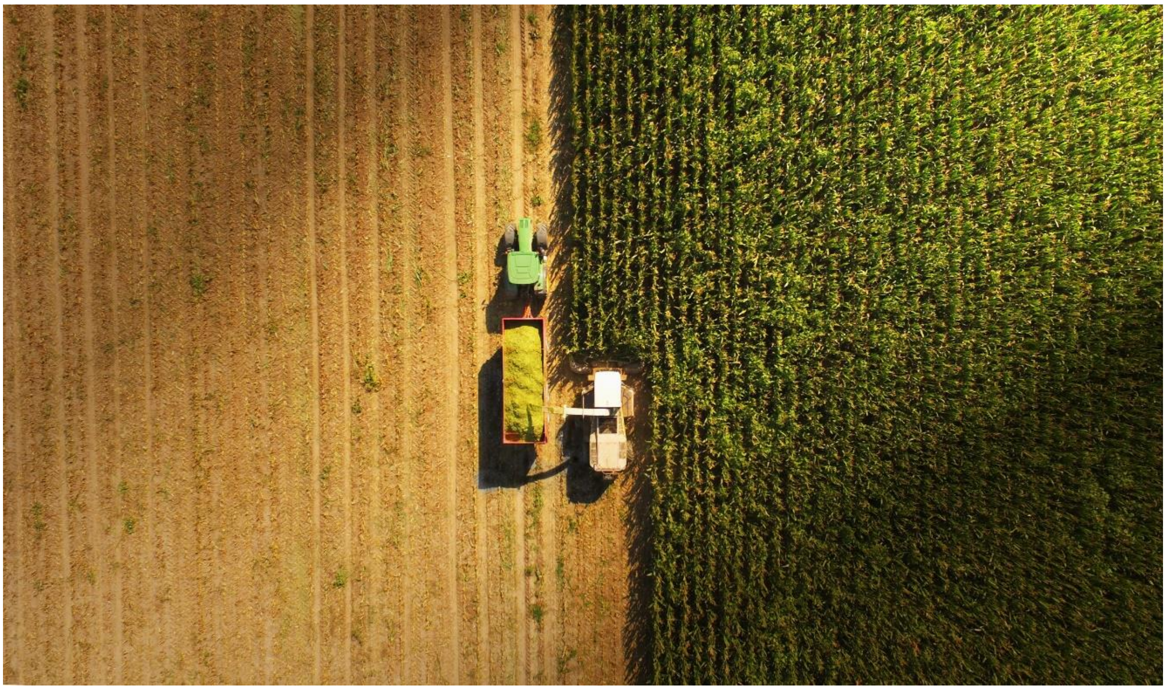
Final Report

UK Food System GHG

Total UK food & drink consumption footprint and pathway to a 50% reduction by 2030



An analysis of the total greenhouse gas emissions linked to the production and consumption of food & drink consumed in the UK, showing the scale of emissions reductions achieved between 2015 and 2019 – and estimates of further emissions reductions that could be achievable by 2030.

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[WRAP, 2021, Banbury, UK Food System GHG Emissions, Prepared by WRAP]

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Executive summary

Overview and purpose of this work

This report provides an analysis of the total greenhouse gas (GHG) emissions linked to the production and consumption of food & drink consumed in the UK, showing the scale of emissions reductions achieved between 2015 and 2019 – and estimates of further emissions reductions that could be achievable by 2030.

It builds on previous work – for example as presented in the National Food Strategy[1] and the most recent Courtauld Commitment milestone report[2] – both of which have identified the significance of the food system in the context of both UK territorial emissions, and its wider global footprint.

Since undertaking previous work, WRAP has launched Courtauld 2030, with a new target of a *"50% absolute reduction in the GHG emissions associated with production and consumption of food and drink in the UK against a 2015 baseline"*

This is a step-change in level of ambition for emissions reduction for the sector. Notably:

- It is aligned to a 1.5°C pathway and encompasses absolute emissions reductions across all emissions scopes;
- It is an important milestone towards meeting wider industry targets – in particular British Retail Consortium (BRC) and Food & Drink Federation (FDF) targets for Net Zero by 2040. This is significant in the context of the well-documented evidence on the importance of early action in keeping to a 1.5°C pathway globally[3];
- Critically – it includes overseas supply chains. The Committee on Climate Change and National Food Strategy both flag the importance of considering the UK's wider consumption footprint - to prevent simply offshoring our emissions.

Setting targets is the first step. It is important that collectively we accelerate action in meeting them. Measurement is an important step to understand where and how reductions can be achieved, where to focus efforts, where to push for a faster pace and where to fill gaps in understanding, etc. There is also a need to continue to monitor progress over time to ensure that actions being taken are having the right effect.

The objectives of this work were to:

1. Develop a new GHG emissions model for the UK food & drink system;
2. Use this to:
    a. Update latest estimates of food system emissions, and reductions to date - improving previous estimates and filling data gaps; and
    b. Investigate the scale of emissions reductions that could come from different types of interventions – and how a 50% reduction target could be achieved.
3. Identify further work needed to improve the food system GHG model, so that it is fit-for-purpose to aid monitoring of food system emissions over time.

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[1] *National Food Strategy, 'The National Food Strategy: The Plan', July 2021, https://www.nationalfoodstrategy.org/.*
[2] *WRAP, 'UK Progress against Courtauld 2025 Targets and UN Sustainable Development Goal 12.3' (Banbury, 2020), https://wrap.org.uk/resources/report/uk-progress-against-courtauld-2025-targets-and-un-sustainable-development-goal-123.*
[3] *For example, as cited in the National Food Strategy*

New GHG emissions model for the UK food & drink system

An extensive new GHG emissions model has been developed that collates emissions estimates across every stage in the UK food & drink value chain, disaggregated by inputs such as electricity, fuel, refrigerants, transport, packaging, UK agricultural products & ingredients and imported products & ingredients.

Building this detailed picture at every stage enables, for the first time, an investigation of the implications of individual changes across the whole food system. For example: What will be the scale of emissions reductions achievable if commitments on renewable energy are met? How much could achieving zero deforestation commitments contribute? What would the impacts be of achieving targets to halve food waste?

This new modelling also updates previous estimates by including aspects such as emissions linked to tropical deforestation, refrigeration and home deliveries, as well as updating underlying emissions factors with latest best-available sources.

Latest estimates of emissions and reductions to date

Table A2 shows estimates of the total GHG emissions associated with production and consumption of food and drink in the UK, across all stages of the value chain. 2015 is the baseline year for the Courtauld Commitment 2030 target. 2019 is the latest year for which most national-level data were available at the time of drafting.

Key findings are that:

- **Total UK food system emissions in 2019 were estimated to be 158 Mt CO_2e.**
    - **This is equivalent to 35% of UK territorial emissions[4]** – <u>though not all of these emissions occur in the UK</u>.
    - Within this, **emissions linked to the production & distribution of food that becomes waste are around 36 MtCO_2e (23% of total food system emissions).** This updates previous estimates, but only includes food waste that arises in the UK (where there is sufficient data). It could be c. 8MtCO_2e higher (up to 28% of food system emissions in total) if including waste occurring in overseas supply chains (assuming wastage rates are similar to those in the UK).
- There has been a **c.8% absolute reduction in GHG emissions associated with the UK's food & drink system between 2015 and 2019.**
- The **majority of this reduction (> 80%) is due to decarbonisation of the UK's electricity grid**: the emissions associated with consuming a unit of electricity were 45% lower in 2019, compared to 2015.
- In line with this, **the stages in the value chain which are significant electricity consumers (food manufacture, hospitality & food service, retail, households) have seen the biggest reductions in GHG emissions (in combination c.12 MtCO_2e).** There have also been some efficiency improvements.
- **GHG emissions associated with overseas production are hard to quantify, but significant (>one third of the total – across food, ingredients and feed – including**

[4] *Based on latest, 2019, total (454.8 MCO_2e), from: https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2019*

deforestation), and in combination have remained largely static in relative terms. It is important to note, however, that significant care should be taken when interpreting changes over time, which are driven by fluctuations in the volumes of food imported.

- **GHG emissions associated with UK agriculture have remained largely static** in recent years, but are also very challenging to measure accurately, and are sensitive to external influences (e.g. extreme weather).
- **Transport emissions in the UK have increased (moderately – c. 1 $MtCO_2e$).** This is an estimate, based on the increase in road mileage observed in national datasets over this time period – a proportion of which is allocated to food transport.
- **Packaging emissions are low in comparison with the emissions associated with producing food, and have remained largely static**. Packaging can help reduce food waste, which reduces emissions in other stages (though not currently fully quantifiable). The amount of packaging placed on the market (and associated emissions) has been broadly constant over recent years. It should be noted, however, that environmental concerns regarding packaging – in particular, single use plastics – are not necessarily well captured using GHG emissions as a metric, as this does not reflect the impacts of marine pollution, bioaccumulation, etc.
- **Refrigerant emissions have decreased by nearly 2 $MtCO_2e$.** This is driven by reduction in refrigerant emissions across all industrial, commercial, domestic and transport sectors, which has declined by c. one third between 2009 and 2018. Much of this reduction is likely to be due to business responding to F-gas regulation and replacing gases that have high global warming potential (GWP) with low/no GWP gases.
- **Successful food waste prevention and diversion strategies in the UK are resulting in low and decreasing emissions associated with food waste management (combined across all stages)** – as the proportion of food waste sent to landfill is relatively low, and decreasing. Other food waste management routes (e.g. AD, composting, incineration) have low, or sometimes negative, GHG emissions because they generate renewable energy or other products (NB – these negative emissions have not been included in the assessment, in accordance with the GHG Protocol methodology)[5].

This analysis builds significantly upon the work outlined in WRAP's most recent Courtauld Commitment milestone report.[6] A full description of the changes, and a full comparison of previous and restated values is included in Section 4.0. This shows that, whilst absolute estimates of UK food system emissions have increased through filling data gaps and methodological refinements, relative reductions remain the same as in the previous analysis, as shown in Table A1.

Table A1: Comparison with previously stated results, progress to target

	Previously stated*	Restated
Reduction 2015-18, total	-5.2%	-5.2%
Reduction 2015-18, per capita	-6.8%	-7.1%

*Previously stated values as reported in:
https://wrap.org.uk/sites/files/wrap/Progress_against_Courtauld_2025_targets_and_UN_SDG_123.pdf

[5] *We also note one significant date gap for the scale of food waste being disposed to sewer (for sectors other than households), which is expected to be particularly relevant for the HaFS sector. This data gap means that total disposal emissions are likely underestimated.*

[6] *WRAP, 'UK Progress against Courtauld 2025 Targets and UN Sustainable Development Goal 12.3'.*

Table A2 – Total UK Food System Emissions Estimates for 2015 - 2019

Stage in the value chain	2015 GHG emissions estimate (Mt CO_2e)	2019 GHG emissions estimate (Mt CO_2e)	Main reasons for change 2015-2019	Data quality / level of confidence in annual estimate and changes over time ***
UK primary production				
… UK agricultural emissions (livestock, soils, fuel)*	46.0	46.3	Emissions largely static (as reported in National Inventory)	
…Embodied emissions from fertiliser production	2.0	2.0	Emissions largely static	
…Embodied emissions from imported feed for use in UK	2.5	2.8	Figure for net imports of feed and food / ingredients is highly variable from one year to the next, and is driven by fluctuations in the volumes of food imported. In particular annual variation is heavily influenced by the UK wheat harvest. This means that reductions in shorter timeframes should be interpreted as stochastic rather than systemic change.	
…Deforestation estimate for feed imports	4.7	4.5		
Overseas food production (net imports)	37.6	35.9		
...Deforestation estimate for tropical commodities	10.9	11.9		
UK food & drink manufacturing	11.1	9.3	Decarbonisation of electricity	
Packaging	5.0	5.1	Changes in packaging volume and composition reported	
Refrigerant (all UK stages)	5.4	3.6	Industry switch to lower impact refrigerants	
Supply chain transport in UK	6.3	6.8	Upward underlying increase in mileage for food transport.	
Hospitality & Food Service (catering)	8.5	7.9	Decarbonisation of electricity	
Retail	7.8	5.3	Reduced demand (e.g. through increased estate efficiency) and decarbonisation of electricity	
Consumer transport for food shopping	4.5	4.6	Increase in reported car usage for shopping trips	
Transport – home deliveries	0.6	0.9	Growth in demand for delivery services	
Home (storage and cooking)	17.6	9.9	Reduced demand (e.g. through improved appliance efficiency) and decarbonisation of electricity	
Waste disposal	1.3	0.8	Food waste reduction and diversion from landfill	
TOTAL	**172**	**158**		
…of which is linked to producing food that is wasted**	43	36		

*Of which: 62% emissions from livestock (enteric fermentation and organic wastes); 28% emissions from soils; 10% emissions from stationary and mobile combustion

** This only includes food waste that arises in the UK (where there is sufficient data). It could be c.8 MtCO_2e higher (up to 28% of food system emissions in total) if including waste occurring in overseas supply chains (assuming wastage rates are similar to those in the UK).

*** **Green** = predominantly based on reputable national datasets which are frequently updated and/or emissions factors which are not subject to significant variability or are frequently updated. **Amber** = based on a range of different estimates and assumptions, which may reduce certainty levels but unlikely to be highly variable . **Red** = subject to significant uncertainty, either in methodology or data availability.

A pathway to achieving 50% reduction in UK food system emissions

For the first time we have modelled the scale of GHG emissions reductions that could come from different types of interventions, such as zero deforestation, decarbonising energy, decarbonising transport, preventing food waste, etc.

Figure A1 demonstrates an example pathway for how a 50% reduction in total food system GHG emissions could be achieved by 2030 (against a 2015 baseline). These estimates have significant uncertainty – but show an *approximate* and *relative* scale of reduction potential. For some interventions, an 'upper' and 'lower' estimate of savings has been included. This reflects the significant uncertainty either in the *scale* or the *pace* of reductions that could be achieved by 2030. A short summary of the scenarios modelled is included in Table A3.

Key findings are that:

- There *is* a pathway to achieving a 50% absolute reduction in the GHG emissions associated with production and consumption of food and drink in the UK.
- This can – mostly - be achieved by ensuring that existing policy, business or sector-level commitments and targets are delivered. But they need to be delivered at the right pace.
- This will require:
  - **Fast progress on agricultural productivity & land management measures** (e.g. peatland restoration, enhanced soil carbon storage, enhancing hedgerows). In the UK this needs to be on a linear trajectory towards meeting NFU Net Zero 2040 estimates. There also needs to be a similar rate of progress in the EU, but it was assumed that slower progress would be made beyond the EU, where decarbonisation mechanisms may be less developed.
  - **Achieving zero deforestation commitments in supply chains** – particularly linked to tropical forest commodities such as palm oil, soy, cocoa, coffee, etc.
  - **Renewable energy commitments being met** – and wider energy infrastructure delivering reduced emissions across the electricity grid.
  - **Significant progress on decarbonising heat** - in line with FDF/SLR estimates for maximum technical potential by 2030.
  - **Some progress on transport decarbonisation**: more widespread adoption of electric vehicles, more consumers adopting zero carbon modes of transport and innovation in supply chains. Whilst HGV decarbonisation remains a challenge, improved route planning and fuel efficiency gains can make an important contribution.
  - **At least halving UK food waste - and prioritising the type of food waste prevention efforts that will maximise impact[7]:**
    - Going beyond SDG12.3 in terms of the current UK interpretation of this goal. Specifically a need to include total food waste (including inedible parts) within the post-farm gate 50% reduction target; and delivering reductions in food waste pre-farm gate.
    - A continued focus on the waste hierarchy, to prioritise efforts to *avoid* food waste. This new modelling has identified the importance of <u>avoiding waste arising in the first place</u>,

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[7] *The scale of GHG emissions reduction that could come from food waste reduction appears relatively modest in Figure A1. This is consistent with other estimates (e.g. WRAP's 2021 report on resource efficiency and Net Zero). However, this modelling updates previous estimates and more appropriately accounts for how, as the different stages of the food system decarbonise, the 'savings' from preventing food waste also reduce. More conservative (but realistic) assumptions have also been used regarding the degree to which food waste that is avoided leads to a like-for-like reduction in the emissions to produce an equivalent volume of food (see Section 3.3.5.2). We note that the reduction potential is likely to be higher if including waste prevention in overseas supply chains, but here we have only modelled a UK food waste reduction scenario (as shown in Figure A1), given the uncertainty in both the volume of food waste occurring in overseas supply chains, and the scale of prevention potential.*

as opposed to producing surplus food which is then sent for redistribution, animal feed, or other valorisation. These beneficial uses of surplus are all vastly preferable to disposal, but there are significant uncertainties regarding emissions reduction potential.

- A continued focus on reducing citizen food waste (in and out of home). Modelling shows that at least 80% of the total GHG reduction potential from food waste prevention is realised in households and within hospitality & food service.
- A need for much more integrated messaging around food waste and consumption behaviours.
  i. Without this there could be potential for rebound effects. For example, other authors have noted that, in cases where householders save money through reducing waste, they may use this additional income to 'trade up' - to instead purchase food items (or other products/services) that may have higher embodied emissions, and thereby reduce (or negate) the overall benefits from food waste prevention[8].
  ii. There may also be instances in which food waste is reduced by consuming more food, rather than by purchasing less and throwing away less. In GHG-terms, over-consumption is as 'wasteful' as throwing food away. This is an important point, as data collated as part of this study suggest that per capita consumption of food has increased between 2015-2019 – and that, if per capita consumption in 2019 was same as 2015, total food system emissions could have been c.5 $MtCO_2e$ lower.
- A need to target high embodied impact foods. The GHG model does not currently enable a detailed analysis by food type, but this will be included in further work.

- **Higher adoption of government dietary recommendations, as set out in the Eatwell Guide.** Again, however, there is a need for much more integrated messaging around food waste and consumption behaviours, to prevent unintended consequences. For example, WRAP estimates that dietary change could potentially result in a large increase in food waste without well thought-through policy interventions and messaging - because fruit and vegetables are wasted at much higher rates than other food items.

<u>This is just one example of a pathway to achieving a 50% reduction target</u> – and there could be other means of realising these emissions reductions.

The purpose of this work was to demonstrate that this scale of reduction could be achievable, and where efforts might appropriately be focused. There are, however, some significant uncertainties and limitations that are important to flag (with full detail on specific data limitations and assumptions included within the body of this report):

- The food system is a complex web of interactions that are subject to a range of forces that are not possible to fully predict, or account for, within modelling. For example weather / climate (and its effect e.g. on crop yields, pests, diseases, supply disruption), competition within global markets, consumer trends and purchasing patterns, etc. Within this modelling, some relatively simple cause / effect assumptions have been made: for example, changes in consumption will result in equivalent changes in production (somewhere in the world). This was considered a reasonable approach, given the objectives – to understand the approximate and relative scale of potential savings from different interventions. However, it is important to note the significant uncertainty regarding predicting emissions reductions, particularly where interventions effect changes in consumption and purchasing of different food types (e.g. food waste prevention, dietary change, avoiding deforestation). The main uncertainty is with regard to how a change in consumption leads to a change in purchasing, and in turn

[8] *Ramy Salemdeeb et al., 'A Holistic Approach to the Environmental Evaluation of Food Waste Prevention',* Waste Management *59 (January 2017): 442–50, https://doi.org/10.1016/j.wasman.2016.09.042.*

how - and where - this leads to a change in production, given global market influences and the potential for rebound effects and other complex interactions.

- The analysis does not currently investigate interactions *between* interventions – such as the degree to which efforts to influence dietary change might effect food waste. This is an area recommended for further work.
- The analysis does not include an assessment of cost, or feasibility of interventions – only that they have been indicated as being technically possible by stakeholders. Building in this form of appraisal, in order to consider the *most efficient* pathway, would add further value.
- The analysis largely considers technical changes (e.g. improving efficiency in different stages of the system). We haven't attempted to model the effect of individual policies, mechanisms such as pricing, or different ways of influencing behaviour change – as these are inherently difficult to quantify.

Figure A1: Example pathway towards achieving 50% reduction in UK food system emissions by 2030 – grouped by type of intervention

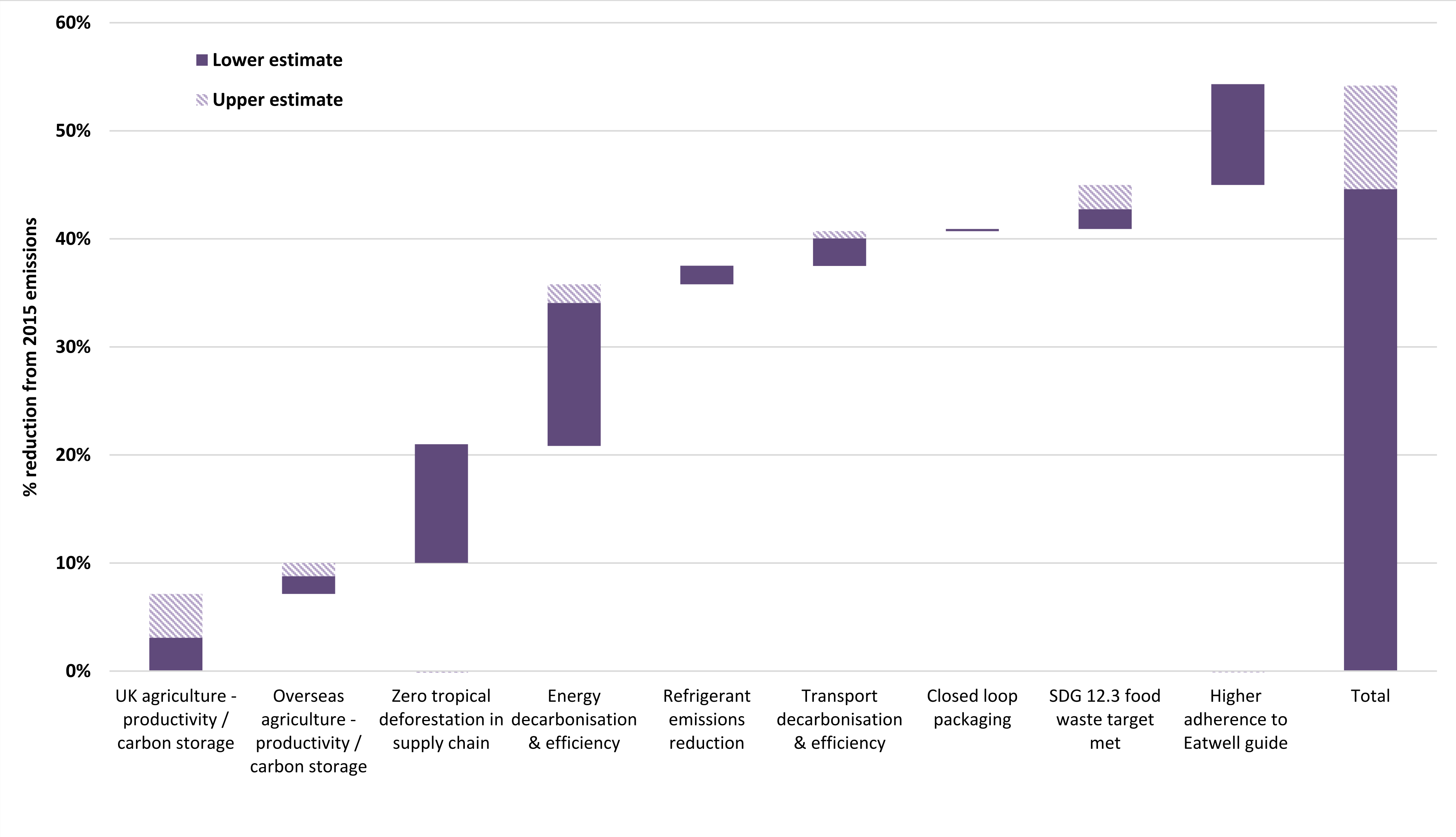

Table A3: Outline of scenarios modelled in Figure A1

Intervention group (as shown in Fig A1)	Key modelling assumptions [*for all references and more detail on modelling assumptions see Section 3.0*]
UK agriculture - productivity / carbon storage	Upper estimate: Linear trajectory to meeting the estimated annual GHG savings outlined in the NFU Achieving Net Zero report through i) productivity measures (pillar 1); and ii) farmland carbon storage (pillar 2). Pillar 3 (bioenergy/renewables) was not included to avoid double counting energy decarbonisation. Lower estimate: Reflects the potential for lower rates of uptake of different farm-level interventions, based on work undertaken by Defra in England (not yet published) – scaled to wider UK. Both scenarios also additional include estimated reductions in the embodied emissions of producing fertiliser and feed, based on AIC and CIEL targets / projections.
Overseas agriculture - productivity / carbon storage	Upper estimate: Assumes the NFU estimates of GHG savings through productivity measures and farmland carbon storage also apply to food imports from Europe – because the EU similarly has a Net Zero target. But assumed that these savings are realised at a slower rate because the EU target is 2050 (vs NFU 2040 ambition). For food imports from countries outside of the EU a conservative assumption was made that the pace of change would be halved. Lower estimate: Assumes the (more conservative) Defra estimates of GHG savings in agriculture also apply to food imports from Europe. For food imports from countries outside of the EU a conservative assumption was made that the pace of change would be halved.
Zero tropical deforestation in supply chains	Assumes that zero deforestation commitments made by retailers and other food businesses are achieved by 2030 – and that this results in no tropical deforestation emissions being linked to UK food & drink supply chains. A very optimistic scenario, but considered appropriate to include because of i) the level of commitments being made with regard to deforestation and land conversion; and ii) the increasing level of scrutiny.
Energy decarbonisation & efficiency	For retail – assumes the BRC Climate Roadmap target of 100% renewable electricity is met; plus there are demand reductions through improved efficiency of heating & lighting. For manufacturing and hospitality & food service (HaFS) – assumes the emissions intensity of grid electricity consumed will decrease in line with the UK Committee on Climate Change Balanced Net Zero Pathway; plus emissions from heat will reduce in line with FDF/SLR Maxtech (upper estimate) vs Realistic (lower estimate) scenarios; plus there are demand reductions through improved efficiency. For household – assumes the emissions intensity of grid electricity consumed will decrease in line with the UK Committee on Climate Change Balanced Net Zero Pathway; plus there are demand reductions through (moderate) improved efficiency of appliances.

