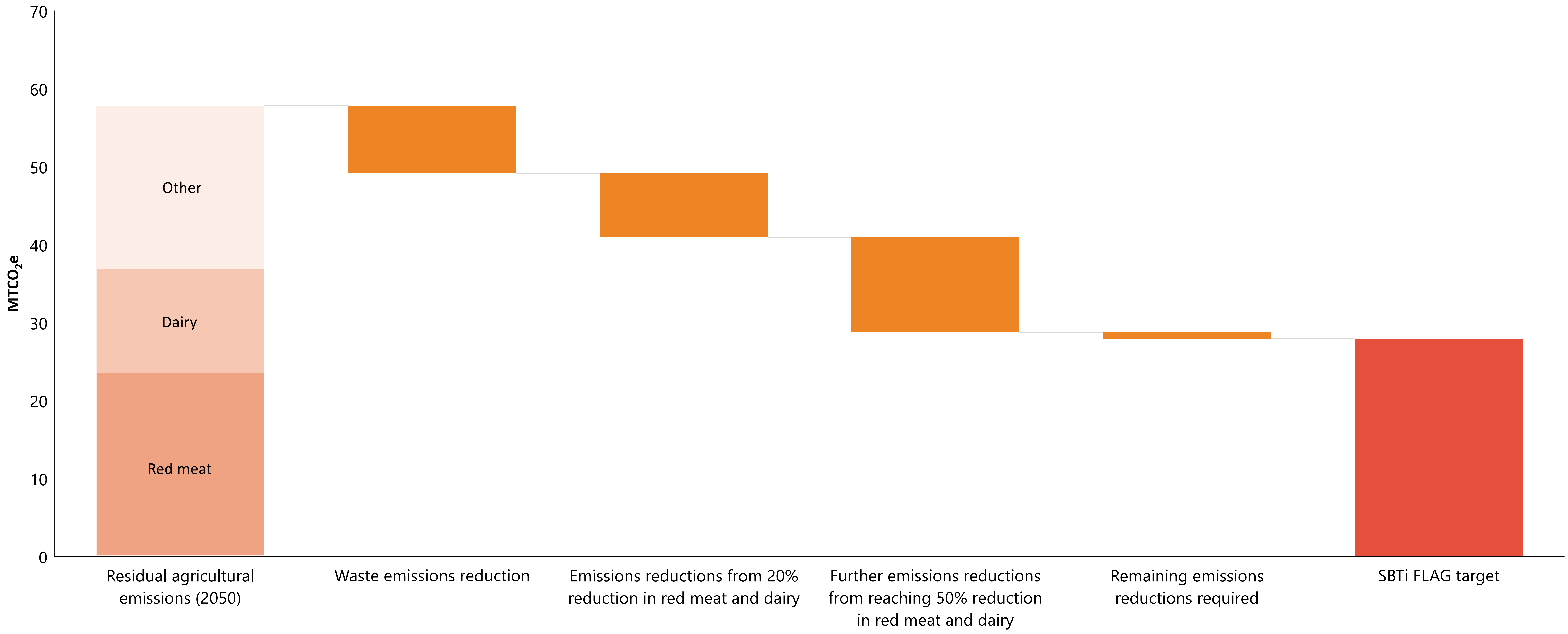
If food waste can be reduced to very low levels, in combination with the High Ambition scenario for agriculture, this would leave a gap of 20 $MTCO_2e$ to achieve SBTi FLAG targets.



If food waste can be reduced to very low levels, in combination with the High Ambition scenario for agriculture and less mature or more challenging measures, this would leave a gap to the SBTi FLAG target which could be more than filled by a(n illustrative) 20% reduction in consumption of red meat and dairy.



Reverting to the combination of food waste and the High Ambition scenario, a 50% cut in red meat and dairy consumption would close the gap to SBTi FLAG.



05 Decarbonising the power sector

The UK's electricity system is expected to be decarbonised by 2035, with potential for food companies to accelerate emissions reductions through self generation, entering Power Purchase Agreements and other power demand reductions.

Electricity is fundamental in the journey of food from farm to fork – powering operations across the value chain, from processing raw ingredients into consumer products to storage and lighting in retail stores. Food companies can pro-actively engage with this transition, both on supply and demand sides.

5.8 $MtCO_2e$
Electricity related emissions in the food sector in 2021

4%
Contribution to total food industry emissions in 2021

69%
Reduction in emissions: 2030 vs. 2021

99%
Reduction in emissions: 2050 vs. 2021

Cost saving
Expected cost of abatement in 2050

Emissions drivers

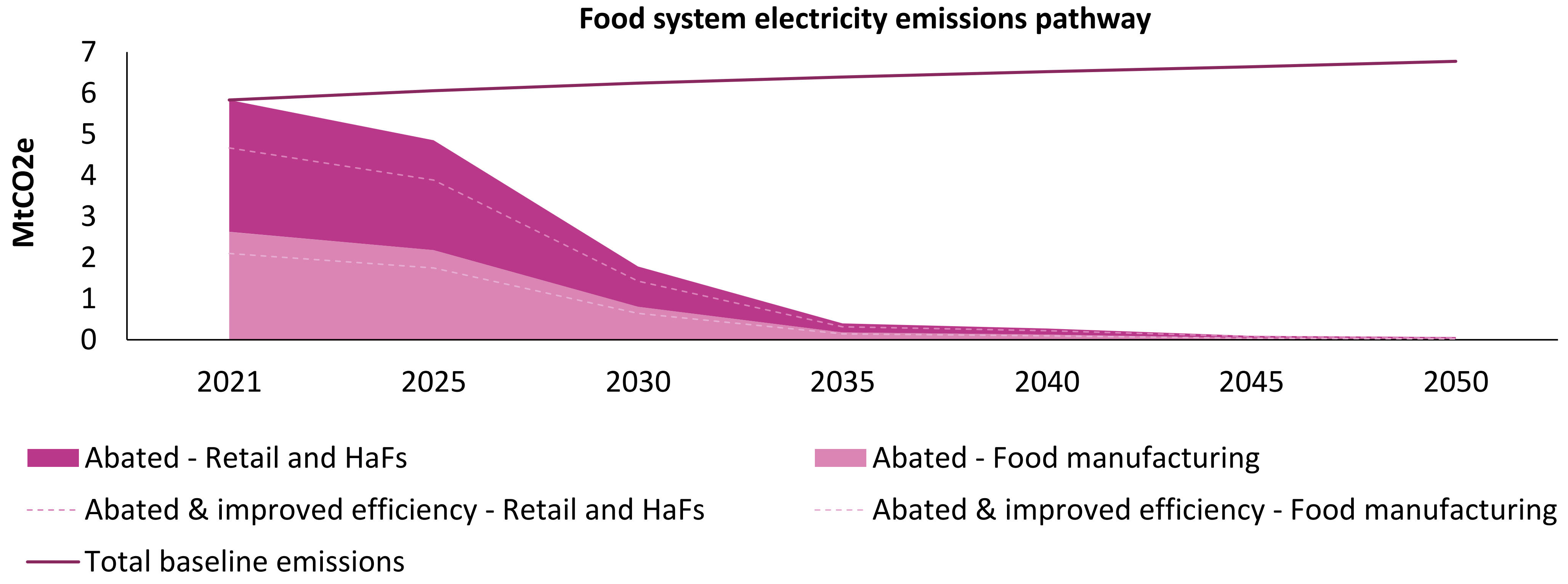
Electricity emissions in the sector come from two sources;

- Manufacturing of food; and
- Lighting and refrigeration in retail and hospitality and food service (HaFS) industry

Abatement

On the supply-side, the industry could simply "piggy-back" on grid decarbonisation, where the current commitment is to achieve almost full decarbonisation by 2035[1], and possibly by 2030 depending on the policy of the new Government to deliver its manifesto ambition. It could proactively engage with this transition through entering Power Purchase Agreements (PPAs) for renewable power generation.

To decarbonise further, there are opportunities for energy efficiency improvement, which could reduce residual emissions (i.e. after supply-side decarbonisation) by 20% and save money for the industry (see graph opposite).



1 The Sixth Carbon Budget: Electricity Generation – Climate Change Committee, 2020

Good progress has been made on decarbonising the UK power grid with greenhouse gas intensity having fallen significantly during this century. Continued grid decarbonisation is a priority for the new UK Government, with the aim of accelerating the emissions intensity into the 2030s.

The UK electricity system is currently planned to be largely decarbonised by 2035, with commensurate reductions in food system electricity emissions. This ambitious transition of the electricity sector is a central pillar of national strategy, supported by implementing policies, e.g. the Electricity Market Reform (EMR).

2021	2030	2035	2040	2050
212 gCO_2/kWh[1]	**46** gCO_2/kWh	**10** gCO_2/kWh	**7** gCO_2/kWh	**2** gCO_2/kWh[2]

Continued deployment of **low-cost renewables**, paired with the **development of CCS** and **hydrogen** markets

Shift to an **entirely low-carbon system**, intensifying the deployment of **zero-carbon generation,** aligning with the **electrification of end-use sectors**

Achievement of a **near-zero emissions electricity grid,** balancing renewable energy variability with flexible demand, storage, and dispatchable low-carbon generation

It is assumed that the grid follows the decarbonisation pathway as set out in the schematic above, and therefore the food industry's electricity consumption will follow suit. Decarbonisation will be achieved through a portfolio of renewables, nuclear and CCuS generation. We note that the new Government wants to accelerate decarbonisation to 2030; therefore, further emissions reductions may be available, subject to the Government turning its ambition into credible plans. As part of this, approaches to reducing grid bottlenecks will be needed, including power transmission, and new distribution connections to support heat and transport electrification.

Earlier emissions reductions could be secured by the industry through utilising Power Purchase Agreements (PPAs) for renewable power generation, which would support the transition. This is strongly preferred to the purchase of renewable electricity certificates, which reduce emissions from an accounting perspective only, and are increasingly expensive.

1 Greenhouse Gas Reporting: Conversion Factors 2021
2 The Sixth Carbon Budget: Electricity Generation – Climate Change Committee

There is an opportunity to reduce food system emissions and reduce electricity costs through energy efficiency improvement.

Energy efficiency is an important element in the food industry's net zero strategy: reducing energy consumption not only curtails carbon emissions but also cuts operational costs. The assessment is that there exists an opportunity for a 20% improvement in energy efficiency by 2030, which could materially decrease food system emissions and reduce costs.

↓20%

Targeted energy consumption reduction by companies with net zero plans

- This is reflected in the net zero plans of many companies across the industry, who are embracing the energy efficiency opportunity and have **targets to reduce energy consumption by 20%**.
- Good progress has been made in recent years across the industry. Investments have generally been shown to have high returns / short payback periods. Further investments are planned in energy management systems, more efficient lighting systems and equipment, upgrading of production lines, etc..

-15°C

Potential 10% energy savings through aligning with European freezer temperature standards

- There is a particular opportunity for energy efficiency improvement through turning freezer temperatures up from **-18 to -15 degrees**, here and in Europe.
- This has been tested rigorously by Nomad Foods and shown to have no adverse effects on various food quality metrics.
- It offers **potential for a saving of 10%** in energy consumption of freezers; this would be supported by changed regulatory guidance.

Strategic opportunity for active energy management approaches

- Decarbonisation of the grid provides further opportunities for active energy management strategies: smart systems that adjust energy use and supply energy in response to intermittent renewable generation and demand peaks, not only **improve efficiency** but also **support grid stability**.

06 Reducing heat emissions through energy efficiency and new technologies

Space and process heating emissions in the food system can be reduced to zero over time through energy efficiency improvement and use of low-carbon technologies, subject to new policies being in place.

Heat is an essential part of the food sector, both in preparing and processing raw produce to consumable products in manufacturing as well as meal preparation in the hospitality and food service (HaFS) sector. Additionally, in the Manufacturing, HFAS and Retail subsectors heat is used to warm spaces for comfortable work environments. As the food system transitions to net zero, heat decarbonisation has an important role to play, with reduction opportunities from energy efficiency improvement and deployment of low-carbon technologies.

6.2 $MtCO_2e$	5%	29%	96%	£839 million
Heat related emissions in the food industry in 2021	Contribution to total food industry emissions in 2021	Reduction in emissions: 2030 vs. 2021	Reduction in emissions: 2050 vs. 2021	Expected cost of abatement in 2050

Emissions drivers

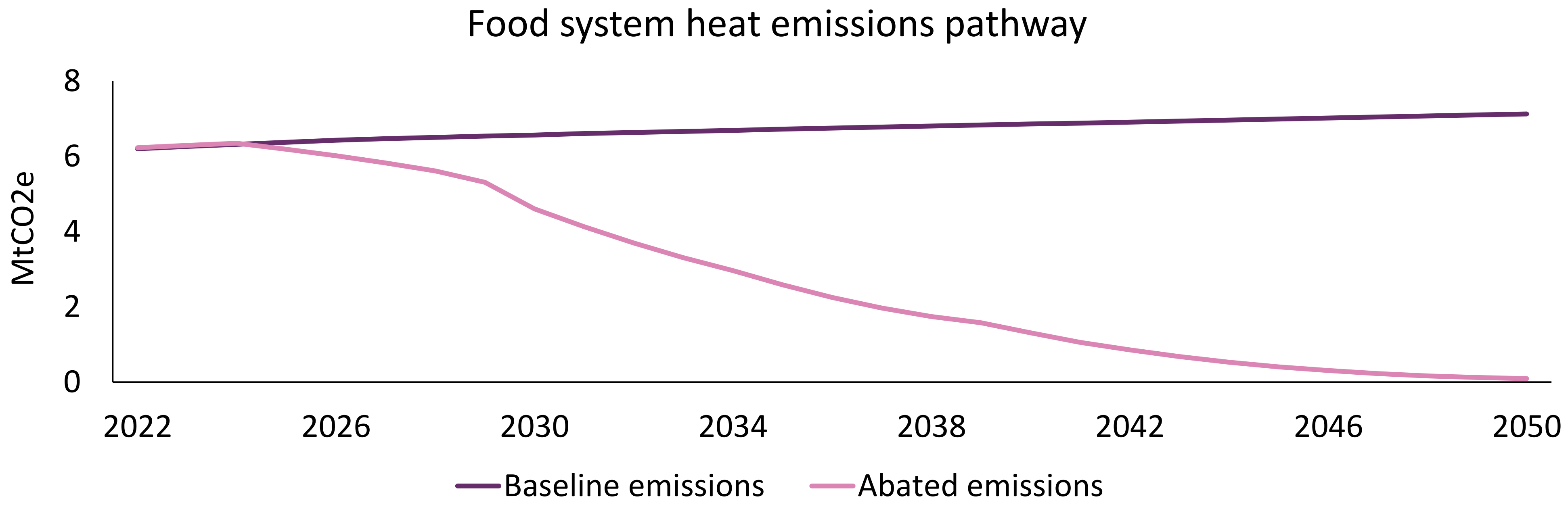
Heat emissions in the industry come from food processing and space heating in Manufacturing, HaFS and Retail through the burning of natural gas, with small amounts of oil and coal, in machinery such as boilers, dryers and ovens.

Abatement

There is a significant energy efficiency opportunity related to heat consumption in the food system, of the order of 20% reduction in energy demand to 2030 with a further 10% reduction to 2050. Addressing this opportunity would make an important contribution to reducing system emissions and the cost savings it offers.

