Department for Energy Security & Net Zero

Unlocking Resource Efficiency

Phase 2 Food & Drink Report

DESNZ Research Paper Series Number 2024/008

April 2024

Acknowledgements

We would like to acknowledge the stakeholders that contributed generously to this study with their knowledge, experience and viewpoints.

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Introduction

The Department for Energy Security and Net Zero (DESNZ) and the Department for Environment, Food and Rural Affairs (DEFRA) commissioned Eunomia Research and Consulting to undertake a research project exploring the potential benefits from increasing resource efficiency in the UK. This report outlines the findings of this research for the food and drink sector.

For the purposes of this report, resource efficiency is defined as any action that achieves a lower level of resource use for a given level of final consumption. This can occur at any stage of the supply chain including production, consumption, and end-of-life. While material substitution may not always meet the definition of resource efficiency set out above, it is in scope of this research where it reduces whole life carbon.

This research was conducted in the second half of 2023, and reports were written in November 2023. As such, this report does not reflect sector developments beyond that point. Technical experts were consulted as part of research activities for this report. The following report reflects our understanding of the available evidence and is accurate to the best of our knowledge; however, if any factual errors are encountered, please contact us at Resource_efficiency@energysecurity.gov.uk.

Methodology

This aim of this research was to achieve four key objectives:

- Identify a comprehensive list of resource efficiency measures for each sector;
- Identify current and anticipated drivers and barriers which are affecting improvements in the identified resource efficiency measures in each sector, and their relative importance;
- Build consensus estimates for the current “level of efficiency” and maximum “level of efficiency” in 2035, for each of the identified resource efficiency measures in each sector; and
- Identify the extent to which industry is currently improving resource efficiency and build consensus estimates for the likely “levels of efficiency” in 2035 given current private sector incentives and the existing policy mix (a “business-as-usual” scenario), for each of the identified resource efficiency measures in each sector.

To achieve these research objectives, a mixed-methods methodology was developed. A literature review was conducted for each sector to synthesise evidence from the existing literature relevant to these objectives. In parallel, stakeholder interviews were conducted with industry and academic experts in each sector to test literature findings and fill any outstanding evidence gaps. A summary of findings was then presented and validated at sector-specific facilitated workshops with sector experts.

This project did not aim to identify policy recommendations but rather understand the potential for resource efficiency in the UK. It should be noted that some areas covered as part of the

research fall under the responsibility of devolved nations of the UK; however, all reports cover the UK as a whole for completeness.

This project has attempted to identify three level of efficiency estimates for each resource efficiency measure:

- The **current level of efficiency** which is the best estimate for the current level of efficiency of the measure i.e., what is happening in the UK now (in 2023);
- The **maximum level of efficiency** which is the maximum level of efficiency that is technically possible by 2035 in the UK, without factoring in barriers that could be overcome by 2035 i.e., what is the maximum level that could be achieved; and
- The **business-as-usual (BAU) scenario** which is the level of efficiency that would be expected in the UK by 2035 with the current policy mix and private sector incentives i.e., what would happen if there were no substantial changes in the policy or private sector environment.

These levels of efficiencies have been identified to understand the potential for resource efficiency and do not represent government targets.

To estimate these levels of efficiency, indicators have been developed for each of the identified measures. These indicators have been chosen based on how well they capture the impact of the relevant measure, and how much data there is available on this basis (both in the literature review and from expert stakeholders).

For some measures, the current level of efficiency is baselined to 2023. This is not an indication of historic progress, but rather has been done in order to understand the potential for further progress to be made (in the maximum and BAU scenarios) where it was not otherwise possible to quantify a current level of efficiency.

Note, the purpose of the indicators in this research is so estimates on the current, maximum and BAU level of efficiency can be developed on a consistent basis. They are not intended be used as metrics to monitor the progress of these resource efficiency measures over time, or to be used as metrics for resource efficiency policies.

A high-level overview of the research stages is presented below. A more detailed version of this methodology is presented in the Phase 2 Technical Summary which accompanies this publication.

Literature Review

The literature sources were identified through an online search, and through known sources from DESNZ, DEFRA, the research team, and expert stakeholders.

Once literature sources had been identified they were reviewed by the research team and given an Indicative Applicability Score (IAS) ranging from 1 to 5 which indicated the applicability of the sources to the research objectives of this study. This score was based on five key criteria: geography, date of publication, sector applicability, methodolo-gies used and level of peer review.

After the five criteria of the IAS had been evaluated, the overall IAS score was calculated, ranging from 1 to 5, according to the number of criteria scoring 'high' and 'low.'

A detailed overview of the parameters used to assess high / medium / low scores for each of the five criteria feeding into the IAS calculation and methodology for calculating the score can be found in Appendix A.

The research team drafted a rapid evidence assessment and literature summaries as part of interim reports for each sector which synthesised the best available evidence from the literature for each of the four research objectives. When drafting these summaries, literature sources with a higher IAS score were weighted more than those with a lower IAS score.

Stakeholder interviews

The findings from the literature review were presented to, and tested with, expert stakeholders from each sector through a series of stakeholder interviews. The interviews aimed to capture a range of sector experts from both academia and industry (covering different aspects of the value chain) but it should be noted this is not an exhaustive or representative sample of the sector. The purpose of these interviews was to test the findings of the literature review against stakeholder expertise, and to fill any evidence gaps from the literature.

Facilitated workshops

Following the completion of stakeholder interviews, one half-day facilitated workshop was conducted for each sector. Stakeholders who participated in interviews were given the chance to contribute to supplement and validate findings.

Stakeholders contributed through sticky notes in a shared virtual Mural board, by participating in the verbal discussions and by voting on pre-defined ranges on the levels of efficiency and the top drivers and barriers. They were also given the chance to contribute further information through a post-workshop survey. The stakeholders were asked to signal the level of confidence they had in their votes and were advised to vote for a 'don't know' option if they felt the information fell outside their expertise. It is possible however that some votes were cast in areas where stakeholders may not have had expertise, so caution is advised when interpreting the findings.

Finally, the findings of the literature review and the stakeholder engagement were combined to reach final conclusions against each research objective. For the estimates on the level of efficiency for each measure (Objectives 3 and 4), a five-tier evidence RAG rating was assigned to indicate the level of evidence supporting the proposed figures. Only where the datapoints were supported by literature sources with high IAS and a high degree of consensus amongst experts in the interviews and workshop, were the datapoints considered to have a "green" evidence RAG rating. The definitions are as follows:

- **Red:** Limited evidence available from literature review or stakeholders
- **Red-Amber:** Some evidence available from literature review but it is not relevant/out of date, Limited evidence from stakeholders, stakeholders are not experts on this measure

- **Amber:** High quality evidence from either literature or stakeholders
- **Amber-Green:** High quality evidence from literature or stakeholders, evidence from stakeholders is supported by some information in the literature (or vice versa)
- **Green:** High quality evidence from literature supported by stakeholder expertise.

It should be noted that the business-as-usual (BAU) level of efficiency was only informed by the stakeholder engagement, so the maximum evidence RAG rating for the BAU is amber.

Limitations

This report was commissioned by the Government to improve the evidence base on the impact of resource efficiency measures. The methodology is designed to provide robust answers to the research objectives, based on the best available evidence at the time the work was undertaken.

While every effort was made to be comprehensive in the literature review, it is inevitable that some relevant literature may not have been captured. A full list of all the literature reviewed is provided in the annexes of each sector report.

The feedback captured during the interviews and workshops represent the views of a sample of stakeholders from industry, trade associations and academia. Effort was made to ensure that interviews and workshops included a cross-section of stakeholders from each stage of the sectors' supply chain, representing a range of backgrounds and perspectives. It is, however, noted that capacity and scheduling limitations meant that some stakeholders, whose view would have been valuable to the research, were not able to participate. As such, the views expressed by research participants in this report are not representative of the sector as a whole.

A key research objective of this project is to estimate the level of efficiency of resource efficiency measures in 2035. Any future projections are inherently uncertain as they depend on a range of different factors such as technological innovation, consumer behaviour change and the macro-economic environment. The estimates from this research are the best estimates that could be produced, based on the current literature and stakeholder expertise. Evidence RAG ratings have been provided to indicate the level of supporting evidence for each of these estimates.

The report does not seek to make recommendations on the appropriate direction of Government policy or independent industry action. DESNZ and DEFRA will seek to conduct further engagement with stakeholders to inform the next steps for resource efficiency policy within Government, ensuring that any omissions or developments in the evidence reviewed in this report are taken into account.

Sector Introduction

The UK's food and drink sector is of high economic significance. In total, the agri-food sector (including agriculture and fishing) contributed £128.3 billion or 6.3% to the national Gross Value Added (GVA) in 2021, of which £115.2 billion was contributed by the food and drink

sector beyond primary production (i.e., excluding agriculture and fishing).[1] The food and drink sector also directly employed 3.7 million people in Great Britain[2] in 2022 (excluding agriculture and fishing).[3]

Food and drink is the UK's largest manufacturing sector, with an annual turnover of £104.4 billion.[4] By GVA, the largest food and drink manufacturing sub-sectors in 2021 were: beverages, contributing £6.5 billion or 21.4% of food and drink manufacturing GVA; 'other food products', contributing £6.3 billion; bakery, contributing £4.4 billion; and meat and meat products, contributing £4 billion.[5] 97% of UK food and drink manufacturing businesses are small to medium sized enterprises (SMEs), but they account for only 22% of the industry's turnover.[6]

The UK food and drink industry is heavily reliant on international supply chains. The sector imports a significant amount of raw materials, ingredients and finished products, in particular, from the EU; 23% of UK domestic consumption originates in the EU.[7] In addition, UK food and drink exports valued at almost £25 billion per year are sent abroad.[8] The presence of international supply chains presents some challenges to identifying and implementing resource efficiency measures.

Efficient use of food and drink resources can reduce the sector's carbon footprint, by reducing the amount of greenhouse gas (GHG) emissions associated with production and consumption of food and drink in the UK. UK food system GHG emissions were estimated at 154.8MtCO2e in 2020.[9] Although not all of these emissions occur in the UK, the total is equivalent to 38% of UK territorial emissions[10] or 27% of UK consumption emissions.[11] In 2019, 23% (36MtCO2e) of food system GHG emissions were associated with the production and distribution of food that becomes waste in the UK.[12] GHG emissions in scope for this report will be significantly less as the study focuses on UK GHG emissions post farm gate. However, improvements in resource efficiency here may have upstream benefits, including in out-of-scope sectors, with food waste prevention being the most obvious example because the GHG emissions associated with that food at each stage of the food supply chain would be avoided. Efficient use of resources can also bring about other benefits such as improvements to water resources and quality, air quality and biodiversity.