Refrigerant emissions reduction	Assumes a c.70% emissions saving through a switch to low GHG refrigerants – based on a 'business-as-usual investment' scenario for retail, but applied to refrigerant use across all sectors (e.g. HaFS, transport)
Transport decarbonisation & efficiency	For UK supply chain transport - assumes 10% reduction in HGV tkm travelled, based on the UK Committee on Climate Change Balanced Net Zero Pathway – plus either achieving 15% reduction in emission intensity, as targeted by the Zemo Partnership (formerly Low Carbon Vehicle Partnership) (lower estimate), or an assumed 30% maximum potential reduction in emissions intensity by 2030, based on a range of sources (upper estimate). For consumer transport – assumes 9% of private car journeys are replaced with zero carbon modes of transport in line with the UK Committee on Climate Change Balanced Net Zero Pathway, alongside a reduction in vehicle emissions based on UK Committee on Climate Change and Department for Transport scenarios, with no reduction in transport demand. For food deliveries – assumes reduction in emissions from delivery vans in line with BRC Climate Roadmap commitments; plus reductions in the emission intensity of other delivery vehicles in line with the UKCCC pathway; plus an assumed increase in the share of food service deliveries made by bicycle.
Closed loop packaging	Assumes additional 20% of total plastic food packaging and 15% of total other packaging types could be sourced through closed-loop recycled content.
Food waste reduction	Upper estimate: Assumes that the SDG 12.3 target is met through a 50% reduction in total food waste, including inedible parts (with food waste being 3.2Mt lower in 2030 than 2018). As well as avoiding disposal emissions, this scenario also assumes that any food waste that is avoided or redistributed leads to a like-for-like reduction in the emissions to produce an equivalent volume of food (based on the projected emissions intensity per tonne of food in 2030 – after the savings above have been accounted). Lower estimate: Assumes that the SDG 12.3 target is met through a 50% reduction in wasted food only, not including inedible parts (with food waste being 1.9Mt lower in 2030 than 2018). Different to the above – this scenario assumes that food waste avoided by consumers (household and hospitality & food service stages) only leads to a 50% displacement of new food production – because the effects of food waste reduction on purchasing are uncertain (for example, food waste could be reduced through consuming more, or reducing food waste could lead to rebound effects such as 'trading up' to higher impact purchases). Similarly, in this scenario only 50% of redistributed food is assumed to lead to displacement of new food production – because of the uncertainties regarding what users of redistribution services might alternatively have purchased.
Higher adherence to Eatwell guide	Assumes the proportion of the population adopting government dietary recommendations, as set out in the Eatwell Guide increase from current levels to 100% of the population with 'intermediate to high' adherence.

Implications for industry action

Findings from this analysis suggest five important takeaways in terms of industry action:

1. Continued focus on decarbonisation of operational emissions – renewable energy, low carbon refrigerants, heat, transport, etc. is important.
2. Developing a better understanding of wider supply chain emissions is imperative.
3. Achieving zero deforestation commitments in supply chains is a clear priority.
4. Action on food waste is a win-win – and efforts can be tailored to maximise contributions towards corporate net zero targets.
5. Influencing consumption behaviours is key.

<u>Continued focus on decarbonisation of operational emissions – renewable energy, low carbon refrigerants, heat, transport, etc. is important</u>

- Many businesses are already focusing considerable effort on reducing their own scope 1 & 2 emissions, and are reaching out to suppliers to help them reduce their scope 1 & 2 emissions.
- Continued focus will pay incremental dividends. The scale of emissions reduction potential will differ dependent on the type business, and where they sit in the value chain.
- Many resources, such as the UK Business Climate Hub, SME Climate Hub and WWF emission possible guidance, as well as platforms like Manufacture 2030 are available to aid supplier engagement.
- Harder to tackle areas include heat and transport decarbonisation. The Food and Drink Federation is shortly to publish a 'Net Zero Handbook' that contains practical guidance in these areas.

<u>Developing a better understanding of wider supply chain emissions is imperative</u>

- For any food & drink business, emissions linked to the production of purchased products and ingredients (which includes all of the emissions which arise in the previous stages of the supply chain) will be the most significant contribution to scope 3 emissions.
- Within the context of businesses' own GHG targets they are arguably the most important emissions to address, but also the most difficult. This analysis has shown that, in the case of agricultural emissions and imported products, they are also the share that have reduced the least to date – and so where further efforts need to continue to be focused.
- Without proper measurement it will be increasing hard to know how to reduce these emissions. Developing a better understanding of scope 3 purchased goods emissions is a critical first step, and there are tools available to help with this.
- Understanding what actions will reduce these emissions, and then understanding if actions taken are having the desired effect (and evidencing these reductions) becomes a bigger challenge. WRAP - through the Courtauld framework - has a programme of work focused on this challenge, including:
    - Developing practical guidance on Scope 3 accounting, tailored specifically to food & drink businesses;
    - Agreeing (initially) a common set of reference GHG emission factors for different foods / ingredients / geographies. Then (more importantly) developing a forward path for more systematic ways of collating data along the supply chain;
    - Piloting supplier engagement approaches: to understand more about the availability of information on GHG emissions, particularly for high impact imported products; and sense

check the best ways of asking for this information (and how variable the responses are) – to help inform the development of any future data requests.

Achieving zero deforestation commitments in supply chains is a clear priority

- Figure A1 shows that one of the most significant interventions in terms of scale of emissions reductions (c.10%) would be through achieving zero deforestation commitments – if this results in no tropical deforestation emissions being linked to UK food & drink supply chains.
- WWF have set out clear guidance for retailers, and others, in terms of the actions needed to achieve this outcome.
- There are also a range of initiatives working in support of this objective, for example:
  - UK Sustainable Palm Oil Initiative
  - UK Sustainable Soya Initiative
  - UK Global Resources Initiative

Action on food waste is a win-win – and efforts can be tailored to maximise contributions towards corporate net zero targets

- Actions to prevent food waste can be taken rapidly and will pay early dividends, as well providing wider, bottom line, benefits.
- Food businesses need to commit to meeting the UN SDG 12.3, then take a 'Target, Measure, Act' approach, working with their entire supply chain from farm to fork.
- Not all food waste prevention is equal in terms of realising GHG emissions reductions. To maximise the contribution of food waste prevention towards corporate emissions targets, for example, it will be important to:
  - Defer to the waste hierarchy and prioritise efforts to *avoid* food waste arising. This analysis highlights the importance of avoiding waste arising in the first place, as opposed to producing surplus that is sent for redistribution, animal feed, or other valorisation. These beneficial uses of surplus are all preferable to disposal, but there are significant uncertainties regarding emissions reduction potential (and these reductions may not be accountable within a GHG Protocol-compliant assessment).
  - Prioritise efforts towards avoiding wastage of higher embodied impact foods, such as meat. In support of this objective, WRAP is coordinating efforts to halve the amount of meat purchases we throw away (both in and out of home), and is tracking these efforts through the Meat in a Net Zero World initiative – which more than 50 major stakeholders across the meat industry are now supporting.
- At a national-level there will need to be a continued focus on reducing citizen food waste (both in and out of home) – and this analysis has also highlighted a need for much more integrated messaging around food waste and consumption behaviours. Without this there could be potential for rebound effects – such as 'trading up' to higher impact purchases, which could negate the benefits of food waste prevention.

Influencing consumption behaviours is key

- Consumers are increasingly interested in the health and sustainability of dietary choices – and given significant health implications linked to the food system, most recently highlighted in the National Food Strategy, there is clear need for action.
- This analysis has shown the scale of GHG emissions reductions that could potentially be achieved if more of the population adhered to existing national dietary guidelines, as set out

in the Eatwell Guide. Other work by WRAP and Leeds University[9] has shown the scale of reductions that could be achieved through reducing average calorie intake to the recommended 2500 kcal per day.

- Influencing diets is a longstanding challenge and requires a range of systemic measures to change behaviour, for example as identified in the National Food Strategy recommendations.
- The food industry has an important role to play, for example through product reformulation and engaging consumers to promote sustainable, healthy diets.
- Providing clear information to help enable informed decision-making on food choices is also becoming an increasingly high profile topic – but is subject to challenges regarding the lack of robust, consistent metrics and data to underpin these (similar to the challenges noted above relating to scope 3 purchased goods).
- In the shorter term there are a number of clear actions that can be taken, such as:
    - Helping consumers to buy and consume the right amount - e.g. by providing smaller packs for individual consumers, or loose product more tailored to individual needs, or giving advice on serving sizes / cooking the right amount;
    - Providing guidance to store, prepare and cook food as eco-efficiently as possible and helping consumers reduce wastage of their purchases – by adopting WRAP's best practice labelling guidance and promoting resources like Love Food Hate Waste.

Further work

This assessment draws on more than 70 published sources and is the most in-depth review to date of the GHG emissions linked the UK food system. However, the complexity of this system means that there are significant uncertainties with some of the existing estimates, and there are areas in which further work would be valuable.

The following are recommended priorities for further work, all of which have particular relevance in the context of the National Food Strategy.

1. **Further investigation of trade-offs and potential for unintended consequences -** to better understand the implications of these and ways to minimise them.

   This should include:

   i. Interactions between interventions – for example, WRAP estimates that dietary change could potentially result in a large increase in food waste, because fruit and vegetables are wasted at much higher rates than other food items; and
   ii. Trade-offs between emissions reductions and other priorities, such as protecting and increasing biodiversity and safeguarding water resources.

   Understanding these potential effects in more detail could help shape the best way to deploy interventions to mitigate these effects as far as possible.

2. **Further investigation of how interventions could be targeted to best effect to reducing the UK's overseas footprint, as well as UK territorial emissions.** In outlining recommendations for ways to reduce the UK's territorial GHG emissions linked to the food system, both the Committee on Climate Change and the National Food Strategy recommendations flag the challenge of offshoring. They note that delivering

[9] *WRAP, 'Net Zero: Why Resource Efficiency Holds the Answers' (Banbury: WRAP, 26 March 2021), https://wrap.org.uk/resources/report/net-zero-why-resource-efficiency-holds-answers.*

emissions reduction within the UK should not be at the expense of increasing food imports that risk increasing emissions elsewhere (sometimes called 'carbon leakage').

Importantly, the analysis presented within this report *does* consider total global impacts of the UK's food consumption, including imports. However – the underlying data sources that are used to quantify imported emissions are subject to both significant uncertainty and significant variability. As in other studies, the values used to estimate the embodied impacts of different imported food, ingredient and feed items are based on historic, often relatively old, datasets that are very infrequently updated – so there is no current means of being able to track progress over time for these imported products and ingredients. There is a significant need to develop a means of improving these estimates – potentially starting with those imported food / ingredient / feed items that disproportionately contribute to net import emissions and for which impacts are known to be highly variable dependent on production systems and geographies (e.g. vegetable oils, meat items, coffee, cheese, wine, fish, soya & maize for feed).

WRAP and others (e.g. through the HESTIA database, Feed UK, etc.) are undertaking further work that could potentially link in with the food system model described in this report to provide a more meaningful way of:

i. Monitoring change over time (to ensure we aren't offshoring emissions). In particular, this could be used is a way of tracking change against a key food system metric recommended in the National Food Strategy: Total UK food system GHG emissions; and

ii. Enabling more detailed insight to better understand more about *how* and *where* to best focus efforts to reduce the total global footprint of the UK food system.

3. **Further investigation of cost (e.g. marginal abatement costs) and feasibility**. The food system GHG model developed to date does not include any assessment of cost, or feasibility of different interventions. Building in this form of appraisal would be a valuable way of considering the most efficient, practical or cost-effective pathway to achieving reductions.

Contents

1.0 Introduction

This report provides an analysis of the total greenhouse gas (GHG) emissions linked to the production and consumption of food & drink consumed in the UK, showing the scale of emissions reductions achieved between 2015 and 2019 – and estimates of further emissions reductions that could be achievable by 2030.

It builds on previous work – for example as presented in the National Food Strategy[10] and the most recent Courtauld Commitment milestone report[11] – both of which have identified the significance of the food system in the context of both UK territorial emissions, and its wider global footprint.

Since undertaking previous work, WRAP has launched Courtauld 2030, with a new target of *"50% absolute reduction in the GHG emissions associated with production and consumption of food and drink in the UK against a 2015 baseline"*

This is a step-change in level of ambition for emissions reduction for the sector – and setting targets is the first step. It is important that collectively we now move to action in meeting them. Measurement is an important step to understand where and how reductions can be achieved, where to focus efforts, where to push for a faster pace and where to fill gaps in understanding, etc. There is also a need to continue to monitor progress over time to ensure that actions being taken are having the right effect.

The objectives of this work were to:

1. Develop a new GHG emissions model for the UK food & drink system;
2. Use this to:
    a. Update latest estimates of food system emissions, and reductions to date - improving previous estimates and filling data gaps; and
    b. Investigate the scale of emissions reductions that could come from different types of interventions – and how a 50% reduction target could be achieved.
3. Identify further work needed to improve the food system GHG model, so that it is fit-for-purpose to aid monitoring of food system emissions over time.

This report sets out the full, transparent details of the modelling approach, the data sources used, assumptions made and the limitations of the assessment.

Described first is the methodology for estimating total UK food system emissions (Section 2.0). As a second stage, the methodology for estimating emissions to 2030 is described (Section 3.0). A summary of results (Section 4.0 and Section 5.0) and recommendations for further work (Section 0) are then presented.

[10] *National Food Strategy, 'The National Food Strategy: The Plan'.*
[11] *WRAP, 'UK Progress against Courtauld 2025 Targets and UN Sustainable Development Goal 12.3'.*

2.0 Methodology for estimating total UK food system emissions

2.1 Background

This GHG modelling takes as its starting point the work previously undertaken to report on progress towards the Courtauld 2025 GHG target, the details of which were published in 2020[12]. The previous work collated relevant (primarily governmental) statistics for different stages across the food system: agriculture; fertiliser manufacture; animal feed production; net imports of food; food packaging; UK supply chain transport; consumer transport; food retail; home related emissions; catering emissions and disposal emissions.

This new GHG modelling aims to build and improve upon the previous work by addressing data gaps, making revisions and improvements, and where possible updating data to reflect the latest available information[13]. In also includes detailed future projections of potential emissions reductions for the first time.

For most published datasets, the latest information available at the time of modelling was for 2019 - and so is the latest year for which estimates of total UK food system emissions were quantified, and the year from which emissions reduction projections were quantified.

2.2 Basic values used

2.2.1 Population

Population estimates up to 2019 are taken from recently published ONS figures.[14] Population projections for subsequent years are taken from the most recent ONS projections.[15]

2.2.2 Emission factors

Emission factors for transport and energy are taken from BEIS greenhouse gas reporting conversion factors for every year measured. Where possible, the values used are emission factors including 'well-to-tank' (WTT) emissions, which represent the embodied GHG in the production, processing and delivery of a fuel or energy carrier.

For vehicle categories, the emissions factors for the average vehicle in that category is used.

When Global Warming Potential (GWP) calculations are made, IPCC AR5 GWP values are used.

2.3 UK Agriculture

Emissions for UK agriculture were derived based on:

i. The UK GHG inventory for agriculture;

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[12] WRAP.

[13] Differences between the results from this and previous work, reasons for those differences and implications are discussed in Section 4.1.

[14] 'United Kingdom Population Mid-Year Estimate - Office for National Statistics', accessed 25 February 2021, https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/timeseries/ukpop/pop.

[15] Office for National Statistics, 'National Population Projections', accessed 10 September 2021, https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2018based.

ii. Embodied emissions from fertiliser production (which are not included in the UK GHG inventory; and
iii. Embodied emissions from imported feed production (which are not included in the UK GHG inventory).

2.3.1 UK GHG inventory for agriculture

UK agricultural GHG estimates were taken from latest BEIS UK greenhouse gas national statistics.[16] The latest available year of statistics was 2019.

The value used is the total agricultural emissions, which includes emissions from livestock, agricultural soils, stationary combustion sources and off-road machinery. In 2019, the relative contribution of GHG emissions from different sources was:

- Emissions from livestock (enteric fermentation and organic wastes) – 62%
- Emissions from soils – 28%
- Emissions from stationary and mobile combustion – 10%

BEIS report a decline in agricultural emissions from 1990. However, they have stayed relatively constant since 2009, fluctuating between 44 – 46 million tonnes CO_2e.

2.3.2 Embodied emissions from fertiliser production

Although the UK GHG inventory for agriculture includes emissions related to fertiliser use, it does not include the embodied emissions associated with its manufacture within its scope. Therefore, these were estimated separately.

The GHG Footprint Reference Values provided by Fertilizers Europe[17] were used for estimating the CO_2e per kilogramme of nutrient production. The Fertilizers Europe value is for the EU-28 (reflecting average European production), which is assumed to be the same as the value for manufacture in the UK.

For fertiliser manufactured outside of the EU, the emission factors used for fertiliser manufacture were taken from Brentrup et al. (2016).[18] The mean values for Russian, US and Chinese production were assumed to represent all non-EU production. As Brentrup et al. use the same Fertilizers Europe GHG Footprint Reference Value for EU production, these papers are directly comparable. This allows us to estimate the additional emissions from production outside of Europe.

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[16] *BEIS, 'Final UK Greenhouse Gas Emissions National Statistics: 1990 to 2019', GOV.UK, 25 March 2021, https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2019.*

[17] *Fertilizers Europe, 'The Carbon Footprint of Fertilizer Production: Regional Reference Values', Fertilizers Europe, accessed 8 June 2021, https://www.fertilizerseurope.com/publications/the-carbon-footprint-of-fertilizer-production-regional-reference-values/.*

[18] *Frank Brentrup, Antoine Hoxha, and Bjarne Christensen, 'Carbon Footprint Analysis of Mineral Fertilizer Production in Europe and Other World Regions' (The 10th International Conference on Life Cycle Assessment of Food, Dublin, Ireland, 2016), https://www.researchgate.net/publication/312553933_Carbon_footprint_analysis_of_mineral_fertilizer_production_in_Europe_and_other_world_regions.*

UK fertiliser consumption figures provided by the Agricultural Industries Confederation (AIC)[19] were then adjusted for share of imported products from Fertilizers Europe (2018).[20]

Available AIC consumption data extended only to the 2017/18 growing season. However, the dataset has data for every year of the preceding eleven years. In order to estimate consumption in 2019, therefore, a linear extrapolation based on the previous eleven years of data was carried out for each nutrient.

2.3.3 Embodied emissions from imported feed production

The approach used for imported feed production follows the methodology and data used for trade in agricultural products more generally, which is outlined in full in Section 2.4:

- Data for volume (tonnes) of traded feedstuff items in SITC category 08, 'Animal Feed', were taken from Eurostat for each assessment year (2015 and 2019) – including import volumes and export volumes.
- Each feedstuff item (e.g. wheat, maize, soy beans/meal/oil), was assigned a GHG emission factor (tonnes CO_2e / tonne production – from cradle-to-gate) from the Global Feed LCA Institute Database[21] - for products either directly matching or the closest approximate (for example: linseed meal was attributed the emissions factor for global average linseed production, as there was no direct estimate for meal). Important to note is that the product-specific emissions factors were held constant for both years of analysis (2015 and 2019), because data to differentiate any change in production emissions are not currently available, which is a significant limitation. See also below commentary on inclusion of estimates of emissions linked to land use change / deforestation.
- Import volumes for feedstuff items in 2015 and 2019 were multiplied by corresponding emission factors. Similarly, export volumes for feedstuff items in 2015 and 2019 were multiplied by corresponding emission factors.
- The total emissions from exported feedstuff items were subtracted from the total for imported feed[22] - to estimate the net embodied emissions linked to the production animal feed for use in UK production systems.

As for all trade in food products, we included an estimate of the emissions associated with land use change (LUC). This was undertaken based on the LUC values provided in the GFLI database for average global production. Given the large uncertainty in accounting for emissions linked to land use change – these estimates were only included for animal feed materials that are most likely to be linked to drivers of tropical deforestation, as this is the most significant and well-known source of land use emissions linked to the food system. Pendrill et al (2019) reported that expansion of agriculture into forests across the tropics was associated with significant net CO_2 emissions – with cattle and oilseed products accounting for over half of these emissions; and oilseed products in particular linked to global trade as

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[19] *AIC, 'Fertiliser Consumption in the UK (Annual Summary)', accessed 8 June 2021, https://www.agindustries.org.uk/resource/fertiliser-consumption-in-the-uk.html.*

[20] *Fertilizers Europe, 'Fertilizers Europe Annual Overview', Fertilizers Europe, accessed 8 June 2021, https://www.fertilizerseurope.com/fertilizers-europe-annual-overview/.*

[21] *GFLI, 'Database & Tool', The Global Feed LCA Institute, 2021, https://globalfeedlca.org/gfli-database/database-and-tool/.*

[22] Emissions from exported feedstuffs were subtracted as they are assumed to have been already included within the UK's agricultural inventory, but if exported they are likely to be leaving the UK's food system (instead being used for food production & consumption elsewhere).

they are produced primarily for export.[23] As such, we included LUC values from the GFLI database for soya and oilseed products only (oil-cakes, meals and other residues from soya beans, groundnuts, linseed, rapeseed, sunflower seed, palm nuts/kernels, coconuts and other oilseeds). This is a limited assessment and may underestimate land use change driven by other agricultural commodities used for feed, such as wheat. It also does not attribute any positive land use change that may be linked to the food system. However, whilst accounting approaches for land use change emissions are still under review by the GHG Protocol/WRI at global-level, it was felt that this was the most sensible approach for an initial assessment.

2.4 Overseas production (net imports)

The approach used to estimate the GHG emissions linked to food & drink products and ingredients produced outside of the UK follows the methodology described above.

- Data for volume of traded food & drink items (tonnes imports and tonnes exports) were taken from Eurostat trade statistics for each assessment year (2015 and 2019). The relevant categories by SITC code for food (01-09, 11) were included, with SITC category 08 ('Animal feed') removed and treated separately (see Section 2.3.3). In addition to these, SITC categories for oil-seeds (222-223), animal fats (410) and vegetable oils (420)[24] were included. Each SITC numeric category was further broken down based on the SITC code: the first two digits represent the 'primary' category, the first three digits the 'secondary' category, and all subsequent digits distinguish 'subcategories'[25]. All calculations summed only the Subcategory values (i.e. specific products) to avoid double counting.
- Each sub-category item was assigned a GHG emission factor (tonnes CO_2e / tonne production – from cradle-to-gate, plus average transportation estimate). Emission factor values were sourced primarily from:
    - Poore and Nemecek (2018)[26] - forest commodities, fish, fruit & vegetables and meat items (with the exception of EU production and UK exports of meat items, which were instead derived from CIEL[27]),
    - Agribalyse database[28] - which was found to be the most consistent source for drinks (i.e. including the highest number of drinks items)

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[23] *Florence Pendrill et al., 'Agricultural and Forestry Trade Drives Large Share of Tropical Deforestation Emissions',* Global Environmental Change *56 (May 2019): 1–10, https://doi.org/10.1016/j.gloenvcha.2019.03.002.*

[24] *We note that all vegetable oil imports to the UK were included in the food system estimate. In practice a proportion of this volume will be used in other industries, not for use in the food chain – so this is an over-estimate. However no UK statistics were available to be able to quantity the relative proportion for food use. Some references for the US suggested that the vast majority of vegetable oil imports are used for food – so we allocated 100% in order to be conservative.*

[25] An example may make this clearer: the product 'Fish, live' with code 03411 is a Subcategory of the Secondary category 'Fish, fresh (live or dead), chilled or frozen' with code 034, part of the primary category 03, which represents fish and seafood. The statistics for each code sum the values of Secondary and Subcategories nested within them.

[26] *J. Poore and T. Nemecek, 'Reducing Food's Environmental Impacts through Producers and Consumers',* Science *360, no. 6392 (1 June 2018): 987–92, https://doi.org/10.1126/science.aaq0216.*

[27] *CIEL, 'Net Zero Carbon & UK Livestock' (CIEL, 10 January 2020), https://www.cielivestock.co.uk/wp-content/uploads/2021/05/CIEL-Net-Zero-Carbon-UK-Livestock-FINAL-interactive-revised-May-2021.pdf.*

[28] *'AGRIBALYSE', accessed 10 September 2021, https://doc.agribalyse.fr/documentation-en/.*

- Clune et al. (2017)[29] – which was found to be the most consistent source for dairy items. This source was also used to fill data gaps for fish and fruit & vegetables.
- GFLI database[30] - cereals, rice and sugar.

Where no direct estimate of the GHG intensity of food exists, the closest approximate was used. Where no suitable direct proxy was available (e.g. tapioca), the average for the product category (e.g. root vegetables) was used.

- In some cases, import volumes were separated into EU and non-EU imports – and assigned a different emission factor accordingly. This was particularly in cases where emissions linked to UK vs EU vs wider global production systems are known to potentially differ significantly – or to have different implications with respect to potential for land use change / deforestation (see below).
- Important to note is that the product-specific emissions factors were held constant for both years of analysis (2015 and 2019), because data to differentiate any change in production emissions are not currently available, which is a significant limitation.
- Import volumes for sub-category items in 2015 and 2019 were multiplied by corresponding emission factors. Similarly, export volumes for sub-category items in 2015 and 2019 were multiplied by corresponding emission factors.
- The total emissions from exported items were subtracted from the total for imported items[31] - to give an estimate the net embodied emissions linked to the production of food & drink products and ingredients produced outside of the UK.

It is worth noting that the figure for net imports is highly variable from one year to the next, and is driven by fluctuations in the volumes of food imported. This means that reductions in shorter timeframes should be interpreted as stochastic rather than systemic change.

As for trade in feed materials, we included an estimate of the emissions associated with land use change (LUC). This was undertaken based on the respective LUC values provided in the Poore and Nemecek and GFLI databases for average global production of different food & ingredient items. As described for feed above, given the large uncertainty in accounting for emissions linked to LUC, these estimates were only included for materials that are most likely to be linked to drivers of tropical deforestation - as this is the most significant and well-known source of LUC emissions linked to the food system. In particular, Pendrill et al (2019) demonstrated the importance of international trade in driving deforestation emissions linked to the production of cattle, oilseeds (and resulting oils, such as palm oil) and high-value commodity crops such as cocoa, coffee, tea, and spices. As such, we included LUC values from the Poore and Nemecek and GFLI database for these specific products that are at highest risk from driving deforestation emissions through global trade.