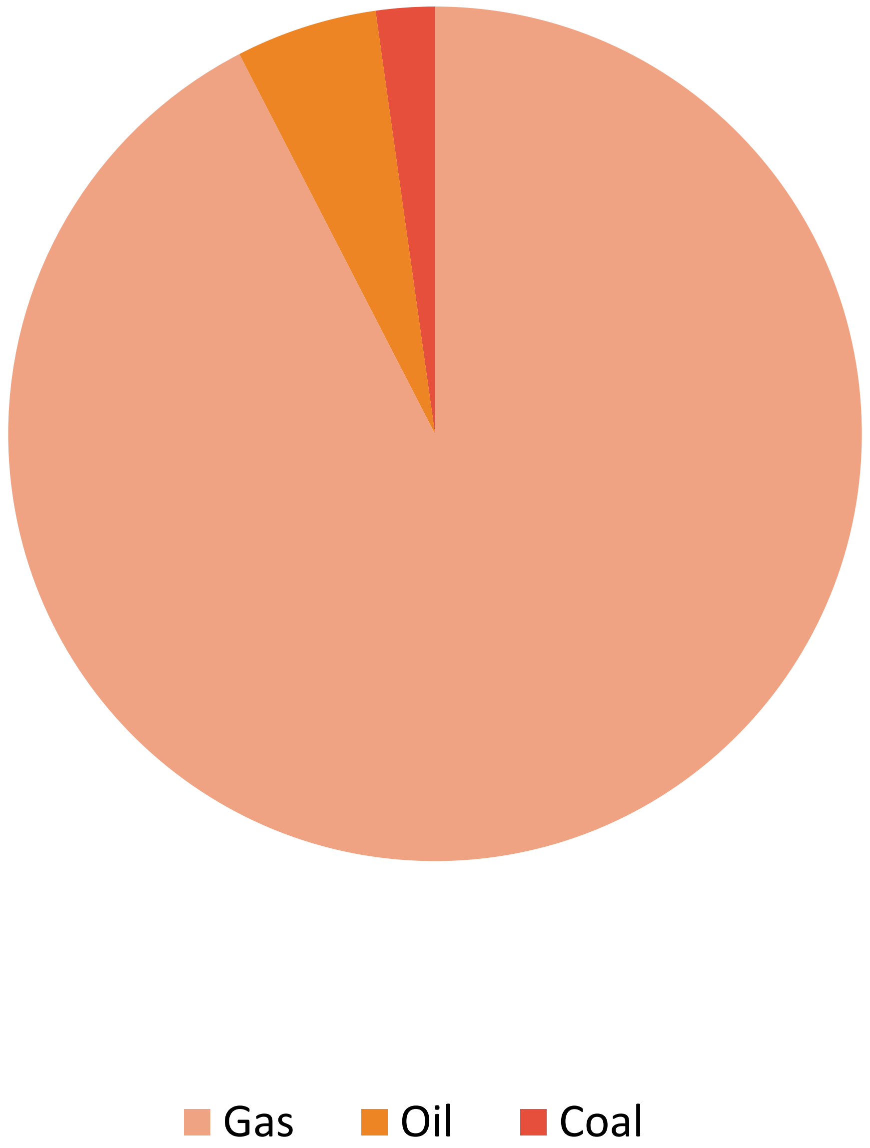
Low-carbon technologies are available or will be available soon, with scope to reduce heat emissions close to zero in the period to 2050.

While deployment of these technologies is desirable from a national strategy perspective, new policies will be needed to align this with commercial objectives.



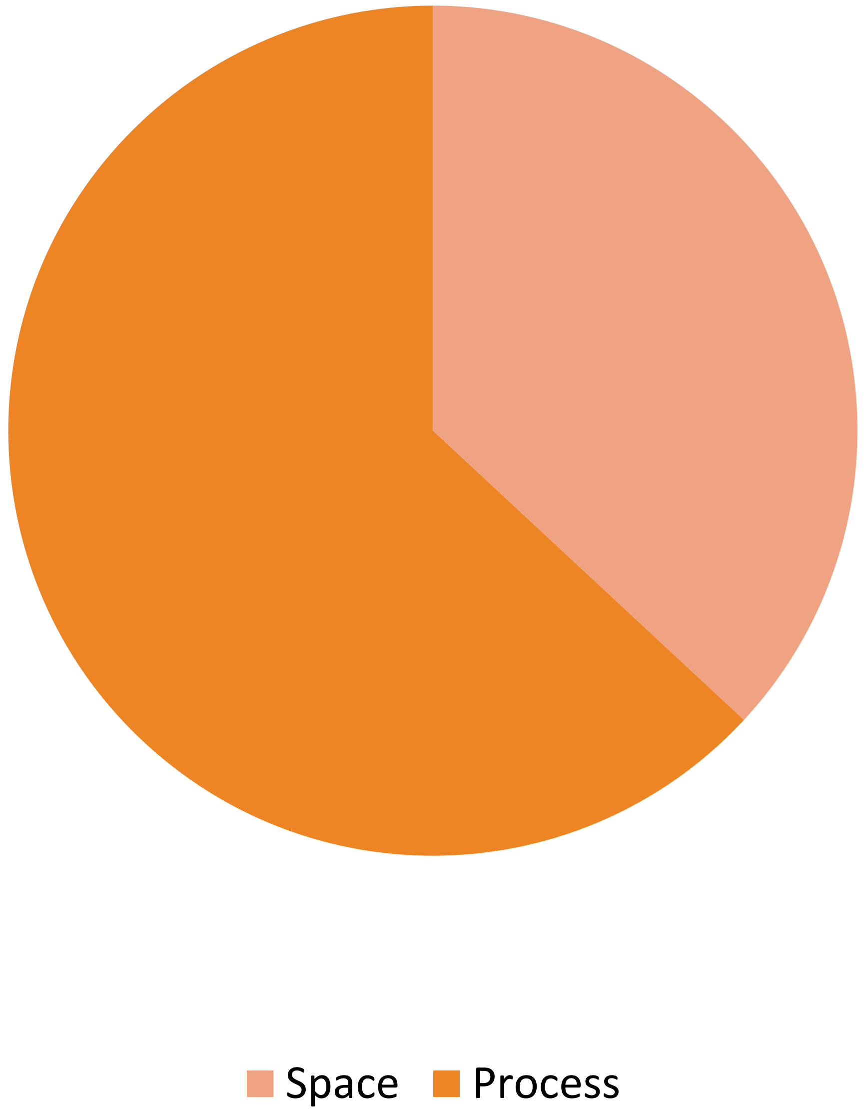
Heat emissions occur largely due to use of natural gas through the supply-chain, and mostly for process heating through gas boilers.

Heat emissions by fuel type (2022)



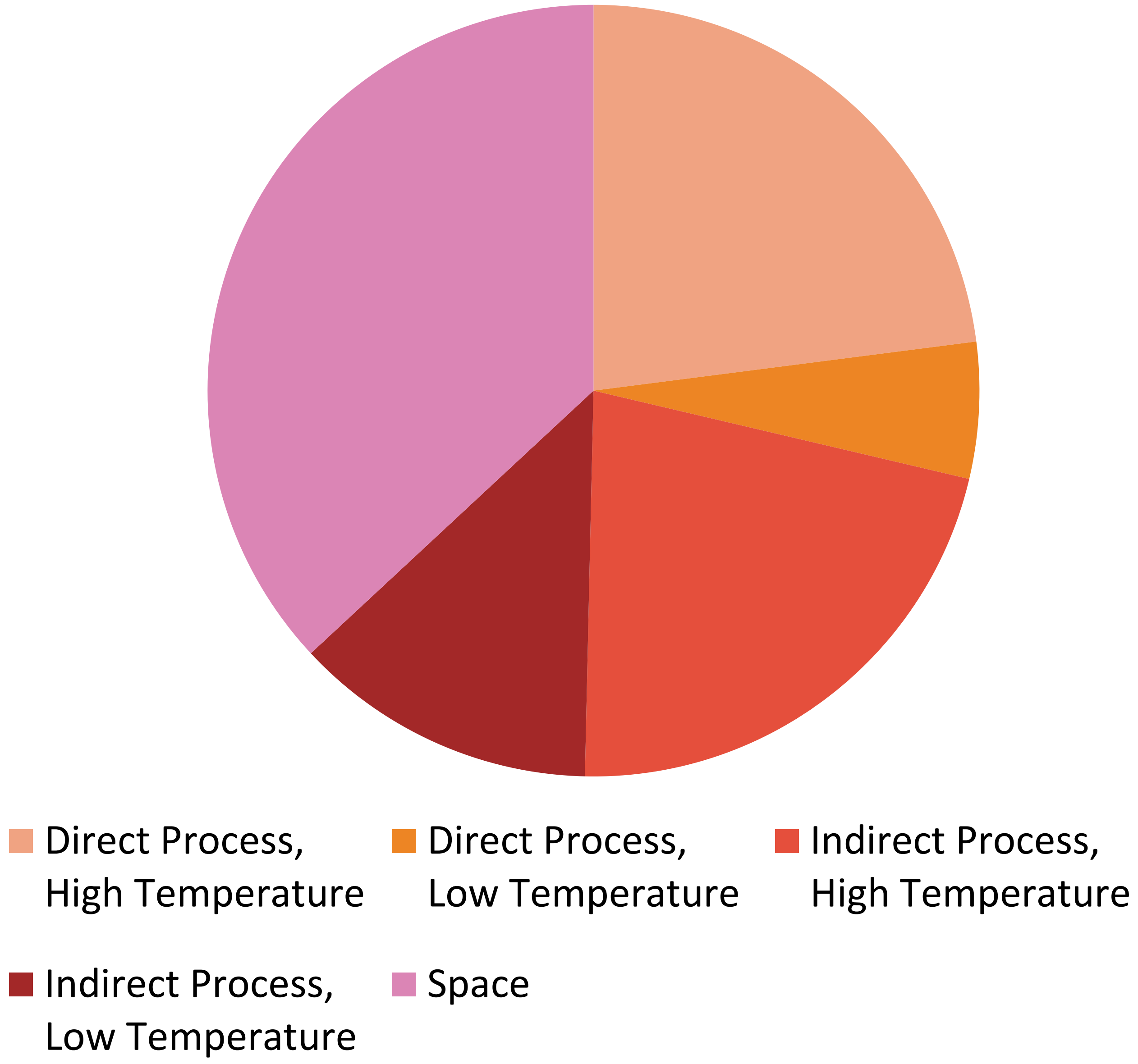
93% of heat emissions are due to the use of Natural Gas, with Oil and Coal contributing 5% and 2% respectively

Heat emissions by use (2022)



Heat is used for space heating and process heating according to the following ratios: 20/80 ratio for Manufacturing, 100/0 for Retail and 51/49 for HaFS

Heat emissions by type of generation (2022)

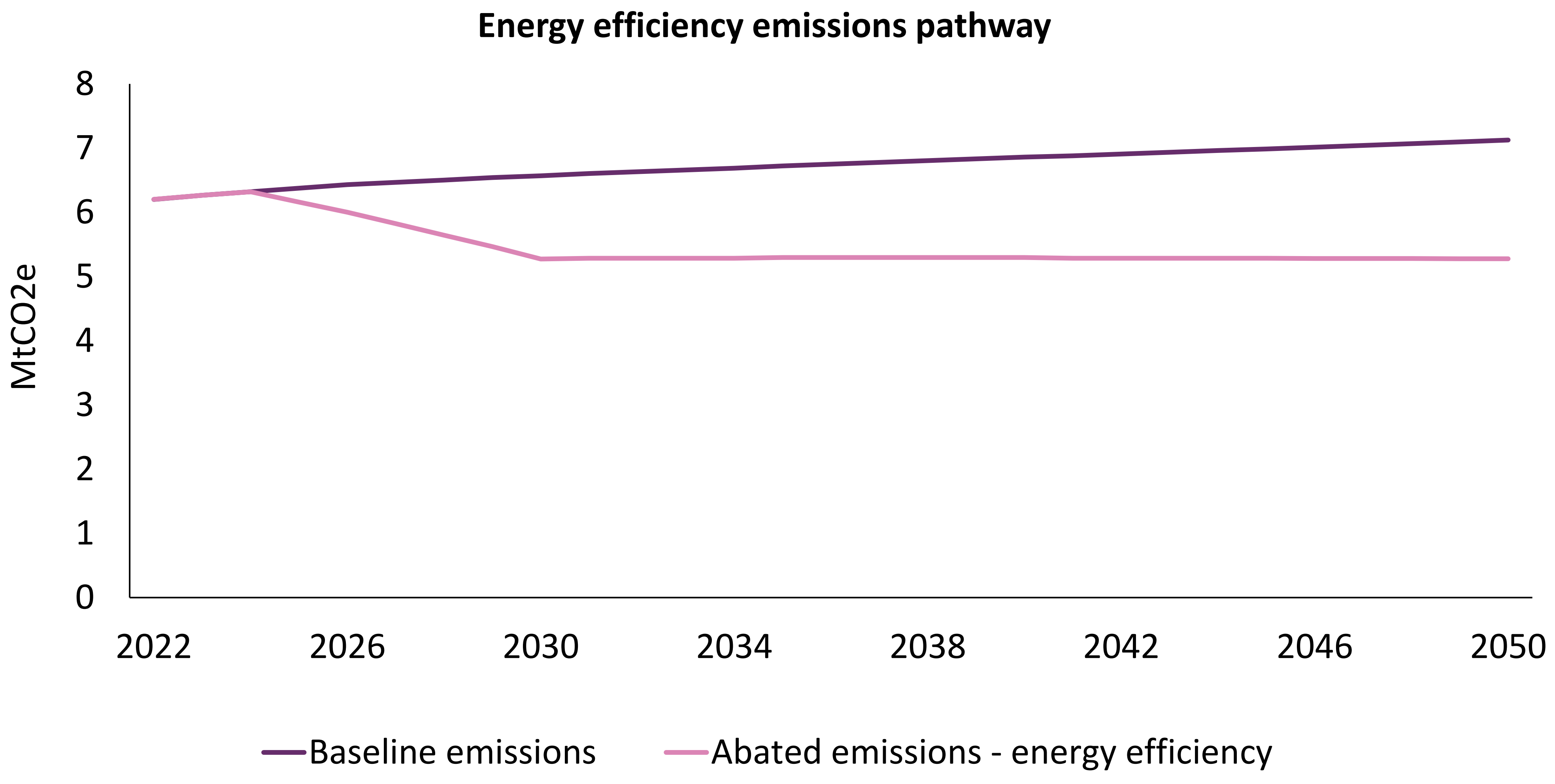


Specific processing techniques (e.g. boiling, roasting, distilling, sterilisation etc.) run on different machines; gas boilers are the biggest source of heat

There is a significant energy efficiency opportunity which would reduce heat emissions and energy costs.

Energy efficiency improvements are the starting point of many net zero plans. The energy savings and resulting costs savings justify implementation and make it an obvious transition step before low-carbon technologies become available and / or cost-effective. Energy efficiency improvements can involve high upfront costs but with relatively short payback periods. Targets to reduce energy consumption by 2030 are common across the industry.