Using food and drink resources more efficiently can also result in cost savings for businesses and households. Resource efficiency in the food and drink sector focuses on reducing inputs, diverting surplus food and drink back into the value chain where possible and minimising food

[1] Defra (2023). National statistics: Food statistics in your pocket.
[2] Excluding Northern Ireland, as equivalent data is not available.
[3] Defra (2023). National statistics: Food statistics in your pocket.
[4] Food and Drink Federation (2022). Our Industry at a Glance.
[5] Defra (2023). National statistics: Food statistics in your pocket.
[6] Defra (2023). National statistics: Food statistics in your pocket.
[7] Defra (2023). National statistics: Food statistics in your pocket.
[8] Food and Drink Federation (2022). Our Industry at a Glance.
[9] WRAP (2022). Tracking UK food system greenhouse gas emissions: 2022 update.
[10] Department for Business Energy and Industrial Strategy (2022). 2020 UK Greenhouse Gas Emissions.
[11] Defra (2023). Official Statistics: Carbon footprint for the UK and England to 2020.
[12] WRAP (2021). UK Food System GHG.

loss and waste throughout the various stages of the value chain. Food and drink wastage at any stage of the value chain can result in financial losses, through loss of raw materials, wasted production inputs, or costs associated with waste management. It has been estimated that household food waste has an annual value of £17 billion, equating to £250 per person per year or £1,000 per year for a household of four.[13]

This report will outline measures to achieve resource efficiencies in the UK food and drink sector and the barriers and drivers to achieving them.

For this report, food is defined as any substance—whether processed, semi-processed, or raw—intended for human consumption.[14] The definition includes drink and any substance that has been used in the manufacture, preparation, or treatment of food. The terms 'food' and 'food and drink' are used interchangeably throughout this paper. In common with agreed guidance on interpreting Sustainable Development Goal Target 12.3 (relating to food waste and losses), both inedible and edible parts of food are considered in scope when discussing resource efficiency measures in this report. The 'inedible' parts are the components, in a particular food supply chain, which are not intended to be consumed by humans, e.g., bones, rinds, and pits/stones. However, it is acknowledged that what is considered inedible varies across different users and over time.[15]

Food waste is defined as the "removal from the food supply chain of food which is fit for consumption, by choice, or which has been left to spoil or expire as a result of negligence by the actor".[16] In the UK context, the definition of food waste usually excludes any material that is sent for redistribution to people, animal feed or conversion into industrial products. Instead, food sent to these routes is collectively referred to as "food surplus".[17] Nonetheless the "food waste hierarchy" applies to both food waste and food surplus, and prevention of both waste and surplus is the most resource efficient option in all cases.[18] This report makes this distinction between surplus and waste in the context of measure 8, where redistribution is accounted for specifically. However, in other areas of the report, when the focus is on prevention of both surplus and waste, the ways in which surplus/waste is avoided are typically grouped together for discussion. In these cases 'waste' prevention is used to refer to food loss, surplus and waste, as the distinction sometimes made between these concepts was judged not to aid the analysis.

Sector scope

The scope of this report covers resource efficiency measures applicable to stages of the food and drink supply chain after harvesting (including any immediate processing of harvested products). Specifically, the supply chain stages considered in scope are: processing and manufacturing; storage and distribution; retail; hotels, restaurants and catering (HoReCa); consumers; and end-of-life management. Significant resource efficiency savings (both in terms

[13] WRAP (2023). Household Food and Drink Waste in the United Kingdom 2021-22.
[14] Hanson, C. (2017). Guidance on Interpreting Sustainable Development Goal Target 12.3.
[15] Hanson, C. (2017). Guidance on Interpreting Sustainable Development Goal Target 12.3.
[16] Food and Agriculture Organization of the United Nations (2014). Definitional Framework of Food Loss.
[17] WRAP (2020). Food surplus and waste measurement and reporting UK guidelines.
[18] Defra (2024). Food and drink waste hierarchy: deal with surplus and waste.

of food losses and reductions in inputs) may be achievable pre-harvest but are not a feature of this study. Additionally, the focus is on the production and consumption of food and drink as physical products, rather than wider resource efficiency measures available in the sector such as those to packaging or logistics.

The following topics are, therefore, out of scope of this study:

- Primary production: based on discussions between the project team, Defra and DESNZ, it was decided that the scope boundary for this research would be drawn at the point of harvest of food. Therefore, all stages of the value chain from the processing of harvested food, through to end-of-life management are considered in scope, while primary production of food, as well as any inputs to primary production, are considered out of scope. It is acknowledged that some primary production decisions and buyer requirements on primary producers may impact subsequent processing options and supply chain efficiency; these are in scope if they lead to waste that arises later in the supply chain than the farm gate.
- Dietary shift: based on discussions between the project team, Defra and DESNZ, it was decided that changes to diet composition and, in particular, dietary shift and moving from meat products to alternative proteins is out of scope for this research, considering the research is focused on resource efficiency defined as lower resource use for a given level of final consumption. [19] [20]
- Over-consumption: based on discussions between the project team, Defra and DESNZ, it was decided that measures related to reducing overconsumption of food and drink by consumers are not in scope for this study, considering the research is focused on resource efficiency defined as lower resource use for a given level of final consumption.
- Food packaging: food packaging was considered out of scope for the food and drink sector, as the most common food packaging materials are covered by other sectors included in the wider resource efficiency research programme (e.g., plastic, glass, paper). However, it is assumed that resource efficiency measures in the other sectors do not result in the deterioration of the product protection provided by food and drink packaging. Conversely, scope to innovate in packaging to reduce food and drink loss and waste (for example, by extending product shelf-life in store or at home) is within the scope of this study, but any wider packaging material trade-offs this may imply are not directly considered.
- Energy efficiency: not considered in scope for this study as it is considered in other studies outside of this research programme.

It is worth noting that food and drink are organic materials, representing a bioeconomy resource loop, making them different in nature to other products under examination using the

[19] Dimbleby, H. (2021) National Food Strategy.
[20] Scarborough, P et al. (2023) Vegans, vegetarian, fish-eaters and meat-eaters in the UK show discrepant environmental impacts. Nature Food. 4, p.565-574

common study methodology outlined for this research programme. While some of the resource efficiency measures defined in this paper are presented as relating to a particular stage in the food and drink supply chain, in reality, the sector is highly interconnected, and actions required for the implementation of the measure will sit across multiple parts of the supply chain and connect to wider economic and environmental considerations beyond the scope of both this paper and even the wider research programme. The interconnectedness of the food and drink supply chain is covered in more detail in Section 9.0.

This report summarises the findings of interviews with nine stakeholders, a workshop with five attendees and a literature review. It is not intended to be a comprehensive study of the drivers/barriers, instead it is a reflection of stakeholder views and literature studied during a fixed time period, in accordance with a fixed scope.

Literature review approach

A literature review was conducted that involved known literature from sector experts, recommended literature from interviews and literature found using relevant search strings. The full list of search strings can be found in Appendix B: Search strings. Further sources were identified from sector experts via the interviews and a Call for Evidence sent directly to stakeholders. The full list of sources used are listed in Appendix C: Literature sources.

The literature review identified 134 sources that discussed resource efficiency in the food and drink sector. This comprised:

- 54 academic papers;
- 52 industry reports;
- 10 technical studies;
- 9 website articles;
- 5 policy documents; and
- 4 academic reports.

The relevant sources were mostly considered of medium to high accessibility and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.04 (out of 5), with 85 sources exhibiting a score of 4 or above. 74 literature sources were UK-specific and only 14 sources were not recent studies.

Interview approach

A total of 9 stakeholders were interviewed broadly representing the food and drink sector value chain: 3 researchers, 2 manufacturers, 1 industry body, 1 redistributor, 1 caterer and 1 non-governmental organisation representative. It should be noted that there were no interviewees

from the retail sector, which limits the extent to which conclusions can be drawn around measures which are heavily dependent on retailer behaviours, particularly measures 4 and 5.

Workshop approach

There were initially 5 participants in attendance at the workshop. However, 1 participant attended for a limited period of time and so was only present for the discussion and voting exercises relating to Measure 6. Another participant attended as a secondary representative and did not participate in voting activities. The participants able to attend the entire workshop represented the manufacturing and redistribution stages of the food and drink sector value chain: 2 manufacturers and 1 redistributor (plus 1 non-voting redistributor).

Drivers and barriers

Drivers and barriers were categorised using two separate systems:

- The PESTLE framework which is focused on the types of changes: political, economic, social, technological, legal and environmental;
- The COM-B framework which is focused on behaviour change:
    - **Capability**: can this behaviour be accomplished in practice?
        - Physical Capability – e.g., measure may not be compatible for certain processes
        - Psychological Capability – e.g., lack of knowledge
    - **Opportunity**: is there sufficient opportunity for the behaviour to occur?
        - Physical Opportunity: e.g., bad timing, lack of capital
        - Social Opportunity: e.g., not the norm amongst the competition
    - **Motivation**: is there sufficient motivation for the behaviour to occur?
        - Reflective motivation: e.g., inability to understand the costs and benefits,
        - Automatic motivation: e.g., lack of interest from customers, greater priorities

List of resource efficiency measures

The list of resource efficiency measures for the food and drink sector identified via the literature review and interviews can be found in Table 1. Changes made to earlier versions of the measures and indicators considered and discussed with stakeholders are described in the following sections of this report.

Measure 8 deals with end-of-life practices according to the UK food and drink surplus and waste hierarchy. It should be noted that some options from the UK food and drink surplus and waste hierarchy are referenced more than once or not at all among the set of indicators for measure 8, depending on whether additional breakdown makes sense for the indicator. This is discussed further in Section 8.1.2.

Appendix D: List of discarded resource efficiency measures in the food & drink sector contains a list of resource efficiency measures that were discarded from the scope of this study.