LUC values from these databases were therefore included for the following items:

- Beef (non-EU sources only as the main driver of LUC for beef cattle is land clearance for grazing in tropical production areas);

[29] *Stephen Clune, Enda Crossin, and Karli Verghese, 'Systematic Review of Greenhouse Gas Emissions for Different Fresh Food Categories',* Journal of Cleaner Production *140 (January 2017): 766–83, https://doi.org/10.1016/j.jclepro.2016.04.082.*

[30] *GFLI, 'Database & Tool'. https://globalfeedlca.org/gfli-database/database-and-tool/*

[31] Emissions from exported items were subtracted as they are assumed to have been already included within other stages of the UK food system emissions estimate (e.g. UK's agricultural inventory, UK manufacturing - but if exported they are likely to be leaving the UK's food system and instead be used for food production & consumption elsewhere).

- Poultry, pork, dairy (all sources, as the principal driver of LUC for these items will be linked to their feed inputs); and
- Cocoa, coffee, tea, cane sugar and spices.
- Oilseeds, vegetable oils and other oilseed products.

As noted for feed above, this is a limited assessment and may underestimate land use change driven by other imported products. It also does not attribute any positive land use change that may be linked to the food system. However, whilst accounting approaches for land use change emissions are still under review by the GHG Protocol/WRI at global-level, it was felt that this was the most sensible approach for an initial assessment.

2.5 UK Food manufacture

UK food manufacturing energy-related emissions were derived from two BEIS datasets – with 2019 the latest year for which data were available:

- Digest of UK Energy Statistics (DUKES)[32]
- Energy Consumption in the UK (ECUK)[33]

DUKES provides a yearly breakdown of final consumption and auto generation by the food, beverages and tobacco industry across a variety of fuel types. From ECUK, the energy use specifically by the tobacco industry can be isolated.

The total final energy consumption of the food and drink sector was derived as the sum of final consumption and auto generation, with tobacco industry use subtracted.

The energy use by fuel type was converted from tonnes of oil equivalent to tonnes of CO_2e using BEIS greenhouse gas reporting conversion factors for each year.[34]

2.6 Refrigerant

The total UK refrigerant emissions leakage associated with food production, transport distribution and consumption was calculated using total refrigerant emissions from BEIS National Atmospheric Emissions Inventory (NAEI) data.[35] This covers refrigerant leakage in all sectors, so was scaled to the UK food and drink sector based on the 2009 FCRN-WWF 'How low can we go?' publication.[36] The FCRN-WWF report estimates that the food and drink supply chain accounts for 78% of total industrial, commercial domestic and transport sector refrigerants. This is therefore multiplied by the BEIS NAEI refrigerant estimates.

2018 was the last year for which data was available, and so 2019 was assumed to be the same as 2018.

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[32] *BEIS, 'Digest of UK Energy Statistics (DUKES): Energy', GOV.UK, accessed 8 June 2021, https://www.gov.uk/government/statistics/energy-chapter-1-digest-of-united-kingdom-energy-statistics-dukes.*

[33] *BEIS, 'Energy Consumption in the UK', GOV.UK, accessed 8 June 2021, https://www.gov.uk/government/statistics/energy-consumption-in-the-uk.*

[34] *BEIS, 'Government Conversion Factors for Company Reporting of Greenhouse Gas Emissions', GOV.UK, accessed 8 June 2021, https://www.gov.uk/government/collections/government-conversion-factors-for-company-reporting.*

[35] *BEIS, 'National Atmospheric Emissions Inventory', accessed 8 June 2021, https://naei.beis.gov.uk/data/.*

[36] *Eric Audsley et al., 'How Low Can We Go? An Assessment of Greenhouse Gas Emissions from the UK Food System and the Scope to Reduce Them by 2050' (FCRN-WWF-UK, November 2009), https://assets.wwf.org.uk/downloads/how_low_report_1.pdf.*

The *production* of refrigerants was not included as a separate calculation. This was due to a lack of data identified. However, where it *was* identified, such as for HFC-134a, estimates suggested that the emissions generating in manufacture of the refrigerant were equivalent to 0.4% the potential impact from the release of the HFC itself.[37] As a result, production emissions were considered negligible and this data gap not a significant one.

2.7 Packaging

Emissions linked to the production of food & drink packaging were calculated by multiplying:

i. WRAP data from Courtauld signatories on annual volumes of food & drink packaging materials placed on the market - grouped into six key packaging materials: paper and board; glass; steel; aluminium; plastics; other (primarily wooden pallets) and other food and drink packaging data[38] ; and
ii. WRAP emission factors for these individual packaging types[39].

2.8 Supply chain transport in the UK

Emissions linked to freight of food & drink in the UK were calculated using Eurostat freight transport statistics for rail and road (tonne-kilometre) for all years where data were available.[40] 2019 is the latest year for which data were available. The latest data download also filled some of the data gaps mentioned in the Courtauld 2018 milestone report, and some values were restated.

These tonne-kilometre values were then adjusted to CO_2e values using BEIS greenhouse gas reporting conversion factors for each specific year. All road freight was assumed to have been transported in an average laden, average HGV.

2.9 Consumer delivery

A new estimate of emissions linked to delivery of food to consumers – whether retail or food service – was included in the latest GHG model.

Consumer delivery was split into two forms: food service delivery; and grocery delivery - which were calculated separately but are summed to form a single estimate for consumer delivery.

2.9.1 Food service delivery

No governmental or industry dataset that could provide a clear overview of the distance travelled for takeaway food was identified. As a result, a number of disparate data sources were to be pieced together, including some assumptions.

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[37] *A McCulloch and A.A Lindley, 'From Mine to Refrigeration: A Life Cycle Inventory Analysis of the Production of HFC-134a',* International Journal of Refrigeration *26, no. 8 (December 2003): 865–72, https://doi.org/10.1016/S0140-7007(03)00095-1.*

[38] *David Daw et al., 'PackFlow Covid-19 Phase II' (Valpak, October 2020), https://wrap.org.uk/resources/report/packflow-covid-19-reports#download-file.*

[39] *WRAP, 'Carbon Waste and Resources Metric' (Banbury, February 2021), https://wrap.org.uk/resources/report/carbon-waste-and-resources-metric.*

[40] *Data code for rail freight: RAIL-GO-GRPGOOD data code for road freight: ROAD_GO_NA_TGTT.*

- Household expenditure on takeaways was taken from the Family Food Survey, which presents this in pence per person per week.[41] From this, yearly expenditure per person was calculated. This was then divided by the average delivery bill, which for 2016 was taken from Statista data as being £6.10.[42] This was understood as being the value per person, and was assumed to stay constant. From this, a yearly number of deliveries per person was derived. This, however, would be assuming that each person's meal is a separate delivery, which would not be the case. So it was further adjusted by the average household size (approximately 2.4) from ONS statistics, under the assumption that by-and-large, takeaways are ordered by household.[43] Based on this calculation, the number of deliveries per household has increased from approximately one every 3.4 weeks in 2010 to one every 2.8 weeks by 2019.

- With data on the number of deliveries, this was then divided into two forms of delivery: those ordered online; and those ordered directly (such as over the phone). As may be expected, the share of deliveries ordered online has substantially grown, from 8% in 2008 to 55% in 2019.[44] With these two shares, the deliveries per person per year were divided into online and direct deliveries.

- In order to translate number of deliveries into distance travelled, some assumptions were made. Firstly, it was assumed that online orders – often associated with urban spaces and use of mobile apps – would involve shorter journeys. Based on evidence from the US[45], 2.6 miles was used as a reasonable radius for a 'local restaurant' from which one might deliver. This distance, which converts to 4.18 kilometres, was used as the average online delivery. Based on other information from the US, five miles is a regular maximum delivery radius.[46] As the maximum radius, we assumed a distance between the maximum distance and distance typical of an online order would be appropriate: taking the mean of 2.6 miles and 5 miles, an average delivery journey of 3.8 miles (6.12 kilometres) was assumed for direct orders. These average distances were multiplied by the number of deliveries per year, per mode of transport.

- Lastly, journeys were allotted to different transport types. Data on the breakdown of vehicle types was not identified, so assumptions were made. Direct deliveries were assumed to be delivered 50% by motorbike, 50% by car. Online deliveries were assumed to be delivered 40% by motorbike, 40% by bicycle and 20% by car. With these relative shares, the distance travelled for food service delivery was divided between modes of transport, which were then multiplied by the relevant emissions factors and summed to form a total. As the transport types are based on assumptions, the results were sensitivity tested by shifting the percentages by up to 20%. The resulting change in emissions was <100 ktCO_2e in 2019 – which, whilst this could represent substantial

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[41] *Defra, 'Family Food Datasets', GOV.UK, 16 November 2020, https://www.gov.uk/government/statistical-data-sets/family-food-datasets.*

[42] *Statista, 'Average Eating out Bill by Delivery Type in Great Britain 2016', Statista, accessed 8 June 2021, https://www.statista.com/statistics/690911/average-eating-out-bill-by-delivery-type-great-britain/.*

[43] *Office for National Statistics, 'Families and Households', 2 March 2021, https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/families/datasets/familiesandhouseholdsfamiliesandhouseholds.*

[44] *Statista, 'Food Delivery and Takeaway Market in the UK' (Statista, December 2020), https://www.statista.com/topics/4679/food-delivery-and-takeaway-market-in-the-united-kingdom-uk/.*

[45] *Jodi L. Liu, 'Beyond Neighborhood Food Environments: Distance Traveled to Food Establishments in 5 US Cities, 2009–2011',* Preventing Chronic Disease *12 (2015), https://doi.org/10.5888/pcd12.150065.*

[46] *'What's the Average Distance for Food Delivery Services?',* Shopfood.Com *(blog), 25 December 2020, https://www.shopfood.com/online-shopping/whats-the-average-distance-for-food-delivery-services/.*

variation within food service delivery, it is of minor impact in the wider context of total food system emissions.

2.9.2 Grocery delivery

An authoritative dataset for grocery was similarly lacking, so a series of assumptions and datasets were used.

- Two values were identified for the year 2016 as a starting point: the number of vans involved in grocery home delivery[47];and the typical mileage of a grocery delivery van in 2016.[48] By combining these two figures, it is possible to estimate the distance travelled by grocery delivery vans in 2016. The RAC report also presents some scenarios for the number of orders in 2020, with three scenarios: a lower bound, an upper bound, and an upper bound which accounts for a smaller average order value.[49] The middle value of these three, which amounts to 180 million orders, was taken for the year 2020. It is assumed that the mileage per van does not change, and that new orders will be met by an increased size of fleet.

- With these two datapoints, a time series was constructed: the years between 2016 and 2020 were assumed to progress in a linear fashion between the two datapoints. In order to derive a value for 2015, our baseline year, a backwards extrapolation was made. The CCC annex on van demand dates the 'start of internet shopping' as 2000: we therefore assumed that in the year 2000 there was no online grocery shopping, and that progression between 2000 and 2016 was in a linear fashion, forming estimates for the years in between those values.

- The estimate of the total distance travelled by grocery vans each year was multiplied by the 'average van' emissions factor for each year, forming an estimate of the emissions associated with grocery delivery. The 'average van' emission factor may be an underestimate, but was not considered to be material.

2.10 Consumer transport

Consumer transport emission estimates were calculated using the Department for Transport's National Travel Survey (NTS)[50], for which the latest data available was 2019. This measures the average distance travelled per person by mode of transport for the purposes of shopping in England. For the purposes of assigning emissions to transport, the car / van passenger data was not included - only data for the car / van driver (to avoid double counting).

The English per-person distances were assumed to be representative of the whole UK population, and was scaled to a UK-wide estimate using ONS population statistics. Due to

[47] *Alan Braithwaite, 'The Implications of Internet Shopping Growth on the Van Fleet and Traffic Activity' (London: RAC Foundation, May 2017), https://www.racfoundation.org/wp-content/uploads/2017/11/The_Implications_of_Internet_Shopping_Growth_on_the_Van_Fleet_and_Traffic_Activity_Braithwaite_May_17.pdf.*

[48] *Ewa Kmietowizc, Sasha Abraham, and Ellie Davies, 'Reducing UK Emissions - 2018 Progress Report to Parliament. Chapter 5 Annex: Growth in van Demand' (Committee on Climate Change, 28 June 2018), https://www.theccc.org.uk/wp-content/uploads/2018/07/PR18-Chapter-5-Annex-Growth-in-Van-Demand.pdf.*

[49] *Braithwaite, 'The Implications of Internet Shopping Growth on the Van Fleet and Traffic Activity'.*

[50] *DfT, 'National Travel Survey', GOV.UK, accessed 8 June 2021, https://www.gov.uk/government/collections/national-travel-survey-statistics.*

lower population density in Wales, Scotland and Northern Ireland, this extrapolation could possibly understate the overall distance travelled.

The transport emissions per mode of transport were calculated by multiplying the distance travelled, adjusted to kilometres, by the BEIS greenhouse gas emissions factors for each specific mode of transport and year.

As the NTS statistics are transport for all shopping purposes, this was adjusted to estimate food and drink shopping only using the share of household expenditure on food and drink from ONS consumer trends statistics for each year.[51] It was assumed that the share of household expenditure on food shopping as a subset of shopping was representative of the share of consumer transport to food shopping as a subset of all shopping-related transport[52].

2.11 Retail

Data for retail energy use were sourced from BEIS published ECUK statistics.[53]

To avoid double counting, the energy use for catering purposes within retail was attributed to the Hospitality and Food Service (HaFS) sector (see 2.12) and removed from retail.

The ECUK statistics present energy use for the total retail sector. In a similar way as for consumer transport, this was adjusted to estimate food and drink retail only, using the share of household shopping expenditure on food and drink from ONS consumer trend statistics for each year.[54] It is assumed that the share of household expenditure on food shopping as a subset of shopping is representative of the share of total retail energy use by food retail[55].

ECUK statistics are broken down by fuel type, which were then converted to CO_2e using BEIS emission factors for each year.

2.12 Hospitality and food service (HaFS)

Data for energy used in HaFS were sourced from BEIS published ECUK statistics[56], where it is classed as 'catering' related energy use. We note that this includes energy used for catering purposes in the retail sector.

ECUK statistics are broken down by fuel type, which were then converted to CO_2e using BEIS emission factors for each year.

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[51] *Office for National Statistics, 'Consumer Trends: Chained Volume Measure, Seasonally Adjusted', accessed 8 June 2021, https://www.ons.gov.uk/economy/nationalaccounts/satelliteaccounts/datasets/consumertrendschainedvolumemeasureseasonallyadjusted.*

[52] Please note that due to an error in the calculation which led to alcohol purchases being double counted in the previous Courtauld report, the share of shopping for food and drink is reduced from previously stated results (from 50% to 45% in 2018). This has led to a reduction in consumer transport emissions of approximately 1 $MtCO_2e$ in 2018.

[53] *BEIS, 'Energy Consumption in the UK'.*

[54] *Office for National Statistics, 'Consumer Trends: Chained Volume Measure, Seasonally Adjusted'.*

[55] Please note that due to an error in the calculation which led to alcohol purchases being double counted in the previous Courtauld report, the share of shopping on food and drink is reduced from previously stated results (from 50% to 45% in 2018). This has led to a reduction in food retail emissions of approximately 0.6 $MtCO_2e$ in 2018.

[56] *BEIS, 'Energy Consumption in the UK'.*

2.13 Home related

Energy consumption for home food related appliances were sourced from BEIS ECUK data[57], which includes consumption by domestic appliances until 2019.

The appliances can be grouped into chilling (freezers and fridges), cooking (oven, hob, microwave) and dishwashers and kettles. ECUK only covers electric ovens and electric hobs.

In order to estimate use of gas ovens and hobs, the (then) Department of Energy & Climate Change 'Energy follow-up survey' was used.[58] This breaks down the share of ovens and hobs which are electric and gas. In the absence of data tracking changes in the ownership of appliances, this share was assumed to stay constant over time. Assuming that demand for energy services from gas and electric appliances are the same, the energy use of electric appliances and their share of total owned cooking appliances can be used to derive an estimate of the energy use of gas appliances. These energy values were then converted using BEIS conversion factors for electricity and natural gas respectively, and summed to derive the GHG emissions for household food-related activities.

Note that although the methodology has not changed, these figures are restated from the previous Courtauld report due to an error in calculation, whereby gas hob and ovens were calculated using the wrong energy demand figure. This has been corrected for all years, leading to a decrease in household GHG emissions. The major changes, corrections and comparisons to the previous work are detailed in Section 4.1.

2.14 Waste disposal

This stage considers the GHG emissions linked to the management of food (and associated inedible parts) which end up in any of the eight destinations encompassed by the definition of food waste [59] (including landfill, anaerobic digestion, composting, incineration, sewer). It does not include emissions linked to the management of 'food surplus' which is redistributed or redirected to other productive uses such as for animal feed, as this is not regarded as waste.

The total annual volume of food waste arisings and volumes sent to different waste management destinations for each stage in the food system were quantified in line with the methodology as described in WRAP's 'Food surplus and waste in the UK: key facts' document[60]. Notably, this is a different methodology from that described in WRAP (2020)[61], leading to a substantial difference in results. This is principally due to the over-allocation of household waste to landfill in the previous WRAP report (previously based on Eurostat waste

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[57] BEIS.

[58] Jack Hulme, Adele Beaumont, and Claire Summers, 'Energy Follow-up Survey Report 9: Domestic Appliances, Cooking and Cooling Equipment' (Department of Energy and Climate Change, December 2013), https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/274778/9_Domestic_appliances__cooking_and_cooling_equipment.pdf.

[59] See page 25 of WRAP, 'Food Waste Reduction Roadmap & Toolkit' (Banbury, September 2020), https://wrap.org.uk/resources/tool/food-waste-reduction-roadmap-toolkit.

[60] WRAP, 'Food Surplus and Waste in the UK - Key Facts', WRAP, June 2021, https://wrap.org.uk/resources/guide/waste-prevention-activities/food-love-waste-data.

[61] 'UK Progress against Courtauld 2025 Targets and UN Sustainable Development Goal 12.3'.

data, which has now been replaced with actual data on destinations for household residual waste[62]).

Note that this report, notably Section 3.3.5.2, also contains food waste estimates for primary production. The wastes at this stage are believed to primarily be left on the land and ploughed back in or re-applied to land as a form of fertiliser. This means that the emissions associated with the application of this food waste is already accounted for in the agricultural emission statistics (see Section 2.3.1) – and so we do not add in additional emissions here, to avoid double-counting.

GHG emission factors for different waste management destinations were developed based on the same methodology and data as the WRAP GHG Waste and Resources Metric[63], but adjusted to use AR5 instead of AR4 Global Warming Potential (GWP) values.

These emission factors were then multiplied by annual waste / destination volumes to generate a total estimate of emissions linked to waste management for each assessment year.

It should be noted that the scope of disposal-related GHG emissions considered here are in line with the GHG Protocol.[64] Because recycling of waste creates a new product from the recycled resource (e.g. compost, digestate, heat, fertiliser, electricity), the emissions from the recycling process are allocated to the *new product*. In the case of food waste recycling, this means the waste treatment emissions from anaerobic digestion, compost and even recovery through energy from waste (EfW) are not considered in the waste disposal stage - but instead are attributed to the subsequent product (digestate, compost, electricity etc.).

The implication for this GHG Model is that full GHG emissions for some destinations, such as landfill or sewer (where they do not generate products used elsewhere), are included in the *waste disposal* section. However, for other waste destinations, emissions are accounted in different stages. For example – emissions linked to composting are accounted in the agriculture stage (where this product is used); and emissions linked to electricity from EfW are accounted within UK electricity grid emissions (used across all stages). As a result, emissions *at the disposal stage* may appear to be lower than the actual environmental impact of each treatment method [65]. However this is consistent with the consumption-based approach.

We also note one significant date gap - as stated in WRAP's 'key facts' document, the scale of food waste being disposed to sewer across the supply chain is not currently known (but estimates are available for households).[66] This is expected to be particularly relevant for the HaFS sector. As a non-recycling waste destination with substantial associated GHG emissions, this data gap means that total disposal emissions are likely underestimated.

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[62] *Defra, 'Local Authority Collected Waste Management - Annual Results', GOV.UK, accessed 8 June 2021, https://www.gov.uk/government/statistics/local-authority-collected-waste-management-annual-results.*

[63] *WRAP, 'Carbon Waste and Resources Metric'. https://wrap.org.uk/resources/report/carbon-waste-and-resources-metric*

[64] *'Greenhouse Gas Protocol', Greenhouse Gas Protocol, accessed 8 June 2021, https://ghgprotocol.org/.*

[65] *For information on the impact associated with the use of digestate on land, see: WRAP, 'AD and Composting Industry Market Survey Report 2020' (Banbury, 2020), https://wrap.org.uk/resources/report/anaerobic-digestion-and-composting-latest-industry-survey-report-new-summaries.*

[66] *WRAP, 'Food Surplus and Waste in the UK - Key Facts' Table 1.*

3.0 Methodology for estimating emissions to 2030

This section covers the second part of the analysis, which builds upon the updated GHG model to forecast emissions to 2030. This was used to examine the progress which would be expected to be made by various proposed roadmaps, policies and interventions, and identify the biggest levers for reducing emissions.

3.1 Structure

The basic calculation principle for modelling possible interventions in each stage builds upon the GHG modelling described in Section 2.0.

Within each stage of the food system, the key parameters which formed each emissions calculation were identified:

- Demand for final services (e.g. total kWh electricity demand, ktoe natural gas demand, km travelled by car etc.).
- Share of final service demand met by a particular fuel, mode of transport etc. (e.g. % of total energy demand met by electricity).
- Emission factor for each service (e.g. kgCO_2e per kWh from a fuel source, kgCO_2e per km travelled).

Each of these parameters therefore reflects a lever which could be changed through stakeholder action.

To give a simple example of the overall modelling approach:

Transport (UK supply chain) (see Section 2.8) relies on data for road and rail freight, expressed as million tonne-km, which is then multiplied by the appropriate emission factors for HGVs and freight trains. For each mode of transport, there are therefore two main parameters: transport demand (million tonne-km); and emission intensity of transport mode (kgCO_2e / tonne-km)

In modelling the change in emissions linked to a potential intervention, firstly a simple *population projection* was formed (see 3.2) in which transport demand increases in line with population, and emission intensity of transport stays constant.

Secondly, possible changes were explored.

- The first variable is transport demand: it would be possible for UK supply chain transport demand to go down. This could reflect reduced demand for food transport, such as shorter, local supply chains or simply reduced food demand. Or could reflect increasing efficiency of transport through smart logistics and better planning. Because the data reflects final demand (a composite variable for both the demand for the *service* and the *efficiency* of its delivery), it is not possible to disentangle these two influences. Any scenarios must be expressed as a reduction in final demand only. This limitation also applies in other stages: demand for electric ovens in the household is expressed in kWh final energy demand, a reduction in which could represent less oven usage (minutes on, meals cooked etc.) *or* an improvement in oven efficiency (lower energy requirement for the same output), or some combination of the two.

- The second variable in this example is emissions intensity of transport - which represents how GHG intensive each tonne-km is. Given the very small role of freight rail, we only considered road transport. In this case, the displacement of polluting vehicles with lower-GHG vehicles such as electric vehicles (EVs) or hydrogen cell trucks using renewable electricity would be expected to reduce the emissions intensity of the average HGV.

These two parameters were calculated both separately and together, leading to three scenarios – of which the combined scenario is what forms the primary analysis:

Reduced demand scenario:

$$(Projected\ Demand * (1 - (Demand\ reduction\ factor)) * Constant\ emission\ factor$$

Decarbonised transport scenario:

$$Projected\ demand * (Constant\ emission\ factor * (1 - Emission\ reduction\ factor))$$

And the combined scenario:

$$(Projected\ Demand * \big(1 - (Demand\ reduction\ factor)\big) * (Constant\ emission\ factor * (1 - Emission\ reduction\ factor))$$

This is one example of the calculation approach for one stage within the food system [transport (UK supply chain)].

In other food system stages the calculations have more steps - but the basic principles remain the same:

- Each calculation is broken down into its constituent parameters / variables.
- Each parameter was reduced by a factor (based on a series of assumptions linked to intervention scenarios).
- These altered parameters were brought together into a single combined calculation which estimated the impact of all of the reduction factors at once for a particular stage.

For the year 2030, it is therefore possible to compare: i) the population projection scenario; and ii) the combined impact reduction scenario for a given intervention. Comparing these gives an estimate of the emission reduction which might be achieved through different interventions.

3.2 Population projection

In most cases, emissions reductions are expressed as relative measures rather than absolute measures. For example, a reduction in the GHG intensity of a given amount of output, such as GHG emissions per kWh electricity used. However, the Courtauld 2030 target is based on an <u>absolute</u> reduction in emissions. Therefore, 2030 forecasts require adjustment to account for changes in key drivers of food consumption. This was done by the creation of a baseline 'population projection' scenario against which relative reductions would be calculated, and from which absolute reductions could be derived.

The baseline took the form of simple population projections: key measures of per capita consumption stay constant from 2019 (the last observed year), but as a result of forecast population growth the 2030, the total consumption goes up in line with population.

This assumes no other changes to the dynamics of the food system. In reality, however, this <u>won't</u> be the case – as policies, plans and investments have already been put in place which will cause changes between now and 2030. It is not, therefore, a typical counterfactual scenario, which would account for these changes.

The population projection is, by necessity, a simplification – which, for example, assumes that increased demand is met by proportional production increases. In reality, complex market forces will interact with both production and consumption, but it was not possible to model these effects, and nor was it the purpose of this work to try and do so.

As the purpose of this analysis was to look at what changes, all else being equal, could help achieve the 2030 Courtauld target, this simplification was considered an acceptable limitation. It is important to be mindful of this limitation, however, when drawing conclusions from the analysis.

3.2.1 Stages with growth projection

For the majority of stages in the food system, a simple calculation was undertaken for the population projection which drew on some core assumptions:

- Demand for the final product, energy service, transport etc. will grow in direct proportion to population growth.
- No further changes to emissions factors of electricity, fuel, vehicles etc. from the 2019 value.
- No further changes to intermediary variables such as energy efficiency of appliances etc. which might impact demand.