This is supported by evidence from the Government, which has the ambition to reduce the UK's final energy consumption from buildings and industry by 15% in 2030 compared to 2021 levels[1], Various policies are in place to support this, for example, Climate Change Agreements, the Energy Savings Opportunity Scheme (ESOS), and support schemes such as the Industrial Energy Transformation Fund (IETF). In addition, CCC-commissioned research has highlighted the significant potential for energy and resource efficiency after 2030, in the period to 2050.



Energy efficiency opportunities include:

- Process and equipment upgrades
- Installing and improving heat recovery systems
- Clustering and networking with other sites and businesses to efficiently utilise waste heat and other by-products

These opportunities are reflected in the modelling:

- A 20% reduction in energy consumption by 2030
- Another 10% reduction in energy consumption by 2050
- No additional costs as energy efficiency investments typically have short payback periods.

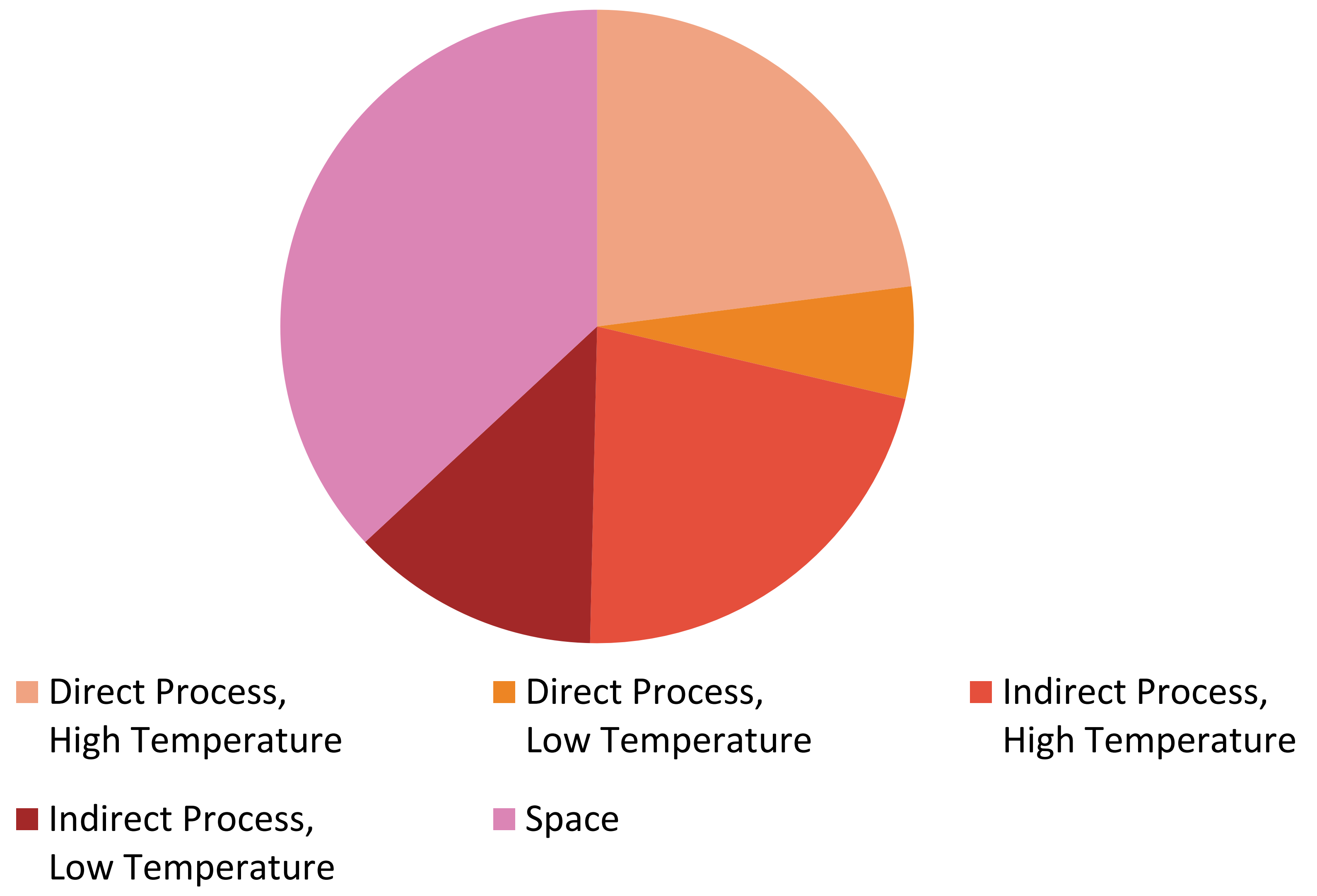
1 Powering Up Britain: Net Zero Growth Plan – Department for Energy Security & Net Zero, 2023

Low carbon technologies exist for all types of heating in the food system – namely heat pumps, electric ovens and boilers, and hydrogen.

The pie chart shows the breakdown of heat emissions between space and the different types of process heating. Within process heating, high-temperature processes account for the biggest share of total emissions.

The table shows that space heating can be switched to heat pumps; low temperature and some high temperature processes can also be switched to heat pumps, and that other high temperature processes can be switched either to electric ovens, electric boilers or low-carbon heating fuels such as hydrogen.

Heat emissions by type of generation (2022)



Current machine	Technique	Low-carbon alternative
Boilers	Low Temp.	Low-temp. Heat Pump, Electric Boiler, Electric Infra-Red Heater, Blue/Green Hydrogen Boiler
	Medium/High Temp.	Medium/High Temp. Heat Pump, Electric Boiler, Blue/Green Hydrogen Boiler
Ovens	Air	Electric Oven, Blue/Green Hydrogen Oven
	Direct-flame	Blue/Green Hydrogen Oven
Dryers	All	Electric Dryer, Electric Infra-Red Heater, Blue/Green Hydrogen Dryer
Other	Various	All of the above, or CCUS for irreplaceable fossil processes (e.g. smoking)

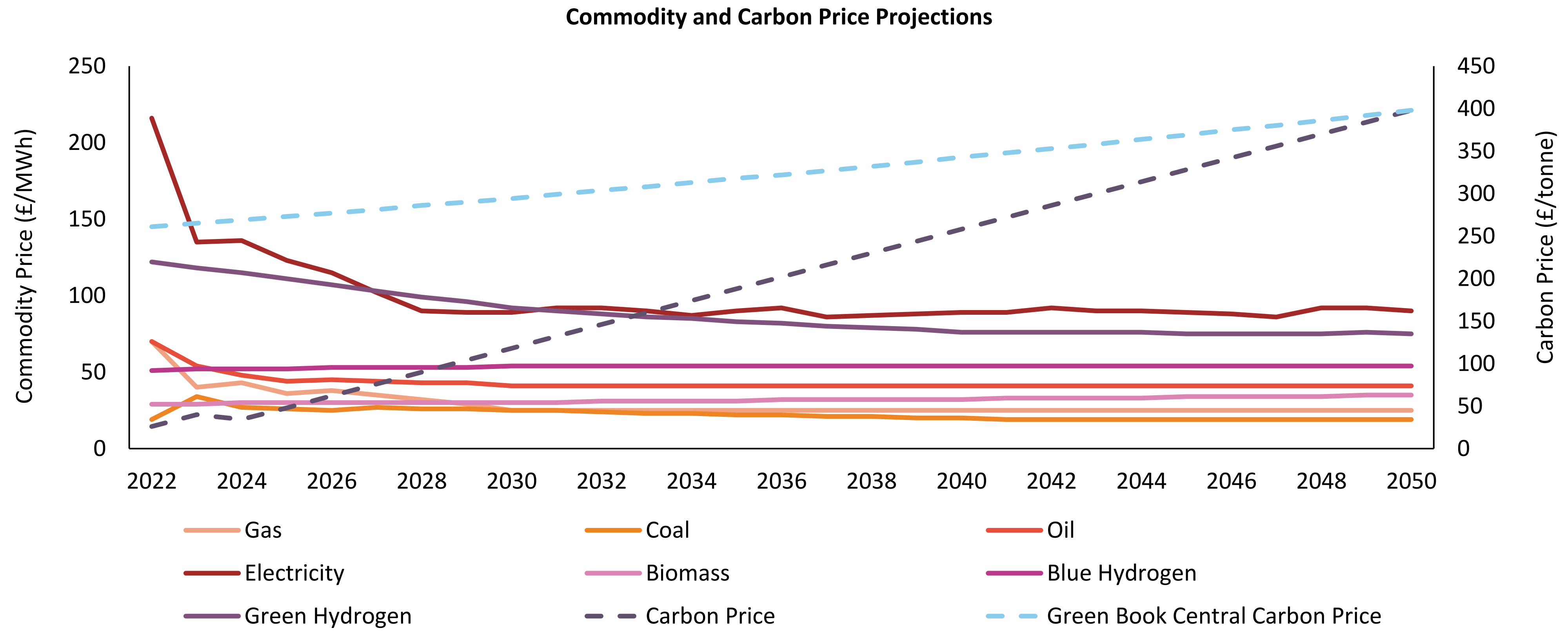
Low carbon technologies become feasible and cost-effective in the 2030s and should be fully deployed by 2050.

For supply-side decarbonisation, the feasibility and cost-effectiveness of low-carbon technologies have been assessed against current conventional alternatives (e.g. gas boilers and ovens – see Table).

Technological feasibility is assessed using an evidence base comprising Government, CCC and other sources on technology readiness, supply-chain constraints, commodity availability and scalability; and applied as a constraint in the modelling. Specifically, full deployment of electric technologies are constrained until 2030 at the earliest, to reflect the lead-time for policy development, planning by companies and building of supply chain capacity, and for development of high temperature heat pumps. For hydrogen, full deployment has been constrained until 2035 at the earliest, to reflect the lead-time for innovation to drive down costs and building of supply-chain capacity.

Cost-effectiveness is modelled comparing Capital Expenditure (CapEx) and Operational Expenditure (OpEx) of each low-carbon and current technologies; CapEx is annuitized assuming a 10% WACC. The modelling uses Government projections of commodity prices, noting that these are lower than current retail prices for electricity, because the latter include significant uplifts to fund policy costs. It is assumed that increasing electricity price volatility can be managed through PPAs. It uses the Government's carbon values (rising from £294/tCO_2 in 2030 to £400/tCO_2 in 2050), which are the benchmark for what ideally should happen on the path to net zero; and, as a sensitivity, a carbon price which escalates from the current market price to £118/tCO_2 in 2030 and then to the Government's 2050 carbon value (£400/tCo_2).

Machine	Total levelised costs* [p/kWh]
Gas boilers	5.2
Gas ovens	6.2
Low-Temp. Heat Pump	3.3
Medium Temp. Heat Pump	6.2
Electric Boiler	9.3
Electric Oven	10.1
Electric Dyer	9.3
Blue Hydrogen Boiler	7.0
Green Hydrogen Boiler	10.1



*Based on 2030

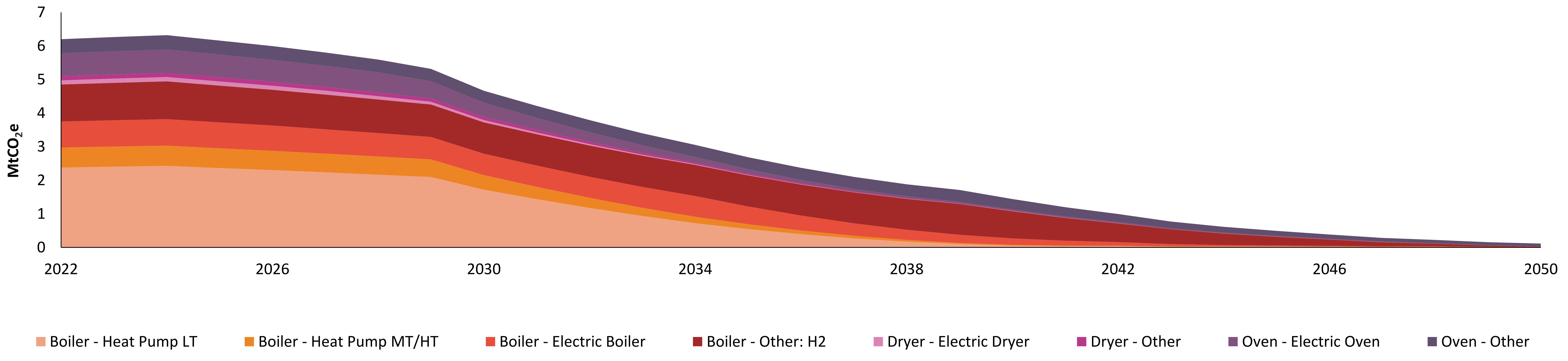
Low carbon technologies become feasible and cost-effective in the 2030s and should be fully deployed by 2050.

Under the Government's carbon values, all electric technologies (i.e. heat pumps, boilers and ovens) are feasible and cost-effective from 2030, with hydrogen being both feasible and cost-effective by 2035. At a minimum, when boilers are being replaced, these should be with electric technologies from these dates. It may also be the case that scrapping of boilers before end of life can be justified, although this will depend on a number of factors (carbon prices, energy prices, supply chain constraints, etc.).

Under the sensitivity for carbon prices, low-temperature and high-temperature heat pumps are feasible and cost-effective in 2030; this is true also for (relatively efficient) electric ovens, compared to long-lived gas ovens subject to very high carbon prices through the 2040s; electric boilers become cost-effective from 2035, compared with gas boilers. With these lower carbon prices, hydrogen switching becomes cost-effective in 2040.

These statements relate to replacement of existing kit at the end of its life. The analysis suggests that early replacement of gas boilers with low-temperature heat pumps is cost-effective at the beginning of the 2030s, and later in the 2030s for high-temperature heat pumps.