Table 1: List of resource efficiency measures for the food and drink sector

#	Lifecycle stage	Strategy	Measure name	Measure indicator
1	Manufacturing	Production efficiencies	Use of by-products in other products	% of production waste valorised
2	Manufacturing	Production efficiencies	Optimising processing to reduce product losses	% of total production that is wasted
3	Distribution	Production efficiencies	Reduction of food waste in distribution and storage	% of food that is distributed that is wasted
4	Pre-processing & Retail	Life extension	Reduction in food waste due to revised product standards	% of harvested food that is wasted due to product standards
5	Retail	Reduced waste generation	Reduction of food waste in retail	% of food at the retail stage wasted
6	Consumer	Reduced waste generation	Reduction of food waste amongst households	% of food purchased by consumers that is wasted in the home
7	HoReCa	Reduced waste generation	Reduction of food waste in HoReCa	% of food in HoReCa that is wasted

8	End-of-life		End-of-life practices according to the UK food and drink surplus and waste hierarchy	% of post-farm gate food surplus that is redistributed (option 2 in the UK food and drink surplus and waste hierarchy) Percentage of post-farm gate food surplus and waste that is made into animal feed (option 3 in the UK food and drink surplus and waste hierarchy) Percentage of post-farm gate food surplus and waste that is made into biomaterials (option 4 in the UK food and drink surplus and waste hierarchy) Percentage of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5 in the UK food and drink surplus and waste hierarchy) Percentage of post-farm gate food surplus and waste that is sent to composting (option 5 in the UK food and drink surplus and waste hierarchy) Percentage of post-farm gate food surplus and waste that is used for landspreading (option 6 in the UK food and drink

				surplus and waste hierarchy) Percentage of food waste that is sent to energy from waste (option 7 in the UK food and drink surplus and waste hierarchy) Percentage of post-farm gate food surplus and waste that is sent to sewer and landfill (option 8 in the UK food and drink surplus and waste hierarchy)

1.0 Measure 1 – Use of by-products in other products

1.1 Food and drink resource efficiency measure

1.1.1 Description

The use of by-products in other products generated during the manufacture of food and drink products that avoids waste or diverts surplus material to a more efficient use (according to the UK food and drink surplus and waste hierarchy) and reduces primary ingredient use.

By-products are generated during many food and drink manufacturing processes. They can be generated as a fundamental output of a particular manufacturing process (e.g., unavoidable additional outputs during the manufacture of animal products, such as shells and bones from fish and seafood processing), or due to accidents or errors that occur during a manufacturing process (e.g., breakages of a fragile product on the production line, but where the material impacted can nonetheless be used for another purpose). Re-incorporating these by-products into the manufacture of other products, either at the same stage of manufacturing, a different stage of manufacturing, or within another sector, can prevent them from becoming waste or divert them to a more efficient use (according to the UK food and drink surplus and waste hierarchy). The use of a by-product in another product can displace the use of alternative material inputs, improving overall resource efficiency.

1.1.2 Measure indicator

The indicator selected was the **percentage of production surplus and waste valorised**. This is a relative measure with the percentage derived from the total amount of surplus and waste reincorporated back into the manufacture of another product divided by the total amount of surplus and waste generated during the manufacturing of food and drink products. The scope of this measure differs from that of Measure 8, which considers destinations for food waste as a percentage of all food waste generated.

1.1.3 Examples in practice

Possible ways described in the literature or provided by stakeholders to reincorporate by-products generated during manufacturing, to avoid their disposal or divert them to a more efficient use (according to the UK food and drink surplus and waste hierarchy), include but are not limited to:

- The manufacture of sugar from sugar beet can generate a range of by-products, including: bioethanol for use in road fuel, betaine for use in cosmetic products, products for soil pH correction, and topsoil. Even prior to these value extraction options, when sugar beet is brought to a manufacturing plant for the production of sugar, soil first has

to be washed off the sugar beet in a fluming process. The soil that is collected during this process can be dried out, conditioned and then sold as a topsoil.[21]

- Chocolate biscuit manufacturers can use broken bits of biscuit, which are generated as a by-product from biscuit manufacturing processes, in the manufacture of chocolate bars.[22]
- Proteins and fats recovered from the manufacture of animal products can be used as an ingredient in products such as ready meals, gravy and soups.[23]
- Brewers' spent grain generated during the beer-brewing process is commonly used as an input to animal feed. Due to its high fibre and protein content, this by-product also has potential for application as a natural fortifier in the production of food products, especially bakery products such as bread and biscuits.[24]
- Bread waste diverted for use in brewing to replace malt in the production of beer, other alcoholic drinks and ethanol.[25]
- Grape marc (stalks, skin) that is produced through the production of wine can be used for ethanol production.[26]

Overall, the generation and use of byproducts is highly diverse, and can be very process and context specific. By-products may be re-incorporated within the same food and drink sub-sector, as an input to another food and drink sub-sector, or as an input elsewhere in the economy. It is also worth noting that the distinction between by - products and co - products is not always clear in application.

1.2 Available sources

1.2.1 Literature review

The literature review identified 18 sources that discussed the use of by-products, although there was little quantitative evidence on the future levels of resource efficiency that could be achieved through this measure. This comprised:

- 12 academic papers;
- 4 industry reports;
- 1 policy document; and
- 1 technical study.

[21] Stakeholder comment.
[22] Stakeholder comment.
[23] Magee, A. (2022). How are food manufacturers tackling waste management? Accessed at link.
[24] Lynch, K.M. (2016). Brewers' spent grain: a review with an emphasis on food and health. Journal of the Institute of Brewing. 122, p.549-771.
[25] Narisetty, V et al. (2021). Recycling bread waste into chemical building blocks using a circular biorefining approach. Sustainable Energy Fuels. 5, p.4842-4849.
[26] Gómez-Brandón, M et al. (2019) Strategies for recycling and valorization of grape marc. Critical Reviews in Biotechnology. 39, p.437-450.

The relevant sources were considered of medium – high accessibility and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.39 (out of 5), with 15 sources exhibiting a score of 4 or above. Only 8 literature sources were UK-specific and only 3 sources were not recent studies.

1.2.2 Interviews

The indicator for this measure remained unchanged throughout the interviews. Only 3 of the stakeholders interviewed engaged in discussion of this measure. However, none of the stakeholders that did not engage in discussion of this measure objected to the measure or the indicator defined. One of the stakeholders that discussed this measure did so in combination with a discussion of Measure 8 ('End-of-life practices according to the UK food and drink surplus and waste hierarchy'). In particular, this stakeholder highlighted that it may not always be clear or consistent across different operations what is defined as a 'by-product', versus what is defined as diversion to uses like animal feed or biomaterials, which are discussed in Measure 8.

1.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 1 with a high level of engagement. The stakeholders represented a small section of the food and drink sector, with discussions and voting activity from manufacturers and a redistributor. For this measure, confidence levels in voting for levels of efficiency were high for all stakeholders. There were three votes for the current level of efficiency, three for the maximum level of efficiency and three for business-as-usual. Discussion topics included the low percentage of food from manufacturing that ends up in landfill and the classification of food waste that undergoes anaerobic digestion as a waste rather than a byproduct. Also discussed was the redirection of by-products in other products from the same company and even within the same product range.

An additional barrier was suggested by stakeholders during the workshop:

Lack of awareness of what can be done with waste outside of a manufacturer's own processes.

The level of engagement in the workshop was as follows:

- Three stakeholders across manufacturing and redistribution were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Three stakeholders actively contributed to verbal discussion, with no contribution on the Teams chat.

1.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

1.3.1 Drivers

Table 3 below shows the main drivers for Measure 1. The most significant drivers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 2: Drivers for food and drink measure 1

Description	PESTLE	COM-B
Revenue generation	**Economic**	**Motivation – automatic**
Cost savings	**Economic**	**Motivation – automatic**
Setting a food waste reduction target	**Social**	**Motivation – reflective**
Risk diversification	Economic	Motivation – reflective
Food waste measurement and public reporting	Social	Motivation – reflective

Revenue generation

The most important driver of the use of by-products in other products is the opportunity to generate additional revenue. When a by-product is utilised in another product, it has economic value and so the manufacturer producing a by-product can generate additional revenue directly through the sale of the by-product, or indirectly through the sale of another product that incorporates the by-product. In some processes, the by-product can become a financially significant part of the overall business model and may be referred to as a coproduct.

Cost savings

If a material is generated as a side effect of the production process and is not used in another product, the manufacturer has to deal with this material as waste. There will likely be costs associated with getting rid of such a waste product. However, if the material can be used in another product, the manufacturer can avoid the costs associated with dealing with the material as waste. There is, therefore, an economic incentive to find ways to use material that does not get used for the primary purpose as a by-product in other products.

Setting a food waste reduction target

UN Sustainable Development Goal (SDG) target 12.3 aims to achieve a 50% per capita reduction in food waste by 2030, versus a 2007 baseline.[27] In 2018, in consultation with stakeholders from across the food and drink supply chain, WRAP and the Institute of Grocery Distribution (IGD) developed a roadmap for how the UK food industry can help to deliver on SDG 12.3. The Food Waste Reduction Roadmap urges food businesses to commit to 'Target, Measure and Act' on food waste.[28] Setting a food waste reduction target that meets or exceeds SDG target 12.3, can help manufacturers focus their objectives and align efforts towards achieving those objectives, e.g., using by-products in other products. Additionally, the measurement requirement setting and monitoring a target, makes it much more likely reduction actions are taken, as areas of waste and associated costs will be visible and more likely to be managed.

Risk diversification

Food and drink products have individual value cycles. These cycles are driven by a variety of external factors and the bottom of one product's value cycle will not necessarily coincide with another's. By incorporating by-products from one manufacturing process in other products, a manufacturer can, therefore, diversify their revenue streams, thereby diversifying the risk profile of their income. This can align directly with revenue generation, with by-products or coproducts effectively cross-subsidising the overall production process.

Food waste measurement and public reporting

Measuring and publicly reporting on their food waste, according to best practice guidelines,[29] provides an incentive for manufacturers to implement food waste reduction measures such as the use of by-products in other products. Measurement is essential to understanding, identifying, and being able to act on a problem, and reporting, including public reporting, can help ensure transparency and accountability within organisations and for wider stakeholders, helping to maintain the importance of action on this issue. Without these features in place, continual improvement may be hard to maintain. There are increasing moves towards food waste reporting within the supply chain. This can create pressure for change from some customers independently of moves towards full public reporting.