The calculations were therefore conducted by taking the 2019 *final demand value* and dividing by the 2019 population.[67] This created a demand per capita value, which was held constant and multiplied by the population forecast through to 2030.[68] This created a simple population projection for *final demand* which was multiplied by the relevant 2019 emission factor to form the baseline projection.

3.2.1.1 Example: Food manufacturing

Below is a worked example to make this clearer: *Food manufacturing* statistics (see Section 2.5) are presented by fuel type, each expressed as kilotonnes of oil equivalent (ktoe). These figures were divided by the 2019 population to create a ktoe/capita value for each fuel type.

Table 1: Manufacturing energy demand, 2019 (ktoe)

Fuel type	2019 demand (ktoe)	2019 per capita (ktoe/capita)
Coal	42	6.3×10^{-7}
Petroleum Products	356	5.3×10^{-6}
Natural Gas	1733	2.6×10^{-5}
Bioenergy and waste	64	9.6×10^{-7}
Net electricity	835	1.3×10^{-5}

[67] *'United Kingdom Population Mid-Year Estimate - Office for National Statistics'.*

[68] *Office for National Statistics, 'National Population Projections', accessed 25 February 2021, https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2013-11-06.*

The ktoe/capita values were multiplied by population forecasts to derive yearly ktoe demand projections until 2030.

Table 2: Manufacturing energy demand, projection (ktoe)

Fuel type	2019	2020	2021	[…]	2028	2029	2030
Coal	42	43	43	[…]	44	44	44
Petroleum Products	356	358	360	[…]	370	371	372
Natural Gas	1733	1743	1752	[…]	1800	1806	1826
Bioenergy and waste	64	65	65	[…]	67	67	67
Net electricity	835	840	844	[…]	868	877	873

To convert the demand projection into a baseline emissions projection, each ktoe figure was adjusted to kWh and then multiplied by the relevant $kgCO_2e$/kWh emission factor from BEIS, before being adjusted from $kgCO_2e$ to $ktCO_2e$. This then formed the *baseline projection.* For food manufacturing, this is below.

Table 3: Manufacturing emissions ($ktCO_2e$)

Fuel type	2019	2020	2021	[…]	2028	2029	2030
Coal	198	199	200	[…]	205	206	207
Petroleum Products	1404	1413	1420	[…]	1459	1464	1468
Natural Gas	4652	4680	4703	[…]	4833	4849	4865
Bioenergy and waste	18	18	18	[…]	19	19	19
Net electricity	3069	3088	3103	[…]	3189	3199	3210
Total Emissions	9342	9397	9444		9705	9737	9768

3.2.2 Stages held constant

For **Agriculture**, the baseline projection holds the 2019 emissions value (46.3 $mtCO_2e$) constant each year through until 2030. Agriculture has been largely steady in its emissions since 2009 (44.4 mtCO2e) so this was considered appropriate as a baseline projection.

3.3 Intervention scenarios

The next step was to replace the various parameters described in Section 3.2 with intervention reduction estimates - informed by literature, stakeholder commitments or other means of estimating the scale of reduction that could be feasible by 2030.

The following sections detail these assumptions and data sources. Throughout, references are made to the 'main scenario', or 'upper' and 'lower' estimates. In situations where multiple possible values were identified, this refers to the intervention values chosen and modelled in the primary Courtauld 2030 scenarios – and as detailed in the results described in Section 4.0. The other considered values are described for transparency and in some cases to give confidence that the values selected and scenarios modelled are reasonable.

3.3.1 Agriculture and food production

3.3.1.1 Agriculture

Because agricultural emissions are not derived from first principles in the GHG model (they are sourced directly from the UK GHG inventory - see Section 2.3.1), the estimation of reduction potential by 2030 was similarly taken directly from existing published estimates.

Three scenarios were considered:

The first (upper estimate) scenario is based on the National Farmers Union (NFU) estimate of how emissions within the UK agricultural sector could be reduced by 2040 – as set out in the 'Achieving Net Zero' roadmap[69]. This splits emission reductions into three 'pillars', with different estimates of annual reduction potential by 2040:

- Productivity improvements - delivering annual emissions reduction of 11.5 $MtCO_2e$ by 2040.
- Farmland GHG storage – delivering annual emissions reduction of 9 $MtCO_2e$ by 2040.
- Bioeconomy measures – delivering annual emissions reduction of 25.5 $MtCO_2e$ by 2040. *[NB – these were not considered because of the potential for double counting with energy-related emission reductions (see Section 3.3.2)]*

Because the NFU Achieving Net Zero roadmap was published in 2020 with a 2040 endpoint, we make a simple assumption that by 2030, 50% of the progress to 2040 will have been made. This therefore rests on two key assumptions: delivery of the ambition, and linear progress towards its target. In the land and agricultural sector, due to the long lead-in time of new changes (such as the adoption of new practices), this assumption of linearity is unlikely to be accurate, but is sufficient for our purposes of estimating the scale of its potential contribution – and is used as an 'upper estimate' scenario.

The reductions were scaled to 2030 and then calculated as a percentage reduction against the baseline for the original NFU study (2018) (**23%** reduction in total – see Table 4).

Table 4: Emission reduction in 2030, by NFU pillar

Pillar	Reduction from total in 2030 (%)
Productivity improvements	13%
Farmland GHG storage	10%
Bioeconomy based measures [NOT INCLUDED]	*28%*

The second (lower estimate) scenario was adapted from Defra work on sustainable intensification shared with WRAP. The Defra project will be published in full later in 2021 and further detail on this scenario can be found there once available.

This work involved the modelling of a series of interventions based on workshops with farmers relating to potential uptake. S-curve uptake pathways were modelled leading to a potentially more realistic trajectory, given the inherent time lag in adoption of agricultural interventions.

[69] *NFU, 'Achieving Net Zero: Farming's 2040 Goal', 2020, https://www.nfuonline.com/news/latest-news/achieving-net-zero-meeting-the-climate-change-challenge/.*

This work was undertaken explicitly for England. However, the reductions as a percentage of English emissions were assumed to be applicable to agricultural emissions across all four nations. Based on the reading of output graphs, in a 'High mitigation' scenario, 8.4% of emissions were expected to be reduced by 2030. Of this, 1.8% from agricultural productivity improvements, 3% from uptake of innovative technologies, and 3.6% from improved land management (such as increased GHG sequestration through techniques including agroforestry, or reducing emissions from peat soils by improving management).

For the 'lower estimate' scenario (as presented in the results section), this **8%** reduction from the Defra project was used as a more conservative estimate of the pace at which interventions might be adopted over the next decade.

A third scenario (investigated for completeness but not included in the core modelling) considered the UKCCC 'Balanced Net Zero' scenario (UKCC-BNZ).[70] This presented realistic achievements by 2035, which was adjusted to a 2030 target based on an assumption of linear progress to 2035. They consider three groups of interventions: low-GHG farming practices; fossil fuel use in agriculture; and measures to release land. Only low-GHG farming practices and fossil fuel use in agriculture were considered within scope of our food consumption analysis. For low-GHG farming practices, the UKCCC estimated that, by 2035, a 6 $MtCO_2e$ reduction could be achieved[71]. Reducing fossil fuel use leads to an additional 2.6 $MtCO_2e$ reduction. When scaled to 2030 and compared to the study's 2018 baseline, these amount to a 9% and 4% reduction respectively, leading to a total reduction of **13%** (i.e. in-between the other two estimates described above).

3.3.1.2 Fertiliser Manufacture

Embodied emissions from fertiliser manufacture are split into two main parameters: the demand for fertiliser and the emission intensity of fertiliser production.

- Demand for fertiliser was considered from two sources. The European Commission (EC) in its Farm-to-Fork strategy have targeted a 20% targeted reduction in synthetic fertiliser use.[72] In addition, the Agricultural Industries Confederation (AIC) have a sustainability roadmap target for a 40% improvement in input and resource efficiency since 1990, against which they estimate that 30% has already been achieved.[73] Calculating the remaining improvement, a further 14% improvement in efficiency – here understood as reduced usage whilst delivering the same output – would be considered an appropriate target, which is comparable to the European Commission target. For the main scenario, the AIC target of 14% was used.

- Possible reductions in the emissions intensity of fertiliser production were also derived from the AIC roadmap.[74] This reports that, from 1990 – 2020, the emission intensity of nitrogen fertiliser production has decreased by 40%. There is a target for 50% reduction vs 1990 levels by 2030. By using the progress already made, it was possible to derive a

[70] Committee on Climate Change, 'The Sixth Carbon Budget: The UK's Path to Net Zero', December 2020, https://www.theccc.org.uk/publication/sixth-carbon-budget/.

[71] In the main report, they report a 4 $MtCO_2e$ reduction. This is due to the more substantial dietary change in their scenario than modelled here. In the method report, it is detailed that when compared to the baseline and not accounting dietary change, a larger reduction is observed.

[72] European Commission, 'Farm to Fork Strategy: For a Fair, Healthy and Environmentally-Friendly Food System' (Brussels: European Commission, May 2020), https://ec.europa.eu/food/horizontal-topics/farm-fork-strategy_en.

[73] AIC, 'A Roadmap for a Sustainable Food Chain', 22 July 2020, 15.

[74] AIC.

reduction required from today's levels by 2030 to achieve this goal: this comes to 16.7%. Although based on the reduction of nitrogen fertiliser, it was assumed that this reduction could be applicable to all fertiliser production. This value was therefore used as the possible reduction in emission intensity of fertiliser production (both EU and non-EU) by 2030. This is applied in the main scenario.

3.3.1.3 Animal feed

Animal feed is split into two parameters: demand for animal feed, expressed in tonnes, and the GHG intensity of animal feed, expressed as tonnes CO_2e / tonne feed.

No specific targets regarding reduction in demand for imported feed were identified. For the main scenario therefore, demand was unchanged from the baseline projection. However - we note that some 'whole system' interventions, such as changing dietary patterns, will result in changes in demand for feedstuffs. This is considered elsewhere (see Section 3.3.5).

The GHG intensity of feed is impacted by three separate calculations which relate to different drivers of animal feed emission intensity reduction:

- Improving the efficiency of feed mills;
- Reducing the GHG intensity of average feed; and
- Reducing / eliminating land use change (deforestation) associated with feed.

Whilst all three impact the same lever (feed GHG intensity) they represent different possible interventions: making the same feed less GHG intensive through manufacturing efficiency; substitution of feed with lower GHG alternatives (such as food and drink co-products or surplus food); ensuring zero deforestation linked to feed supply chains, such as soya. These three calculations are considered in turn.

- For feed mill efficiency, a figure was derived from the AIC roadmap.[75] This states that, since 1990, feed mills have reduced GHG emissions by 23%. The target for 2030 when compared to 1990 is to reduce this by 50%. Using the progress made to date, it is possible to infer that a 35% reduction from today's levels would be needed to achieve the goal. However, this 35% reduction would not be appropriate to apply to the feed's entire emission profile as the production of the raw feed materials are a more significant contributor than the feed manufacturing process. The same AIC document states that approximately 85% of feed emissions are from the raw material, leaving just 15% which is subject to manufacturing efficiency improvements. Multiplying the 35% reduction by the 15% of feed emissions which it effects, a 5% reduction in feed emissions intensity is assumed. This reduction is assumed to apply evenly to both EU-manufactured and non-EU manufactured animal feed, and is applied in the main scenario.

- In addition to processing improvements, it is possible to reduce the emission intensity of feed by excluding certain emission-intensive protein sources and replacing them with lower-intensity ones. A recent report by CIEL claims that this could reduce feed footprints by up to 40%.[76] This is not explicitly described as a target, however if we consider it as a target for 2050 against which linear progress is made, by 2030 some 15% of the way to the target would be achieved. Scaling to apply the intervention only to the 85% of animal feed emissions from raw material, there could be some 5% reduction in feed emissions intensity by 2030. This is applied in the main scenario.

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[75] *AIC.*

[76] *CIEL, 'Net Zero Carbon & UK Livestock'.*

- The elimination of deforestation-related LUC emissions involved a 100% reduction in the LUC-based emission intensity of animal feed by 2030, for both EU- and non-EU imported feed (see Section 2.3.3 for a description of how LUC emissions were quantified and which feed raw materials they apply to).

3.3.1.4 Net food trade

As for animal feed, food net trade is split into two parameters which can be altered: the net import demand, expressed in tonnes, and the average emission intensity of imported food, expressed as tonnes CO_2e / tonne traded.

Note also that net imports are a function both of how much is imported and how much is exported. Although an over-simplification, for the purposes of this scenario it was assumed that reductions in emissions linked to net imports are due to changes in imported food items only (not changes to exports).

As for animal feed, no demand reduction was identified outside of the reduction inherent in 'whole system' interventions like dietary change and food waste reduction. As a result, no further reductions to import demand were modelled in this part of the modelling (instead this is estimated separately in the dietary change and food waste reduction scenarios described in Section 3.3.5).

The GHG intensity of imported food is subject to two parameters: agricultural efficiency improvements and dietary/purchasing change (types and quantities of food purchased). The former refers to maintaining the same types and quantities of food purchased - but producing them in a more environmentally efficient manner. The latter relates to the substitution of GHG intensive diets with less GHG intensive diets; or reducing overconsumption or avoiding purchasing food that is then thrown away. Because dietary/purchasing change impacts not just primary production but the whole food system, it is treated as a separate intervention as is not considered here (see Section 3.3.5 for how whole food system changes were calculated). As a result, here we only consider agricultural improvements.

Agricultural efficiency improvements were derived from the same '% reduction' scenarios ('upper' and 'lower' estimates) applied to UK agriculture (see Section 2.3.1) – but different assumptions were made about the rate of progress that might be achievable, both within the EU and beyond the EU:

- The EU has a 2050 net zero target for the entire economy[77] (similar to the UK) – and the emissions reduction achievable by 2030 was assumed to be on a linear trajectory and adjusted accordingly (e.g. NFU Achieving Net Zero roadmap endpoint is 2040 for the UK, but adjusted to 2050 for the EU, with a lower rate of emissions reduction achieved by 2030 than the UK scenario).
- Outside of the EU it was assumed that there could be more variable rates of reduction (e.g. as not all countries have binding targets). As such, a more conservative assumption was made – that the rate of progress in reducing emissions would be half of that within the EU.

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[77] *European Commission, 'A Clean Planet for All: A European Strategic Long-Term Vision for a Prosperous, Modern, Competitive and Climate Neutral Economy' (Brussels: European Commission, 28 November 2018), https://ec.europa.eu/clima/policies/strategies/2050_en.*

As for animal feed, the elimination of deforestation-related LUC emissions involved a 100% reduction in the LUC-based emission intensity of imported food by 2030, for both EU- and non-EU imported food (see Section 2.4 for a description of how LUC emissions were quantified and which products/ ingredients they apply to).

3.3.2 Energy

The following relates to the assumptions made in scenarios where the emissions are based upon energy use. This is relevant to the stages: Retail; HaFS; Manufacturing; and Household.

In each case, the calculation of emissions reduction scenarios followed the same principles, with changes made to two parameters:

- Demand for final energy use for a given fuel/energy type; and
- Emission intensity of each fuel/energy type.

3.3.2.1 Electricity decarbonisation

Electricity decarbonisation is expressed as a reduction in the GHG emissions intensity of electricity per kWh. Across all stages, where electricity was used from the national grid (as opposed to auto-generation), the scenario was taken from the UKCCC-Balanced Net Zero (BNZ) pathway[78]. In the UKCCC study, the GHG intensity of electricity in 2019 is cited as 220gCO_2e/kWh, and prospective 2030 intensity of 50gCO_2e/kWh. The rate of change between these two values was derived, which is equal to an 80% reduction in emission intensity. This value was therefore taken as a feasible reduction in the emission intensity of energy by 2030. This is applied throughout the main scenario.

In Retail, Manufacturing and HaFS, we also consider the possibility of auto-generation by businesses through the deployment of renewable electricity, such as on-site solutions (rooftop solar PV) or investment in renewable energy infrastructure (such as financing wind farms). For Retail, this is in line with the pledge made in the BRC's Roadmap to source 100% renewable electricity.[79]

To express the change associated with 100% renewable electricity as a percentage reduction in electricity emissions intensity, life-cycle assessment (LCA) values of the emission intensity of renewable energy technologies were used. Amponsah et al. (2014)[80] reviewed the LCA of renewable energy technologies in peer reviewed literature. From this, the average value for solar emissions intensity was taken as 49.2 kgCO_2e/kWh, calculated from the median values from the LCA studies identified. The average value for wind energy was taken as 13.4 kgCO_2e/kWh, calculated from the mean of two values: the median LCA values for offshore wind (9 kgCO_2e/kWh) and onshore wind (17.7 kgCO_2e/kWh). It was assumed that the auto-generation renewable energy mix is split evenly between wind and solar. The combined emission factor of electricity in an 100% renewable energy scenario was therefore calculated as 31.1 kgCO_2e. Compared to the emission factor in our 2019 baseline year (316 kgCO_2e/kWh), switching to 100% renewable energy results in a reduction in emissions intensity of 90%.

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[78] *Committee on Climate Change, 'The Sixth Carbon Budget: The UK's Path to Net Zero'.*

[79] *BRC, 'Climate Action Roadmap: Net Zero Roadmap for the Retail Industry' (British Retail Consortium, 2020), https://brc.org.uk/climate-roadmap/.*

[80] *Nana Yaw Amponsah et al., 'Greenhouse Gas Emissions from Renewable Energy Sources: A Review of Lifecycle Considerations',* Renewable and Sustainable Energy Reviews *39 (November 2014): 461–75, https://doi.org/10.1016/j.rser.2014.07.087.*

3.3.2.1.1 Retail

The electricity GHG emissions intensity depends on the scenario chosen. If the BRC Roadmap is achieved, 100% renewable electricity is pledged by 2030, which would result in a 90% reduction in emissions intensity for electricity use. Alternatively, the UKCCC-BNZ scenario projects a 80% reduction in emissions linked to grid electricity.

Given the progressive commitments made by the retail sector, the main scenario in this analysis is based on the 100% renewable scenario / 90% reduction.

3.3.2.1.2 HaFS

As above, the electricity GHG emissions intensity depends on the scenario chosen. For HaFS and Manufacturing, we explored a scenario comparable to the BRC commitment for Retail, in which 100% renewable electricity auto-generation is achieved by 2030. If this 'RE100' scenario is applied, a reduction of 90% in electricity emissions intensity could be achieved. Alternatively, the UK grid reduction of 80% under UKCCC-BNZ would be achieved.

Given the more fragmented nature of this sector, the main scenario used in this analysis is based on the more conservative UKCCC-BNZ / 80% reduction.

3.3.2.1.3 Manufacturing

As above, the electricity emissions intensity depends on the scenario chosen – and for HaFS and Manufacturing, we explored a scenario comparable to the BRC commitment for Retail, in which 100% renewable electricity auto-generation is achieved by 2030. If this 'RE100' scenario is applied, a reduction of 90% in electricity emissions intensity could be achieved. Alternatively, the UK grid reduction of 80% under UKCCC-BNZ would be achieved.

Given the more fragmented nature of this sector, the main scenario used in this analysis is based on the more conservative UKCCC-BNZ / 80% reduction.

3.3.2.1.4 Household

The electricity emissions intensity for households is determined by the UK national grid. Therefore, it is determined by the UKCCC-BNZ scenario, entailing an 80% reduction in the emissions intensity of electricity. This is applied throughout the main scenario.

3.3.2.2 Heat decarbonisation

Decarbonisation of heat is expressed as a reduction in the emission intensity of heat sources. It is only considered here as applicable to the HaFS and Manufacturing stages.

The DUKES and ECUK data sources (see Sections 2.5 and 2.12 for Manufacturing and HaFS respectively) estimate energy use by source fuel. Therefore, in both cases, assumptions were required regarding the fuel being used for heat. In the HaFS sector, oil and natural gas represent 100% of fossil fuel energy use. These were both assumed to be specifically for heat purposes, and therefore are affected by heat decarbonisation. In the Manufacturing sector, natural gas accounts for 92% of the total fossil fuel use, and this was assumed to be the key fuel source relating to heat.

Heat decarbonisation will primarily be achieved through electrification. However, for simplicity, rather than reallocating the emissions from fossil fuels to electricity, heat decarbonisation was calculated as a reduction in fossil fuel emission intensity.

3.3.2.2.1 Manufacturing

For reductions in the emission intensity of heat generation, scenarios were taken from the FDF/SLR's 2020 heat decarbonisation study[81]. In this, three scenarios are considered: 'BAU'[82], 'Realistic' and 'Maxtech'. The reductions for the different scenarios over time are presented in the FDF/SLR report, Figure 1. They consider only the 'FDF Sub-sector' of Manufacturing, which they estimate in 2020 to have heat-related emissions of 3,863 ktCO_2e. By 2030, this changes to 3,841 kt CO_2e in 'BAU', 3,387 CO_2e in 'Realistic' and 2,436 CO_2e in 'Maxtech'. However, these are stated as being the total reductions in emissions, i.e. they are accounting for possible sector growth (such as through increased demand for manufactured goods associated with population growth). Demand increases due to population growth are accounted elsewhere in the model (see Section 3.2) so to ensure consistency, an adjustment was made to ensure the reduction in emission intensity of heat was not understated and ensuring the reduction in absolute emissions is comparable between our outputs and those in the FDF/SLR report. Using a factor of 1.052 to account for forecast population growth from 2019 to 2030, the total reduction was adjusted to a reduction in emission intensity which would account for population-based demand growth. The reductions before and after adjustment are presented in Table 5.

Table 5: Derived emission reductions from FDF/SLR scenario

Scenario	Total reduction observed in FDF/SLR (2020)	Derived reduction in emission intensity, accounting for population growth
BAU	1%	5%
Realistic	12%	16%
Maxtech	37%	40%

Due to the uncertainty of heat decarbonisation delivery, in the upper estimate the 'Maxtech' scenario is applied, in the lower estimate the 'Realistic' scenario is applied.

3.3.2.2.1 HaFS

HaFS scenarios were derived from the FDF/SLR's heat decarbonisation study.[83] It was assumed that heat decarbonisation technology used in the Manufacturing sector could equally be applied to the HaFS sector. The values used are the same as in Section 3.3.2.2.1, and have been adjusted for population growth to derive a reduction in emission intensity of 6% in 'BAU', 17% in 'Realistic' and 40% in 'Maxtech'.

As for manufacturing, the upper estimate applies the 'Maxtech' scenario and the lower estimate the 'Realistic' scenario.

[81] *FDF/SLR, 'Decarbonisation of Heat across the Food and Drink Manufacturing Sector' (Food & Drink Federation, 2020), https://www.fdf.org.uk/fdf/resources/publications/decarbonisation-of-heat-across-the-food-and-drink-manufacturing-sector/.*

[82] Note that the use of 'BAU' is for consistency with the terminology in the FDF/SLR paper, and is distinct from the baseline projection used in our calculations (see ection 3.2).

[83] *FDF/SLR, 'Decarbonisation of Heat across the Food and Drink Manufacturing Sector'.*

3.3.2.3 Demand reduction

Change in final energy demand is expressed as a reduction in percentage terms, and is applied evenly to all energy sources. Because it is *final* energy demand which is being reduced, this figure represents either a reduction in demand for energy services (e.g. turning off lights overnight) or improved efficiency of appliances (e.g. delivering the same amount of light with less energy, such as through efficient LED bulbs), or a combination of both.

3.3.2.3.1 Retail

A feasible scale of energy demand reduction was taken from the BRC Roadmap[84]. In the roadmap a BEES publication is cited, which examined improvements which could be made in space heating and retail lighting to improve efficiency. In the roadmap this is expressed as an approximate reduction in total retail energy demand which could be achieved through efficiency improvements. For heating: 3.7% of retail energy demand could be reduced; through lighting improvements 10% of retail demand could be reduced. These were combined to form a value of retail energy demand reduction proposed in the BRC roadmap of 13.7%. This reduction is applied evenly to all energy sources in the main scenario.

3.3.2.3.2 HaFS

A feasible scale of reduction was derived from a 2013 academic study in which energy use was monitored in commercial gastro-pub kitchens to identify possible reductions in energy use through behaviour changes in kitchens.[85] The authors identify feasible efficiency improvements in walk-in-fridges through maintenance; grill use; and avoiding 'hot holding' through heat lamps and *bain-maries*. The possible reductions from these behaviour changes are weighted by the relative share of kitchen energy use, which yielded a conclusion that behaviour changes could result in a commercial gastro-pub kitchen using 73% of the energy currently used.

The same study presented the split of energy consumption in HaFS businesses, with kitchens accounting for 63% of the energy use. Assuming no improvements in the efficiency of the other parts of the business, these kitchen behaviours could lead to a 17% reduction in the total energy demand of HaFS businesses.

It was assumed that the study, which focused on gastro-pubs, could be extrapolated to other HaFS businesses. Because no improvements were assumed to bar, restaurant or other areas of the business, this could be considered a conservative estimate of improvements. This was applied to the main scenario.

3.3.2.3.3 Manufacturing

No additional reductions in demand were identified or included for manufacturing.

3.3.2.3.4 Household

Household food-based energy demand is expressed on a per-appliance basis (see Section 2.13), so changes in demand were similarly calculated per appliance. Possible reductions were taken from a 2012 Household Electricity Survey conducted for the (then)

[84] *BRC, 'Climate Action Roadmap: Net Zero Roadmap for the Retail Industry'.*

[85] *S. Mudie et al., 'Electricity Use in the Commercial Kitchen',* International Journal of Low-Carbon Technologies*, 26 September 2013, ctt068, https://doi.org/10.1093/ijlct/ctt068.*

DECC.[86] In this survey, the average consumption per appliance was measured, with average annual savings per household expressed in kWh when appliances substituted for more efficient ones. This was converted to a percentage value of possible savings. Because the Household Electricity Survey is dated, and a notable reduction in household energy demand from kitchen appliances was observed, the possible savings were compared to the observed change. This was done by comparing the proposed kWh reduction per appliance in DECC (2012) with the change in average appliance consumption from 2012 and 2019, using table A3 of ECUK (2020)[87]. Only savings from goods relating to chilling were included in the Household Electricity Survey. To derive a possible reduction for other kitchen goods, the average additional reductions of chilled goods (26%) was taken and applied to other appliances.