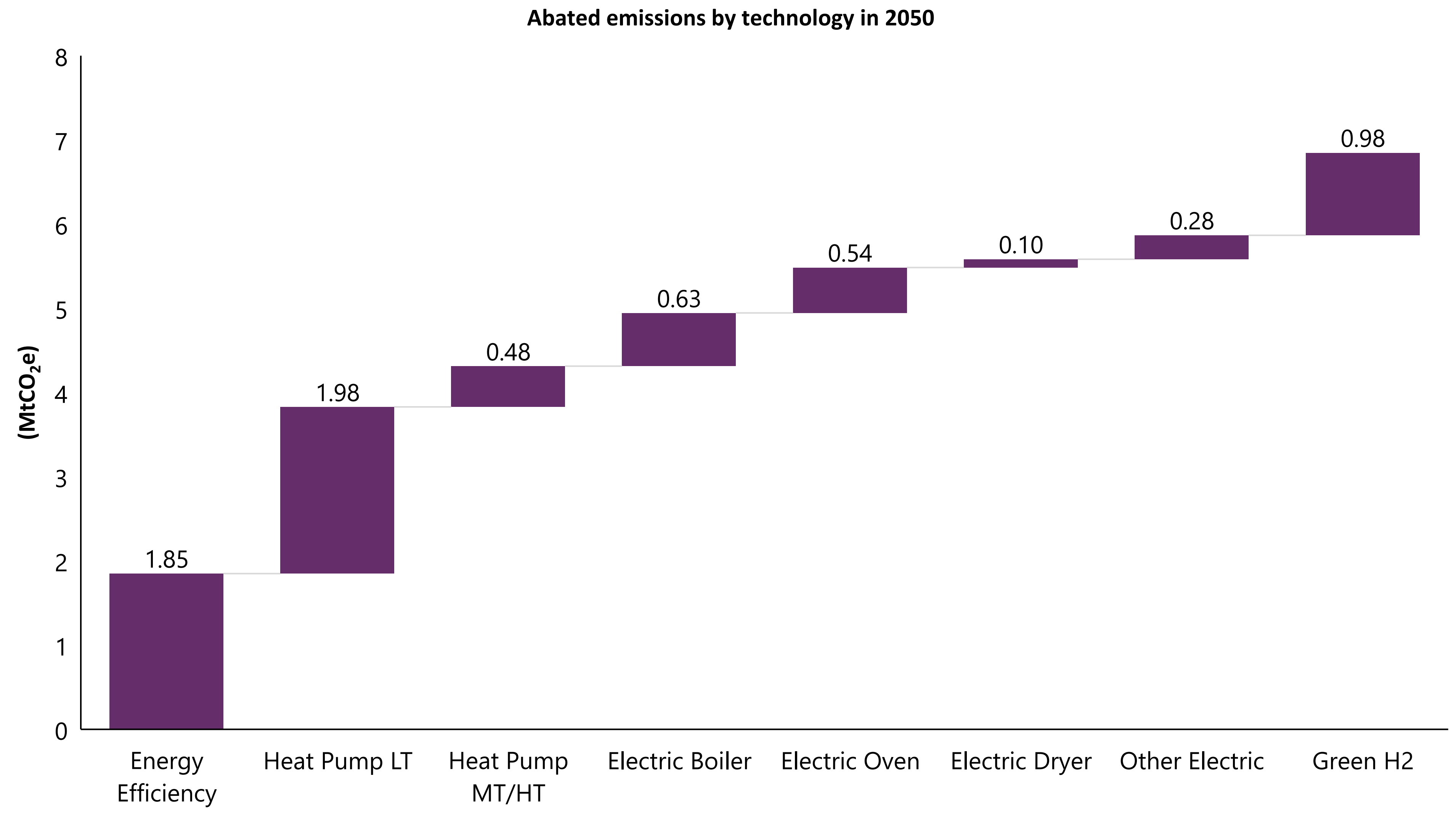
Heat emissions reductions over time by different types of heat source

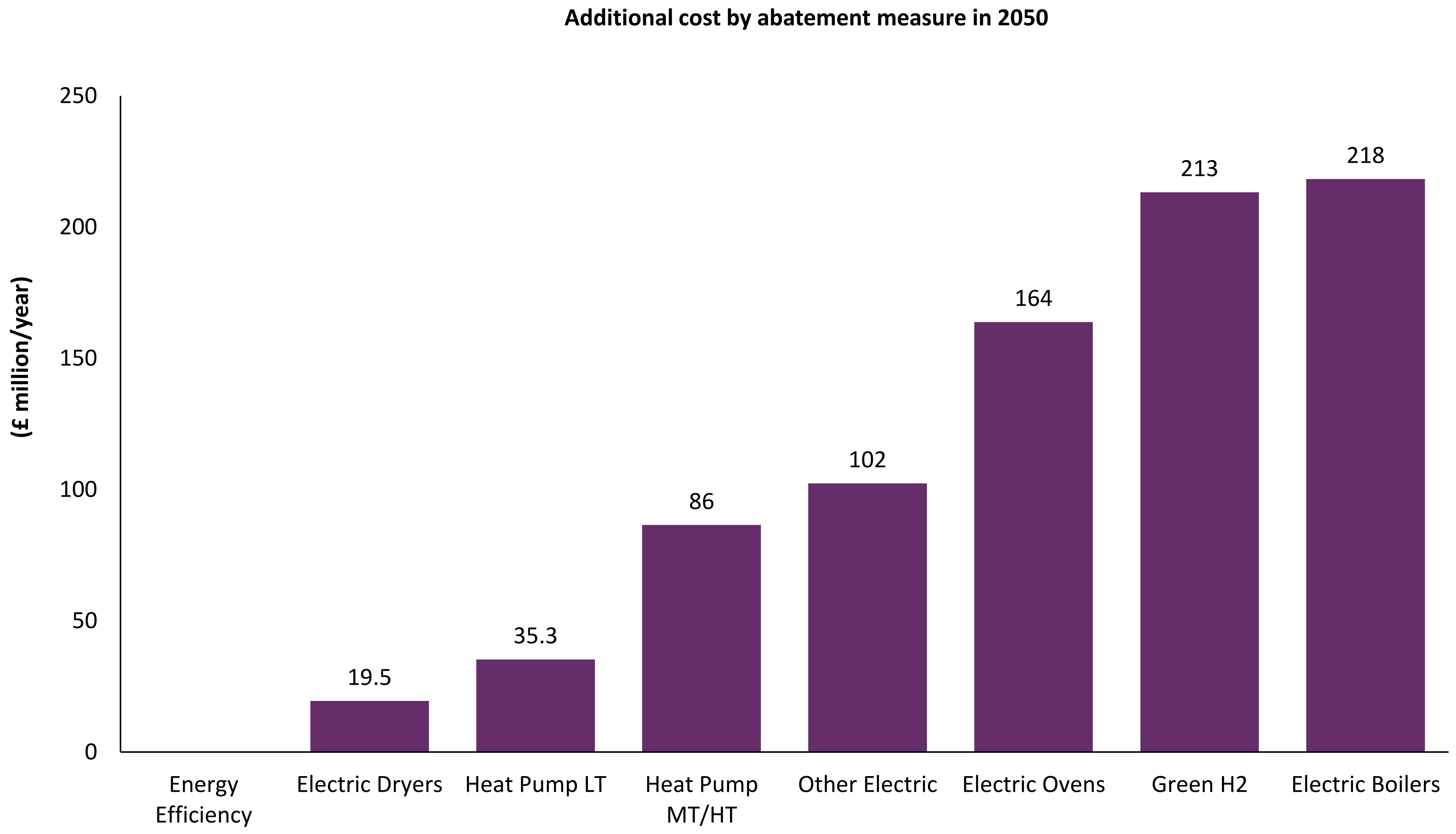


The main contributors to heat transition are energy efficiency improvement and heat pumps – with a total cost for decarbonising heat of around £550 mn in 2050.

The largest contributors to heat sector transition in the food system are **energy efficiency improvements and heat pumps**, the latter both for space and process heating.

The costs associated with decarbonisation are estimated based on cost differentials between current and low-carbon technologies. The (annual) cost of full heat decarbonisation is of the order **£840 mn in 2050** (split between abatement type in the righthand figure below),





The path for heat decarbonisation is **heavily dependent on policies for support**: at higher carbon prices, all electric technologies should be deployed from 2030; with lower (but still high) carbon prices, heat pumps and electric ovens should be deployed from 2030, with electric boilers and other more expensive electric technologies deployed beyond 2035, and hydrogen being deployed later in the 2030s. In this latter case, the consequence would then be accelerated deployment of more expensive technologies through the 2040s, to reach zero emissions by 2050. In both cases, there would have to be removal of current distortions in relative gas/electricity prices due to policy costs being added to electricity prices, in order for heat decarbonisation to proceed.

New policies are required to address current barriers to low-carbon heat deployment – rebalancing of gas/electricity prices, grants, and prioritisation of grid connection.

Barriers to ddoption

The analysis illustrates that deployment of low-carbon heat from 2030 is cost effective from a societal perspective. However, **for individual firms (i.e. from private perspective) there are several barriers to adopting low carbon measures** that have been well documented, and highlighted in interviews with food companies for this report:

- **High costs of electricity** relative to gas prices make it very challenging to justify switching from gas to electricity. In the UK industrial or commercial electricity prices are **about 5 times** the price of gas*, and the highest in Europe. This is a consequence of the significant policy costs related to decarbonising the electricity system that are passed to consumers through their bills; whereas there are very few policy costs placed on gas bills.
- **Delays in getting upgrades or new connections to the electricity grid**. The growing deployment of EVs and ambition to scale up heat pumps in homes in addition to connecting up to 50 GW of offshore wind capacity by 2030 is placing significant demands for upgraded and new connections on the grid, causing significant delays. Respondents to the recent Industrial Electrification Call for Evidence indicated the average wait for a grid connection is 5 years.
- **The significant upfront cost of buying new electric equipment**, particularly for less mature technologies relative to gas. The installation costs associated with conversion to electricity can also significantly increase the costs of switching.
- **In respect to hydrogen, barriers to uptake relate to the nascency of the sector** and uncertainty of availability and access to the infrastructure to be secure continuous hydrogen supplies.

Solutions

To address these barriers, new policies will be required, namely to rebalance relative gas and electricity prices, and to prioritise grid connection for increased electricity demand from the industry:

- Rebalancing gas and electricity prices will ultimately require the application of a **carbon price for gas** at levels much higher than current ETS prices (e.g. £135/tCO_2e to support high-temperature heat pump deployment, £175/tCO_2 to support electric oven deployment, £225/tCO_2 to support electric boiler deployment, and £275/tCO_2 to support hydrogen switching); and the stripping of policy costs from the electricity price – these currently comprise about 40% of retail electricity prices compared to about 6% for gas.
- In the interim, **grant funding will be important to support trialling technologies**. The Industrial Transition Fund (IETF) has been used to great effect by the industry in this respect (see next page) and should be extended for a new round, given that currently funding is only available to 2028.
- **Full electrification of heat will add around 1.5 GW of demand to the grid in the period to 2050.** Currently grid connection is very difficult, with long delays. If the industry is to decarbonise through electrification, grid connection will have to be prioritised from 2030.

While new policies are developed, the recommended approach for the industry is to **proactively engage with government; use grant funding for trialling; plan for deployment subject to policies being in place; and execute plans when new policies are introduced** – doing so without policies would not make commercial sense. At the current time, heat pumps have the best prospects for early deployment, subject to new policies. While policy uncertainty remains, the aim should be to extend existing assets for as a long as possible.

The Industrial Energy Transformation Fund (IETF) has been used to good effect in the food system – and it should be extended to continue supporting heat decarbonisation.

The IETF provides grant support to industry with up to £500m to be allocated by 2028 across three competition topics:

- Energy Efficiency technology deployment projects.
- Decarbonisation technology deployment projects.
- Studies: feasibility and engineering studies to guide investment.

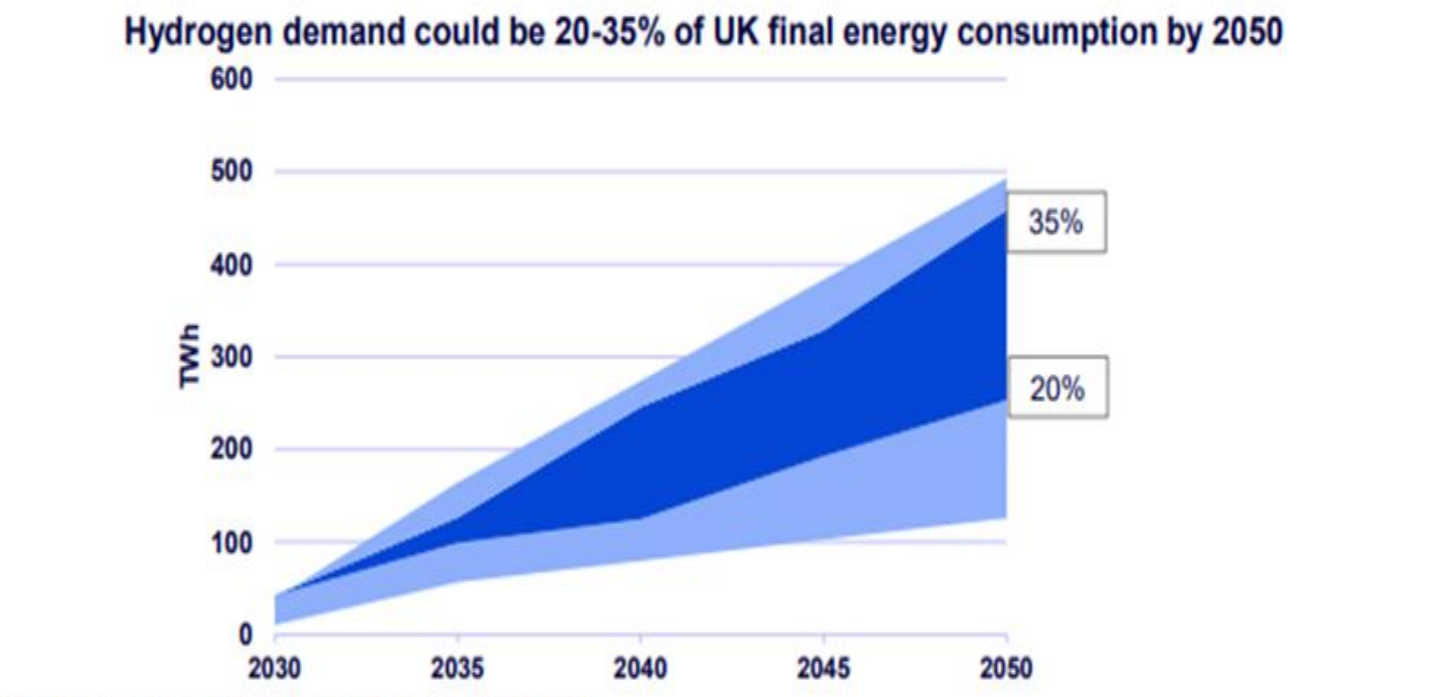
Below are case studies providing examples of some Food industry projects in receipt of IETF grants:

Business	Project	Project type	Project highlights	Grant awarded
Britvic Soft Drinks Limited	Installation of heat pumps - Beckton Low Carbon Heat Network	Deep Decarbonisation Deployment	• Implementation of the latest low carbon technologies at its production site at Beckton so that waste heat can be recovered from its existing systems, and its temperature increased using a heat recovery system.	£4,447,763
Simpsons Malt Limited	Tweed Valley Maltings Energy Centre	Deep Decarbonisation Deployment	• The Energy Centre will comprise a 12MW electric boiler – powered by curtailed wind energy – and three 6MW biomass boilers using locally-sourced, low-grade woodchip, and will reduce the carbon emissions generated during the energy-intensive kilning stage of the malting process.	£3,554,672
A.D. Harvey	Combined decarbonisation of the hot water and refrigeration processes	Deep Decarbonisation Deployment	• The technical solution will capture the waste heat (natural body heat from chickens and heat used in the preparation process) using a state-of-the-art ammonia glycol refrigeration system. The heat is then recirculated back into the process using a heat pump and a series of heat exchangers coupled to a mass hot water store.	£2,046,643
Pioneer Foods (UK) Limited	Energy efficiency improvements of low temperature ovens	Energy Efficiency Deployment	• Maximising energy efficiency of the industrial drying process through well-established technologies that can be retrofitted to the pre-existing ovens to reduce overall gas consumption and carbon emissions while increasing overall process efficiency.	£136,417
Bumble Hole Foods	Heat pumps for hot water provision	Study: Feasibility and Engineering	• Study to explore the use of heat pump(s) to provide process heat to the pasteuriser and associated CIP/washing processes and replace the current centralised gas and gas oil-fired steam boiler system. Study outputs will be used to determine feasibility and commercial viability.	£24,704
Tate & Lyle Sugars	Reduce natural gas consumption, recover heat and enhance manufacturing processes	Study: Feasibility and Engineering	• Front End Engineering Design ("FEED") study to explore implementing technologies that enable re-use of more of its heat production than it currently does, as well as integrate innovative new sugar manufacturing technologies that use less energy.	£71,827