1.3.2 Barriers

Table 3 below shows the main barriers for Measure 1. The most significant barriers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 3: Barriers for food and drink measure 1

Description	PESTLE	COM-B
The market price of the product obtained, relative	**Economic**	**Motivation – reflective**

[27] WRAP (2023). Food System Transformation – The Courtauld Commitment 2030.
[28] WRAP (2023). The Food Waste Reduction Roadmap Toolkit.
[29] WRAP (2020). UK food surplus and waste measurement and reporting guidelines.

to the cost of the manufacturing process		
Lack of information on the viability and performance at the industrial scale	**Economic**	**Opportunity – social**
Availability of the by-product	Technological	Capability – physical
The logistics associated with supplying a by-product	Technological	Capability – physical
Economies of scale	Economic	Opportunity – physical
Need for standardisation of certain processes	Technological	Capability – physical
Lack of awareness of how waste could be used outside own processes	Social	Capability – psychological

The market price of the product obtained

The market price of the product obtained when a by-product is incorporated into another product may not be sufficient to justify the cost of the manufacturing process required to incorporate the by-product. In this case there is an economic barrier to the measure. Fluctuating prices may also deter investment or make utilisation of a by-product stream economically viable only above certain price points.[30]

Lack of information on the viability and performance of a technology or process at the industrial scale

A lack of information about the viability and performance at industrial scale of manufacturing processes to incorporate by-products into other products creates uncertainty for the manufacturer. This may prevent the manufacturer from investing in the systems and infrastructure required to incorporate their by-products into another product.[31]

Availability of the by-product

If the supply of a by-product is unreliable or inconsistent (in terms of quantity or composition), it can be difficult for a manufacturer to incorporate this material stream as an input to the

[30] European Commission's Knowledge Centre for Bioeconomy (2020). Brief on food waste in the European Union
[31] European Commission's Knowledge Centre for Bioeconomy (2020). Brief on food waste in the European Union

manufacture of another product, at scale, or to justify the investments necessary to be able to do so.[32]

The logistics associated with supplying a by-product

Facilitating the recovery of a by-product produced during the manufacture of a food/drink product, as well as the transfer of the by-product to another manufacturing process, may require particular processes and infrastructure. The resources required to establish and maintain these processes and infrastructure can be a barrier to this measure. This may be a particular issue where supply is limited or materials arising are not concentrated relative to market demand.[33]

Economies of scale

SMEs may lack the scale, finance and/or knowledge to realise opportunities for utilising by-products generated during their manufacturing process in other products. Investment is usually required to establish a process for extracting a by-product and a sufficiently large source of the by-product is necessary for its sale and distribution to be economically viable. Scale may, therefore, be a barrier for smaller manufacturing plants.[34]

Need for standardisation of certain processes

Many of the end processes that would allow for valorisation of food waste into bio-based products are currently at a low level of technology readiness. Many of these processes (e.g., the extraction of bioactive proteins from fish waste) are not yet sufficiently standardised for application at industrial scale.[35] [36]

Lack of awareness

Food and drink manufacturers may lack awareness of what can be done with waste generated during the manufacture of their products, outside of their own manufacturing processes.[37]

1.4 Levels of efficiency

Table 4: Levels of efficiency for food and drink measure 1

Indicator: Use of by-products in other products

[32] European Commission's Knowledge Centre for Bioeconomy (2020). Brief on food waste in the European Union
[33] Raak, N. et al. (2017) Processing- and product-related causes for food waste and implications for the food supply chain. Waste Management, 61, p461-472.
[34] Santagata, R. et al., (2021) Food waste recovery pathways: challenges and opportunities for an emerging bio-based circular economy. A systematic review and an assessment. Journal of Cleaner Production. 286, 125490.
[35] European Commission's Knowledge Centre for Bioeconomy (2020). Brief on food waste in the European Union
[36] Caldeira et al., (2020) Sustainability of food waste biorefinery: A review on valorisation pathways, techno-economic constraints, and environmental assessment. Bioresource Technology. 312, 123575.
[37] Added during stakeholder workshop.

Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	60 – 90%	80 – 100%	60 – 90%
Evidence RAG	Red	Red	Red

1.4.1 Current level of efficiency

There was limited quantitative evidence available on the current level of efficiency for Measure 1. None of the stakeholders interviewed were able to provide a quantitative estimate of the current level of efficiency for Measure 1. The difficulty in providing quantitative estimates is, in large part, due to high variability in the current level of efficiency across different food and drink sub-sectors and products. Two of the stakeholders interviewed suggested that the current level of efficiency for Measure 1 would be very high for the manufacture of particular food and drink products, e.g., sugar.

Similarly, none of the literature sources reviewed provided a quantitative estimate of the current level of efficiency for Measure 1. However, one literature source gave the volumes of animal by-products and other food by-products produced in food manufacturing in the UK per year; 0.6Mt and 2.2Mt, respectively.[38]

Participants in the stakeholder workshop estimated the current level of efficiency for this measure to be high. One stakeholder estimated 80-90%, while another estimated close to 100%. However, the stakeholder that estimated close to 100% explicitly noted the inclusion of waste sent to anaerobic digestion in their estimate, which is not considered within scope for this measure.

It should be noted that this measure is focussed on supply chain waste valorised, whereas Measure 8 considers the end-of-life treatment of waste from the whole food chain.

The reported range for supply chain waste is 60-90%. The lower end of the range is adjusted downwards from the estimates given by stakeholders in the workshop, given the potential conflation of by-products and anaerobic digestion in these estimates. This estimate has been given a red evidence RAG rating, due to the lack of supporting quantitative evidence available in the literature and from other stakeholders.

[38] WRAP (2022). Food surplus and waste in the UK – key facts.

1.4.2 Maximum level of efficiency in 2035

There was also very limited quantitative evidence available on the maximum level of efficiency in 2035 for Measure 1. None of the literature sources reviewed provided a quantitative estimate.

Participants in the stakeholder workshop estimated that the maximum level of efficiency for this measure should be close to 100%. Although, as noted above, it's possible that workshop participants were classifying waste sent to disposal measures other than landfill as waste valorised as a by-product, even though disposal is not included within the scope of waste valorisation. These estimates can be contrasted with two provisional estimates provided in one of the stakeholder interviews. This stakeholder estimated that, at minimum, if focus were placed only on the valorisation of waste (i.e., with no other reduction in overall waste levels), the percentage of waste valorised could reach 30% by 2035. While, if aggressive food and drink waste prevention was pursued in parallel, the percentage of waste valorised could reach 50-60% by 2035 (i.e., capacity might be similar but would represent a larger share of a smaller total). However, it should be noted that while the workshop discussion focussed on supply chain waste, which is the scope of the defined measure, the estimates provided during the stakeholder interview discussions extended to waste from the whole food chain.

The reported range for this measure is 80-100%. The estimate provided during the stakeholder workshop was taken as a starting point, given the focus on supply chain waste. However, the lower end of the range is adjusted downwards from the estimate given by stakeholders in the workshop, given the potential conflation of by-products and anaerobic digestion in these estimates. This estimate has been given a red evidence RAG rating, due to the lack of supporting quantitative evidence available in the literature and from other stakeholders.

1.4.3 Business-as-usual in 2035

There was also very limited quantitative evidence available on the business-as-usual level of efficiency in 2035 for Measure 1. None of the literature sources reviewed provided a quantitative estimate.

Participants in the stakeholder workshop estimated that the business-as-usual level of efficiency for this measure should be high. One stakeholder estimated 80-90%, while another estimated close to 100% (possibly including waste sent to anaerobic digestion).

The reported range is 60-90%. The lower end of the range is adjusted downwards from the estimates given by stakeholders in the workshop, given the potential conflation of by-products and anaerobic digestion in these estimates. This range has been given a red evidence RAG rating, due to the lack of supporting quantitative evidence available in the literature and from other stakeholders.

2.0 Measure 2 – Optimising processing to reduce product losses

2.1 Food and drink resource efficiency measure

2.1.1 Description

Optimising food and drink manufacturing processes to reduce the waste generated during the manufacture of food and drink products.

The efficiency of food and drink manufacturing techniques and processes can impact the quantity of waste generated and thus the product yield. Various food and drink manufacturing processes could be optimised to improve resource efficiency. Examples include, but are not limited to, ingredient measurement, storage temperature, product assembly, cooking/baking and product packing.

2.1.2 Measure indicator

The indicator selected was the **percentage of total production that is wasted**. This is a relative measure with the percentage derived from the total amount of waste generated during food and drink manufacturing divided by the total amount of food and drink manufacturing throughput.

2.1.3 Examples in practice

Possible ways described in the literature or provided by stakeholders to optimise food and drink manufacturing processes to minimise the amount of waste generated include:

- Preventing contamination on the processing line, which results in the disposal of product batches;
- Reducing errors in processing that result in defect products, which end up as waste;
- Optimising processes and equipment to reduce trimmings that end up as waste;
- Improving operational practices to reduce waste generated due to machinery related issues, e.g., when machinery settings are switched or when machinery breaks down;[39]
- Optimising ingredient ordering by, e.g., minimising over-ordering margins; and
- Optimising inputs for the manufacturing process, e.g., consistency of the input crop.

In addition, one interviewee emphasised the positive role of implementing continual improvement programmes within operations, which could contribute to all of the above.

[39] Tatum, M. (2017). Ten ways manufacturers waste food. Accessed at link.

2.2 Available sources

2.2.1 Literature review

The literature review identified 22 sources that discussed processing optimisation, although there was little quantitative evidence on the future levels of resource efficiency that could be achieved through this measure. This comprised:

- 10 academic papers;
- 6 industry reports;
- 2 academic reports.
- 2 policy documents; and
- 2 technical studies.

The relevant sources were considered of medium - high accessibility and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.14 (out of 5), with 16 sources exhibiting a score of 4 or above. Only 10 literature sources were UK-specific and only 4 sources were not recent studies.

2.2.2 Interviews

The indicator for this measure remained unchanged throughout the interviews. Six of the stakeholders interviewed engaged in discussion of this measure, although some were able to discuss the measure in much more detail than others. None of the eight interviewees objected to the measure or the indicator defined.

2.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 2 with a medium level of engagement. The stakeholders represented a small section of the food and drink sector, with discussions and voting activity from manufacturers and a redistributor. There was a mixture of medium confidence and high confidence levels in voting for levels of efficiency for this measure. There were three votes for the current level of efficiency, three for the maximum level of efficiency and three for business-as-usual. The discussion touches on the complexity of recording waste at different stages of the manufacturing process. Also discussed was the importance of the definition and treatment of waste. There was also the acknowledgement of the high efficiency of the UK food manufacturing industry and the challenges of achieving further gains.

An additional barrier was suggested by stakeholders during the workshop:

Levels of resource efficiency are already relatively high in many sectors and processing plants. There are only small gains to be made.

The level of engagement in the workshop was as follows:

- Three stakeholders across manufacturing and redistribution were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Two stakeholders actively contributed to verbal discussion, with no contribution on the Teams chat.

2.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

2.3.1 Drivers

Table 5 below shows the main drivers for Measure 2. The most significant drivers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 5: Drivers for food and drink measure 2

Description	PESTLE	COM-B
Avoided costs	**Economic**	**Motivation – automatic**
Continuous improvement programmes	**Technological**	**Capability – physical**
Setting a food waste reduction target	**Social**	**Motivation – reflective**
Avoided environmental impacts	Environmental	Motivation – reflective
Standardising containers and packaging	Technological	Opportunity – social
Staff training	Social	Capability – psychological
Food waste measurement and public reporting	Social	Motivation – reflective
Incentivising and training staff to take action to reduce food waste	Social	Opportunity – social

Avoided costs

When products are lost during food and drink manufacturing, the costs associated with producing the item to that point in the value chain also represent a loss. By reducing product

losses through optimising manufacturing processes, lost input costs are also reduced. Interviewees stated that this was typically the key driver for gains to date.

Continuous improvement programmes

A food or drink manufacturer may implement a continuous improvement programme internally or with support from an external partner. A continuous improvement programme might involve activities such as identifying key metrics, setting clear goals, regular monitoring and reporting and root cause analysis. This can help the manufacturer to identify where food and drink waste is occurring and to implement solutions to reduce it. One interviewee, in particular, stressed the value this could add across various processes and changes.