This led to a proposed reduction through improved energy efficiency of appliances. This was then scaled by an assumed uptake of increased efficiency appliances of 20% by 2030, from which a final reduced energy demand could be identified per appliance. From this scaling, for most appliances the proposed efficiency improvement is 4-5%, apart from fridge-freezers against which a further 11% was calculated as possible.

In the <u>upper estimate</u>, these efficiency improvements are factored in. In the <u>lower estimate</u>, no change to appliance efficiency is assumed.

3.3.3 Transport

The following describes the relevant reports identified for transport and assumptions made. Due to differences in datasets, this is split by sub-sector.

3.3.3.1 Supply chain transport

Supply chain transport in the UK is split into: demand for transport (which can be understood as the product of demand changes and efficiency improvements); and reductions in emissions intensity.

The assumptions for supply chain transport are primarily informed by the UKCCC's Balanced Net Zero (BNZ) Scenario[88], the International Transport Forum (IFT)'s 2018 overview on road freight decarbonisation[89] and the International Energy Agency (IEA)'s 'Future Truck Scenario'[90]. What these sources (particularly the latter two) indicate is that 'alternative fuels' for logistics (particularly HGVs), including electric road systems (ERS), EVs, advanced biofuels, hydrogen etc. are not expected in the short- to medium-term, although their development is needed by 2050 for the purposes of meeting climate targets. The IEA forecast that the contribution of ultra-low GHG and zero-emission technologies "come relatively late – these technologies begin to exert an impact in 2035"[91], and the IFT's expert

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[86] *Jean-Paul Zimmerman et al., 'Household Electricity Survey: A Study of Domestic Electrical Product Usage' (Milton Keynes: DECC, 2012), https://www.gov.uk/government/publications/household-electricity-survey--2.*

[87] *BEIS, 'Energy Consumption in the UK'.*

[88] *Committee on Climate Change, 'The Sixth Carbon Budget: The UK's Path to Net Zero'.*

[89] *Francisco Furtado, 'Towards Road Freight Decarbonisation: Trends, Measures and Policies', International Transport Forum Policy Papers (Paris: ITF, 12 May 2018), https://www.oecd-ilibrary.org/content/paper/3dc0b429-en.*

[90] *International Energy Agency,* The Future of Trucks - Implications for Energy and the Environment *(IEA, 2017), https://www.oecd-ilibrary.org/content/publication/9789264279452-en.*

[91] *International Energy Agency.*

survey suggested most respondents seeing full-battery electric, ERS and hydrogen fuel cell coming after 2030[92].

This suggests that the BRC's roadmap milestone of "100% zero GHG HGVs" by 2035 is relatively optimistic[93]. For the long-term ambitions of the food and retail sector, the kind of investment required to drive low GHG logistics technology is crucial, but the uncertainty of technical and policy developments suggest that we cannot rely on technical developments. To meet shorter term targets such as 2030, it is important to focus on lower hanging fruit which can be enacted through technology integration, retrofitting, training and behavioural changes. It is not an either/or situation: both technology development and quick wins are required, but for the timescale of the Courtauld 2030 target, the efficiency gains are of more direct relevance, this is therefore the area our scenario focuses more on.

Demand for transport, measured in tonne-km, is a product of a number of variables including the demand for movement of foodstuffs in logistics processes, the efficiency of those processes (e.g. efficient route planning of journeys, the amount of empty space left in trucks etc.). The possible saving in demand by 2030 was based on a number of informed assumptions: for example, the UKCCC state that through improved logistics and planning, it is possible to reduce the total HGV miles travelled by 10% by 2030. It is unclear if this is on relative or absolute terms, so both were calculated to allow for sensitivity testing. If the reduction is relative, a 10% reduction is applied to *per capita* demand for supply chain transport services. As a result of population growth, the absolute reduction is smaller than 10%. The alternative calculation uses a factor of 1.05 to account for population growth from 2019-30. For an absolute reduction of 10% to be achieved and accounting for this growth, the reduction per capita in 2030 is 14.5%. However, the more conservative **10%** reduction is applied in the main scenario of our analysis.

Transport emission intensity, measured as kg CO_2e per km travelled is similarly a function of multiple parameters: the fuel efficiency of a vehicle (how much power is required to move a payload a certain distance) but also the GHG intensity of that power source. It would be possible to reduce emissions on the same power source by improving fuel efficiency, or by substituting for a less carbon intensive fuel. As previously mentioned, the outlook for fuel efficiency improvements in the short run is more promising than alternative fuel technologies.

Fuel efficiency measures such as retrofits, behavioural change and training and technology integration are 'easy wins' which can lead to a substantial reduction in emissions: some example cases suggest that fuel consumption can be reduced by as much as 12% through 'eco-driving' instructions[94]. As a benchmark for what could be achieved through substantial fuel economy efforts, the IEA use the Global Fuel Economy Initiative (GFEI) target of 35% improvement in fuel efficiency against a 2015 benchmark by 2035.[95] Assuming linear trajectory, this is a 26% increase in fuel efficiency by 2030. Although it is against a 2035 benchmark, we calculate the same change from 2019, so assume a 26% improvement in fuel efficiency by 2030 could be achieved through determined effort. In a situation where emission intensity of fuel stays constant, this fuel efficiency improvement would be associated with a 21% reduction in the fuel emission factor.

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[92] *Furtado, 'Towards Road Freight Decarbonisation: Trends, Measures and Policies', fig. 16.*

[93] *BRC, 'Climate Action Roadmap: Net Zero Roadmap for the Retail Industry' Section 6.3.*

[94] *Furtado, 'Towards Road Freight Decarbonisation: Trends, Measures and Policies'.*

[95] *International Energy Agency,* The Future of Trucks - Implications for Energy and the Environment.

The UKCCC indicates that by 2030, 12% of HGV sales could be electric. However, they do not indicate what size of the fleet would be electric, which is what would be relevant for our calculations. This was used as the starting point for a series of assumptions to derive possible fleet changes: using the average age of a truck in the EU[96] (13 years) to derive a replacement rate of 8% per year, and assuming that in 2020, as the starting year, that 100% of sales were of diesel, a linear trajectory was taken whereby the share of new E-HGV (meaning here a combination of EV types as applied to HGVs, including battery, overhead cables or dynamic induction on an ERS) sales went up to 12% by 2030. This was supplemented with assumptions on hydrogen fuel cell trucks and diesel hybrid vehicles. Based on the expert judgement in the 2018 ITF paper, hybrid HGVs were expected to be widely in use between 2020-2030, whereas hydrogen fuel cell were not expected to be in widespread use until 2030-2050 and after.[97] Like E-HGVs, a linear trajectory from no sales in 2020 to the assumed share in 2030 for each fuel type. From this, the distribution of the fleet across fuel types could be calculated:

Table 6: Assumed HGV fleet, by vehicle type

Freight vehicle fuel type	Share of sales (2030)	Share of fleet (2030)
Diesel	25%	68%
Diesel Hybrid	60%	25%
Electric	12%	5%
Fuel cell (Hydrogen)	3%	1%

To convert this into a change in emission intensity, the forecast life cycle emissions for a series of fuel types were taken from a 2017 International Council on Clean Transportation (ICCT) report.[98] They present forecasts for the life cycle emissions in five year intervals between 2015-2030. As the closest analogue to our baseline year (2019), the reduction in emissions associated with each fuel type vis-à-vis the default (diesel) fuel was taken for 2020-2030. Vehicles sold as diesel were expected to have no change in emission intensity; hybrid diesel approximately 26%; hydrogen fuel cell approximately 71% and E-HGV approximately 84%. As these numbers were derived from the change displayed on an unlabelled graph, they are only rough approximations of the ICCT calculations. Based on the 2030 fleet share for each of the four fuel types, and the associated emissions intensity reduction, a total reduction of 12% in emissions intensity was derived.

Because emission intensity of transport is a combination of fuel efficiency and the emission intensity of fuel, these two values can be combined. In a situation in which the fuel efficiency increases in line with the GFEI target (21% - as described above) and the fleet changes as described above, the total reduction in emissions factor would be **30%**.

The 'upper estimate' scenario applies this combination of vehicle fuel efficiency and decarbonisation of fuel, with a 30% reduction value. The 'lower estimate' scenario considers only the 15% savings pledged by the Zemo Partnership (formerly Low Carbon Vehicle

[96] *'Average Age of the EU Motor Vehicle Fleet, by Vehicle Type | ACEA - European Automobile Manufacturers' Association', accessed 21 May 2021, https://www.acea.be/statistics/article/average-age-of-the-eu-motor-vehicle-fleet-by-vehicle-type.*

[97] *Furtado, 'Towards Road Freight Decarbonisation: Trends, Measures and Policies', fig. 16.*

[98] *Marissa Moultak, Nic Lutsey, and Dale Hall, 'Transitioning to Zero-Emission Heavy-Duty Freight Vehicles' (Washington: The International Council on Clean Transportation, September 2017), fig. 6, https://theicct.org/sites/default/files/publications/Zero-emission-freight-trucks_ICCT-white-paper_26092017_vF.pdf.*

Partnership), voluntary industry-supported target cited in BRC and AIC documents.[99] In both cases, the UKCCC's 10% reduction in distance travelled through efficiency is included.

3.3.3.2 Consumer delivery

Consumer delivery can be broken into two main forms of delivery: food service delivery; and grocery delivery.

For food service delivery, the same vehicular emission factors and reductions as for consumer transport (see 3.3.3.3.2 for more detail) are used, whereby motorcycles are reduced in emission intensity by 2% by E10 biofuel adoption[100] and cars by 29.5% in a low-intensity electricity grid scenario in line with the UKCCC sixth GHG Budget.[101] In addition to these reductions in emissions intensity, a modal shift was assumed whereby the total share of food service deliveries by bicycle increases by 50%. The relative split of motorised delivery between motorcycles and cars was kept constant. This is applied in the main scenario.

For grocery delivery, our scenario was informed by the BRC Roadmap targeting of 100% zero tailpipe emission LCVs by 2030. To inform the life cycle emission reduction associated with electric van and truck usage, adjusted data derived from Yang et al. (2018) was used.[102] In this paper, they compare light and medium diesel trucks with light and medium electric trucks. However, the LCA scope uses the electricity grid in China. In order to make the analysis more accurate to the UK, the relative contribution of electricity generation emissions were read from Figure 4 and then adjusted from Chinese to UK electricity generation, based on the Chinese energy mix provided in the Yang et al. paper and the 2019 UK electricity grid. When based on the UKCCC forecast 2030 grid emission intensity (see 3.3.2.1), emissions for light and medium delivery trucks are reduced 86% and 58% respectively when compared to their diesel counterparts[103]. Based on an assumption that the grocery delivery fleet is comprised of 90% of medium trucks and 10% of light trucks, and that the BRC target of 100% electric LCV is met, this results in a 61% reduction in the emissions intensity of the grocery delivery fleet. This is applied in the main scenario.

In the main scenario, no change in demand beyond the baseline projection was forecast (see 3.2). In reality, delivery sectors are likely to see substantial growth, but will displace some consumer transport in doing so. There was insufficient data to make assumptions on the feedback between these two transport modes and therefore whilst the demand projection is limited, this was a necessary limitation considering the very small part of overall food system emissions it accounts for.

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[99] *BRC, 'Climate Action Roadmap: Net Zero Roadmap for the Retail Industry'; AIC, 'A Roadmap for a Sustainable Food Chain'; Zemo Partnership, 'Zemo Partnership | Accelerating Transport to Zero Emissions', accessed 14 September 2021, https://www.zemo.org.uk/.*

[100] *DfT, 'The Road to Zero: Next Steps towards Cleaner Road Transport and Delivering Our Industrial Strategy', Industrial Strategy report (London: Department for Transport, July 2018).*

[101] *Committee on Climate Change, 'The Sixth Carbon Budget: The UK's Path to Net Zero'.*

[102] *'Life Cycle Assessment of Commercial Delivery Trucks: Diesel, Plug-In Electric, and Battery-Swap Electric',* Sustainability *10, no. 12 (2 December 2018): 4547, https://doi.org/10.3390/su10124547.*

[103] Note that this is quite a different conclusion to that presented in the cited Yang et al. paper, due to the very substantial difference in emissions associated with electricity production in China at the time of the paper's publication and the forecast 2030 UK grid emissions.

3.3.3.3 Consumer transport

Consumer transport for food shopping purposes is split into a number of parameters and intervention scenarios. Within each of these, the impact is applied separately to each mode of transport listed in the National Travel Survey data source (see Section 2.10 for detail on how transport is calculated).

3.3.3.3.1 Transport displacement

The first intervention relates to displacing consumer transport modes. This involves maintaining the same amount of kilometres travelled but changing how they were travelled.

Two possible parameters are considered:

- The share of private journeys made by zero-GHG transport modes; and
- Share of journeys made by public transport.

In 2019, the share of private journeys made by zero-GHG modes (walking and cycling) was 4.5%.

Two alternative scenarios were considered - of which the second was used in the main results scenario:

- The first is taken from a recent DFT document in which they state an intention to double cycling activity and increase walking per person per year[104]. The deadline for this increase was unclear. Based on Figure 13's projection for cycling increases to 2025, a rough 50% increase in zero-GHG modes was approximated. Based on the current share of private journeys, a 50% increase would lead to zero-GHG shopping as 6.7% of private journeys.
- A second, more ambitious, scenario was also considered based on the UKCCC's 'Balanced Net Zero' scenario. They assume that 9% of car miles could be reduced or shifted to zero GHG modes by 2035. At present, cars are responsible for approximately 93% of private travel (i.e. not including public transport), so 9% of car miles amounts to 8.4% of total private journeys being feasibly switched to cycling or walking. Combined with the current share of private journeys which are cycling or walking (approximately 7%), it was assumed that 15% of private journey distance could be completed by walking or cycling in 2030.

Note that this displacement applied only to private modes of transport, i.e. walking and cycling replacing car, van and motorcycle journeys. It was assumed that cycle trips were not displacing bus and other public transport journeys.

The share of journeys made by public transport is similarly a changeable parameter. In 2019, the share of journeys made by public transport was 11%. However, no scenario for modal shift from private to public was identified. As a result, increased public transport was not considered in the main scenario.

3.3.3.3.2 Transport decarbonisation

The second set of changes relates to the emission intensity of vehicles. Alongside zero GHG modes of transport (walking and cycling), four groups of motorised vehicles are considered: private cars; motorcycles; buses; and taxis.

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[104] *DfT, 'Decarbonising Transport: Setting the Challenge' (London: Department for Transport, 2020).*

For private cars, two scenarios were considered - of which the second was used in the main results scenario:

- Firstly, the DFT's decarbonisation report forecasts reduction in GHGs from cars of 52% by 2050 from 2018[105]. Assuming a linear trajectory, by 2030 the emissions of private cars could be reduced by 19.5%.
- The second scenario was based on the UKCCC 'Balanced Net Zero' scenario, which proposes that 43% of the car fleet could be EVs by 2030[106]. To scale this as a reduction in the emissions intensity of the wider car fleet, we assume the non-EV car fleet is constant in its emission intensity, with only EVs reducing overall average emissions. To calculate the reduction in life cycle emissions associated with using EVs, a comparison analysis by Carbon Brief was consulted[107]. This cites a peer-reviewed paper comparing life cycle emissions of different European cars, including the 2019 Nissan Leaf with 40 kWh battery (the best selling EV in Europe and assumed representative of the average EV). In 2019, they estimate the EV to have 29 g/km CO_2e life cycle emissions associated with the fuel cycle (emission from charging), 38 g/km CO_2e associated with manufacture and 28 g/km CO_2e associated with battery manufacture. The total 2019 EV emissions are 94 g/km CO_2e. Compared to the BEIS average car emission factor as 222 g/km in 2019, this entails a 58% reduction in emissions when using an EV. However, the 'fuel cycle' part of an EV footprint relates to electricity emission intensity; as this goes down, so does the EV lifecycle emissions. Therefore, the emissions associated with the UKCCC 'Balanced Net Zero' electricity forecast were also calculated. In this case, total EV emissions are 71 g/km CO_2e, which is equivalent to a 68% reduction in emission intensity when compared to the 2019 average car. When multiplied by the 43% of the fleet which is electric, a reduction of 25-29% in the emission intensity of private car journeys was modelled (value dependent on electricity scenario). In the main scenario, the UKCCC estimate on grid decarbonisation is active, leading to the more substantial (29%) reduction in car emission intensity.

For motorcycles, no roadmaps were identified specifically related to decarbonisation in the near term future. However, the BEIS 'Road to Zero' report[108] includes description of the switch to E10 biofuel, which would be expected to lead to 2% lower emissions than using E5 for the same distance. Assuming no other rapid decarbonisation of motorcycle transport, the E10 reduction was considered appropriate for the main scenario.

For buses, two scenarios were considered - of which the first was used in the main results scenario.

- Firstly, a DFT forecast that, by 2050, bus and coach travel would see a 25% reduction in emission intensity compared to 2018. Assuming linear progression, we would expect a 9.4% reduction by 2030.
- The second scenario is based on the Confederation for Passenger Transport's pledge to only buy ultra-low or zero (tailpipe) emission vehicles from 2025, which is also referred to in the DFT report[109]. This is combined with a calculation from the academic literature that the optimum bus replacement rate is between eight and fourteen years, from which

[105] *DfT.*

[106] *Committee on Climate Change, 'The Sixth Carbon Budget: The UK's Path to Net Zero'.*

[107] *'Factcheck: How Electric Vehicles Help to Tackle Climate Change', Carbon Brief, 13 May 2019, https://www.carbonbrief.org/factcheck-how-electric-vehicles-help-to-tackle-climate-change.*

[108] *DfT, 'The Road to Zero: Next Steps towards Cleaner Road Transport and Delivering Our Industrial Strategy'.*

[109] *'Moving Forward Together | CPT', accessed 23 March 2021, https://www.cpt-uk.org/moving-forward-together/.*

we use the assumption of twelve years on average[110]. Starting in 2025 with twelve year replacement rate, if we assume purchases have been spread out across years, we would expect 43% of the fleet to have been replaced by 2030. However, we did not identify a study which we were able to use quantifying the benefit of adopting 'ultra-low or zero emission' vehicles, in part because it is a term which will encompass many different types. If we were to assume that the reduction is comparable to switching a car to battery electric, the reduction in emissions intensity of buses could be as high as 28% by 2030. However, due to the uncertainty of such assumptions, the more conservative DFT forecast of 9.4% reduction was used for the main scenario.

For taxis, the values were inferred from the 'Road to Zero' report[111]. This states that taxi fleets are expected to be capable of zero (tailpipe) emission journeys faster than the private fleet, and that the government was exploring mandatory measures for taxi fleets in urban areas to be capable of zero emission journeys by 2032. Based on this, an assumption was made of the share of the taxi fleet which could be expected to be EV by 2030: this was assumed to be 80% higher than the private fleet. Using the UKCCC expectations of the private fleet, this amounts to 77% of the taxi fleet being EV. Using the same emission reductions as private vehicles associated with this switch multiplied by the fleet share, a reduction in emissions between 45-53% was derived (energy scenario dependent). In the main scenario, the UKCCC estimate on grid decarbonisation is active, leading to the more substantial (53%) reduction in car emission intensity.

3.3.3.3.3 Transport demand

A third lever of change is a reduction in the demand for shopping-related travel. This could be achieved through greater distribution of stores allowing for shorter journeys, more infrequent, bigger shops or through greater efficiency of journeys, through car sharing or multi-purpose trips. Similarly, a reduction in travel may be associated with an increase in grocery delivery.

No scenarios were identified explicitly targeting a reduction in transport demand. As a result, and to be conservative in the main scenario, we did not anticipate any reduction in demand.

3.3.4 Other

3.3.4.1 Packaging

For packaging, a scenario was included that estimated reductions in emissions that could be achieved through greater use of closed-loop recycled material in food & drink packaging.[112]

WRAP data on the differing emissions factors for closed-loop recycled and virgin material for each packaging type was used. Using these figures, it is possible to estimate the potential GHG reduction achievable through increasing the use of recycled content (Table 7).

[110] *William Emiliano et al., 'An Optimization Model for Bus Fleet Replacement with Budgetary and Environmental Constraints',* Transportation Planning and Technology *43, no. 5 (3 July 2020): 488–502, https://doi.org/10.1080/03081060.2020.1763656.*

[111] *DfT, 'The Road to Zero: Next Steps towards Cleaner Road Transport and Delivering Our Industrial Strategy'.*

[112] *WRAP, 'Carbon Waste and Resources Metric'; Daw et al., 'PackFlow Covid-19 Phase II'.*

Table 7: GHG reduction achievable through increasing the use of recycled content

Material type	Reduction in emission factor switching from virgin to closed-loop material
Paper and board	13%
Glass	41%
Steel	62%
Aluminium	77%
Plastics	27%
Other (assumed wood)	76%

For the main scenario, we made a broad assumption - across nearly all packaging types – that an additional 15% total packaging could be replaced with closed-loop recycled content by 2030. Plastics was the exception, with 20% being modelled, based on current closed loop recycling rates in plastic packaging and the incoming tax on plastic with less than 30% recycled content[113]. This was applied in the main scenario.

A scenario investigating an overall reduction in packaging production was not included at this stage - due to uncertainties in how such a reduction might influence other factors, such as the amount of food waste. WRAP is undertaking further work looking at the effect of packaging on food waste (e.g. packed versus loose fresh produce items). With further evidence on these effects, there is future potential to add additional scenarios in this area – for example, investigating the effects of reducing packaging emissions through greater reuse, light-weighting, provision of loose product, etc.

3.3.4.2 Refrigerant

Estimates relating to the degree to which refrigerant emissions could be reduced were taken from an academic paper which explicitly examined the possibility of reducing refrigerant-based emissions in UK retail[114]. It was assumed that these reductions in refrigerant in UK retail would be applicable to all other stages with refrigerant emissions, such as in transport, HaFS & food service or manufacturing.

The authors present three costed scenarios. The core scenario adheres to legislation by replacing HFCs and was estimated to lead to a 71% reduction by 2030. In higher-ambition scenarios reductions of 93% and 99% could be achieved - but with varying cost profiles.

For the purposes of the main scenario, the 71% core scenario was used - but it should be acknowledged that greater investment could allow even further reductions in refrigerant-based emissions.

[113] *For current plastic packaging information, for all packaging and not just food packaging, see: WRAP, 'The UK Plastics Pact', accessed 9 October 2021, https://wrap.org.uk/taking-action/plastic-packaging/the-uk-plastics-pact; For plastic tax, see: HMRC, 'Introduction of Plastic Packaging Tax from April 2022', GOV.UK, accessed 9 October 2021, https://www.gov.uk/government/publications/introduction-of-plastic-packaging-tax-from-april-2022/introduction-of-plastic-packaging-tax-2021.*

[114] *Matthew Hart et al., 'A Roadmap Investment Strategy to Reduce Carbon Intensive Refrigerants in the Food Retail Industry',* Journal of Cleaner Production *275 (December 2020): 123039, https://doi.org/10.1016/j.jclepro.2020.123039.*

3.3.4.3 Waste treatment

The UKCCC recommend a ban on organics going to landfill from 2025, which is consistent with proposals for mandatory food waste separation and treatment for households and businesses.[115]

In the main scenario, we assume that the compliance rate for this is high, leading to a 90% reduction in the waste being landfilled in 2030. Of this, some 50% is assumed recycled (compost / anaerobic digestion) with the other half recovered (such as through energy-from-waste).

WRAP data on the annual tonnages of food sent to landfill, recycled and recovered at each stage of the food system were combined with projections for food waste arisings in 2030 and emissions estimates, to quantify emissions associated with disposal. These projections were derived from the food waste reduction scenario (see Section 3.3.5.2). Note that, as a result, the impact of reducing the amount of waste to landfill interacts with food waste reduction: as food waste is decreased, the benefit of diversion is reduced.

3.3.5 Whole system interventions

The GHG model works by building up a food system emission profile stage-by-stage and assigning emissions to the different supply chain stages, rather than to the volume or composition of food types produced, processed and distributed. However, not all possible interventions relate to these stages specifically. Some interventions - notably those that affect what we produce and how much of it we produce – have implications across the entire system.

Two interventions of this nature: related to dietary change (Section 3.3.5.1) and food waste prevention (Section 3.3.5.2) were therefore considered separately, with the emissions reductions subsequently applied to the entire food system rather than being allocated to specific stages.

3.3.5.1 Dietary Change

The GHG model's mode of calculation is top down by supply chain stage rather than by product group. This means that we consider the emissions across an entire stage (e.g. agriculture, manufacture, transport) regardless of the food products which pass through that stage. We do not attempt to allocate those emissions to different product types.

However, the composition of the final consumer plate and dietary choices are relevant as they determine, for example, what agricultural products are produced in the UK (and how much processing they need), and the balance of imports and exports of food & drink items, ingredients and feedstuffs.

Influencing the types of food & drink consumed (and therefore produced) are a well-documented lever for improving the sustainability of the food system. It is therefore considered here as a possible intervention, with aggregate impacts across all food system stages.

Using the total estimate of food system GHG emissions (see Section 4.0) it is possible to create a 'top down' estimate of average daily dietary consumption. Taking total emissions in

[115] *Committee on Climate Change, 'The Sixth Carbon Budget: The UK's Path to Net Zero'.*

2019 as 158 $MtCO_2e$, adjusting to a daily value and dividing by population, we derive an estimate of the average footprint of food consumption emissions per person in the UK to be 6.5 $kgCO_2e$ / capita / day.

This approach contrasts with most dietary models, which work on the basis of examining the composition of the consumer plate and using life-cycle assessment (LCA) data for specific food groups to build up an estimate of consumption-based emissions. However, despite different approaches, the value derived in this study for the footprint of food consumption (6.5 $kgCO_2e$ / capita / day) is comparable to – albeit higher than – a recent (2017) estimate from WWF of the footprint of adult diets (cited as 5.8 $kgCO_2e$ / capita / day [116]). The reason for this difference could be due to both the relative completeness of the top down food system estimate; as well as differences in underlying data sources. However, the relativeness closeness of the comparison gives us confidence in the approach used (and that emissions are not being underestimated).