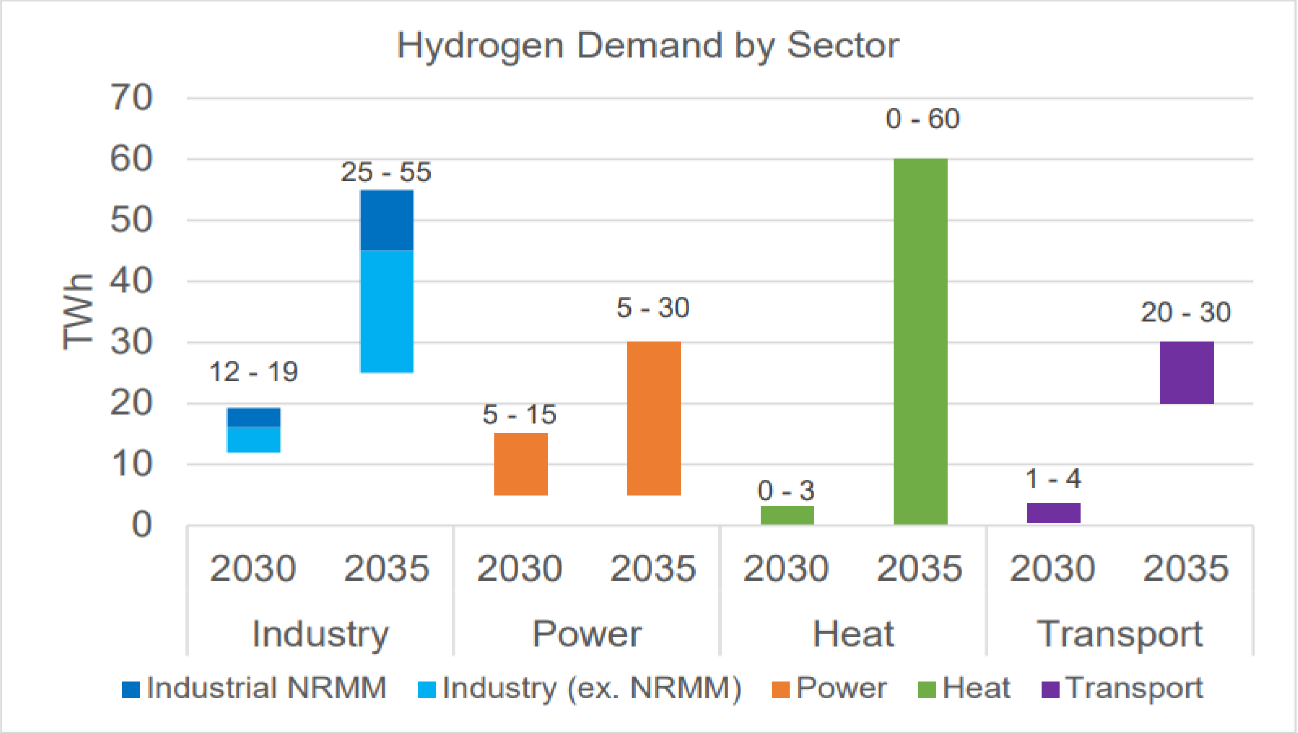
07 The role of hydrogen in decarbonising industry and transport

Hydrogen is key to the Government's net zero transition strategy – with potential applications in the food system to fertiliser production, food processing, and heavy goods vehicles (HGVs).

- Hydrogen has a potentially key role to play in achieving net zero targets, as set out in the Government's Hydrogen Strategy, which suggested that **hydrogen demand could grow significantly and contribute up to 35% of final energy use by 2050.**
- Hydrogen can be green (produced by electrolysis) or blue (produced from natural gas). Given residual emissions of blue hydrogen, **green hydrogen is desirable in the context of net zero.**
- Hydrogen has several potential applications across the food system including:
    - **Industry:** It is well suited for high temperature heat processes, industrial boilers & CHP units, e.g. in sugar & fertiliser manufacture. Adoption is dependent on-site locations with access to network infrastructure, ensuring continuous supplies for 24/7 operations.
    - **Transport:** HGVs, rail and nonroad mobile machinery could all use hydrogen. There is also a potential role for hydrogen-based fuels in shipping (ammonia) and aviation (sustainable aviation fuels in the nearer term, or hydrogen planes in the longer term). The extent of its use will depend on cost relative to alternative low-carbon options and availability of hydrogen.
    - **Buildings:** *there is* significant potential for heating buildings if the gas grid is repurposed. The Government is due to make a strategic decision on repurposing the grid for hydrogen vs electrification (2026).
- The figures opposite and on the next page show the previous government's understanding how demand for hydrogen could materialise.



% = hydrogen as proportion of total energy consumption in 2050.
Source: Central range – illustrative net zero consistent scenarios in CB6 Impact Assessment. Full range – based on whole range from UK Hydrogen Strategy Analytical Annex. Final energy consumption from ECUK (2019).



Hydrogen Transport and Storage Networks Pathway (publishing.service.gov.uk)

The previous Government was working towards setting up 4 low carbon industrial clusters by 2030 – this offers opportunities for the food system where companies are in close proximity to clusters.

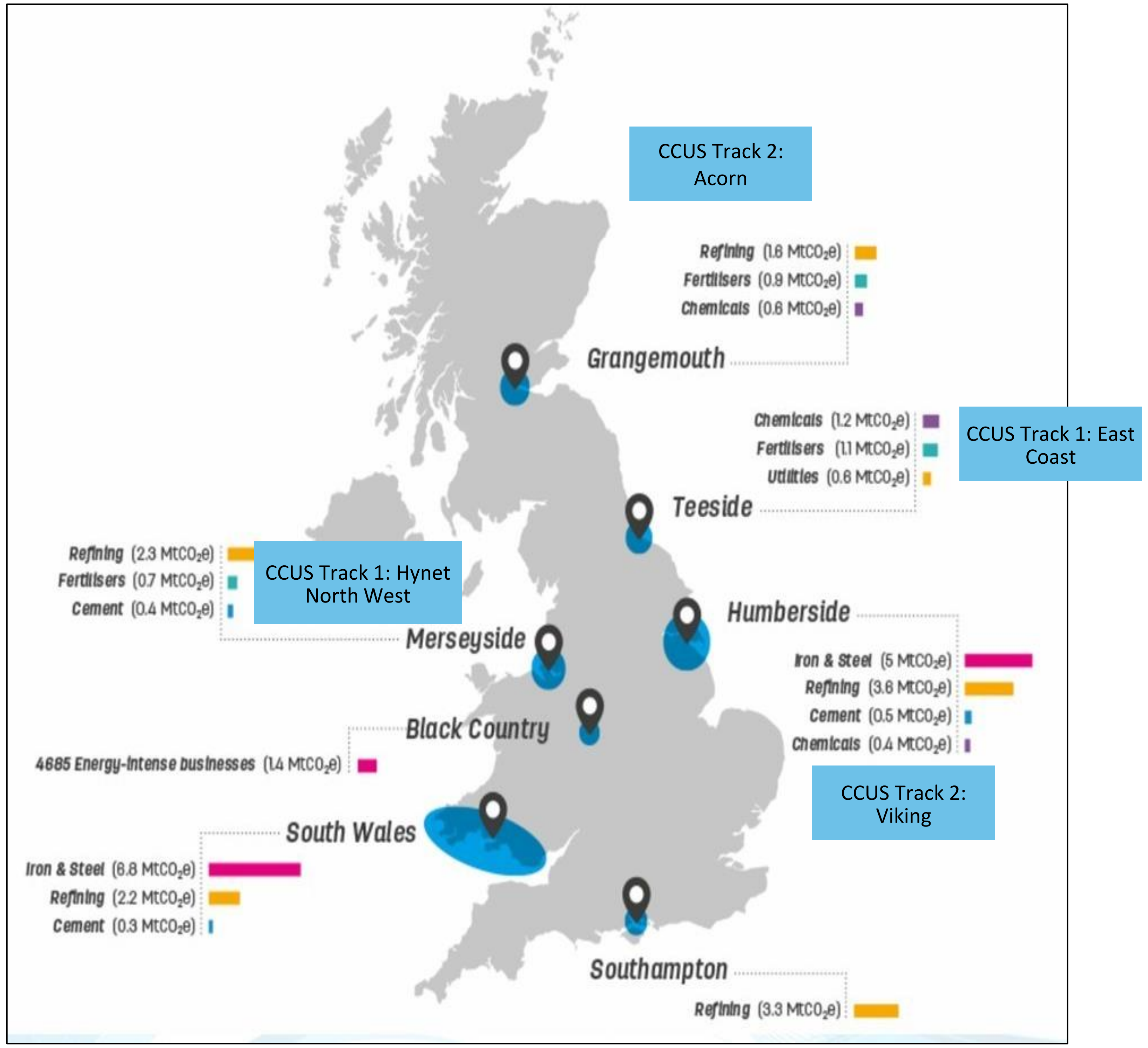
Significant funding has been committed to developing the hydrogen economy in the UK.

The previous Government's ambition was for up to 10GW of low carbon hydrogen production capacity by 2030, from green and blue sources. This would be concentrated around the four selected industrial CCUS Track 1 and 2 clusters (Hynet, East Coast Cluster, Acorn and Viking – see map opposite), with some green hydrogen projects spread more widely. It is being supported by significant funding commitments to develop the production capacity, and infrastructure for transport and storage including:

- **£1bn CCS Infrastructure Fund**
- **£500m Industrial Energy Transformation Fund**
- **£240m Net Zero Hydrogen Fund**
- **Revenue mechanism to support private sector investment in CCUS & H2 projects (via business models)**
- **£960m Green Industries Growth Accelerator**

Given the highly dispersed nature of the food industry, this would offer opportunities only for those firms in close proximity to these clusters; examples of such firms are provided on the next page.

Location of industrial CCUS Track 1 and 2 clusters relative to industrial emissions clusters



Some companies in the food industry are engaged in hydrogen development projects for fuel switching.

Hydrogen Case studies: Successful hydrogen projects in the UK may access multiple incentives, including the HPBM for hydrogen supply and the IETF for offtaker end-use capex costs. The table below features some prominent hydrogen end-use projects in the UK and highlights some of the incentives that they have accessed.

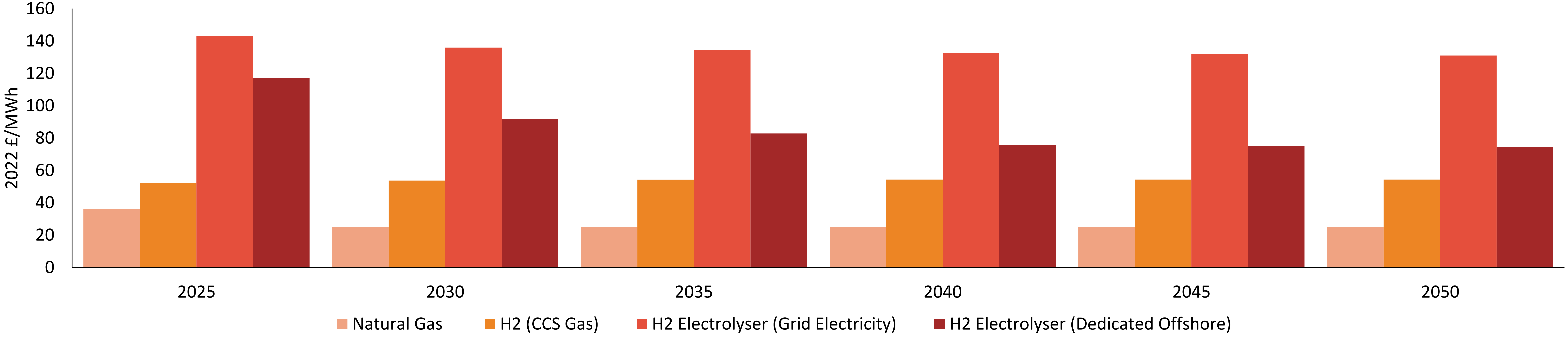
Business	Industry	Project	Project highlights	Incentives accessed
The Kraft Heinz Company	Food & Drink	Green Hydrogen Fuel Switch at Kitt Green	Hydrogen project developer Carlton Power will develop a 20MW green hydrogen plant at Kraft Heinz's Kitt Green site. The plant will supply hydrogen to the Kraft Heinz manufacturing facility, displacing more than 50% of the plant's existing natural gas demand and reducing its carbon emissions by 16ktCO_2/yr.	• Carlton Power are seeking HPBM funding via HAR2, allowing Kraft Heinz to purchase hydrogen at reduced cost.
KP Snacks Ltd	Food & Drink	Hydrogen Fuel Switch at Billingham	A study to explore the techno-economic feasibility of both blending hydrogen into KP Snacks' existing fryers and conducting a conversion to 100% hydrogen.	• IETF grant of £418k awarded. • Hydrogen supply plans unknown.
Marlow Foods Ltd	Food & Drink	Hydrogen Fuel Switch at Billingham	A study to explore the feasibility of installing hydrogen dual-fuel burners at the Quorn manufacturing site, to meet the facility's growing heat requirements.	• IETF grant of £115k awarded. • Hydrogen supply plans unknown.
Budweiser	Food & Drink	Hydrogen Fuel Switches at Two Breweries	Budweiser worked with Protium energy to develop green hydrogen production facilities at two of their breweries. The green hydrogen will be used for both supplying heat to the breweries' manufacturing operations and fuelling hydrogen HGVs.	• Unknown
Ingevity UK Ltd	Chemicals	Hydrogen Fuel Switch at Warrington	Ingevity plans to install three new hydrogen-ready boilers, along with associated infrastructure to allow for switching the heat generation requirements from natural gas to hydrogen	• IETF grant of £2.6m awarded to install hydrogen-ready equipment. • Planning to offtake hydrogen from HyNET HPP2, which is seeking HPBM funding.

Green hydrogen costs are likely to fall as a result of Government investment, with potential for it to be cost-effective relative to gas in the 2030s, although this is highly uncertain.

Costs are driven by source of fuel, with scope for reduction of green hydrogen costs through dedicated renewable generation, production at scale, and innovation.

- There are significant cost variations between different hydrogen production technologies. Fuel costs (gas or electricity) are the biggest driver of hydrogen production costs, making production very sensitive to fuel price fluctuations – see chart below
- Blue hydrogen is currently relatively low cost, reflecting maturity of technologies and scale economies in production; for these reasons, there is limited scope for cost reduction.
- Green or electrolyser hydrogen production costs can be significantly lowered by using dedicated renewables instead of using grid electricity.
- Further cost reductions are expected to derive from the technological learning and scaling of production facilities that wider deployment will deliver as the hydrogen economy evolves.

Levelised costs of hydrogen technologies compared to gas[1]



It is assessed that the largest opportunity for emissions reduction through hydrogen is fertiliser production, with niche applications in food processing and heavy goods vehicles (HGVs).

Fertiliser

Green hydrogen could be used as a zero-carbon means for fertiliser production. The timing of this is dependent on hydrogen availability and cost – both in the UK and internationally, given that domestic fertiliser production is currently based on imported ammonia, and much of fertiliser is imported.