Setting a food waste reduction target

The rationale for manufacturers to set a food waste reduction target is the same as outlined in Section 1.3.1.

Avoided environmental impacts

There are environmental impacts associated with producing inputs to the manufacturing stage of the food and drink value chain. By reducing product losses through optimising manufacturing processes, environmental impacts occurring upstream in the supply chain can be reduced through an overall reduction in manufacturing inputs.[40] This may act as a motivator for food and drink manufacturers to reduce product losses during manufacturing, especially where they have made environmental commitments.

Standardising containers and packaging

Excessive product handling can damage food and drink products, contributing to food and drink waste during manufacturing. Standardising containers and packaging can help to reduce product handling by reducing the need for quality inspections, thereby reducing food and drink waste during manufacturing. However, firms' flexibility may be constrained by the integration of processing and packaging lines, meaning that packaging changes would require wider process changes.

Staff training

Provision of training opportunities in skills relevant for food waste prevention during the manufacturing process enables staff to better implement food waste reduction actions. One interviewee highlighted that a major driver of losses is mistakes and accidents. In addition to functional skills, training may include cultural skills e.g., continuous improvement mentalities.

Food waste measurement and public reporting

[40] Laurentiis, V. (2020) No time to waste: assessing the performance of food waste prevention actions. Resources, Conservation and Recycling. 161, 104946,

The rationale for manufacturers to measure and publicly report on food waste is the same as outlined in Section 1.3.1.

Incentivising and training staff to take action to reduce food waste

A range of incentives can be employed in manufacturing settings to encourage staff across the business to adopt behaviours that drive food waste reductions. For example, linking financial incentives for senior management to performance on food waste reduction, or including food waste measurement in job descriptions and staff inductions.

2.3.2 Barriers

Table 31 below shows the main barriers for Measure 2. The most significant barriers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 6: Barriers for food and drink measure 2

Description	PESTLE	COM-B
Poor operational practices	**Social**	**Capability – physical**
Poor instrumentation and controls	**Technological**	**Capability – physical**
Working and career conditions in the food system	Social	Motivation – automatic
Economies of scale	Economic	Opportunity – physical
Levels of resource efficiency are already relatively high in many sectors and processing plants, reducing scope for gains	Technological	Capability – physical
High cost of implementing resource efficiency initiatives	Economic	Capability - physical
Lack of awareness	Social	Motivation - automatic

Poor operational practices

Operational practices in food and drink manufacturing may not be optimised to prevent food and drink waste. This results in food and drink waste being produced both systematically (e.g., over-ordering of ingredients or more line changeovers than is optimal), and as a result of accidents occurring, during the manufacturing process. Poor operational practices can

therefore be a barrier to minimising food and drink waste during manufacturing. It should be noted that some of these production choices or constraints may be the result of wider market demands (e.g., on product mix or specifications), not simply decisions made on site.[41] [42]

Poor instrumentation and controls

A range of equipment and processes are employed in food and drink manufacturing to monitor production processes and ensure product quality. Food and drink waste may be generated during manufacturing when the instrumentation and quality controls in place are inadequate for ensuring manufacturing processes run correctly and efficiently. Poor instrumentation and controls and the costs associated with improving them can, therefore, be barriers to reducing product losses during manufacturing.[43]

Working and career conditions in the food system

Employment conditions may not facilitate employee engagement and skill acquisition that would help anticipate and prevent waste. Low wages, the repetitive nature of work, challenging working conditions, limited benefits or growth opportunities, and high staff turnover can all be barriers to reducing product losses during food and drink manufacturing if these conditions make it harder for workers to identify, prioritise, or act on efforts directed towards reducing food waste.[44]

Economies of scale

SMEs may lack the scale, finance and/or knowledge to realise opportunities for optimising manufacturing processes to reduce food and drink waste.

Levels of resource efficiency are already relatively high in many sectors and processing plants, reducing scope for gains

The UK food and drink manufacturing industry is already highly efficient across many sectors and processing plants, meaning the scope for improvement in the level of efficiency for this measure is fairly limited.

High cost of implementing resource efficiency initiatives

[41] Department of the Environment, Climate and Communications (2022) Ireland's National Food Waste Prevention Roadmap 2023-2025
[42] Canali. M et al. (2017) Food Waste Drivers in Europe, from Identification to Possible Interventions. Sustainability. 9, 37.
[43] Department of the Environment, Climate and Communications (2022) Ireland's National Food Waste Prevention Roadmap 2023-2025
[44] ReFED (2023). Building a Food System That Works for Everyone: A Look at the Intersection of Food Waste with Justice, Equity, Diversity, and Inclusion.

Resource efficiency initiatives can be costly to implement and require upfront investment.[45] A lack of financial resources can be a major obstacle in the implementation of resource efficiency measures, particularly for small and medium sized enterprises.

Lack of awareness

Many managers and employees in the food and drink manufacturing industry are not aware of the issues associated with food waste and the importance of monitoring and preventing food waste. Lack of awareness means individuals are less likely to exhibit behaviours that could promote resource efficiency.

2.4 Levels of efficiency

Table 7: Levels of efficiency for food and drink measure 2

Indicator: Percentage of production that is wasted			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	2 – 5%	2 – 3%	2 – 5%
Evidence RAG	Green	Amber	Amber

2.4.1 Current level of efficiency

Data published by WRAP indicates that there is 1.4Mt of food waste in the UK manufacturing sector per year, of which 0.7Mt is wasted food excluding the inedible parts. This literature source also reports that, as a share of food handled, food waste in manufacturing is 3.8%.[46]

A second literature source published by WRAP provides an estimate of the current level of efficiency for Measure 2, for producers and manufacturers committed to WRAP's food waste reduction roadmap. Among this group, food waste as a proportion of food handled, excluding the inedible parts and including the inedible parts respectively, is estimated to have been 2.44% and 3.8% in 2021.[47]

At the EU level, data published by the European Commission indicates that the percentage of food produced that is wasted during processing and manufacturing is 4.72%.[48]

[45] Farooque, M et al. (2019) Barriers to Circular Food Supply Chains in China. Supply Chain Management An International Journal. 24, 4.
[46] WRAP (2023). UK Food Waste & Food Surplus – Key Facts.
[47] WRAP (2022). The Food Waste Reduction Roadmap progress report 2022.
[48] European Commission's Knowledge Centre for Bioeconomy (2020). Brief on food waste in the European Union.

While these data points reflect an average across the range of food and drink products, the current level of efficiency for Measure 2 will vary for particular products. For example, a literature source published by WRAP estimates that 7% of milk is wasted during milk processing and handling.[49] Fresh food and drink can pose greater challenges in general, with one interviewee noting that ambient foods tend to be relatively efficient.

Multiple stakeholders agreed that the food and drink manufacturing industry is already highly efficient. In support of this judgement, one stakeholder provided a quantitative estimate for the current level of efficiency for Measure 2 of 2-3%, which corroborates the UK data points discovered in the literature reviewed. One other stakeholder provided a quantitative estimate for the current level of efficiency of Measure 2. This estimate of 10% is an outlier, compared with the other quantitative estimates gathered, but could reflect performance in specific contexts. The upper end of the reported range has, therefore, been curtailed to 5% to reflect the bulk of the supporting evidence.

Stakeholder workshop participants emphasised that the UK food and drink manufacturing industry is already highly efficient and agreed with an estimated current level of efficiency of 2-5%.

A green evidence RAG rating was given to this measure because there is alignment across multiple literature sources, with high quality ratings, as well as one stakeholder's quantitative estimate and agreement from workshop participants.

2.4.2 Maximum level of efficiency in 2035

There was limited quantitative evidence available on the maximum level of efficiency in 2035 for Measure 2. None of the literature sources reviewed provided an estimate of the maximum level of efficiency across the whole food and drink sector. However, one literature source estimated possible savings in the amount of milk wasted during processing and handling, equating to a maximum efficiency level for Measure 2 of 5.1% or, equivalently, a 27% reduction in the current level of efficiency for milk.[50] Applying this to the reported range for the current level of efficiency for Measure 2 gives an estimated range of 1.5–3.6%.

Two stakeholders provided quantitative estimates for the maximum level of efficiency by 2035 for Measure 2. One stakeholder estimated 1-2%, commenting that it would be very difficult to achieve 0%, but that maximising possibilities for redistribution should help manufacturers to get close to 0%. Another stakeholder estimated a 7–15% reduction in their estimated current level of efficiency, equating to a maximum level of efficiency in the range 1.7–2.8%.

Stakeholder workshop participants broadly agreed with these estimates, with one stakeholder suggesting an estimate of 2-4% and another stakeholder suggesting to narrow the estimated range to 2-3%.

[49] WRAP (2018). Opportunities to Reduce Waste along the Journey of Milk, from Dairy to Home.
[50] WRAP (2018). Opportunities to Reduce Waste along the Journey of Milk, from Dairy to Home.

The reported range for this measure is 2 – 3%. An amber evidence RAG rating was given to this measure because, while there is coherence between the quantitative estimate obtained from the literature, the estimate given by a stakeholder during interviews and estimates provided stakeholders during the stakeholder workshop, there is some uncertainty around the applicability of the literature estimate to the wider food and drink sector.

2.4.3 Business-as-usual in 2035

There was very limited quantitative evidence available on the business-as-usual level of efficiency in 2035 for Measure 2. None of the literature sources reviewed estimated a business-as-usual level of efficiency.

Two stakeholders commented that improvements in this measure would be marginal in a business-as-usual scenario. One stakeholder gave an estimate of 5–10%, however, this stakeholder provided an outlying estimate of 10% for the current level of efficiency for Measure 2 and so the range given here reflects a small improvement relative to this stakeholder's baseline.

Stakeholder workshop participants agreed with an estimated business-as-usual level of efficiency of 2-5%.

Therefore, the reported range for this measure is unchanged from the reported current level of efficiency for Measure 2: 2–5%. Continued marginal gains are expected, but the scope of these gains is within the range of uncertainty for the estimate of current performance. An amber evidence RAG rating was given to this measure because there are no supporting literature sources and stakeholder support for the reported range indicated during the interviews relies on interpretation of their qualitative responses.

3.0 Measure 3 – Reduction of food waste in distribution and storage

3.1 Food and drink resource efficiency measure

3.1.1 Description

Refining the techniques and processes employed during the distribution and storage of food and drink products, to reduce the amount of food waste occurring during this stage of the supply chain.