To estimate the possible emissions reductions associated with dietary change, a recent paper examining the possible environmental effects of widespread adoption of the Eatwell Guide (the nationally recommended diet) was considered.[117] This publication uses data from multiple studies to estimate the health and environmental impacts of greater adherence to the recommendations outlined in the Eatwell Guide. It presents possible reductions (in $kgCO_2e$) associated with increasing adherence to the Eatwell Guide recommendations, specifically from moving from either 'very low' adherence (adopting 0-2 of the recommendations in Eatwell) or 'low' adherence (adopting 3-4 recommendations) to 'intermediate to high' adherence (adopting 5-9 recommendations).

Because of the differences in methodology between top-down dietary estimates and LCA-based dietary estimates, rather than use these kg values directly, they were converted into a percentage reduction in dietary emissions. Moving from 'low' to 'intermediate to high' adherence corresponds to a 13% decrease in dietary emissions, and from 'very low' to 'intermediate to high' a 30% reduction is reported in the paper. These were combined with current levels of adherence as displayed in the paper, to generate a weighted average percentage change.[118] This meant, for example, that those already 'intermediate to high' do not see any reduction in their dietary emissions. These values are displayed in Table 8.

Table 8: Current adherence and GHG savings from higher Eatwell adherence, derived from Scheelbeek (2020)

Level of adherence	Approximate % of population	Reduction in dietary GHGs associated with a switch to 'intermediate-high adherence'	Reduction weighted by share of population
Very low adherence (0-2)	25%	30%	7%
Low adherence (3-4)	44%	13%	6%
Intermediate to high adherence (5-9)	31%	n/a	n/a

[116] *Gerard Kramer et al., 'Eating for 2 Degrees: New and Updated Livewell Plates' (WWF, August 2017), https://www.wwf.org.uk/eatingfor2degrees.*

[117] *Pauline Scheelbeek et al., 'Health Impacts and Environmental Footprints of Diets That Meet the Eatwell Guide Recommendations: Analyses of Multiple UK Studies',* BMJ Open *10, no. 8 (August 2020), https://doi.org/10.1136/bmjopen-2020-037554.*

[118] *Scheelbeek et al., fig. 1.*

Using this weighted average it was derived that an average reduction in dietary emissions of approximately 13% would be possible through improved adherence to the Eatwell Guide.

This value was used as the possible reduction in dietary emissions by 2030.

Because these emissions will arise across the entire food system, we have not attempted to disaggregate these emissions reductions across different stages. Most of the savings are expected to be realised in the primary production stages, as this is where differences in emissions between different product types are greatest, but it was not possible within the scope of work to determine *where* these reductions would occur (e.g. changes to UK agricultural production, or changes to the composition of net imports).

We have applied this as a reduction in GHG emissions across the whole food system – but we note that this may be an over-estimate – or double count emissions savings elsewhere – because dietary emissions in our 2030 scenario will reduce regardless of whether diets change (because of improvements of agricultural efficiency, decarbonisation of electricity and transport etc). However, the majority of the emissions reductions reported in the Scheelbeek et al paper are a result of switches from higher emissions food types to lower emissions food types. There is uncertainty in the relative rate of reduction in emissions between these food types (e.g. whether plant-based or meat-based food decarbonise quicker). If decarbonising at a similar rate then switches between food types could still result in a similar % change (albeit a lower absolute reduction, as emissions for all food types are reduced).

3.3.5.2 Food waste prevention

Food waste[119] emerges across the entire food system. To calculate the potential for reducing food system GHG emissions through reducing food waste, we therefore needed to consider emissions across every stage in the value chain.

The food waste calculations were split into two distinct parts, each of which took a number of steps. An abridged summary of these steps is as follows, with further detail below.

Firstly, we calculated the **emissions associated with food that ends up as waste**[120]. This was achieved through the following steps:

i. Quantify food waste arising at each stage of the value chain.
ii. Calculate the embodied emissions associated with food at each stage of the value chain.
iii. Calculate the emissions associated with disposal of food at each stage of the value chain.
iv. Normalise the food system emissions by tonnes purchased for consumption (tCO_2e/tonne food).
v. Combine values (ii), (iii) and (iv) to derive (for each stage): the embodied emissions (tonne CO_2e) and disposal emissions (tonne CO_2e) for a tonne of food which is lost or wasted.

[119] The term 'food waste' in this report is used to cover both food and drink, and what others may refer to as 'food loss and waste' – i.e. food that goes to any of the eight destinations defined as waste under the UK Food Waste Reduction Roadmap, from any stage of the food system.

[120] This includes both wasted food (what some refer to as 'edible parts') and the associated inedible parts.

vi. Combine values (v) and (i) to derive the scale of emissions associated with wasted food per year.

Following this first stage, calculations were undertaken to forecast the **emissions savings associated with preventing food waste**. This required the following steps to be taken:

vii. Estimate the scale of potential food waste prevention (tonnes) by 2030 across each stage in the value chain.

viii. Estimate the proportion of the food waste prevention (vii) that is either *avoided* waste (meaning the waste does not arise) and the share which is *reduced* (meaning that there is still surplus material, but it is diverted from waste treatment – e.g. by redistributing it, using for animal feed or valorising into industrial products, etc.). Of waste *reduced*, this was further disaggregated into an estimate of the proportion that would be either redistributed to humans; or used for other purposes (e.g. animal feed or industrial products).

ix. For the share *avoided* and the share *redistributed to humans* – determine assumptions regarding the degree to which this action results in the *reduction of food ingredient / food purchases* – and the avoided need to produce these items.

x. Combine food waste prevention (vii) with disposal emissions (iii) to derive the reduction in disposal emissions through food waste prevention.

xi. Combine the estimated reduction in food ingredient / food purchases (ix) with embodied emissions data (ii) to derive the potential emissions reduction through avoiding the production of these purchases.

xii. Combine disposal emissions (x) and avoided production emissions (xi) to derive a total estimate for the potential reduction in GHG emissions that could result from food waste prevention.

The calculation steps, data sources and assumptions are outlined in more detail below.

i. Quantify food waste arising at each stage of the value chain

The food chain was split into five stages - consistent with the stages used in WRAP reporting.

Directly measured waste data is available for food waste at the manufacturing, retail, HaFS and household stages[121].

For food waste arising in primary production, WRAP's modelled indicative estimate is used[122] - with two adjustments to reflect the broader scope of this assessment. WRAP's modelled estimate for food waste in primary production only estimates a single year, and only considers food for direct human consumption. Crops grown for animal feed are not included and they are not included within the definition of 'food waste'. The methodology detailed in the paper was therefore re-created with small adjustments for scope:

- Primary production from fisheries was included where they had not been previously; and

[121] *WRAP, 'UK Progress against Courtauld 2025 Targets and UN Sustainable Development Goal 12.3'.*

[122] *WRAP, 'Food Waste in Primary Production in the UK' (Banbury, July 2019), https://wrap.org.uk/resources/report/food-waste-primary-production-uk.*

- The share of crops grown directly for feeding to animals was included. We note that this is not considered 'food waste' – but has been included here for completeness.[123]

We note the significant uncertainty in this modelled estimate for primary production, which is an ongoing data limitation – and WRAP is undertaking further work to improve estimates.

WRAP directly observed estimates were last reported for the year 2018. The primary production estimate, as a calculation based on commodity-specific production figures, was extended to 2019. As all other stages considered in this modelling use 2019 as the final year of observation, the food waste estimates were normalised to 2019. To do this, it was assumed that across manufacturing, retail, HaFS and household, the *per capita* food waste has stayed the same as in 2018. This assumes that no further progress has been made towards the SDG 12.3 target, which is measured on a per capita basis. This is consistent with the assumptions and population-based extrapolations used elsewhere in this model (see Section 3.2). As a result, the modelled total food waste in tonnes increases slightly from 2018-19, in line with population growth. <u>This estimate is for the purposes of consistency across this model and does not constitute an estimate by WRAP of actual food waste per sector in 2019.</u>

ii. Calculating the embodied emissions associated with each stage of the value chain

In order to calculate the embodied emissions associated with each stage of the food value chain, each component of the food system GHG emissions (as outlined in Section 2.0) was allocated to a stage of the food value chain. Each sequential stage is additive, so includes the emissions per tonne from the prior stage.

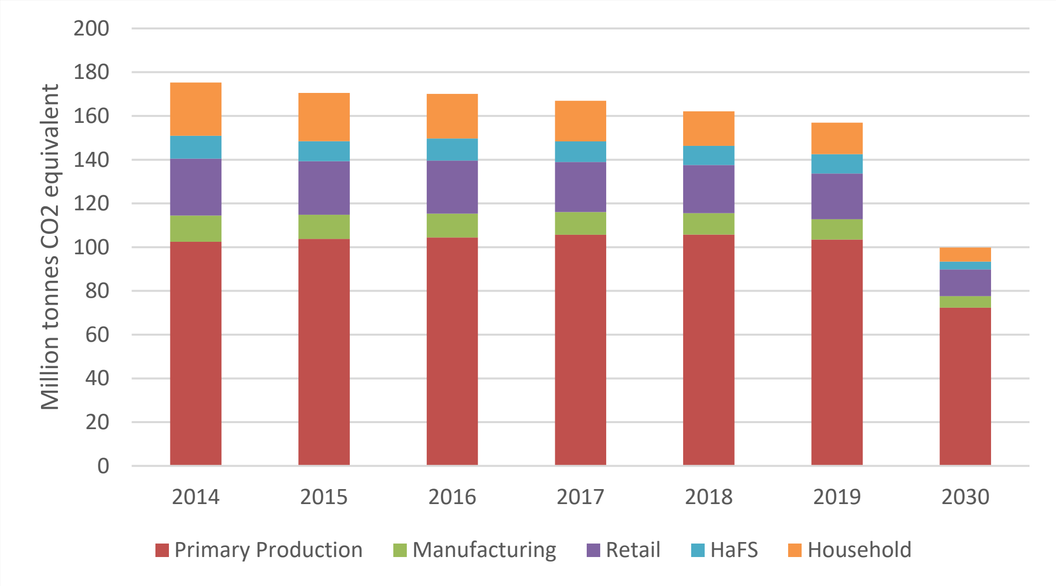
Figure 1 shows this allocation of food system GHG emissions across different value chain stages, and how this changes over time (and is projected to change).

Note - for the purposes of forecasting the potential reduction in GHG emissions through food waste prevention in 2030, the embodied emissions were calculated based on the forecast emissions in 2030 (rather than current emissions levels) – as shown in Figure 1. The estimated emissions reductions from reducing food waste were therefore calculated as a second stage after all other interventions described in Section 3.0 had been applied.

The implications of this are simply that as the food system decarbonises, the GHG 'savings' from preventing food waste also reduce.

[123] Estimates for animal feed suggest that between 2015-2019, production for animal feed accounted for approximately 20-23% of total primary production (between 11.7-14.6 million tonnes). However, animal feed waste accounted for between 10-12% of total primary production waste (between 0.18-0.21 million tonnes).

Figure 1: Emissions per value chain stage



iii. Calculating the emissions from waste disposal at each stage of the value chain

Quantifying disposal emissions was based on the approach described in Section 2.14. The same data sources, emissions factors and calculations are used for estimating disposal emissions for each value chain stage, up until 2019.

For the 2030 forecast, the emission factors are adjusted in line with the intervention in Section 3.3.4.3. For each stage, the emission factor is therefore reduced in line with the reduction associated with the landfill ban – and, as the waste treatment of food becomes less carbon intensive, the disposal emissions saved by avoiding food waste are reduced.

The calculations described in that Section 3.3.4.3 involve building up estimates stage-by-stage and deriving a whole-system waste disposal emission estimate. This calculation therefore uses the stage-specific results without aggregating them.

The exception to this process is the disposal emissions associated with primary production waste. This waste is believed to primarily be left on the land and ploughed back in or re-applied to land as a form of fertiliser. This means that the emissions associated with the application of this food waste is already accounted for in the agricultural emission statistics (see Section 2.3.1) – and so we do not add in additional emissions here, to avoid double-counting.

iv. Normalising by tonnes purchased for consumption

In order to apply the total embodied emission estimates (see part ii) to food waste arisings, it was necessary to normalise the total emissions ($MtCO_2e$) into a rate of embodied emissions (tCO_2e/tonne food). To do this, a metric for food consumption which could be used as a benchmark for the food system was needed. There was a need for this normalising unit to be something which is tracked over time, accessible and credible.

The approach taken was to use data available on purchases for consumption collected by Defra in the Family Food Survey (FFS).[124] This collates information both on household food purchases for consumption at the home (i.e. primarily from retail) but also purchases for consumption at HaFS establishments. The final point of purchase is also the logical end point of the food system: all stages before it operate in order to eventually reach the consumption stage.

v. Deriving emissions estimates for a tonne of food lost or wasted at each stage in the value chain

Based on the calculated data, two normalised values were identified for each stage in the value chain:

- The embodied emissions (tCO_2e) per tonne of food purchased. This was calculated as total emissions at that stage (see part ii) divided by the volume of food purchased for consumption (see part iv)
- The disposal emissions (tCO_2e) per tonne of food disposed (see part iii).

These normalised values for 2019 are displayed in Table 9. Note that the relatively low disposal emissions is partly driven by the consumption-based scope of the analysis, which attributes recycling-based emissions to new products rather than waste disposal. This is explained in Section 2.14.

Table 9: Normalised embodied and disposal emissions per stage

Supply chain stage	2019 Embodied emissions (tCO_2e/t purchased)	2019 Disposal emissions (tCO_2e/t wasted)	2030 Embodied emissions forecast (tCO_2e/t purchased)	2030 Disposal emissions forecast (tCO_2e/t wasted)
Primary Production	2.38	0.00	1.58	0.00
Manufacturing	2.59	0.02	1.70	0.02
Retail	3.07	0.00	1.97	0.00
HaFS	3.27	0.12	2.04	0.01*
Household	3.40	0.08	2.11	0.03

*To note - the big decrease in disposal emissions here is because the HaFS Sector has the largest share of waste disposed to landfill – which reduce significantly under the 2030 'landfill ban' scenario (see Section 3.3.4.3). The importance of landfill is magnified by the data gap around waste to sewer, as mentioned in 2.14.

NB – where values are zero, this is because there is no waste sent to landfill (the only disposal route for which emissions are attributed, in compliance with the GHG protocol)

vi. Deriving the scale of emissions associated with UK food waste

For each stage, the normalised values per tonne (see part v) are combined with the amount of food wasted (see part i). With this, it is possible to estimate the embodied and disposal emissions associated with wasted food, and combine these to form an estimate of total emissions. This total annual estimate of emissions associated with UK food waste is shown in Table 10.

[124] *Defra, 'Family Food Datasets'.*

Table 10: Emissions associated with UK food waste

All expressed as million tonnes CO_2e	2015	2016	2017	2018	2019
Embodied emissions	**41.4**	**42.0**	**42.7**	**37.1**	**35.1**
… Primary production	4.4	4.3	5.1	4.2	4.1
… Manufacturing	4.7	4.7	4.6	4.1	3.9
… Retail	0.9	0.9	0.9	0.9	0.9
… HaFS	3.7	3.9	4.0	3.8	3.6
… Household	27.7	28.2	28.1	24.1	22.6
Disposal emissions	**1.3**	**1.1**	**0.9**	**0.8**	**0.7**
… Primary production	0.00	0.00	0.00	0.00	0.00
… Manufacturing	0.03	0.03	0.02	0.02	0.02
… Retail	0.00	0.00	0.00	0.00	0.00
… HaFS	0.23	0.19	0.15	0.14	0.14
… Household	1.09	0.91	0.75	0.61	0.52
Total emissions	**42.7**	**43.1**	**43.6**	**37.9**	**35.7**

* NB – a small proportion (0.16-0.2 $MtCO_2e$) of this is wasted feed, as opposed to wasted food

Please note - these values differs from the estimate reported previously in the Courtauld milestone report, where emissions associated with wasted food were reported as 29 $MtCO_2e$ in 2015 and 25 $MtCO_2e$ in 2018.[125] There are three main reasons for this difference:

- This estimate of food system emissions is more comprehensive than previous estimates – and fills some key data gaps, which has increased the overall emission estimate.
- The calculation method has been improved - by better representing the attribution of embodied emissions to different stages of the supply chain. As a result, the additional embodied impact of waste in the home (in comparison to e.g. waste in primary production or manufacturing) is larger. As household food waste is the biggest overall volume, this had led to an increase in emissions.
- The addition of an estimate for food waste in primary production means that a greater proportion of total UK food waste (and associated emissions) is captured.

It was not possible to extend this analysis to include an estimate of emissions linked to food waste which occurs *outside* of the UK – because sufficient data on the scale of waste arisings is not available. As an approximation of potential scale – if we assume that domestic and overseas food production are similar in scale (by volume), we could assume that waste volumes (and associated emissions) could be similar in scale to the emissions estimate for primary production + manufacture in Table 10 = an additional c. 8$MtCO_2e$ in 2019. However, this warrants further investigation.

When compared with the total emissions associated with the food system (see Section 4.0), this suggests that the share of total food system emissions linked to the production & distribution of food which is then wasted is approximately 23%, down from 25% in 2015 as a result of ongoing food system decarbonisation efforts.

These findings are comparable to other estimates: for example, it has been reported elsewhere that approximately one quarter of food emissions come from food lost and

[125] *WRAP, 'UK Progress against Courtauld 2025 Targets and UN Sustainable Development Goal 12.3'.*

wasted.[126] Likewise, based on a recent publication, in 2015 the global food system contributed some 34% to total anthropogenic GHG emissions.[127] If applied to the UK and combined with our estimate that in 2015 25% of the UK's food system emissions were associated with wasted food, some 8% of total emissions could be attributed to food waste. This is comparable to the oft-quoted FAO figure suggesting that, globally, some 8% of anthropogenic emissions are from global food losses and waste.[128] More recently, the WWF have updated this estimate to 10% through a new estimation of on-farm losses on-farm losses.[129] Given that our estimate does not include overseas farm losses, were these to be included, it is likely that the figures would remain comparable. Whilst the scopes of these estimates are typically global rather than specific to the UK, the ballpark similarities can act as a sense-check of the results here.

vii. Identifying food waste prevention potentials

The potential food waste prevention tonnages achievable by 2030 are derived from WRAP forecasts and modelling, building on previously published analysis and evidence[130]. Two different scenarios are considered, which vary based on the scope of food waste prevention targets:

1. Achieving SDG12.3 based on applying the 50% reduction target to the wasted food ('edible' parts) fraction (Scenario 1: SDG12.3 [Wasted food])
2. Achieving SDG12.3 based on applying the 50% reduction target to total food waste (i.e. the wasted food fraction plus associated inedible parts) (Scenario 2: SDG12.3 [Total food waste])

UN SDG12.3 was announced in 2015:

"By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses".

In the absence of detailed guidance from the UN on the scope of SDG12.3, The Champions 12.3 Group issued their own global guidance[131] in 2017. This stated that countries and companies should:

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[126] *Hannah Ritchie, 'Food Waste Is Responsible for 6% of Global Greenhouse Gas Emissions', Our World in Data, 18 March 2020, https://ourworldindata.org/food-waste-emissions.*

[127] *M. Crippa et al., 'Food Systems Are Responsible for a Third of Global Anthropogenic GHG Emissions',* Nature Food*, 8 March 2021, https://doi.org/10.1038/s43016-021-00225-9.*

[128] *Nadia Scialabba, 'Food Wastage Footprint & Climate Change' (FAO, 2015), http://www.fao.org/documents/card/en/c/7338e109-45e8-42da-92f3-ceb8d92002b0/.*

[129] *WWF-UK, 'Driven to Waste: The Global Impact of Food Loss and Waste on Farms' (Woking: WWF-UK, 2021), https://wwf.panda.org/discover/our_focus/food_practice/food_loss_and_waste/driven_to_waste_global_food_loss_on_farms/.*

[130] *WRAP, 'UK Food Waste – Historical Changes and How Amounts Might Be Influenced in the Future' (Banbury: WRAP, 2014), https://wrap.org.uk/resources/guide/uk-food-waste-historical-changes-and-how-amounts-might-be-influenced-future; WRAP, 'Quantification of Food Surplus, Waste and Related Materials in the Grocery Supply Chain' (Banbury: WRAP, May 2016), https://wrap.org.uk/resources/report/quantification-food-surplus-waste-and-related-materials-supply-chain; WRAP, 'UK Progress against Courtauld 2025 Targets and UN Sustainable Development Goal 12.3'; WRAP, 'Net Zero: Why Resource Efficiency Holds the Answers'.*

[131] *Champions 12.3, 'Guidance on Interpreting Sustainable Development Goal Target 12.3', October 2017, https://champions123.org/publication/guidance-interpreting-sustainable-development-goal-target-123.*

- Measure and report amounts of both wasted food & inedible parts (i.e. total food waste[132])
- Report progress vs SDG12.3 on the basis of total food waste OR wasted food only (i.e. the 'edible' parts'), if there is the ability to separately measure the latter
- Apply the '50%' target reduction from 'farm to fork'

The UK has followed the Champions 12.3 Guidance, and most recently published an update of UK food waste in January 2020.[133] This report contained a comprehensive set of data on the absolute (tonnages) and relative (per capita) levels of food waste from households, HaFS, retail and manufacture, and how these had changed compared to the UK baseline (2007) and the last published update in 2015. Changes were reported for both total food waste and separately for the wasted food ('edible') fraction. Based on the latter the UK reported a reduction of 27% compared to the SDG12.3 50% target, suggesting the UK was around halfway to achieving SDG12.3.

UNEP is the custodian of the Food Waste Index (FWI), which tracks food waste generation at global level (that is the '50%' part of SDG12.3). Details of the FWI were published in March 2021[134], and require countries to:

- Measure and report amounts of both wasted food & inedible parts (i.e. total food waste)
- Report progress vs SDG12.3 on the basis of total food waste (not wasted food only (i.e. the 'edible' parts')
- Apply the '50%' target reduction to households, retail and HaFS only (but the FWI does allow the reporting of food waste from manufacture not covered by the Food Loss Index)

The report also states 'disaggregation by edible and inedible parts is valuable to policymakers in guiding policy interventions to make the best possible use of food resources, supporting a circular food system and the application of the waste hierarchy', but recognised that currently few countries have the ability to disaggregate their food waste data (the UK being one). In order to simplify reporting, this disaggregation is proposed as an advanced reporting option.

The UK/WRAP already publish the information required by the FWI, but going forwards will publish progress against SDG12.3 on the basis of both total food waste and on wasted food separately.

WRAP will continue to follow the Champions 12.3 guidance to apply the 50% reduction target across all sectors (where data is available, i.e. excluding pre-farm gate until the evidence base for this part of the supply chain is sufficiently robust), and will continue to report data on food waste at a sector level and aggregated for the UK.

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[132] Total food waste = wasted food (i.e. the parts which were intended for human consumption, sometimes referred to the 'edible' fraction) + inedible parts (i.e. those parts associated with food that are not intended to be consumed (such as bones, egg shells). A food waste prevention programme is much more likely to be focused on and affect wasted food rather than the inedible parts, especially from households, retail and HaFS

[133] *WRAP, 'UK Progress against Courtauld 2025 Targets and UN Sustainable Development Goal 12.3'.*

[134] *Hamish Forbes, Tom Quested, and Clementine O'Connor, 'Food Waste Index Report 2021' (Nairobi: United Nations Environment Programme, 2021), https://wedocs.unep.org/bitstream/handle/20.500.11822/35280/FoodWaste.pdf.*

Because significant progress has already been made towards the SDG 12.3 target, the reductions expressed are additional reductions from 2018 until 2030.

In the <u>lower estimate scenario</u>, where a 50% reduction in **wasted food** is achieved (compared to a 2007 baseline), the total food waste reduction per capita from 2019 to 2030 is 23%, split unevenly across sectors (see Table 10).

In the <u>upper estimate scenario</u>, a 50% reduction in **total food waste** is achieved, compared to a 2007 baseline. The total reduction in food waste per capita from 2019 to 2030 amounts to 37%, also split unevenly between sectors (Table 11). In this scenario it is not possible to achieve a 50% reduction in total food waste from reductions in wasted food only. Projected levels of wasted food are lower than those in Scenario 1 (achieving ca 60% per capita reduction compared to the 2007 baseline, the maximum thought realistic based on WRAP's analysis and experience), but in order to achieve the overall 50% reduction in total food waste there would also need to be a reduction in the levels of inedible parts (of around 645,000 tonnes).

The reduction observed to 2018 and modelled up to 2030 across the different sectors is displayed in Table 11 for the lower estimate scenario and Table 12 for the upper estimate scenario.

As previously mentioned, food waste at primary production is not part of the 50% target due to insufficiently robust data. As a result, it is not included in Table 11 and Table 12. The modelling of primary production waste, based on previous WRAP publication with adjustments to the method to account for animal feed and fisheries (see part i), for the years 2015-2019 is displayed in Table 13. The modelled reduction for primary production is the same in both waste scenarios and is based on expert judgement within WRAP. The reduction by 2030 amounts to 13.5%, so this value is used in both scenarios.