It is assumed that hydrogen is available in sufficient volume by 2035 at the earliest and that the carbon price could reach the switching value of £275/tCO_2 by this time, with progressive decarbonisation of production thereafter and zero emissions by 2050. A delayed path to hydrogen-based production - either because it takes longer for sufficient hydrogen volumes to become available and/or because the carbon price does not reach the switching value - would imply an accelerated trajectory through the 2040s, still reaching emissions by 2050.

The estimated cost of green fertiliser for domestic and imported food is of the order £2.2 bn in 2050.

Food manufacturing

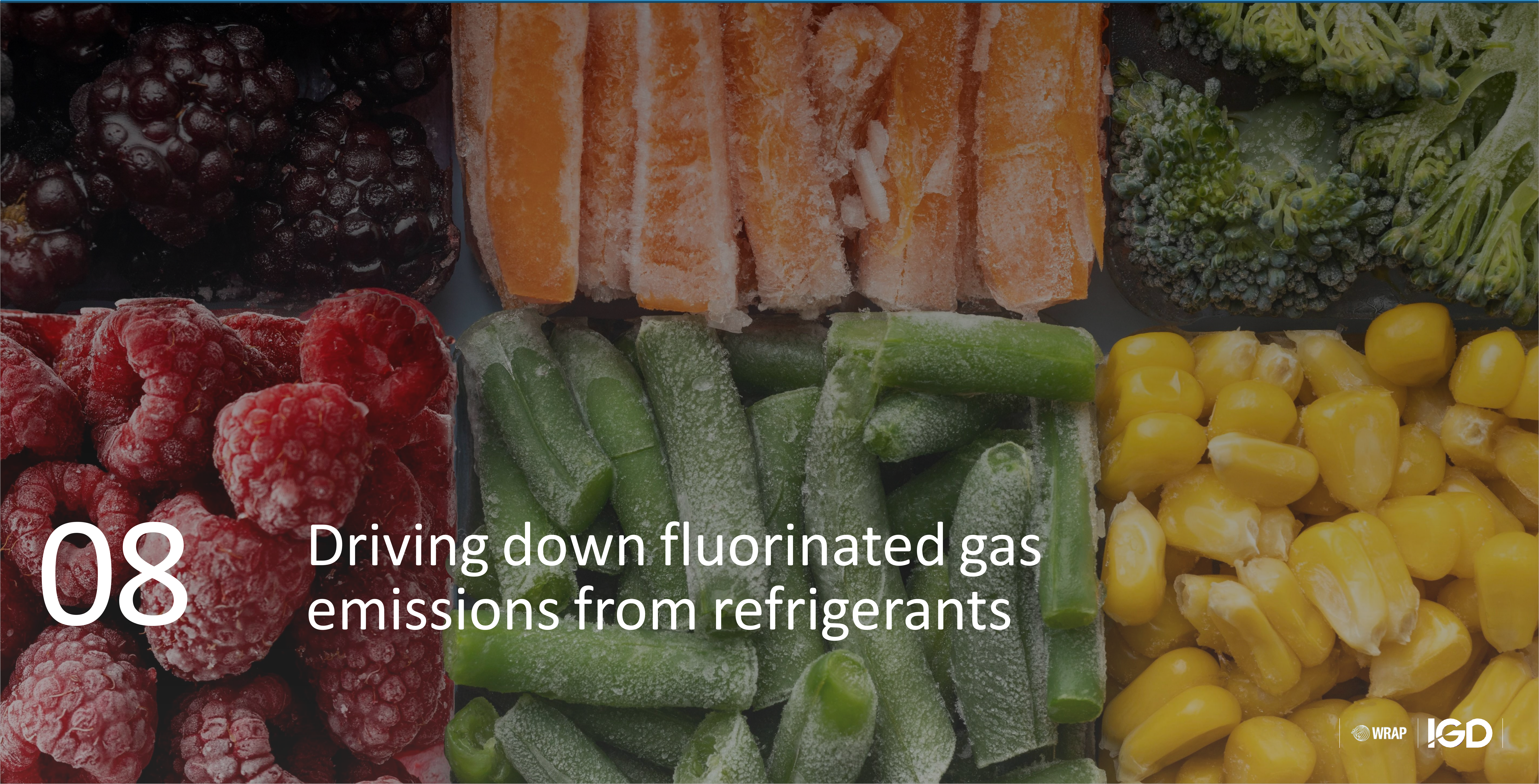
Where food manufacturing can be electrified, this should be the preferred option, given that it will be cheaper than use of hydrogen. Where electrification is not possible, hydrogen may be a viable alternative. This is subject to availability and the carbon price being sufficiently high.

It is assumed niche use of hydrogen in food manufacturing from 2035 at the earliest, should these conditions be met at this time. A later trajectory for hydrogen-based decarbonisation would ensue where these conditions are not met.

Transport

Hydrogen HGVs could offer a solution where range or payload constraints of battery HGVs are binding. This will be dependent on innovation relating to battery HGVs. At the current time, it is likely that hydrogen HGVs would only be for niche use, given their relatively high cost, and scope for addressing the constraints of battery vehicles.

Therefore, while a role for hydrogen HGVs is not ruled out, the planning assumption should be for battery HGVs as the main means for industry decarbonisation.



08 Driving down fluorinated gas emissions from refrigerants

The carbon footprint of refrigerants is driven by the emission of highly potent fluorinated gases (F-gases) – this can be reduced through available technologies, as required by regulations.

Refrigerants play a crucial role in the food industry, from preserving the integrity of perishable goods during transport to ensuring optimal storage conditions in supermarkets and commercial kitchens. As the food industry moves to net zero, the management of refrigerant gases can make an important contribution, given their current carbon footprint. By shifting towards eco-friendly refrigerants and adopting advanced cooling technologies, the sector can significantly reduce its reliance on high-global-warming-potential (GWP) substances, thereby decreasing its greenhouse gas emissions and contributing to the UK's climate change mitigation efforts.

3.7 $MtCO_2e$
Refrigerant related emissions in the food industry in 2021

3%
Contribution to total food industry emissions in 2021

73%
Reduction in emissions: 2030 vs. 2021

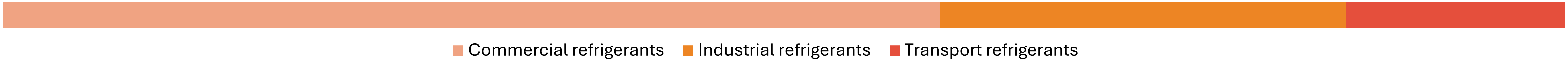
83%
Reduction in emission: 2050 vs. 2021

Cost neutral/ saving
Expected cost of abatement in 2050

Emissions drivers

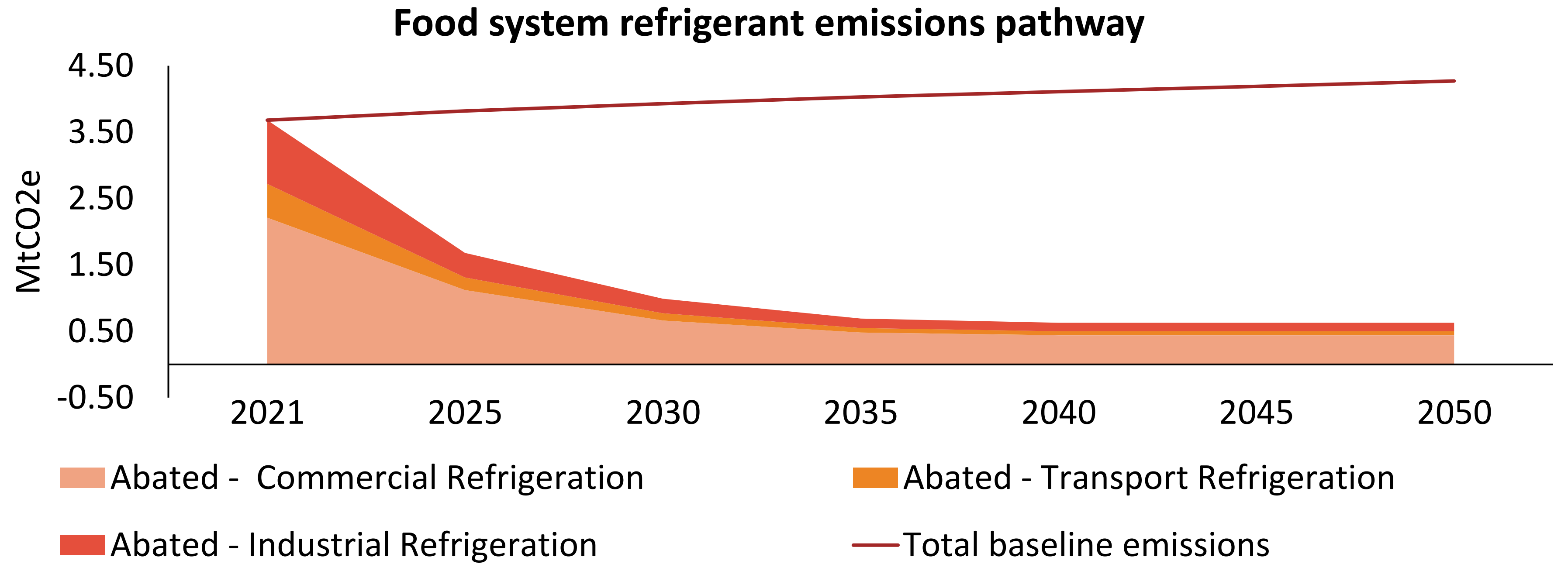
Refrigerant emissions in the industry are driven by three key areas;

- Commercial refrigeration used to display and store perishable goods;
- Industrial refrigeration used during large-scale cooling processes in manufacturing and storage facilities; and
- Transport refrigeration when distributing cold-sensitive products.



Abatement

Technologies exist and are cost-effective for refrigerants which would cut significantly F-gas emissions[1]. Uptake of these technologies is required under the UK's F-Gas regulations and the global mandate of the Kigali Amendment to the Montreal Protocol. In the modelling, it is assumed that these are met, resulting in an 83% reduction in refrigerant emissions by 2035 (see graph opposite).



1 The Sixth Carbon Budget: F gases – Climate Change Committee, 2020

Low-carbon refrigerants are cost-effective and are being taken up across the food system – emissions should fall to very low levels by 2030.

Given availability of low-carbon refrigerants, together with the UK's stringent F-gas regulations mandating a 79% phased reduction by 2030 relative to 2015, and the Kigali Amendment enforcing an 86% reduction by 2035 relative to 2011, the food industry has a clear path to drastically reduce its refrigerant emissions[1].

Affordable alternative refrigerants with a lower GWP offer a dual-benefit

- The transition to lower GWP refrigerants is not only environmentally beneficial but also financially viable, as cost-comparable or cheaper alternatives are already available in the market.
- Given their cost-effectiveness, prioritising the switch to lower GWP refrigerants should be an immediate focus in capital expenditure decisions and inventory turnover strategies.

The industry is embracing the challenge

- The industry recognises its responsibility and is embracing the challenge: good progress is being made replacing old refrigeration units with more carbon-efficient alternatives, in line with regulatory requirements and policy mandates.

Residual emissions will require future innovation to minimise

- While new technologies have much lower emissions than those previously deployed, they are not zero, i.e. residual emissions around 20% of current levels will remain in 2035.
- To address these residual emissions, it is likely that there will be further technology innovation, such that residual emissions would be negligible in the food system context, with scope for off-setting at the margin should this be deemed acceptable.

1 F gas regulation in Great Britain: Assessment Report – Department for Environment Food & Rural Affairs, 2022

09 Moving to low carbon transport

Surface transport emissions are one of the largest components of the carbon footprint after agriculture – they can be reduced through fuel and logistics efficiency improvement and use of low-carbon vehicles.

Transportation is integral to the UK food industry, ensuring seamless movement from agricultural production to consumer access. Transport accounts for a significant part of the food system's carbon footprint. The wider economy move towards low-carbon vehicles offers opportunities for the food system tom decarbonise this part of its carbon footprint.

7.2 $MtCO_2e$ – Surface transport related emissions in the food industry in 2021

6% – Contribution to total food industry emissions in 2021

10% – Reduction in emissions: 2030 vs. 2021

99.6% – Reduction in emissions: 2050 vs. 2021

£755 million – Expected cost of abatement in 2050

Emissions drivers

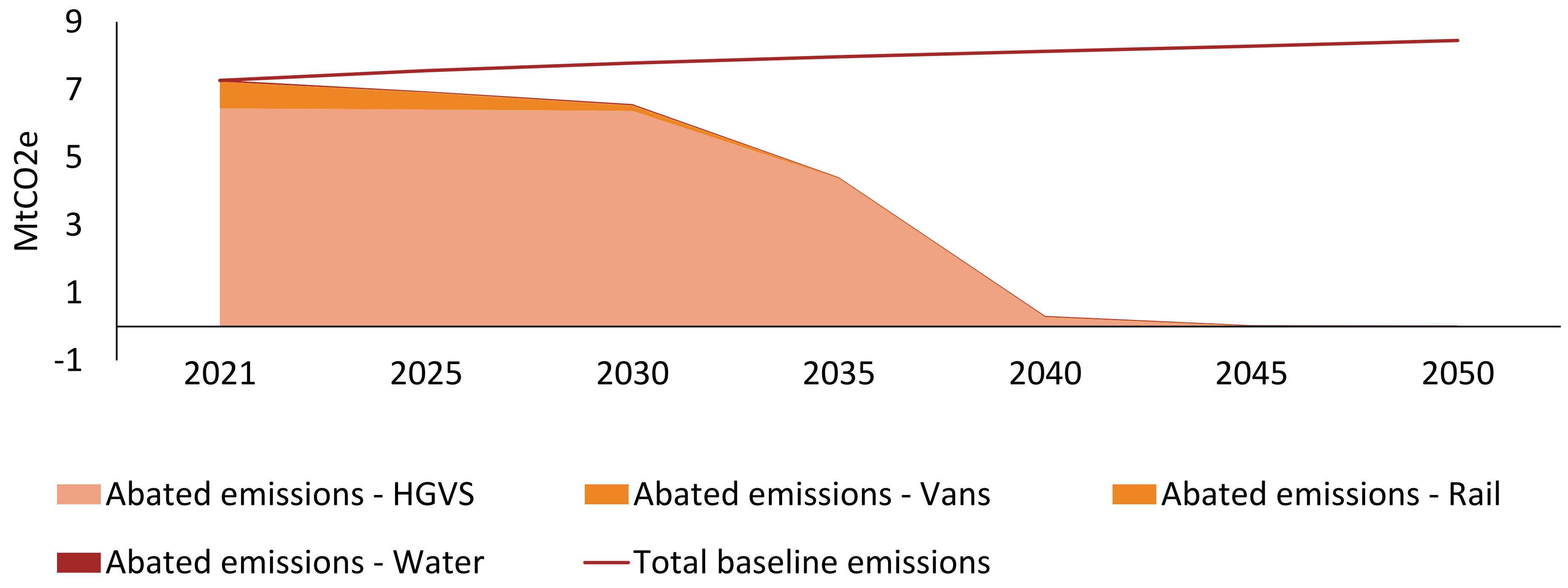
Transport emissions are primarily driven by heavy goods vehicles (HGVs), which are responsible for the bulk of emissions. Grocery delivery services also constitute a significant source. Water and rail transport, while being more carbon-efficient, account for only around 1% of the industry's transport emissions.