Food and drink products usually need to be transported from where they are manufactured to where they reach the final consumer, in a retail or HoReCa setting, or between different value chain stages prior to this. In addition, between leaving a manufacturing plant and arriving at its final destination, a food or drink product may be stored at an intermediate location before onward transportation. Waste can occur throughout this distribution process, for various reasons, e.g., damage from handling errors or spoilage. A potential cause of the latter is breaks in the cold chain, which is a particular focus for improvement. Refining the techniques and processes employed throughout the distribution process to reduce food waste during distribution and storage can, therefore, improve resource efficiency. Neither energy efficiency in the cold chain, nor reductions in fugitive emissions from refrigeration are in scope consideration here, in line with the focused scope of this study overall.

3.1.2 Measure indicator

The indicator selected was the **percentage of food that is distributed that is wasted**. This is a relative measure with the percentage derived from the total amount of waste generated during the distribution and storage of food and drink divided by the total amount of food and drink distribution throughput.

3.1.3 Examples in practice

Possible ways described in the literature or provided by stakeholders to reduce food and drink waste during distribution include:

- Chilled docking areas at storage warehouses and retail premises to help reduce the risk of breaks in the cold chain when food and drink products are being transferred from delivery vehicles to the warehouse/store.[51]
- Automated operation of cold storage warehouses (e.g., robotic placement of items in storage and collection of items for onward transportation) helps to maintain the storage

[51] Stakeholder comment.

temperature. Whereas when humans operate the warehouse, they introduce heat into the environment.[52]

- Automated loading of food and drink products from storage warehouses to delivery vehicles, reduces the risk of product losses through human error during loading.[53]
- Regular preventative maintenance and alignment of food machinery. Equipment failure results in leakages and product losses. Regular check-ups and maintenance can reduce food waste in this category.[54]
- Optimising roll cage designs to reduce the risk of damage to milk bottles during transit and transfer and, thus, reduce milk waste.[55]
- Smart packaging that allows for the tracking and monitoring of the conditions of packaged foods during their storage and transportation, though, for example, sensor-enabled radio frequency identification (RFID) tags that can detect changes in food properties, such as pH, conductivity, dielectric constant, viscosity, food volatiles, and gases.[56]

3.2 Available sources

3.2.1 Literature review

The literature review identified 11 sources that discussed reduction of food waste in distribution, although there was little quantitative evidence on the current levels of resource efficiency and the future levels of resource efficiency that could be achieved through this measure. This comprised:

- 7 academic papers;
- 1 industry report;
- 1 academic report;
- 1 policy document; and
- 1 technical study.

The relevant sources were considered of medium - high accessibility and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.36 (out of 5), with 9 sources exhibiting a score of 4 or above. Only 2 literature sources were UK-specific and only 2 sources were not recent studies.

[52] Stakeholder comment.
[53] Stakeholder comment.
[54] Jagtap. S and Rahimifard. S. (2019) The digitisation of food manufacturing to reduce waste – Case study of a ready meal factory. Waste Management. 87, p387-397.
[55] WRAP (2018). Opportunities to Reduce Waste along the Journey of Milk, from Dairy to Home.
[56] Chen et al. (2020). The role of smart packaging system in food supply chain. Journal of Food Science. 85, p. 517-525.

3.2.2 Interviews

Five stakeholders engaged directly in the discussion of Measure 3. Two indicators were originally defined for this measure: percentage of food waste due to handling; and percentage of food waste due to cold chain inconsistency. However, stakeholders that discussed this measure found it difficult to separate the causes of food wasted during distribution and storage. Instead, stakeholders generally preferred to discuss and estimate the total share of food distributed that is wasted. One stakeholder was willing to discuss the percentage of food waste due to cold chain inconsistency separately but was not able to provide quantitative estimates for this indicator. Therefore, the indicator for this measure was changed to the percentage of food that is distributed that is wasted, even though the challenges and solutions for the cold chain may be distinct in practice.

The measure itself was also amended as a result of stakeholder input. One stakeholder emphasised that the distribution stage of the food and drink value chain can include storage at an intermediate location, as well as transport between the manufacturing location and the retail or HoReCa location. Storage was, therefore, added to the measure name to explicitly recognise the inclusion of this step in the distribution stage of the supply chain.

3.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 3 with a high level of engagement. The stakeholders represented a small section of the food and drink sector, with discussions and voting activity from manufacturers and a redistributor. There was a mixture of medium confidence and high confidence levels in voting for levels of efficiency for this measure. There were three votes for the current level of efficiency, three for the maximum level of efficiency and three for business-as-usual. Stakeholders discussed the challenges and inefficiencies of reducing food waste in cold chain distribution and storage. Also mentioned were persistent issues such as equipment breakdowns and overstocking due to operational practices. It was acknowledged that there is room for improvement for this measure, yet improvement is unlikely as some causes, such as vehicle unreliability, may not be practical to eliminate.

One additional barrier was suggested by stakeholders during the workshop:

Levels of resource efficiency are high already. There are only small gains to be made.

The level of engagement in the workshop was as follows:

- Three stakeholders across manufacturing and redistribution were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Three stakeholders actively contributed to verbal discussion, with no contribution on the Teams chat.

3.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

3.3.1 Drivers

Table 8 below shows the main drivers for Measure 3. The most significant drivers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 8: Drivers for food and drink measure 3

Description	PESTLE	COM-B
Avoided costs	**Economic**	**Motivation – automatic**
Simple education measures for workers	**Social**	**Capability – psychological**
Setting a food waste reduction target	**Political**	**Motivation – automatic**
Avoided environmental impacts	Environmental	Motivation – reflective
Data availability	Technological	Capability – physical
Food waste measurement and public reporting	Political / Legal	Capability – psychological
Incentivising and training staff to take action to reduce food waste	Social	Opportunity – social

Avoided costs

When food and drink is wasted during distribution, the costs associated with producing the item to that point in the value chain also represent a loss. By reducing food waste in distribution, lost input and manufacturing costs are also reduced.[57] Interviews suggest this is a primary driver of efforts to reduce supply chain waste to date.

Simple education measures for workers

[57] Laurentiis, V. (2020) No time to waste: assessing the performance of food waste prevention actions. Resources, Conservation and Recycling. 161, 104946,

Food and drink waste during storage and distribution can be caused by human errors in handling food and drink products, e.g., a pallet of chilled products may be left standing outside in direct sunlight during transfer to or from a delivery vehicle. Simple education measures, e.g., placing a blue sticker on anything that needs to be kept in cold chain, can help to prompt the correct handling of products by food and drink distribution workers.[58]

Setting a food waste reduction target

The rationale for distribution and storage providers to set a food waste reduction target is the same as outlined in Section 1.3.1.

Avoided environmental impacts

There are environmental impacts associated with producing food and drink products to the distribution stage of the food and drink value chain. By reducing food waste during distribution, environmental impacts occurring upstream in the supply chain can be reduced.[59] This may act as a motivator to reduce food and drink waste during distribution, especially where businesses have made explicit commitments.

Data availability

For chilled and frozen products, the ability to log the temperature conditions that a food or drink product exists in throughout the distribution process, particularly when the product is passed between different supply chain actors, can help to identify breaks in the cold chain. This information can help reduce food and drink waste in distribution, as problematic processes and exchange points can be identified and addressed, both over time and potentially in terms of real time management.

Food waste measurement and public reporting

The rationale for distribution and storage providers to measure and publicly report on food waste is the same as outlined in Section 1.3.1.

Incentivising and training staff to take action to reduce food waste

The rationale for distribution and storage providers to incentivise and train staff to take action to reduce food waste is the same as outlined in Section 2.3.1.

3.3.2 Barriers

Table 9 below shows the main barriers for Measure 3. The most significant barriers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 9: Barriers for food and drink measure 3

[58] NRDC (2017) Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill
[59] Laurentiis, V. (2020) No time to waste: assessing the performance of food waste prevention actions. Resources, Conservation and Recycling. 161, 104946,

Description	PESTLE	COM-B
Complex ownership arrangements	**Economic**	**Capability – physical**
Delivery issues	Economic	Capability – physical
Primary production methods	Technological	Capability – physical
Levels of resource efficiency are already relatively high across many enterprises and products, meaning scope for improvement is limited	Technological	Capability – physical
Cold chain inefficiencies	Technological	Capability – physical

Complex ownership arrangements

Ownership arrangements for food and drink products as they pass between different stages of the supply chain can be complex. This can act as a barrier to preventing food and drink waste arising during storage and distribution because it is not clear which actor should take responsibility for waste prevention. As a result, waste – and responsibility for it – may be shifted around the supply chain, rather than being eliminated.

Delivery issues

Food and drink waste may occur during distribution when there are problems related to delivering food and drink products into retail or HoReCa settings.[60] Such delivery issues might occur due to, for example, delays to the transportation of food and drink products, which could directly result in food and drink waste for short shelf-life products or may result in the rejection of deliveries that have missed their delivery window, ultimately resulting in food and drink waste if suitable redistribution arrangements are not already in place. Since these delivery issues are often beyond the control of the distributer, they can act as a barrier to reducing food and drink waste during distribution.

Primary production methods

The production methods employed during the primary production of food and drink can impact on the quality of the item produced, e.g., the level of stress of livestock before slaughter,[61] [62] or

[60] Department of the Environment, Climate and Communications (2022) Ireland's National Food Waste Prevention Roadmap 2023-2025
[61] Carrasco-Garcia, A. (2020) Effect of stress during slaughter on carcass characteristics and meat quality in tropical beef cattle. Asian-Australasian Journal of Animal Sciences. 33, p1656-1665.
[62] Rutherford, N., Lively, F., Arnott, G., (2019) Evaluating rumen temperature during the pre-slaughter phase as a predictor for meat quality. Precision Livestock Farming '19, p.165

premature grain harvesting leading to higher moisture content and greater susceptibility to mould growth and insect infestation.[63] This can have a knock-on effect on how the product reacts further down the supply chain, e.g., to storage. The quality of the product produced can, therefore, impact on the extent to which food and drink waste occurs during storage and distribution.

Levels of resource efficiency are already relatively high across many enterprises and products, meaning scope for improvement is limited

Based on the workshop and interviews conducted in this study, it can be concluded that food and drink distribution and storage is already highly efficient across many enterprises and products, meaning the scope for improvement in the level of efficiency for this measure is fairly limited.