Table 11: Actual (2007 to 2018) and modelled (2018 to 2030; lower estimate scenario) changes in UK wasted food

	2007			2018			2030			% reduction (2007 to 2030; per capita)	% reduction (2018 to 2030; per capita)
	Total food waste (t)	Wasted food (t)	Wasted food per capita	Total food waste (t)	Wasted food (t)	Wasted food per capita	Total food waste (t)	Wasted food (t)	Wasted food per capita		
Household	8,100,000	6,100,000	100	6,600,000	4,500,000	68	5,300,000	3,200,000	46.7	53.3%	22.4%
Retail	290,000	290,000	4.7	277,000	277,000	4.2	200,000	200,000	2.9	38.3%	30.2%
Manufacture	1,900,000	1,100,000	16.9	1,500,000	770,000	11.6	1,300,000	540,000	7.9	53.3%	16.2%
HaFS	920,000	680,000	10.7	1,100,000	810,000	12.2	800,000	510,000	7.4	30.8%	29.7%
Total	**11,200,000**	**8,200,000**	**132**	**9,477,000**	**6,400,000**	**96**	**7,600,000**	**4,475,000**	**64.9**	**50.8%**	**22.5%**

Table 12: Actual (2007 to 2018) and modelled (2018 to 2030; upper estimate scenario) changes in total UK food waste

	2007		2018		2030		Reduction in tonnage required to achieve SDG12.3 (2018 to 2030)			% reduction per capita		
	Total food waste (t)	Total food waste per capita	Total food waste (t)	Total food waste per capita	Total food waste (t)	Total food waste per capita	Wasted food (t)	Inedible parts (t)	Total food waste (t)	2007-2018	2007-2030	2018-2030
Household	8,100,000	132	6,600,000	100	4,400,000	63	1,827,000	373,000	2,200,000	24.2%	52.3%	37.0%
Retail	290,000	5	277,000	4	188,000	3	89,000	n/a	89,000	10.6%	42.0%	35.7%
Manufacture	1,900,000	30	1,500,000	23	1,050,000	15	230,000	220,000	450,000	24.6%	49.9%	33.9%
HaFS	920,000	15	1,100,000	17	685,000	10	363,000	52,000	415,000	-13.7%	32.6%	40.6%
Total	**11,210,000**	**181**	**9,477,000**	**143**	**6,323,000**	**91**	**2,509,000**	**645,000**	**3,154,000**	**20.9%**	**50.1%**	**36.9%**

Table 13: Modelled food waste in primary production (2015-2019) and forecast reduction (2030)

Primary production food waste	2015	2016	2017	2018	2019	[...]	2030 forecast reduction
Tonnes	1,747,731	1,643,671	1,876,102	1,681,522	1,721,513	[...]	1,569,565
kg/capita	27	25	28	25	26	[...]	22

viii. Estimating the type of food waste prevention

Food waste prevention can be achieved either by avoiding the generation of food surplus or waste or by diverting surplus to a non-waste destination, such as redistribution or animal feed production. In this analysis we use the following terminologies and assumptions:

- Food waste ***prevention*** is the prevention of food becoming waste by any means. This includes either avoiding waste generation in the first place, or diverting food surplus away from waste disposal / treatment routes, to instead be put to productive use - e.g. by redistributing it, using for animal feed or valorising into industrial products, etc. <u>All types of food waste prevention contribute to the progress towards SDG 12.3.</u> The values described in part vii are all food waste *prevention.* But these volumes of prevented waste can be further defined as either food waste *avoidance* and food waste *reduction* – with implications for how emissions reductions are estimated.
- Food waste ***avoidance*** is where any surplus or waste is avoided from occurring in the first place (i.e. meaning the waste does not arise) - for example through better planning, purchasing more appropriate amounts of food, etc. In most – but necessary not all – cases this action results in the *reduction of food or ingredient purchases*. For example, if a manufacturer avoids waste arising and needs less inputs to produce the same level of outputs.
- Food waste ***reduction*** is the diversion of food surplus to another productive, non-waste destination, such as redistribution to humans, conversion to animal feed or valorisation into other industrial products. The implication here is that the *same amount of food or ingredients are purchased*, but now there are additional products – which are put to productive uses.

There are some important differences between waste avoidance and waste reduction, in terms of the potential to reduce GHG emissions. These are explained visually in diagrams presented in Figure 2, Figure 3 and Figure 4, and described further in part ix.

Figure 2: Waste *avoidance* in the supply chain

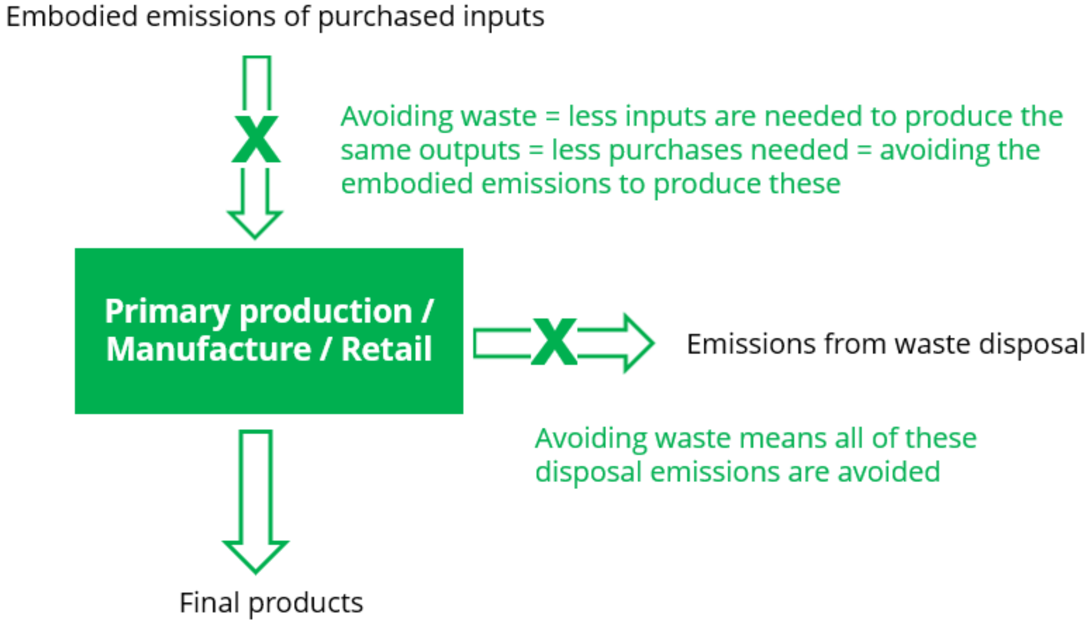


Figure 3: Waste *reduction* in the supply chain

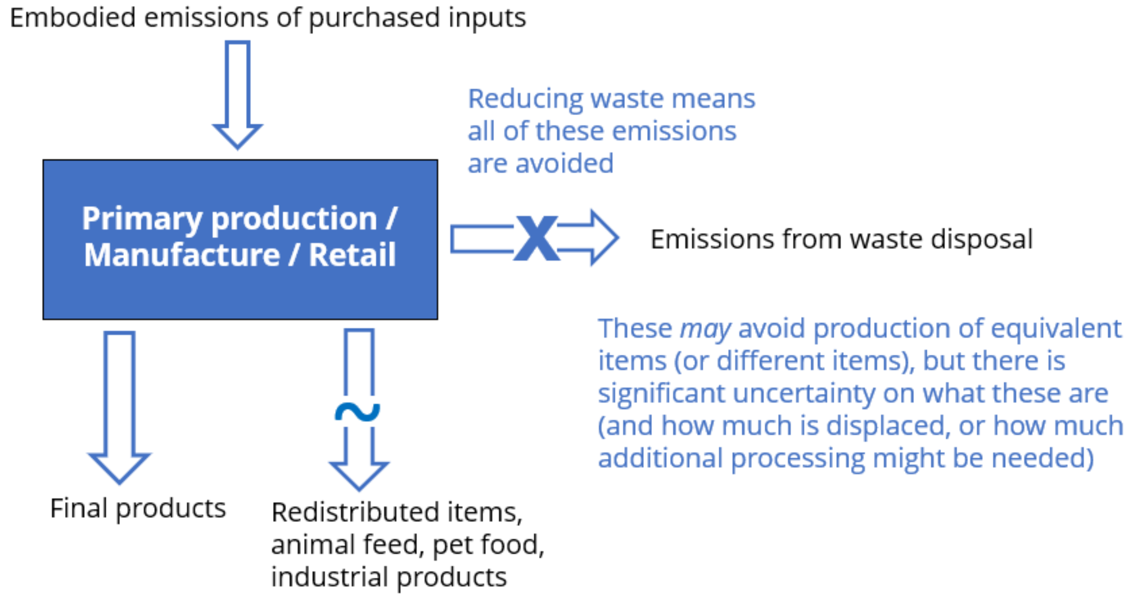
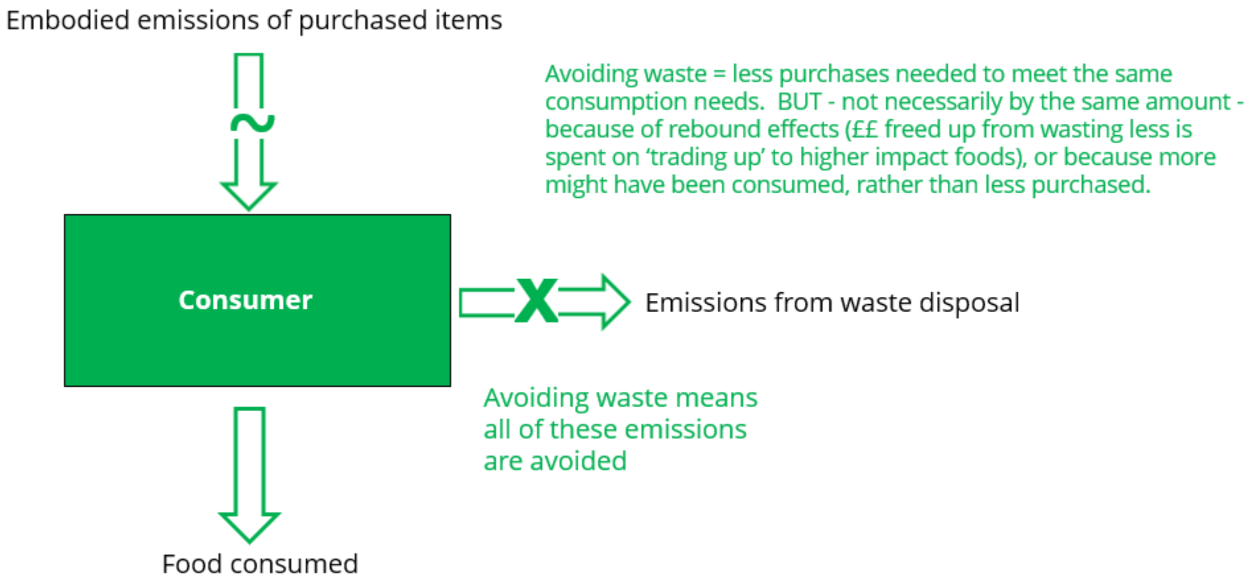


Figure 4: Waste avoidance at consumer stages (household and HaFS)



Estimates for the different types of waste prevention predicted for different stages in the food system were based on a separate WRAP modelling.

These are detailed in Table 14 and

Table 15 – with different assumptions used for the 'upper estimate' scenario and the 'lower estimate' scenario.

Note - one reason for variation between destinations in the two scenarios is that the lower estimate focuses on *edible* food waste reduction, whereas the upper scenario also focuses on reducing waste of inedible parts. The implications are that dealing with inedible waste may pose greater challenges, as some of it is difficult to 'avoid' (e.g. peels and bones), requiring a higher share of surplus to be sent to animal feed or biomaterial processing, which can valorise those inedible parts which could not be redistributed to humans. As a result, although the tonnages prevented will be higher in the upper estimate, in some sectors a greater *share* of that prevention will be avoidance.

Table 14: Food waste (FW) prevention split by avoidance vs reduction – assumptions used in lower estimate scenario

		Household	Retail	Manufacture	HaFS
% of FW prevention which is **avoidance**		100%	48%	40%	93%
% of FW prevention which is **reduction**		0%	52%	60%	7%
of which	*% of reduction which is redistribution to people*	*0%*	*81%*	*42%*	*100%*
	% of reduction which is diversion to animal feed	*n/a*	*19%*	*54%*	*0%*
	% of reduction which is diversion to biomaterial processing	*n/a*	*0%*	*4%*	*0%*

Table 15: Food waste (FW) prevention split by avoidance vs reduction – assumptions used in <u>upper estimate scenario</u>

		Household	Retail	Manufacture	HaFS
% of FW prevention which is **avoidance**		83%	47%	24%	81%
% of FW prevention which is **reduction**		17%	53%	76%	19%
of which	*% of reduction which is redistribution to people*	*0%*	*84%*	*29%*	*38%*
	% of reduction which is diversion to animal feed	*100%*	*16%*	*19%*	*63%*
	% of reduction which is diversion to biomaterial processing	*0%*	*0%*	*51%*	*0%*

ix. Developing assumptions for the degree to waste avoidance and redistribution results in the reduction of food ingredient / food purchases – and the avoided need to produce these items.

The division of food waste prevention into separate categories (part viii) was necessary to address the issue of displacement, which causes substantial uncertainty in our understanding of the impacts of food waste avoidance. Central to this is the question as to what knock-on effect there is from the avoidance of food waste in a particular stage. For example, by becoming more efficient and avoiding waste, does a household reduce its weekly shop, or do they consume more or trade-up to potentially more impactful foods?

In order to calculate emissions reductions associated with food waste prevention, we developed a series of assumptions, which are also shown visually in Figure 2, Figure 3 and Figure 4:

- All food waste *prevention* avoids disposal of that food waste. Therefore, savings in disposal emissions (part iii) per stage are applied to all food waste prevention. Food waste *avoidance* involves reduced purchasing of food or ingredients in line with the waste prevented. Therefore, this has an opportunity to displace the embodied emissions to produce those purchases. However, for consumer purchases (in and out home) this might not always be the case. For example, other authors have noted rebound effects[135], where money saved by wasting less is spent on 'trading up' to higher impact foods, rather than reducing purchasing. Or there may also be instances in which food waste is reduced by consuming more food, rather than by purchasing less and throwing away less. To reflect this uncertainty, we included an '<u>upper estimate</u>' and '<u>lower estimate</u>' scenario corresponding respectively to <u>100%</u> and <u>50%</u> of food waste avoidance leading to reduction in embodied emissions at the 'household' and 'HaFS' stages.
- Food waste *reduction* is split into two groups: redistribution and other non-waste destinations (part xiii). That which is redistributed is subject to the same <u>upper/lower</u> estimate scenarios assuming that redistribution displaces <u>100%</u> and <u>50%</u> of food

[135] *Ramy Salemdeeb et al., 'A Holistic Approach to the Environmental Evaluation of Food Waste Prevention',* Waste Management *59 (January 2017): 442–50, https://doi.org/10.1016/j.wasman.2016.09.042.*

redistributed respectively, therefore saving embodied emissions. For animal feed and other valorisation destinations, however, we *do not attribute any embodied emissions savings.* This is because there is significant uncertainty regarding:

- What types of materials might be displaced (e.g. an alternative type of animal feed – but what type?);
- How much is displaced (e.g. food surplus material may not be like-for-like in nutritional value for animal feed); and
- How much additional processing (e.g. drying) might be needed.

As a result of these assumptions, we calculate the disposal emissions reduction through food waste prevention and the embodied emissions reduction through food waste prevention separately. All food waste prevention reduces disposal emissions, but only *some* food waste prevention reduces embodied emissions.

x. Disposal emissions reduced through food waste prevention

Food waste prevention tonnages (part vii) were combined with disposal emissions (part iii) to derive the reduction in disposal emissions through food waste prevention.

As is described in part iii, the disposal emissions saved per stage interact with the policy intervention detailed in the waste treatment stage (see Section 3.3.4.3). This reduces the disposal emission savings for each tonne of food waste avoided. As a result, the savings are lower than they would be if food waste reduction was treated in isolation.

The differences between the 'upper' and 'lower' estimate scenarios are modest in terms of total GHG emissions avoided, but represent nearly a 50% increase in the reduction of disposal emissions in the upper estimate when compared to the lower estimate. This is driven entirely by the increase in food waste prevention which is associated with the more ambitious target of 50% reduction in edible and inedible parts, as all food waste prevention destinations lead to an avoidance of disposal-related emissions.

Table 16: Disposal-related emissions reduced through food waste prevention

Supply chain stage	Upper estimate		Lower estimate	
	Reduction in emissions in 2030 (Mt CO_2e)	Share of emission reduction	Reduction in emissions in 2030 (Mt CO_2e)	Share of emission reduction
Primary Production	0.00	0%	0.00	0%
Manufacturing	0.01	9%	0.00	7%
Retail	0.00	0%	0.00	0%
HaFS	0.01	6%	0.00	8%
Household	0.08	85%	0.05	85%
Total	**0.09**		**0.06**	

*Note, the total may be different to the sum of supply chain stages due to rounding

NB – where values are zero, this is because there is no waste sent to landfill (the only disposal route for which emissions are attributed, in compliance with the GHG protocol. We note a significant data gap for food waste to sewer in the HaFS stage, however)

xi. Embodied emissions reduction through food waste prevention

The estimated reduction in food ingredient / food purchases (derived from part ix) were combined with embodied emissions data (part ii) to derive the potential emissions reduction through avoiding the production of these purchases.

Table 17: Embodied emissions reduced through food waste prevention

Supply chain stage	Upper estimate		Lower estimate	
	Reduction in emissions in 2030 (Mt CO_2e)	Share of emission reduction	Reduction in emissions in 2030 (Mt CO_2e)	Share of emission reduction
Primary Production	0.36	6%	0.21	7%
Manufacturing	0.43	7%	0.26	9%
Retail	0.19	3%	0.09	3%
HaFS	0.84	13%	0.40	14%
Household	4.54	71%	1.85	66%
Total	**6.36**		**2.81**	

The embodied emissions reductions are driven by both the total amount prevented and the relative distribution of food waste reduction across different destinations. In particular, the increased prevention at the household stage is particularly important in driving down embodied emissions due to the larger embodied GHG per tonne of food wasted at the household level. The differences between the 'upper' and 'lower' estimate scenarios are significant, and result principally from the different scenario assumptions regarding the amount of purchases that are displaced through waste avoidance (see part ix).

xii. Total emissions reduction through food waste prevention

Estimates for disposal emissions reductions (part x) were added to estimates for embodied emissions reduction (part xii) to give a total estimate for emissions reduction through food waste prevention.

Table 18: Total emissions reduction through food waste prevention

Supply chain stage	Upper estimate		Lower estimate	
	Reduction in emissions in 2030 (Mt CO_2e)	Share of emission reduction	Reduction in emissions in 2030 (Mt CO2e)	Share of emission reduction
Primary Production	0.36	6%	0.21	7%
Manufacturing	0.43	7%	0.26	9%
Retail	0.19	3%	0.09	3%
HaFS	0.85	13%	0.40	14%
Household	4.62	72%	1.90	66%
Total	**6.45**		**2.86**	

For both scenarios, around 98% of the GHG emissions saved result from *avoidance* of food waste (linked to reduction in purchases and avoided need to produce these purchases), with only c.2% from disposal-related savings. At least 80% of the total GHG savings come from reductions in food waste in households HaFS.

4.0 Results: total UK food system emissions estimates for 2015 – 2019

Table 19 shows resulting estimates of the total GHG emissions associated with production and consumption of food and drink in the UK, across all stages of the value chain.

2015 is the baseline year for the Courtauld Commitment 2030 target. 2019 is the latest year for which most national-level data were available at the time of drafting.

Key findings are that:

- **Total UK food system emissions in 2019 were estimated to be 158 Mt CO_2e.**
    - **This is equivalent to 35% of UK territorial emissions**[136] – though not all of these emissions occur in the UK.
    - Within this, **emissions linked to the production & distribution of food that becomes waste are around 36 MtCO_2e (23% of total food system emissions).** This updates previous estimates, but only includes food waste that arises in the UK (where there is sufficient data). It could be c. 8MtCO_2e higher (up to 28% of food system emissions in total) if including waste occurring in overseas supply chains (assuming wastage rates are similar to those in the UK).
- The **majority of this reduction (> 80%) is due to decarbonisation of the UK's electricity grid**: the emissions associated with consuming a unit of electricity were 45% lower in 2019, compared to 2015.
- In line with this, **the stages in the value chain which are significant electricity consumers (food manufacture, hospitality & food service, retail, households) have seen the biggest reductions in GHG emissions (in combination c.12 MtCO_2e).** There have also been some efficiency improvements. The results for the household stage in particular are quite striking, with a nearly 50% decrease in emissions from the sector since 2015. This is due to a combination of two factors:
    - Firstly, the decarbonisation of the electricity grid (which has reduced a similar degree over time). Because the household sector uses primarily electricity for cooking and chilling appliances, this reduction is more observable than in sectors such as retail or HaFS which use a greater diversity of fuels.
    - Secondly, according to data from ECUK, kitchen appliances have seen a rapid efficiency increase in the last few years.[137] For example, this data suggests the average refrigerator consumes approximately 80% of the energy it did in 2015. The reduction is most pronounced in cooling appliances, where the total energy consumption has declined approximately 13% since 2015; for cooking appliances it has declined just 2%.
- **GHG emissions associated with overseas production are hard to quantify, but significant (>one third of the total – across food, ingredients and feed – including deforestation), and in combination have remained largely static in relative terms.** It is important to note, however, that significant care should be taken when interpreting 'changes' over time, for a number of reasons:

[136] *Based on latest, 2019, total (454.8 MCO_2e), from: https://www.gov.uk/government/statistics/final-uk-greenhouse-gas-emissions-national-statistics-1990-to-2019*

[137] *BEIS, 'Energy Consumption in the UK' Table A3.*

- The figure for net imports is highly variable from one year to the next, and is driven by fluctuations in the volumes of food imported. In particular, this depends on the UK wheat harvest. This means that reductions in shorter timeframes should be interpreted as stochastic rather than systemic change.
- In reality, some of the emissions modelled reflect a change in emissions attributable to UK consumption in a year. But this does not necessarily mean a 'real world' reduction in emissions to the atmosphere occur in short term. For example, if the UK ceases to import soy from Brazil but instead sources from the USA, a significant 'reduction' in emissions would be accounted. However it is likely this change in sourcing has not resulted in any real world change in emissions compared to business as usual. In time, changes to consumption could influence production, but the impacts are mediated by complex market interactions.
- Deforestation emissions have been quantified based values provided in Poore & Nemecek (2018) and the GFLI database. These use a popular method first proposed in PAS2050, which allocates total land use change in a country to crops based on whether a crop's production is expanding and/or contracting in a given year[138]. While these country-average LUC methods are long-established, a notable uncertainty is that deforestation does not occur uniformly over a country and some regions may be more / less likely to export crops to the UK. This means that a 'country average' could be over or under-estimating LUC emissions significantly for the UK.
- It is important to also note that the modelling approach used means that emissions associated with exported products (produced in the UK) are subtracted from imports. This appropriately reflects the net balance of emissions linked to UK consumption. But it means a mis-match in where these emissions are reported (i.e which line item in Table 19). In reality, when food items are exported, this will mean a reduction in the 'UK agriculture' and 'manufacturing' emissions balance sheet. But they are reported within the 'overseas food production (net imports)' line As such, whilst the total UK emissions are appropriately accounted, the share of emissions reported for UK agriculture and manufacturing are likely over-stated.

- **GHG emissions associated with UK agriculture have remained largely static** in recent years, but are also very challenging to measure accurately, and are sensitive to external influences (e.g. extreme weather). Methane from livestock is the largest single contributor – but there are ongoing discussions regarding the relative warming potential from methane[139] . It is also important to note the point above regarding emissions estimates for UK agriculture not reflecting exports.

- **Transport emissions in the UK have increased (moderately – c. 1 MtCO_2e).** This is an estimate, based on the increase in road mileage observed in national datasets over this time period – a proportion of which is allocated to food transport. For consumer transport, whilst there has been a slight decrease in transport demand per person, the biggest mode of transport (car/van) has stayed constant, and the emission profile of the average car has seen very little change. As a result, population growth and a slight increase in the share of shopping expenditure which was on food has

[138] This approach is sometimes called 'statistical' Land Use Change (sLUC), and includes direct and indirect LUC. sLUC is likely to be an accepted method in GHG Protocol land sector guidance being piloted in 2021 and launched in late 2022. This method is also referenced in the EU PEF guidelines and EnviFood Protocol.

[139] A new usage of the GWP100 metric (named GWP*) has recently been developed to recognise the difference in how sustained emissions of methane and CO_2/N_2O affect global average surface temperature, which is not fully captured by the current metric. This new metric will be assessed by the IPCC as part of its forthcoming 6th Assessment Report.

masked the minor relative savings. Supply chain transport has similarly seen very minor gains in efficiency with demand fluctuations being the key driver.

- **Packaging emissions are low in comparison with the emissions associated with producing food, and have remained largely static**. Packaging plays a protective function to reduce food waste, which reduces emissions in other stages (though not currently fully quantifiable). The amount of packaging placed on the market (and associated emissions) has been broadly constant over recent years. It should be noted, however, that environmental concerns regarding packaging – in particular, single use plastics – are not necessarily well captured using GHG emissions as a metric, as this does not reflect the impacts of marine pollution, bioaccumulation, etc.

- **Refrigerant emissions have decreased by nearly 2 MtCO_2e.** This is driven by reduction in refrigerant emissions across all industrial, commercial, domestic and transport sectors, which has declined by approximately one-third between 2015 and 2018. Much of this reduction is likely to be due to business responding to F-gas regulation and replacing gases that have high global warming potential (GWP) with low/no GWP gases.

- **Emissions associated with food waste management (combined across all stages) are low, and decreasing** – as the proportion of food waste sent to landfill is low, and decreasing. Other food waste management routes (e.g. AD, composting, incineration) have low, or sometimes negative, GHG emissions because they generate renewable energy (NB – these negative emissions have not been included in the assessment, in accordance with the GHG Protocol methodology). We also note one significant date gap for the scale of food waste being disposed to sewer, which is expected to be particularly relevant for the HaFS sector. This data gap means that total disposal emissions are likely underestimated.