Abatement

The UK's broader transport decarbonisation strategy entails a move to electric vehicles. Significant switching for vans is planned for the 2020s, and for HGVs in the 2030s. There is also the opportunity for fuel efficiency improvements for conventional vehicles in the 2020s, and for logistics efficiency improvements across all timeframes[1] (see graph opposite).

While the food sector will not drive transport system decarbonisation, it can be an important player. Relevant companies in the food system should engage with broader programmes for electric vehicles and plan for their widespread uptake, subject to policies being in place, from the early 2030s.

Food system surface transport emissions pathway



1 The Sixth Carbon Budget: Surface Transport – Climate Change Committee

Electric vans are feasible and cost-effective and already in wide use – the aim should be for full deployment of electric vans by 2035 at the latest.

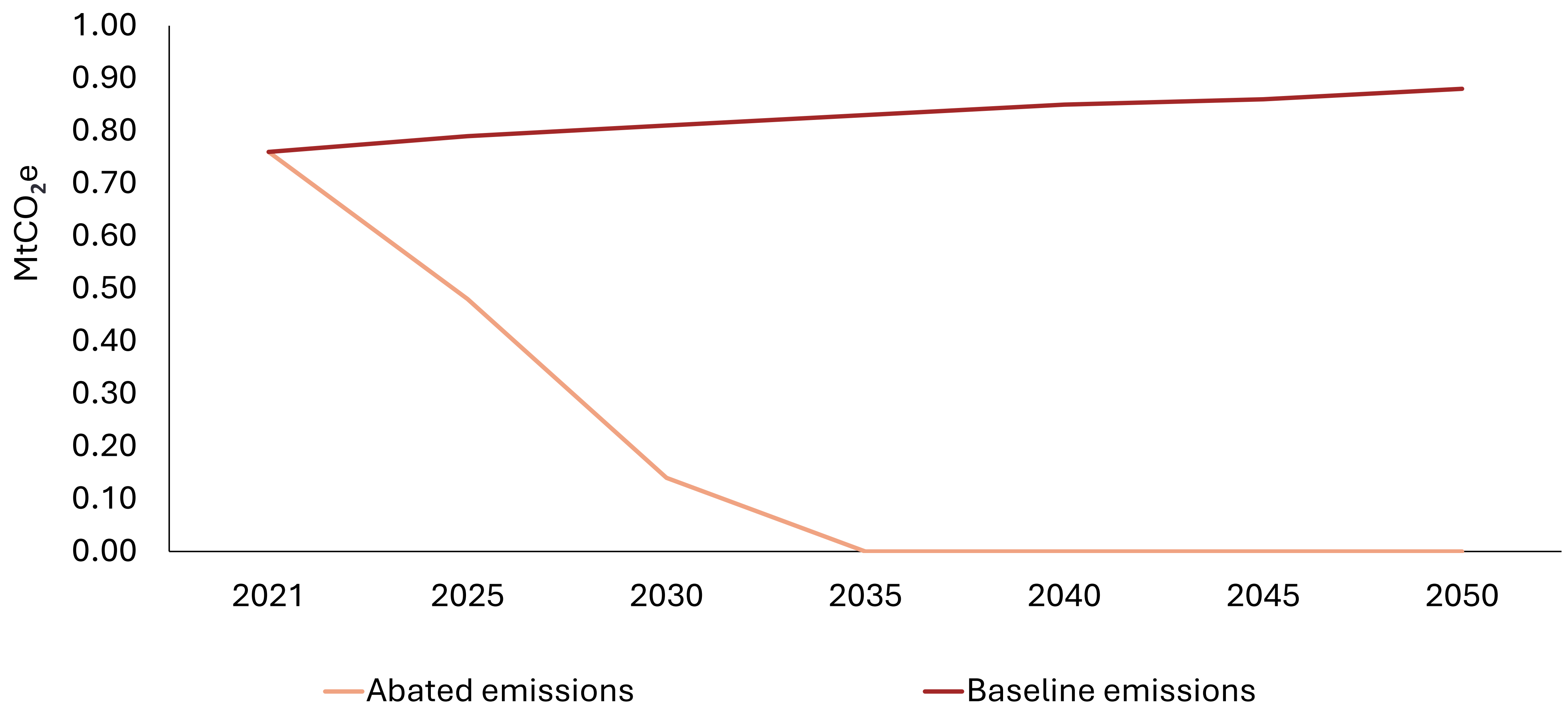
Grocery delivery vans are a critical link in the UK food industry's supply chain, bridging supermarkets to consumers' doorsteps. Electric vans are both feasible and cost-effective, and the aim should be to decarbonise these by the early 2030s at the latest. The industry is addressing this opportunity, with good progress and ambitious plans for investing in electric vans.

0.8 $MtCO_2e$	82%	100%	-£63 million
Grocery delivery related emissions in the food industry in 2021	Reduction in emissions: 2030 vs. 2021	Reduction in emissions: 2050 vs. 2021	Expected cost of abatement in 2050 (i.e,. cost saving)

Grocery delivery vans are a key component of the UK food industry's commitment to reducing its carbon footprint. The transition from conventional combustion-engine vans to electric alternatives is already underway, with economic analyses suggesting that electric vans are a cost-effective solution after accounting for infrastructure and operating costs[1]. Industry leaders like Tesco and John Lewis & Partners have set ambitious targets to electrify their delivery fleets by 2030, and Sainsbury's has a 2035 target[234].

The high mileage and frequent turnover of delivery vehicles make the rapid adoption of electric vans both feasible and practical. As a result, it is projected that van-related emissions will be significantly reduced by 2030, with a complete transition to a decarbonised fleet by 2035.

Food system grocery delivery emissions pathway



While good progress has been made and ambitious plans are in place, this is not universal. For those companies yet to embark on the transition to electric vans, targets and plans are needed, including for vehicle finance and purchase, establishing charging stations, updating maintenance facilities, and training staff to handle new electric technologies. Such commitments make sense from carbon and cost perspectives.

1 The Sixth Carbon Budget: Surface Transport – Climate Change Committee
2 Annual Report 2024 – Tesco
3 Ethics & Sustainability: Transport – John Lewis Partnership
4 Annual Report 2024 – Sainsbury's

Most surface transport emissions are due to heavy goods vehicles (HGVs) – with scope to reduce these to zero by the 2040s.

HGVs are the backbone of the UK food industry's logistics, transporting goods from farms to factories to distribution centres to retail outlets. As the transport sector moves towards decarbonisation, the role of low-carbon HGVs in the food industry's net zero strategy becomes increasingly prominent. Transitioning HGVs to cleaner energy sources, namely electricity (and possibly hydrogen) is a key pillar of broader food system decarbonisation.

The food system HGV transition has two parts. The first occurs in the short-term and is driven by efficiency gains; the second occurs over the medium and long-term and is due to switching from conventional to low-carbon vehicles.

It is anticipated that there will be a 10% reduction in new HGV emissions between 2020 and 2030 due to advancements in fuel efficiency; this is incorporated into the modelling. This could be complemented by niche use of biofuels, although these are expensive (e.g. using waste vegetable oil).

There is also scope for logistics efficiency improvements to reduce fuel consumption by 20%, given current empty running at 40%, Addressing this will require coordination across the industry and a programme of action.

Post-2030, there is scope for emissions to be reduced to zero through the electrification of HGVs. However, this shift is dependent on continued technological innovation and robust policy support to overcome the challenges associated with electrifying heavy-duty transport[1]. Biofuels are unlikely to be the long-term solution for HGVs, given lack of feedstocks and relatively high value of these in other sectors.

The industry should proactively engage with programmes to decarbonise HGVs, trialling new technologies in the 2020s and planning to roll these out in the 2030s, subject to continued innovation and policy support.

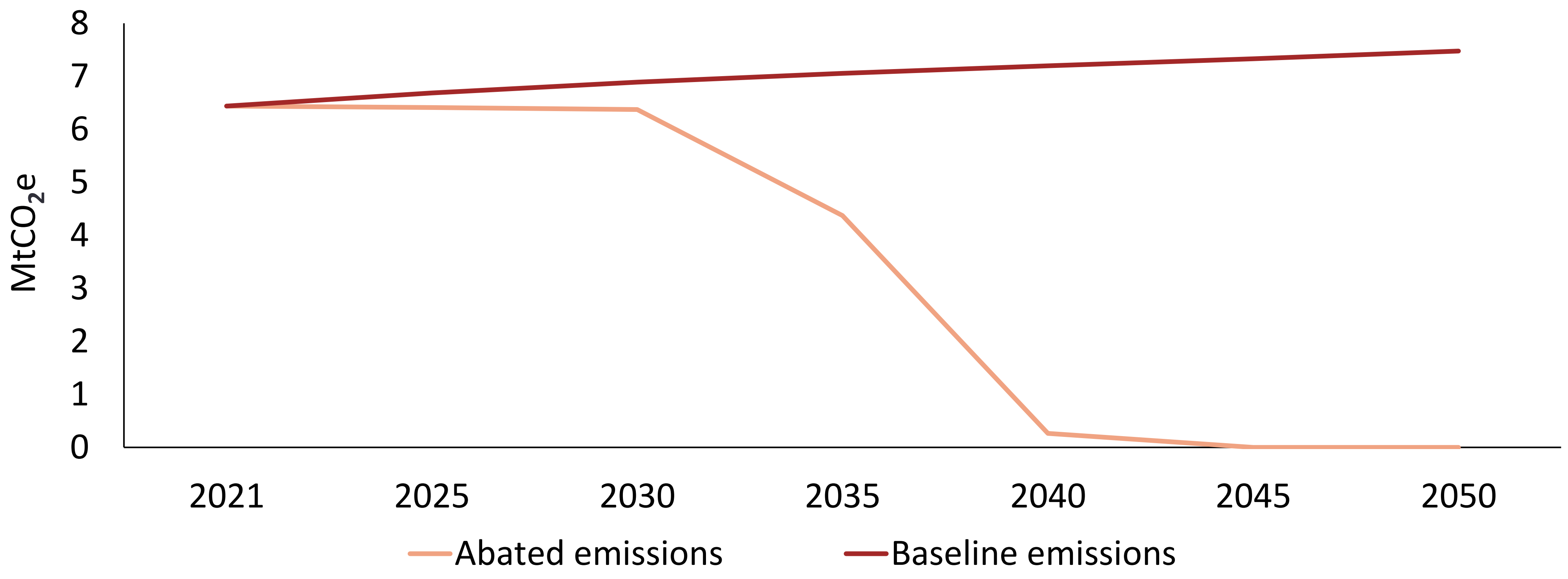
6.4 $MtCO_2e$
HGV related emissions in the food industry in 2021

1%
Reduction in emissions: 2030 vs. 2021

100%
Reduction in emissions: 2050 vs. 2021

£831 million
Expected cost of abatement in 2050

Food system HGV emissions pathway



1 The Sixth Carbon Budget: Surface Transport – Climate Change Committee

Heavy goods vehicles (HGVs) emissions can be reduced through fleet and logistics efficiency improvement in the 2020s; and switching to low-carbon vehicles in the 2030s.

The decarbonisation of HGVs is a critical component of the UK food industry's transition to net zero. By 2030, a 10% reduction in new HGV emissions is anticipated, translating to a fleet average efficiency improvement of around 7.5% due to the industry's rapid vehicle turnover rate, with opportunities for further emissions reductions due to better logistics efficiency. This lays the foundations for more significant emissions reductions beyond 2030, with electrification as the primary lever. Subject to continued innovation and policy support, all new HGVs for the food system could be zero-carbon from the mid-2030s.

↓ 7.5% Carbon emissions can be cut through increasing existing fleet efficiency

- European regulatory requirements and programmes are driving HGV fleet efficiency improvements. These will benefit the UK, both generally and with regard to the food system. The expected 10% fuel efficiency improvement through the 2020s would translate to a 7.5% fleet efficiency improvement, given a five-year turnover of the fleet.
- Logistics fuel efficiency is undermined by 40% empty running. Coordinating across networks could reduce this significantly and offers the opportunity for a 20% fuel efficiency improvement, as identified in previous work for the IGD. Addressing this opportunity would require coordination across the industry and a programme of activity. This would be justified given the opportunities for reduction of carbon emissions and costs.
- There is also an opportunity to move some freight from road to rail. This was highlighted by Dave Lewis in his review of food system resilience for the Government in 2021. Currently there is very little movement of food by rail, notwithstanding that there is spare freight capacity on the network. In addition to resilience benefits, moving food by rail could result in reduced emissions where rail is electrified. This is an area that could be considered further, noting that it is very challenging and could only be justified on multiple benefits rather than carbon alone..

Limitations exist that currently prevent electric HGV market penetration

- There are currently electric battery HGVs in operation, although these are subject to various challenges.
- The current range of battery HGVs is 200+ miles. The payload for a battery electric HGV is around 20% lower than for conventional HGVs, reflecting the weight of batteries.
- The upfront cost of battery HGVs is currently around £300k, and hydrogen fuel cell vehicles are about £500k, compared to £100k for a conventional HGV[1].
- While battery HGVs have slightly lower operating costs than conventional ones, hydrogen vehicles are more expensive to operate due to the cost of hydrogen production.

1 The Sixth Carbon Budget: Surface Transport – Climate Change Committee

The modelling for an ambitious reduction of HGV emissions involves significant deployment from the early 2030s.

The cost for HGV abatement in 2050 is 111.2 £/tCO_2

In 2035, it is modelled that 96% of sales of new HGVs will be Zero Emissions Vehicles

Industry should continue to work with government

Innovation and policy support will be key to low-carbon HGV rollout

- An ambitious future has been modelled, where battery HGVs are deployed increasingly form 2030 and account for the vast majority of new vehicle purchase from 2035; and the fleet becomes decarbonised by 2040, assuming a five-year turnover of the HGV stock, which reflects current food industry practice[1].
- In reality, the take-up of battery HGVs may well start later than this. It may also be the case that there is a role for hydrogen vehicles, depending on innovations for this technology and for battery HGVs.
- While there is uncertainty over the precise path through the 2030s, the key points are that significant penetration of low-carbon HGVs across the fleet is unlikely in the early 2030s; while full decarbonisation should be achieved well before 2050.
- The CCC's estimate of abatement costs has been used for HGVs. Specifically, their cost for HGV abatement in 2050 is 110 £/tCO_2. On this basis, the cost of fleet decarbonisation with associated abatement of 7.5 MtCO_2 in 2050 is of the order £830 million[1].

- The Government has a comprehensive plan for developing low-carbon HGVs. This is aimed at driving innovation, including reducing costs, extending range, and improving charging technology. The industry is proactively engaged in this programme, for example, through trialling of battery HGVs and charging infrastructure.
- Further financial incentives may be needed to support rollout, depending on the extent of cost innovation.
- For the full HGV fleet to be decarbonised, this could require charging capacity of 5 GW. This capacity is likely to be required in part where power networks are currently constrained, and a policy driven prioritisation of connections would be required.
- Subject to innovation and policy support, the industry could deploy low-carbon vehicles at scale in the mid-2030s.
- It is recommended the same approach as for other parts of the food system: industry should engage with the Government, plan for deployment including identifying dependencies, monitor closely developments, and execute plans subject to innovations being made and policies being in place.