Cold chain inefficiencies

Refrigeration and cold chain logistics are responsible for a large amount of greenhouse gas emissions, associated with both energy consumption and refrigerant leakage.[64] Increased cold chain refrigeration could result in greater energy consumption, especially if technology is energy inefficient. While energy efficiency is out of scope for this report, it is important to consider how the emissions associated with cold chain inefficiencies may negate the environmental benefits resulting from a reduction in food waste due to cold chain improvements.[65]

3.4 Levels of efficiency

Table 10: Levels of efficiency for food and drink measure 3

Indicator: Percentage of food that is distributed that is wasted			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	1 – 4%	0.9 – 3.8%	1 – 4%
Evidence RAG	Amber-Green	Amber	Amber

[63] Kumar, D., Kalita, P. (2017) Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. Foods. 6(1), 9.
[64] WRAP (2022). The Courtauld Commitment 2030: Progress and Insights Report 2021/2022.
[65] Clairland et al., (2020) Review of Energy Efficiency Technologies in the Food Industry: Trends, Barriers, and Opportunities. IEEE Access. 9. p48015-48029

3.4.1 Current level of efficiency

There was very limited quantitative evidence available on the current level of efficiency for Measure 3. None of the literature sources reviewed provided a direct estimate of the percentage of food that is distributed that is wasted. However, four sources gave combined estimates relating to food waste during the distribution and retail supply chain stages.

Data for the European Union, published by the European Commission, indicates that 1.02% of food produced is wasted during distribution and retail.[66] A study by Stenmarck et al.,[67] estimates that food waste during distribution and retail is 9kg/capita/year, while a study by Caldeira et al.[68] estimates that food waste during distribution and retail is 13kg/capita/year, or equivalently 1.05% of the quantity of food entering the EU food supply chain each year.

Stakeholders found it difficult to provide quantitative estimates for this measure, in part due to variability across different product types. One stakeholder estimated the current level of efficiency for fruit and vegetables to be 2.5–5% but suggested that the percentage would be much less for other food and drink products. For example, waste would be much lower for products such as long-life ambient foods, a point endorsed by another interviewee. Another stakeholder commented that the amount of food waste generated due to cold chain inconsistency during distribution is very minimal in the UK, and so the level of efficiency in distribution is already very high.

Stakeholder workshop participants emphasised that UK food and drink distribution and storage is already highly efficient and agreed with an estimated current level of efficiency of 1-4%. One of the workshop participants added that they suspect the lower end of this range is most likely.

The reported range for this measure is 1 – 4%. An amber-green evidence RAG rating was given to this measure because, although there was agreement across stakeholders, there is uncertainty around the applicability of the quantitative estimates uncovered in the literature to the distribution part of the supply chain alone, as well as uncertainty around the applicability of the quantitative estimate provided by a stakeholder during interviews to the wider food and drink sector.

3.4.2 Maximum level of efficiency in 2035

There was almost no quantitative evidence available on the maximum level of efficiency for Measure 3. None of the literature sources reviewed provided quantitative estimates for this measure.

One stakeholder commented that the maximum level of efficiency by 2035 for Measure 3 would still be greater than 0%. Another stakeholder estimated that the maximum level of efficiency would be a 5–10% improvement on the current level of efficiency, equating to an

[66] European Commission's Knowledge Centre for Bioeconomy (2020). Brief on food waste in the European Union.
[67] Stenmarck et al. (2016). Estimates of European food waste levels.
[68] Caldeira et al. (2019). Quantification of food waste per product group along the food supply chain in the European Union: a mass flow analysis. Resources, Conservation and Recycling. 149, p. 479-488.

estimate of 0.9–3.8%. The decimal places in this estimate are not intended to represent precision, merely that there is scope for marginal gains from the current baseline.

Stakeholder workshop participants agreed with an estimated maximum level of efficiency of 0.9 – 3.8%.

The reported range for this measure is 0.9 – 3.8%. An amber evidence RAG rating was given to this measure because there was agreement across stakeholders, but no supporting evidence was gathered from the literature reviewed.

3.4.3 Business-as-usual in 2035

There was almost no quantitative evidence available on the business-as-usual level of efficiency in 2035 for Measure 3. None of the literature sources reviewed provided quantitative estimates for this measure.

The stakeholders interviewed were also unable to provide quantitative estimates for this measure. Although, one stakeholder commented that the scope for improvement in this measure, relative to other measures considered in this study, is small.

Stakeholder workshop participants agreed with an estimated business-as-usual level of efficiency of 1-4%.

The reported range for this measure in a business-as-usual scenario is unchanged from the current range: 1–4%. While some improvements are likely, these fall within the range of uncertainty for the current range. This measure was given an amber evidence RAG rating due to the lack of quantitative evidence from the literature reviewed.

4.0 Measure 4 – Reduction in food waste due to revised product standards

4.1 Food and drink resource efficiency measure

4.1.1 Description

Revising food and drink product standards to reduce unnecessary wastage of food and drink products fit for human consumption.

The UK has world-leading standards on food safety designed to safeguard consumer health, which are an essential part of the food system. However, these are not the only standards with which food must comply. The acceptance of food and drink products into retail settings is dependent on the product meeting a range of standards, including both marketing standards[69] set by Government, and retailers' standards. The objective of these standards is to ensure that safe, high-quality food and drink products are brought to the market. For example, for fresh produce, these can be optical standards based on the shape and appearance of the product, or for frozen products, a temperature threshold below which the product must be kept throughout the distribution process. [70]

Sometimes a food or drink product is rejected by the intended buyer because it has not met a particular standard. If redistribution arrangements are not in place, or the item cannot be handled effectively via available redistribution logistics and infrastructure in a timely fashion, or diverted to animal feed or by-products, then the product becomes food or drink waste. (end-of-life practices according to the UK food and drink surplus and waste hierarchy are covered in more detail in Section 8.0). Food and drink waste could, therefore, be reduced by revising these product standards such that they do not incentivise unnecessary waste, provided of course that food and drink safety is maintained. However, in order to contribute to overall food waste reduction, any product changes introduced by the revision of product standards (e.g., reformulation, shelf-life extension, or packaging changes) cannot result in a transfer of waste between different stages of the supply chain, rather than an overall reduction.

Although this measure functionally differs from other resource efficiency measures discussed in this paper, the data collection required to quantify the measure is challenging because food and drink waste arises at a supply chain stage in the aggregate, the contributing causes can be hard to isolate. This is also a measure where the contributing factors to waste are particularly likely to arise with supply chain actors that differ to those with whom the waste actually occurs.

[69] CBI Ministry of Foreign Affairs (2022). Entering the United Kingdom market for fresh fruit and vegetables.
[70] Stakeholder comment.

4.1.2 Measure indicator

The indicator selected was the **percentage of harvested food that is wasted due to product standards**. This is a relative measure with the percentage derived from the total amount of food and drink waste generated because a product has been rejected by a retailer or HoReCa provider for not meeting a standard, divided by the total amount of harvested food and drink.

4.1.3 Examples in practice

Possible ways described in the literature or provided by stakeholders to reduce food and drink waste by revising standards include:

- The temperature specified by a retailer for the delivery of a chilled or frozen food product may have contingency built in. The amount of product rejected because this standard has not been met, and thus the amount of food waste generated, could therefore be reduced by reducing the contingency built into the temperature threshold.[71]
- Organisations that specialise in collecting and redistributing fresh produce rejected by retailers due to its size or aesthetic appearance, help to prevent food waste being generated due to strict standards.[72]
- Allowing greater flexibility in requirements in relation to product weight, which can cause manufacturers to over-order ingredients to ensure that delivery weight never falls short.[73]
- Revising product labelling standards that result in products becoming unsellable when mispackaging accidents occur because the contents is no longer aligned with the information provided on the packaging.[74]

4.2 Available sources

4.2.1 Literature review

The literature review identified 6 sources that discussed the reduction of food waste from revised standards, although there was little quantitative evidence on the current levels of resource efficiency and no evidence on the future levels of resource efficiency that could be achieved through this measure. This comprised:

- 4 academic papers;
- 1 industry report; and
- 1 policy document.

[71] Stakeholder comment.
[72] Bambridge-Sutton, A. (2023) How Oddbox is combatting food waste in the UK. Accessed at link.
[73] Stakeholder comment.
[74] Stakeholder comment.

The relevant sources were considered of medium - high accessibility and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 4.17 (out of 5), with 4 sources exhibiting a score of 4 or above. Only 2 literature sources were UK-specific and all 6 were recent studies.

4.2.2 Interviews

6 stakeholders engaged in discussion of Measure 4, although some were able to discuss the measure in much more detail than others.

The original indicator specified for this measure was the percentage of food waste due to strict standards (e.g., optical defects). Most stakeholders did not object to the measure or indicator definition, but one stakeholder highlighted that this measure should include consumption stage impacts of strict standards, as well as production stage impacts. Another stakeholder discussed standards relating to temperature thresholds for the storage of chilled and frozen produce. Given these inputs, the indicator name for this measure is no longer specified as relating only to optical defects, to avoid restricting the scope of product standards considered. Waste at household stage (from all causes) is dealt with in Measure 6, so the current measure has not been explicitly adjusted in this regard.

One stakeholder raised an issue around the scope of the indicator. The indicator for this measure was specified as the percentage of *harvested* food that is wasted due to product standards, but the stakeholder commented that the indicator's value would be much higher if the indicator was specified as the percentage of food *produced* that is wasted due to product standards, because farm labour is taught not to harvest food that will not meet specifications. However, given the scope boundaries for this study, the indicator has not been adjusted to consider pre-harvest food.

The measure and indicator names have also been refined to avoid any perception that product health and safety could be undermined through the implementation of this measure. The indicator is defined as the percentage derived from the total amount of food and drink waste generated because a product has been rejected by a retailer or HoReCa provider for not meeting a standard, divided by the total amount of harvested food and drink.

4.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 4 with a high level of engagement. The stakeholders represented a small section of the food and drink sector, with discussions and voting activity from manufacturers and a redistributor. There was a mixture of medium confidence and high confidence levels in voting for levels of efficiency for this measure. There were two votes for the current level of efficiency, two for the maximum level of efficiency and two for business-as-usual. There were discussions around levels of efficiency and how food is determined to be waste.

The level of engagement in the workshop was as follows:

- Three stakeholders across manufacturing and redistribution were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Three stakeholders actively contributed to verbal discussion, with no contribution on the Teams chat.

4.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

4.3.1 Drivers

Table 11 below shows the main drivers for Measure 4. The most significant drivers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 11: Drivers for food and drink measure 4

Description	PESTLE	COM-B
Changing consumer preferences and awareness	**Social**	**Opportunity – social**
Educating industry about changing consumer preferences	Social	Opportunity - social
Technical expertise on shelf-life and open life extension	Social	Capability – psychological
Developing partnerships across the supply chain	Economic	Opportunity - physical

Changing consumer preferences and awareness

Even without direct intervention, consumer preferences change over time. Increased consumer demand for food and drink products that do not meet strict standards (e.g., the acceptability of 'wonky' vegetables), can help to drive retailers and food service outlets to relax their product requirements, thereby reducing food and drink waste.[75] Additionally, deliberate strategies of consumer education, and supportive promotional and pricing strategies, can help to improve the acceptability of a wider range of food and drink products to consumers, including, for example, off-grade produce.