Table 19 – Total UK Food System Emissions Estimates for 2015 - 2019

Stage in the value chain	2015 GHG emissions estimate (Mt CO_2e)	2019 GHG emissions estimate (Mt CO_2e)	Main reasons for change 2015-2019	Data quality / level of confidence in annual estimate and changes over time ***
UK primary production				
… UK agricultural emissions (livestock, soils, fuel)*	46.0	46.3	Emissions largely static (as reported in National Inventory)	
…Embodied emissions from fertiliser production	2.0	2.0	Emissions largely static	
…Embodied emissions from imported feed for use in UK	2.5	2.8	Figure for net imports of feed and food / ingredients is highly variable from one year to the next, and is driven by fluctuations in the volumes of food imported. In particular annual variation is heavily influenced by the UK wheat harvest. This means that reductions in shorter timeframes should be interpreted as stochastic rather than systemic change.	
…Deforestation estimate for feed imports	4.7	4.5		
Overseas food production (net imports)	37.6	35.9		
…Deforestation estimate for tropical commodities	10.9	11.9		
UK food & drink manufacturing	11.1	9.3	Decarbonisation of electricity	
Packaging	5.0	5.1	Changes in packaging volume and composition reported	
Refrigerant (all UK stages)	5.4	3.6	Industry switch to lower impact refrigerants	
Supply chain transport in UK	6.3	6.8	Upward underlying increase in mileage for food transport.	
Hospitality & Food Service (catering)	8.5	7.9	Decarbonisation of electricity	
Retail	7.8	5.3	Reduced demand (e.g. through increased estate efficiency) and decarbonisation of electricity	
Consumer transport for food shopping	4.5	4.6	Increase in reported car usage for shopping trips	
Transport – home deliveries	0.6	0.9	Growth in demand for delivery services	
Home (storage and cooking)	17.6	9.9	Reduced demand (e.g. through improved appliance efficiency) and decarbonisation of electricity	
Waste disposal	1.3	0.8	Food waste reduction and diversion from landfill	
TOTAL	**172**	**158**		
…of which is linked to producing food that is wasted**	43	36		

*Of which: 62% emissions from livestock (enteric fermentation and organic wastes); 28% emissions from soils; 10% emissions from stationary and mobile combustion

** This only includes food waste that arises in the UK (where there is sufficient data). It could be c. 8MtCO2e higher (up to 28% of food system emissions in total) if including waste occurring in overseas supply chains (assuming wastage rates are similar to those in the UK).

*** **Green** = predominantly based on reputable national datasets which are frequently updated and/or emissions factors which are not subject to significant variability or are frequently updated. **Amber** = based on a range of different estimates and assumptions, which may reduce certainty levels but unlikely to be highly variable . **Red** = subject to significant uncertainty, either in methodology or data availability.

4.1 Differences from previously stated results

This analysis builds significantly upon the work outlined in WRAP's Courtauld 2025 milestone report for 2018[140]. As a result of updating the analysis and filling data gaps there have been some changes – most notably:

- Some emissions sources added that were not included in previous estimates:
  - Estimates for GHG emissions from tropical deforestation
  - Refrigerant emissions.
  - Transport emissions from food delivery.
- Updates to underlying emission factors used for net trade in food and feedstuffs (see Section 2.3.3 and Section 2.4) – to reflect current best available datasets. In particular, a change to the emissions factor used for beef imported from the EU (assuming this is closer to UK production method, being predominantly sourced from Republic of Ireland). Also correcting the previous omission of oils & fats – for which all imports were assumed to be used in the food industry. This is likely to be an overestimate, as some will be used for other industrial purposes, but no UK statistics were available to determine relative proportions for different industrial uses (one dataset for the US suggested that food uses far outweigh other industrial uses).
- Updated methodology for disposal emissions to better reflect the destinations of household residual waste (see 2.14) has led to a decrease in emissions, this is largely due to reallocation of waste from landfill to recovery (energy from waste).
- Corrections of errors:
  - Correction of an error in the calculation of food and drink as a share of shopping which had previously double counted alcohol, leading to a higher share of total purchases being considered 'food and drink' purchases.
  - Removal of car/van passenger emissions from consumer transport estimate to avoid double counting.
  - Correction of an error in estimating gas oven and hob demand for households which was previously overestimating demand.
- Source data restated in some latest datasets (e.g. for UK agriculture).

The changes between the previously stated 2015 and 2018 values and new, restated estimates are summarised Table 21.

Notable is that, whilst absolute estimates of UK food system emissions have increased through filling data gaps and methodological refinements, relative reductions remain the same as in the previous Courtauld 2025 milestone analysis (Table 20).

Table 20: Comparison with previously stated results, progress to target

	Previously stated*	Restated
Reduction 2015-18, total	-5.2%	-5.2%
Reduction 2015-18, per capita	-6.8%	-7.1%

*Previously stated values as reported in:
https://wrap.org.uk/sites/files/wrap/Progress_against_Courtauld_2025_targets_and_UN_SDG_123.pdf

[140] *WRAP, 'UK Progress against Courtauld 2025 Targets and UN Sustainable Development Goal 12.3'.*

Table 21: Comparison with previously stated results

Stage in the value chain	2015 ($Mt\ CO_2e$)			2018 ($Mt\ CO_2e$)			Main driver of change
	Previously stated*	Restated	Change	Previously stated*	Restated	Change	
UK primary production							
… UK agricultural emissions (livestock, soils, fuel)	45.1	46.0	0.9	45.6	45.8	0.2	Restated source values
… Embodied emissions from fertiliser production	2.0	2.0	0.0	2.0	2.0	0.0	
… Embodied emissions from imported feed for use in UK	4.9	2.5	-2.4	4.3	2.8	-1.5	Methodological refinement; improvement of emission factors
… Deforestation estimate for feed imports	0.0	4.7	4.7	0.0	4.1	4.1	Not previously estimated
Overseas food production (net imports)	36.8	37.6	0.8	39.1	38.9	-0.2	Methodological refinement; improvement of emission factors; inclusion of oilseeds and animal fats previously unaccounted
... Deforestation estimate for tropical commodities	0.0	10.9	10.9	0.0	12.2	12.2	Not previously estimated
UK food & drink manufacturing	9.4	11.1	1.7	8.5	9.8	1.3	Restated source values
Packaging	5.0	5.0	0.0	5.1	5.3	0.2	Methodological refinement; improvement of emission factors
Refrigerant (all UK stages)	0.0	5.4	5.4	0.0	3.6	3.6	Not previously estimated
Supply chain transport in UK	6.5	6.3	-0.2	7.6	7.5	-0.1	Restated source values
Hospitality & Food Service (catering)	7.4	8.5	1.1	6.8	8.0	1.2	Restated source values
Retail	7.9	7.8	-0.1	5.3	5.5	0.2	Error correction and restated source values
Consumer transport for food shopping	8.0	4.5	-3.5	8.1	4.9	-3.2	Error corrections
Transport - home deliveries	0.0	0.6	0.6	0.0	0.9	0.9	Not previously estimated
Home (storage and cooking)	18.3	17.6	-0.7	12.2	10.9	-1.3	Error correction and restated source values
Waste disposal	2.1	1.3	-0.8	1.8	0.8	-1.0	Methodological refinement; more accurate waste destination data
Total	**154**	**172**	**18**	**146**	**163**	**17**	
Total per capita ($t\ CO_2e$)	**2.4**	**2.6**	**0.3**	**2.2**	**2.5**	**0.3**	

*Previously stated values as reported in: https://wrap.org.uk/sites/files/wrap/Progress_against_Courtauld_2025_targets_and_UN_SDG_123.pdf

5.0 Results: estimates of emissions reductions by 2030

In the second part of the analysis, we quantified the emissions reductions that could be realised through different types of interventions across the food system between 2019 and 2030.

The findings demonstrate an example pathway for how a 50% reduction in total food system GHG emissions could be achieved by 2030 (against a 2015 baseline) – as shown in Figure 5.

These estimates have significant uncertainty (see Section 5.1) – but show the approximate and relative scale of reduction potential.

Emissions reduction are grouped in Figure 5 by type of intervention – but in some cases will be realised across several stages of the value chain and across multiple sectors (e.g. energy and transported related savings will be realised across manufacturing + retail + HaFS + households in particular). We have grouped them in this way because, in some cases, it is not fully possible to determine *where* emissions reductions would occur.

For some interventions, an 'upper' and 'lower' estimate of savings has been included. This reflects the significant uncertainty either in the *scale* or the *pace* of reductions that could be achieved by 2030.

A short summary of the scenarios modelled is included in Table 22.

Key findings are that:

- There *is* a pathway to achieving a 50% absolute reduction in the GHG emissions associated with production and consumption of food and drink in the UK.
- This can – mostly - be achieved by ensuring that existing policy, business or sector-level commitments and targets are delivered. But they need to be delivered at the right pace.
- This will require:
  - **Fast progress on agricultural productivity & land management measures** (e.g. peatland restoration, enhanced soil carbon storage, enhancing hedgerows). In the UK this needs to be on a linear trajectory towards meeting NFU Net Zero 2040 estimates. There also needs to be a similar rate of progress in the EU, but it was assumed that slower progress would be made beyond the EU, where decarbonisation mechanisms may be less developed.
  - **Achieving zero deforestation commitments in supply chains** – particularly linked to tropical forest commodities such as palm oil, soy, cocoa, coffee, etc.
  - **Renewable energy commitments being met** – and wider energy infrastructure delivering reduced emissions across the electricity grid.
  - **Significant progress on decarbonising heat** - in line with FDF/SLR estimates for maximum technical potential by 2030.
  - **Some progress on transport decarbonisation**: more widespread adoption of electric vehicles and active travel by consumers; and innovation in supply chains. Whilst HGV decarbonisation remains a challenge, improved route planning and fuel efficiency gains can make an important contribution.

- **At least halving UK food waste - and prioritising the type of food waste prevention efforts that will maximise impact[141]:**
  - Going beyond SDG12.3 in terms of the current UK interpretation of this goal. Specifically a need to include total food waste (including inedible parts) within the post-farm gate 50% reduction target; and delivering reductions in food waste pre-farm gate.
  - A continued focus on the waste hierarchy, to prioritise efforts to avoid food waste arising. The detailed modelling described in Section 3.3.5.2 highlights the importance of avoiding waste arising in the first place, as opposed to producing surplus that is sent for redistribution, animal feed, or other valorisation. These beneficial uses of surplus are all preferable to disposal, but there are significant uncertainties regarding emissions reduction potential.
  - A continued focus on reducing citizen food waste (in and out of home). The results of detailed modelling (outlined in Section 3.3.5.2) show that at least 80% of the total GHG reduction potential from food waste prevention is realised in households and hospitality & food service.
  - A need for much more integrated messaging around food waste and consumption behaviours.
    i. Without this there could be potential for rebound effects. For example, other authors have noted that, in cases where householders save money through reducing waste, they may use this additional income to 'trade up' - to instead purchase food items (or other products/services) that may have higher embodied emissions, and thereby reduce (or negate) the overall benefits from food waste prevention[142].
    ii. There may also be instances in which food waste is reduced by consuming more food, rather than by purchasing less and throwing away less. In GHG-terms, over-consumption is as 'wasteful' as throwing food away. This is an important point, as data collated as part of this study suggest that per capita consumption of food has increased between 2015-2019 – and that, if per capita consumption in 2019 was same as 2015, total food system emissions could have been c.5 MtCO_2e lower.
  - A need to target high embodied impact foods. The GHG model does not currently enable a detailed analysis by food type, but this will be included in further work.
- **Higher adoption of government dietary recommendations, as set out in the Eatwell Guide.** c. 70% of the population are currently at low, or very low adherence – but not equally across all points of guidance. For example, the adherence for the proportion of red & processed meat in diets is estimated to be relatively high (65%), but adherence for the proportion of fruit & veg in diets is low (25%)[143]).

[141] NB - the scale of GHG emissions reduction that could come from food waste reduction appears relatively modest in Figure A1. This is consistent with other estimates (e.g. WRAP's 2021 report on resource efficiency and Net Zero). However, this modelling updates previous estimates and more appropriately accounts for how, as the different stages of the food system decarbonise, the 'savings' from preventing food waste also reduce. More conservative (but realistic) assumptions have also been used regarding the degree to which food waste that is avoided or redistributed leads to a like-for-like reduction in the emissions to produce an equivalent volume of food. The reduction potential is likely to be higher if including waste prevention in overseas supply chains, but here we have only modelled a UK food waste reduction scenario (as shown in Figure A1), given the uncertainty in both the volume of food waste occurring in overseas supply chains, and the scale of prevention potential.

[142] *Ramy Salemdeeb et al., 'A Holistic Approach to the Environmental Evaluation of Food Waste Prevention',* Waste Management *59 (January 2017): 442–50, https://doi.org/10.1016/j.wasman.2016.09.042.*

[143] *Scheelbeek et al., 'Health Impacts and Environmental Footprints of Diets That Meet the Eatwell Guide Recommendations'.*

5.1 Limitation and uncertainties

This is just one example of a pathway to achieving a 50% reduction target – and there could be others means of realising these emissions reductions. The purpose of this work was to demonstrate that this scale of reduction could be achievable, and where efforts might appropriately be focused. There are, however, some significant uncertainties and limitations that are important to flag.

In particular:

- The food system is a complex web of interactions that are subject to a range of forces that are not possible to fully predict, or account for, within modelling. For example weather / climate (and its effect e.g. on crop yields, pests, diseases, supply disruption), competition within global markets, consumer trends and purchasing patterns, etc. Within this modelling, some relatively simple cause / effect assumptions have been made: for example, changes in consumption will result in equivalent changes in production (somewhere in the world). This was considered a reasonable approach, given the objectives – to understand the approximate and relative scale of potential savings from different interventions. However, it is important to note the significant uncertainty regarding predicting emissions reductions, particularly where interventions effect changes in consumption and purchasing of different food types (e.g. food waste prevention, dietary change, avoiding deforestation). The main uncertainty is with regard to how a change in consumption leads to a change in purchasing, and in turn how - and where - this leads to a change in production, given global market influences and the potential for rebound effects and other complex interactions.
- In reality, some of the emissions modelled reflect a change in emissions attributable to UK consumption in a year. But this does not necessarily mean a 'real world' reduction in emissions to the atmosphere occur in short term. For example, if the UK ceases to import soy from Brazil but instead sources from the USA, a significant reduction in emissions would be accounted. However it is likely this change in sourcing has not resulted in any real world change in emissions compared to business as usual. In time, changes to consumption could influence production, but the impacts are mediated by complex market interactions.
- The analysis does not include an assessment of cost, or feasibility of interventions – only that they have been indicated technically possible by stakeholders elsewhere. Building in this form of appraisal, in order to consider the *most efficient* pathway, is a recommendation for further work.
- The analysis does not currently investigate interactions *between* interventions – such as the degree to which efforts to influence dietary change might effect food waste. This is considered within further work (see Section 0).
- The analysis largely considers technical changes (e.g. improving efficiency in different stages of the system). We haven't attempted to model the effect of individual policies, mechanism such as pricing, or different ways of influencing behaviour change – as these are inherently difficult to quantify.

Figure 5: Example pathway towards achieving 50% reduction in food system emissions by 2030 – grouped by type of intervention

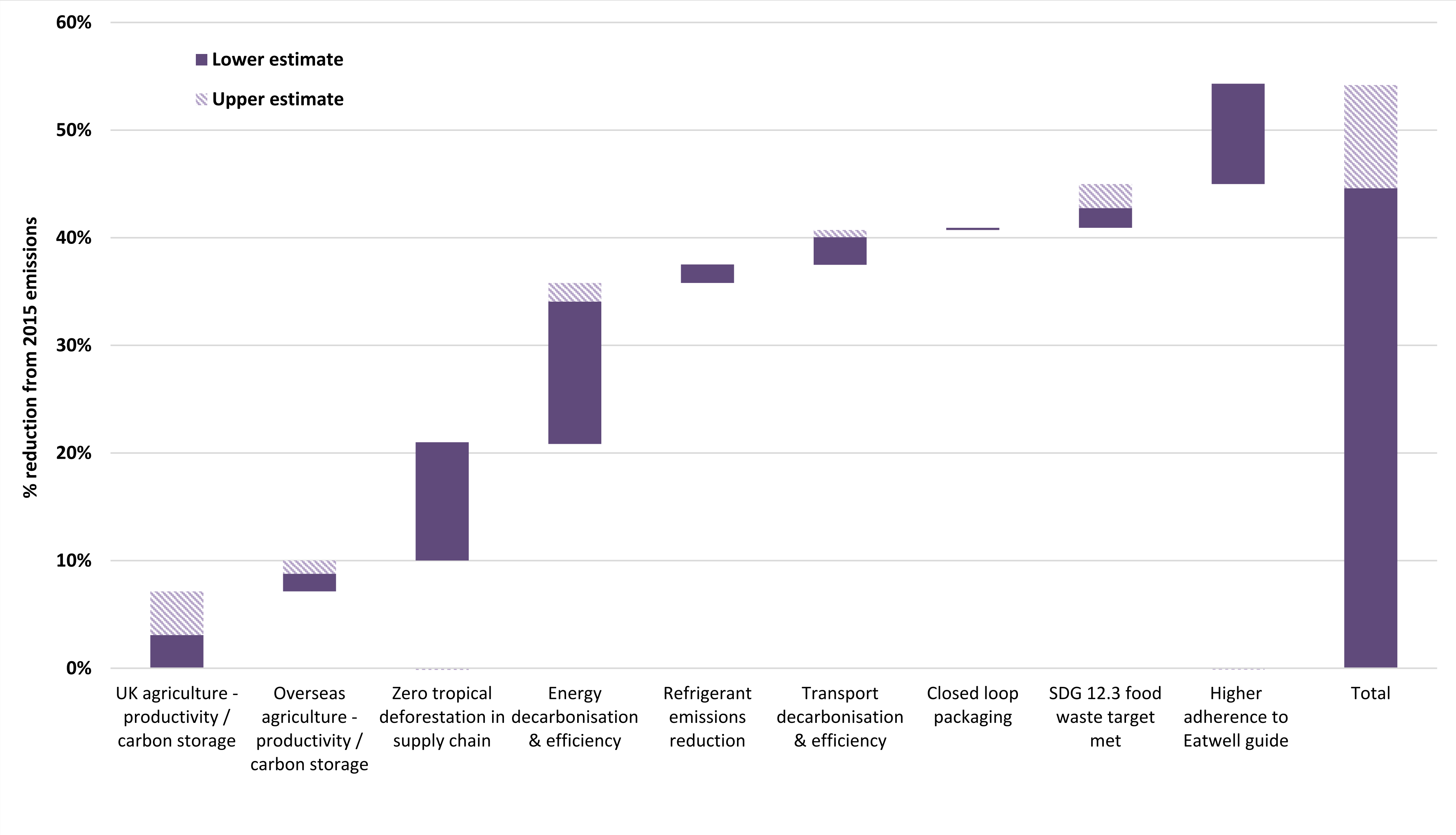


Table 22: Outline of scenarios modelled in Figure 5

Intervention group (as shown in Fig 5)	Key modelling assumptions [for all references and more detail on modelling assumptions see Section x]
UK agriculture - productivity / GHG storage	Upper estimate: Linear trajectory to meeting the estimated annual GHG savings outlined in the NFU Achieving Net Zero report through i) productivity measures (pillar 1); and ii) farmland carbon storage (pillar 2). Pillar 3 (bioenergy/renewables) was not included to avoid double counting energy decarbonisation. Lower estimate: Reflects the potential for lower rates of uptake of different farm-level interventions, based on work undertaken by Defra in England (not yet published) – scaled to wider UK. Both scenarios also additional include estimated reductions in the embodied emissions of producing fertiliser and feed, based on AIC and CIEL targets / projections.
Overseas agriculture - productivity / GHG storage	Upper estimate: Assumes the NFU estimates of GHG savings through productivity measures and farmland GHG storage also apply to food imports from Europe – because the EU similarly has a Net Zero target. But assumed that these savings are realised at a slower rate because the EU target is 2050 (vs NFU 2040 ambition). For food imports from countries outside of the EU a conservative assumption was made that the pace of change would be halved. Lower estimate: Assumes the (more conservative) Defra estimates of GHG savings in agriculture also apply to food imports from Europe. For food imports from countries outside of the EU a conservative assumption was made that the pace of change would be halved.
Zero tropical deforestation in supply chain	Assumes that zero deforestation commitments made by retailers and other food businesses are achieved by 2030 – and that this results in no tropical deforestation emissions being linked to UK food & drink supply chains. A very optimistic scenario, but considered appropriate to include because of i) the level of commitments being made with regard to deforestation and land conversion; and ii) the increasing level of scrutiny.
Energy decarbonisation & efficiency	For retail – assumes the BRC Climate Roadmap target of 100% renewable electricity is met; plus there are demand reductions through improved efficiency of heating & lighting. For manufacturing and hospitality & food service (HaFS) – assumes the emissions intensity of grid electricity consumed will decrease in line with the UK Committee on Climate Change Balanced Net Zero Pathway; plus emissions from heat will reduce in line with FDF/SLR Maxtech (upper estimate) vs Realistic (lower estimate) scenarios; plus there are demand reductions through improved efficiency. For household – assumes the emissions intensity of grid electricity consumed will decrease in line with the UK Committee on Climate Change Balanced Net Zero Pathway; plus there are demand reductions through (moderate) improved efficiency of appliances.

Refrigerant emissions reduction	Assumes a c.70% emissions saving through a switch to low GHG refrigerants – based on a 'business-as-usual investment' scenario for retail, but applied to refrigerant use across all sectors (e.g. HaFS, transport)
Transport decarbonisation & efficiency	For UK supply chain transport - assumes 10% reduction in HGV tkm travelled, based on the UK Committee on Climate Change Balanced Net Zero Pathway – plus either achieving 15% reduction in emission intensity, as targeted by the Zemo Partnership (formerly Low Carbon Vehicle Partnership) (lower estimate), or an assumed 30% maximum potential reduction in emissions intensity by 2030, based on a range of sources (upper estimate). For consumer transport – assumes 9% of private car journeys are replaced with zero GHG modes of transport in line with the UK Committee on Climate Change Balanced Net Zero Pathway, alongside a reduction in vehicle emissions based on UK Committee on Climate Change and Department for Transport scenarios, with no reduction in transport demand. For food deliveries – assumes reduction in emissions from delivery vans in line with BRC Climate Roadmap commitments; plus reductions in the emission intensity of other delivery vehicles in line with the UKCCC pathway; plus an assumed increase in the share of food service deliveries made by bicycle.
Closed loop packaging	Assumes additional 20% of total plastic food packaging and 15% of total other packaging types could be sourced through closed-loop recycled content.
Food waste reduction	Upper estimate: Assumes that the SDG 12.3 target is met through a 50% reduction in total food waste (vs a 2007 baseline), including inedible parts (with food waste being 3.2Mt lower in 2030 than 2018). As well as avoiding disposal emissions, this scenario also assumes that any food waste that is avoided or redistributed leads to a like-for-like reduction in the emissions to produce an equivalent volume of food (based on the projected emissions intensity per tonne of food in 2030 – after the savings above have been accounted). Lower estimate: Assumes that the SDG 12.3 target is met through a 50% reduction in wasted food only (vs a 2007 baseline), not including inedible parts (with food waste being 1.8 – 1.9Mt lower in 2030 than 2018). Different to the above – this scenario assumes that food waste avoided by consumers (household and hospitality & food service stages) only leads to a 50% displacement of new food production – because the effects of food waste reduction on purchasing are uncertain (for example, food waste could be reduced through consuming more, or reducing food waste could lead to rebound effects such as 'trading up' to higher impact purchases). Similarly, in this scenario only 50% of redistributed food is assuming to a leads to a 50% displacement of new food production – because of the uncertainties regarding what users of redistribution services might alternatively have purchased.
Higher adherence to Eatwell guide	Assumes the proportion of the population adopting government dietary recommendations, as set out in the Eatwell Guide increase from current levels to 100% of the population with 'intermediate to high' adherence.

Data points for **Figure 5**:

Intervention group (as shown in Fig 5)	% Reduction from 2015 emissions	
	Upper estimate	*Lower estimate*
UK agriculture - productivity / GHG storage	7%	3%
Overseas agriculture - productivity / GHG storage	3%	2%
Zero tropical deforestation in supply chain	11%	11%
Energy decarbonisation & efficiency	15%	13%
Refrigerant emissions reduction	2%	2%
Transport decarbonisation & efficiency	3%	3%
Closed loop packaging	0.2%	0.2%
Food waste reduction	4%	2%
Higher adherence to Eatwell guide	9%	9%
Total	**54%**	**45%**

6.0 Further work

This assessment draws on more than 70 published sources and is the most in-depth review to date of the GHG emissions linked the UK food system. However, the complexity of this system means that there are significant uncertainties with some of the existing estimates, and there are areas in which further work would be valuable.

The following are recommended priorities for further work, all of which have particular relevance in the context of the National Food Strategy.

1. **Further investigation of trade-offs and potential for unintended consequences - **to better understand the implications of these and ways to minimise them.

   This should include:

   i. Interactions between interventions – for example, WRAP estimates that dietary change could potentially result in a large increase in food waste, because fruit and vegetables are wasted at much higher rates than other food items; and

   ii. Trade-offs between emissions reductions and other priorities, such as protecting and increasing biodiversity and safeguarding water resources.

   Understanding these potential effects in more detail could help shape the best way to deploy interventions to mitigate these effects as far as possible.

2. **Further investigation of how interventions could be targeted to best effect to reducing the UK's overseas footprint, as well as UK territorial emissions.** In outlining recommendations for ways to reduce the UK's territorial GHG emissions linked to the food system, both the Committee on Climate Change and the National Food Strategy recommendations flag the challenge of offshoring. They note that delivering

emissions reduction within the UK should not be at the expense of increasing food imports that risk increasing emissions elsewhere (sometimes called 'carbon leakage').

Importantly, the analysis presented within this report *does* consider total global impacts of the UK's food consumption, including imports. However – the underlying data sources that are used to quantify imported emissions are subject to both significant uncertainty and significant variability. As in other studies, the values used to estimate the embodied impacts of different imported food, ingredient and feed items are based on historic, often relatively old, datasets that are very infrequently updated – so there is no current means of being able to track progress over time for these imported products and ingredients. There is a significant need to develop a means of improving these estimates – potentially starting with those imported food / ingredient / feed items that disproportionately contribute to net import emissions and for which impacts are known to be highly variable dependent on production systems and geographies (e.g. vegetable oils, meat items, coffee, cheese, wine, fish, soya & maize for feed).

WRAP and others (e.g. through the HESTIA database, Feed UK, etc.) are undertaking further work that could potentially link in with the food system model described in this report to provide a more meaningful way of:

i. Monitoring change over time (to ensure we aren't offshoring emissions). In particular, this could be used is a way of tracking change against a key food system metric recommended in the National Food Strategy: Total UK food system GHG emissions; and
ii. Enabling more detailed insight to better understand more about *how* and *where* to best focus efforts to reduce the total global footprint of the UK food system.

3. **Further investigation of cost (e.g. marginal abatement costs) and feasibility**. The food system GHG model developed to date does not include any assessment of cost, or feasibility of different interventions. Building in this form of appraisal would be a valuable way of considering the consider the most efficient, practical or cost-effective pathway to achieving reductions.

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