1 The Sixth Carbon Budget: Surface Transport – Climate Change Committee

10 Opportunities to reduce aviation and shipping emissions

There are opportunities for deep cuts in international transport emissions for imported goods.

International transport plays an important role in providing access to a diverse food supply and ensuring food security.

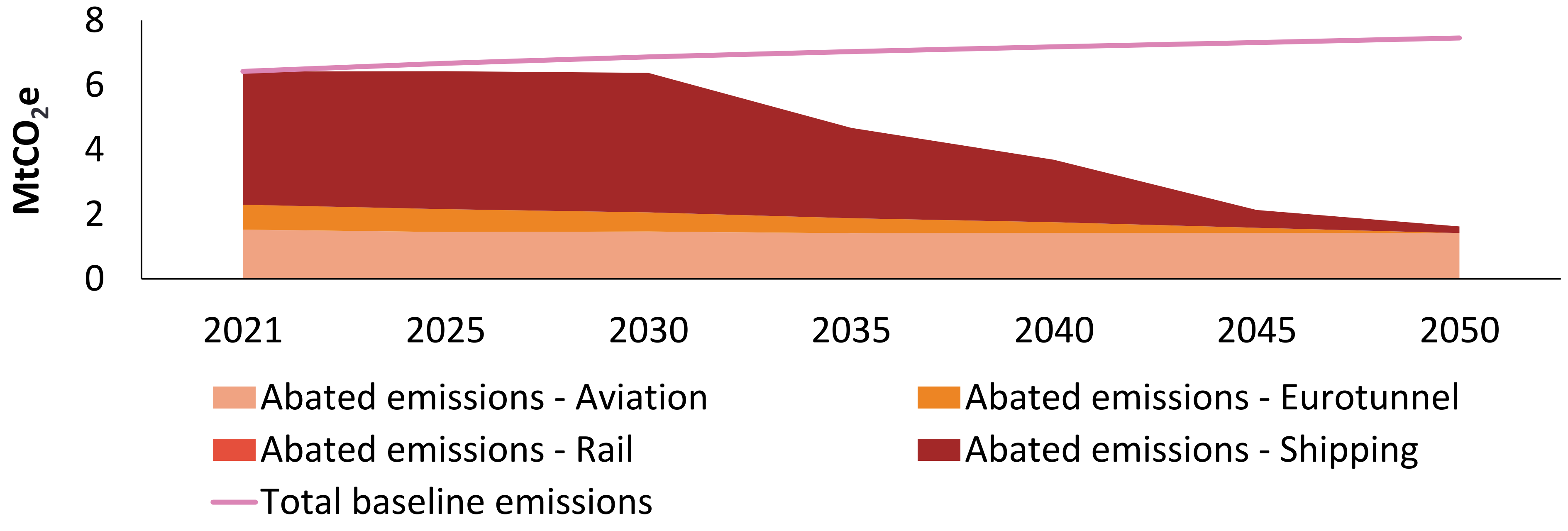
6.4 $MtCO_2e$	**5%**	**3%**	**75%**	**TBD**
International transport related emissions in the food industry in 2021	Contribution to total food industry emissions in 2021	Reduction in emissions: 2030 vs. 2021	Reduction in emissions: 2050 vs. 2021	Expected cost of abatement in 2050

Emissions drivers

Emissions from international transport are largely driven by shipping and aviation, with small contributions result from rail and Eurotunnel emissions.

There is scope to reduce international transport emission by 75% by 2050 compared to 2021 (see graph opposite). This includes reducing shipping emissions by ~95% by 2050, due to fleet efficiency improvements, electrification, and the use of zero-carbon fuels[1]. Similarly, aviation emissions can be reduced by 30% through fuel efficiency improvements and biofuels use[2]. Trucking emissions associated with Eurotunnel transport are reduced to nil by 2050 in line with domestic transport analysis (see Section 9). Rail emissions are reduced by ~55% by 2035 due to the electrification of the network and the replacement of existing diesel trains[4].

Food system international transport emissions pathway



1 The Sixth Carbon Budget: Shipping – Climate Change Committee
2 Meeting the UK aviation target – options for reducing emissions to 2050 – Climate Change Committee, 2009
3 The Greener Way To Travel, Eurotunnel – LeShuttle
4 The Sixth Carbon Budget: Surface Transport – Climate Change Committee

The largest opportunity in international transport is for reducing international shipping emissions, with scope too for significant cuts in aviation and rail emissions.

Shipping

Emissions from shipping were around 4.12 $MtCO_2e$. In 2021 There is scope to reduce these emissions by 95% to 2050, as assessed by the CCC, and relating to three levers[1]

- Fleet carbon-efficiency improvements: via a combination of slow steaming, operational optimisation, ship hull design and new engine efficiency improvements, onboard renewable power generation and wind propulsion systems.
- Electrification: used for a limited number of niche hybrid and full electric propulsion vessels.
- Zero-carbon fuels: Used to displace fossil marine fuels

On this basis, a 95% emission reduction between 2021 and 2050 is assumed.

Aviation

Aviation emissions are around 1.5 $MtCO_2e$, i.e. relatively small within international transport emissions.

The CCC has identified scope for a 30% fleet efficiency improvement by 2050, through more fuel-efficient planes and engines, and use of biofuels[2]

A 30% reduction in emissions by 2050 is assumed in the modelling.

There are further opportunities to reduce aviation emissions close to zero through switching from aviation to shipping.

Eurotunnel

Eurotunnel emissions account for around 12% of total international transport emissions in 2021 and are largely contributed to by the vehicles used to transport goods through Europe and the Eurotunnel. Decarbonisation is therefore assumed in line with domestic HGVs (see section 9). This assumes significant abatement to 2040, going to nil by 2050.

The Eurotunnel itself has minimal emissions associated but does have targets to reduce to net zero by 2050, which it is assumed will be achieved.

Rail

The total emissions from the rail sector for international transport are currently very small, although as noted in the discussion of surface transport, there may be scope for switching from road to rail in future.

The CCC assume that rail emissions are reduced by around 55% by 2035, owing to the rail network being electrified and a mix of hydrogen, battery-electric, and electric hybrid trains replacing existing diesel trains[4]. It is assumed that this order of emissions reductions can be achieved for foreign rail, but on a slower timeframe, reflecting uncertainty over rail policy in other countries.

1 The Sixth Carbon Budget: Shipping – Climate Change Committee
2 Meeting the UK aviation target – options for reducing emissions to 2050 – Climate Change Committee, 2009
3 The Greener Way To Travel, Eurotunnel – LeShuttle
4 The Sixth Carbon Budget: Surface Transport – Climate Change Committee

11 Increasing packaging recycling and reuse

Packaging plays a crucial role in the industry and has a significant carbon footprint from production of packaging materials – with scope to cut this by at least 50%.

Packaging plays a crucial role in the food industry. It is important in ensuring food preservation through extending the shelf life of food and preventing damage, which in turn prevents food wastage. Packaging is also key to food safety, as it protects food from contamination and can facilitate the ease of transportation of food products.

5.9 $MtCO_2e$	**5%**	**32%**	**50%**	**TBD**
Packaging related emissions in the food industry in 2021	Contribution to total food industry emissions in 2021	Reduction in emissions: 2030 vs. 2021	Reduction in emission: 2050 vs. 2021	Expected cost of abatement in 2050

Emissions drivers

The emissions in the packaging sector are driven by embodied emissions in packaging materials. Based on IGD analysis[1], packaging emissions can be addressed through the following levers:

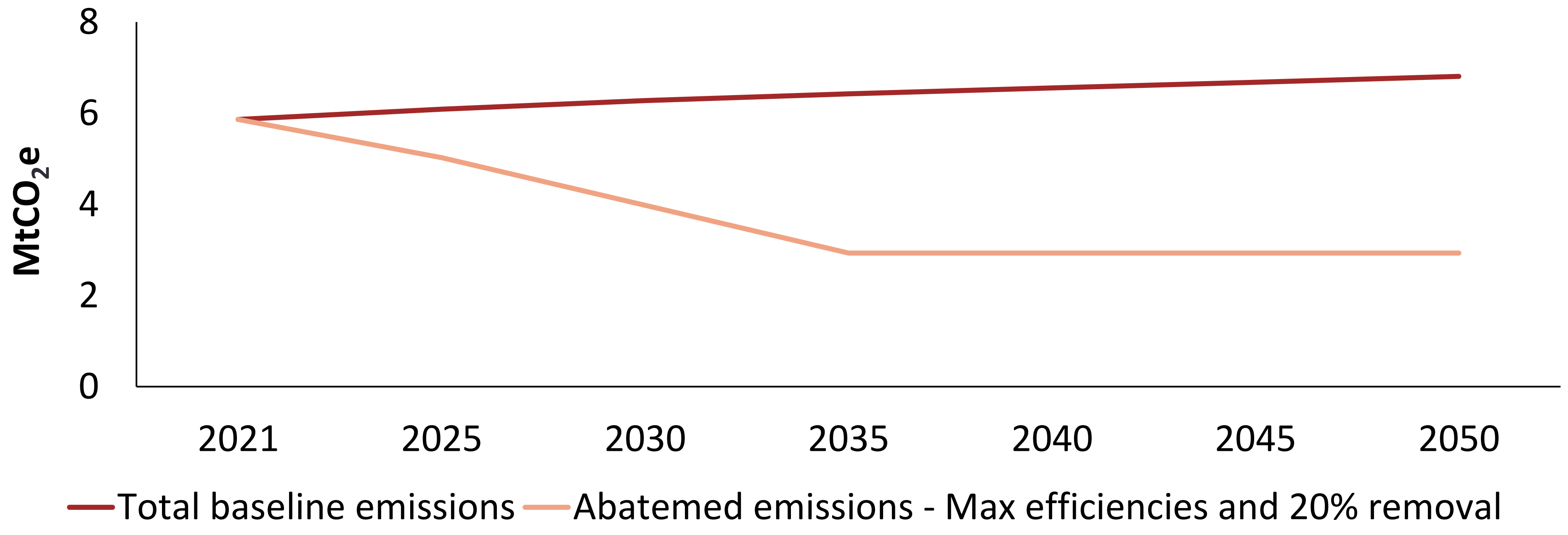
- Removing packaging from circulation (e.g. using the least material required)
- Increasing recycled content of packaging (e.g. incorporating recycled plastic)
- Decarbonising supply chains and processes associated with creating packaging (e.g., efficiency improvements, electrification)

Abatement

The modelling assumes a 50% emissions reduction by 2035. This reflects IGD analysis of what is possible1; and a more conservative timeframe than IGD's 2030 ambition, given current progress and long lead times for change. Further emissions reductions will be required beyond 2035, with scope for this in the three categories above; this is modelled as growing to a 50% reduction in emissions by 2050 (see graph opposite).

Industry effort, policy support, collaboration and investment in infrastructure will be required to drive emissions reductions to 2035 and beyond. When considering changes to packaging, implications for food waste reduction are important. Specific areas of policy which are highly relevant here include: Extended Producer Responsibility; the Deposit Return Scheme; the Plastic Packaging Tax; single-use plastic bans and restrictions.

Food system packaging emissions pathway



1 - Halving the environmental impacts of the UK packaging system – IGD, 2022

12 Carbon markets and offsets

Residual emissions: offsetting will be very expensive and should be seen as a last resort.

Residual scope 3 emissions could be addressed through carbon offsets – but this would be very costly and should be a last resort, if it is to be deployed at all. No decision needs to be made on this now, but it is an important area in the context of industry commitments to net zero, which would entail credit purchase.

- The analysis has shown that non-FLAG emissions can be reduced close to zero by 2050. However, there would still be non-FLAG emissions remaining of 30 $MtCO_2e$, even if a 70% emissions reduction could be achieved, the latter being very demanding.
- In principle these could be offset through credit purchases. In order for this to be a viable option, multiple problems with current carbon markets would need to be addressed (efficacy, accounting, permanency, transparency, etc.).
- The price of offset credits is currently low and expected to increase. Equally, the price of credits in trading schemes, while higher, is also relatively low.
- However, current market prices are not a good proxy for future prices, which would be expected to be very high in a net zero world. For example, the UK Government's carbon values for a net zero world increase to £400/tCO_2 by 2050 in a central scenario.
- While these seem high, they reflect an assessment of marginal abatement costs that would drive carbon prices in a net zero world.
- Even in a world where new Direct Air Capture technologies are successful and take pressure out of carbon markets, carbon prices of £200 / tCO_2 in 2050 are expected. Offsetting residual emissions at this price would cost £6 billion annually. Given the possibility of much higher carbon prices, this should be regarded as a lower bound.

- Given this potential cost, it is recommended that purchase of credits should be seen as a last resort and that all other options to reduce emissions be pursued vigorously by the industry.
- Such purchase would effectively be a tax on the industry with impacts for consumers. To the extent that this would not be a progressive tax, there is a question around whether it would be appropriate to purchase credits, or whether emissions reductions might be better funded from other sources (e.g. partnerships between the industry and government to invest in new forests).

13 Appendices

Appendix A: Acronyms/Glossary

Acronym	Meaning
3NOP	3-Nitrooxypropanol
AD	Anaerobic Digestion
AD cattle	Anaerobic Digestion for cattle
bn	Billion
CAP	Common Agricultural Policy
CapEx	Capital Expenditure
CCC	Committee on Climate Change
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilisation, and Storage
CDP	Carbon Disclosure Project
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COP	Conference of the Parties
DA	Devolved Administration
Defra	Department for Environment, Food & Rural Affairs
EI	Emissions Intensity
ELM	Environmental Land Management
EMR	Electricity Market Reform
EUDR	EU Deforestation-free Regulation
FDTP	Food Data Transparency Partnership
FEED	Front End Engineering Design
FIs	Financial Institutions
FLAG	Forest, Land and Agriculture
FSA	Food Standards Agency
GHG	Greenhouse Gas
GW	Gigawatt
GWP	Global Warming Potential
H2	Hydrogen
HaFS	Hospitality and Food Service
HAR2	Hydrogen Allocation Round
Heat pump LT	Heat Pump Low Temperature
Heat pump MT/HT	Heat Pump Medium/High Temperature
HGVs	Heavy Goods Vehicles
HPBM	Hydrogen Production Business Model
HPP	Hydrogen Power Plant
IETF	Industrial Energy Transformation Fund
IGD	Institute of Grocery Distribution
NUE	Nitrogen Use Efficiency
Industrial NRMM	Industrial Non-Road Mobile Machinery
LRVC	Long Run Variable Cost
LUC	Land Use Change
LULUCF	Land Use, Land-Use Change, and Forestry
LWG	Live Weight Gain
$MtCO_2e$	Million Tonnes of Carbon Dioxide Equivalent
MW	Megawatt
N_2O	Nitrous Oxide
NHS	National Health Service
NZBA	Net Zero Banking Alliance
OpEx	Operational Expenditure
pH	Potential of Hydrogen (acidity/alkalinity measure)
PPAs	Power Purchase Agreements
SBTi	Science Based Targets initiative
SDG	Sustainable Development Goals
SFI	Sustainable Farming Incentive
SRUC	Scotland's Rural College
tCO_2e	Tonnes of Carbon Dioxide Equivalent
TPT	Transition Plan Taskforce
UAE	United Arab Emirates
UK	United Kingdom
UKDR	UK Deforestation-free Regulation
WRAP	Waste and Resources Action Programme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