[75] Cristóbal et al. (2018) Prioritizing and optimizing sustainable measures for food waste prevention and management. Waste Management. 32, p3-16.

Educating industry about changing consumer preferences

Educating retailers and food service providers about changing consumer preferences around food and drink products that do not meet strict standards (e.g., the acceptability of 'wonky' vegetables), can help to encourage these supply chain actors to relax their product requirements, thereby reducing food and drink waste.

Technical expertise on shelf-life and open life extension

Technical expertise is required to determine when it is safe to extend the specified shelf-life and open life of a food or drink product. When safe to do so, extending a product's shelf-life and open life could help to prevent the product from becoming waste.[76] Therefore, increasing technical expertise on shelf-life and open life extension can help to drive reductions in food waste. Better supply chain data (see Measure 3) may help inform and optimise these judgements.

Developing partnerships across the supply chain

By developing partnerships, supply chain actors can ensure that product standards imposed by one actor in the supply chain do not have knock-on implications for other supply chain actors, which result in the generation of food waste in another part of the supply chain.

4.3.2 Barriers

Table 12 below shows the main barriers for Measure 4. The most significant barriers, as prioritised by stakeholder workshop participants, are shown in bold. Note that barriers to redistribution specifically are discussed in Measure 8.

Table 12: Barriers for food and drink measure 4

Description	PESTLE	COM-B
Perception that consumers will only buy products to a particular standard	**Social**	**Opportunity – social**
Reputational risk	**Political / Economic**	**Motivation – reflective**
Supply chain relationships	Economic	Opportunity – physical
Traceability of customers	Technological	Capability – physical
Need for re-labelling of products	Economic	Capability – physical

[76] Stakeholder comment; WRAP (2022). Retail Survey 2021/22: Reducing household food waste through changes to the retail environment.

Perception that consumers will only buy products to a particular standard

Retailers and HoReCa providers often assume that consumers will only be willing to purchase products of a particular standard. Given this perception, relaxing strict product standards is viewed as a risk to business by these providers.[77]

Reputational risk

Retailers and HoReCa providers may perceive there to be a reputational risk associated with relaxing certain product standards, particularly standards relating to redistribution of their surplus product (especially if the product is branded). Aversion to these risks can, therefore, act as a barrier to revising product standards with the aim of reducing food waste.

Supply chain relationships

Oftentimes, product standards imposed by one actor in the supply chain have knock-on implications for other supply chain actors, which result in the generation of food waste in another part of the supply chain. For example, standards on product shelf-life imposed by retailers may help to reduce food waste at the retail stage, but this pushes increased risk to upstream actors in the supply chain, as the time available for getting stock to the retailer is reduced. Such dependencies can be a barrier to reducing food waste through revised product standards because overall food waste is dependent on behaviour across multiple actors.

Traceability of customers

One interviewee identified that a lack of customer traceability can reduce the willingness of retailers to relax strict product standards because products cannot be effectively recalled in the case of food safety issues.[78] The ability to track all customer purchases of a food or drink product and trace all the relevant customers in the event of a safety issue offers an organisation greater flexibility to relax product standards.

Need for re-labelling of products

In some cases, relaxing a product standard may necessitate relabelling of a food or drink product, e.g., when mispackaging accidentally occurs. The costs associated with re-labelling products may act as a barrier for the producer to sell the product through the intended channel. Instead, the product arises as surplus.

4.4 Levels of efficiency

Table 13: Levels of efficiency for food and drink measure 4

Indicator: Percentage of harvested food that is wasted due to product standards

[77] Trento et al. (2021) Industry-retail symbiosis: What we should know to reduce perishable processed food disposal for a wider circular economy. Journal of Cleaner Production. 318, 128622.
[78] Stakeholder comment.

Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	2-5%[79]	2-3%	2-5%
Evidence RAG	Red	Red	Red

4.4.1 Current level of efficiency

Very limited quantitative evidence was available on the current level of efficiency for Measure 4.

A study by Porter et al.[80] estimates that in the UK 0.47 – 4.5 million tonnes of avoidable food loss and waste is generated per year, due to on-farm cosmetic grade-outs. This is estimated to equate to 6–39% of total farm production being lost for aesthetic reasons, with a reported central estimate of 20%.[81] However, this quantitative evidence relates only to food waste resulting from aesthetic standards imposed on fresh produce, which is a subset of the food waste relevant to this measure. It also relates to specifically on-farm waste, some of which may not be within the scope of the current study if a decision is taken pre-harvest not to harvest a crop (but would be in scope if sorted post-harvest, including on the farm).

None of the stakeholders interviewed were able to provide quantitative estimates for the specified indicator. One stakeholder indicated that their estimate for the current level of efficiency for Measure 4 could not be separated from their estimate of the current level of efficiency for Measure 2. This alludes to the main challenge with data collection for this measure: waste arises at a supply chain stage in the aggregate, but the contributing causes are hard to isolate.

Another stakeholder provided a quantitative estimate for the percentage of food produced that is currently wasted on-farm due to specifications: 5%. However, as above, some of this waste is not within the scope of this study.

Stakeholder workshop participants agreed that the current level of efficiency for this measure is less than 5%. Consensus on this estimate was reached among workshop participants.

The reported value for this measure is 2-5%. A red evidence RAG rating was given to this measure because the quantitative evidence available from the literature does not cover the full scope of the measure. In addition, there is significant divergence between the quantitative

[79] It should be noted that this estimate is based on stakeholder consensus from the workshop, but some of the evidence sources reviewed suggest much higher levels of loss, especially during on farm sorting. There may also be significant variance by product.
[80] Porter et al. (2018). Avoidable food losses and associated production-phase greenhouse gas emissions arising from application of cosmetic standards to fresh fruit and vegetables in Europe and the UK. Journal of Cleaner Production. 201, p.869-878.
[81] Porter et al. (2018). Avoidable food losses and associated production-phase greenhouse gas emissions arising from application of cosmetic standards to fresh fruit and vegetables in Europe and the UK. Journal of Cleaner Production. 201, p.869-878.

estimates provided by stakeholders and the quantitative evidence available in the literature, although, again, the estimates do not all cover the same scope as this measure. The true figure is likely to vary significantly by sector.

4.4.2 Maximum level of efficiency in 2035

Limited quantitative evidence was available on the maximum level of efficiency in 2035 for Measure 4, for the specified indicator. None of the literature sources reviewed provided quantitative estimates for this measure. One stakeholder indicated that an additional 500,000 tonnes reduction in food waste due to product standards could be achieved by 2035 in a high ambition scenario. However, this stakeholder included pre-harvest food in their estimation. Another stakeholder indicated that their estimate for the maximum level of efficiency for Measure 4 could not be separated from their estimate of the maximum level of efficiency for Measure 2.

Stakeholder workshop participants agreed on an estimate of 2-3% for the maximum level of efficiency for this measure. While there is uncertainty about the current level of efficiency, this assessment does reflect a belief there is scope for reductions.

The reported range for this measure is 2-3%, based on the stakeholder workshop. A red evidence RAG rating was given to this measure, given the unavailability of supporting quantitative evidence from the literature or stakeholder interviews. Similar caveats apply as for estimates of current efficiency.

4.4.3 Business-as-usual in 2035

Limited quantitative evidence was available on the business-as-usual level of efficiency in 2035 for Measure 4. None of the literature sources reviewed provided quantitative estimates for this measure and none of the stakeholders interviewed were able to provide quantitative estimates. One stakeholder indicated that their estimate for the business-as-usual level of efficiency for Measure 4 could not be separated from their estimate of the business-as-usual level of efficiency for Measure 2. Another stakeholder suggested that the BAU level of efficiency in 2035 would be unchanged from the current level of efficiency.

Stakeholder workshop participants agreed on an estimate of less than 5% for the business-as-usual level of efficiency for this measure. Crucially, given there is uncertainty about the current baseline, this estimate reflects an assumption there will be minimal change in the business-as-usual scenario.

The reported range for this measure is 2-5%, based on the stakeholder workshop. A red evidence RAG rating was given to this measure, given the unavailability of supporting quantitative evidence from the literature or stakeholder interviews. Similar caveats apply as for the estimates of current and maximum efficiency.

5.0 Measure 5 – Reduction of food waste in retail

5.1 Food and drink resource efficiency measure

5.1.1 Description

Refining the techniques and processes employed during retail of food and drink products to reduce the amount of food waste occurring during this stage of the supply chain.

Food and drink waste can occur in a retail setting for a variety of reasons, e.g., due to handling errors in store or sub-optimal stocking practices. Optimising the techniques and processes employed during the retail of food and drink, to reduce food and drink waste can, therefore, improve resource efficiency.

5.1.2 Measure indicator

The indicator selected was the **percentage of food at the retail stage that is wasted**. This is a relative measure with the percentage derived from the total amount of waste generated during the retail of food and drink divided by the total amount of retail food and drink throughput.

5.1.3 Examples in practice

Possible ways described in the literature or provided by stakeholders to reduce food and drink waste in retail include:

- Retailers can employ dynamic markdown, whereby the amount of markdown for products nearing the end of their shelf-life is a function of the amount of stock left on the shelf. This can help to minimise the amount of surplus product, thus reducing food and drink waste.[82]
- Retailers can optimise their shelf stocking practices to minimise the risk of failing to sell products before they reach the end of their shelf-life, e.g., by ensuring the old stock is rotated to the shelf-edge when shelves are restocked.[83]
- Retailers can optimise their demand forecasting and ordering practices to minimise the amount of surplus product, thus reducing food and drink waste in retail.[84] However, it should be noted that this can impact on the risk of generating food and drink waste at other stages in the supply chain.
- Retailers, and other food and drink supply chain actors, can develop partnerships with redistribution organisations to maximise the amount of surplus product that is diverted

[82] Stakeholder comment.
[83] Government of Ireland (2022). Ireland's National Food Waste Prevention Roadmap.
[84] Stakeholder comment.

from waste and instead redistributed for human consumption, animal feed or returned as by-products.[85]

- UK retailers can reconsider long term fixed-price contracts for items like fresh fruit and vegetables, which can mean that the price mechanism does not work effectively to alleviate issues of under- or over-production.[86]

5.2 Available sources

5.2.1 Literature review

The literature review identified 21 sources that discussed the reduction of food waste in retail, although there was little quantitative evidence on the current levels of resource efficiency and the future levels of resource efficiency that could be achieved through this measure. This comprised:

- 10 academic papers;
- 8 industry reports;
- 2 policy documents; and
- 1 website article.

The relevant sources were considered of medium to high accessibility and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.81 (out of 5), with 10 sources exhibiting a score of 4 or above. Only 9 literature sources were UK-specific and only 4 sources were not recent studies.

5.2.2 Interviews

6 stakeholders engaged in discussion of Measure 5, although some to a minimal extent. Two indicators were originally defined for this measure: percentage of food waste due to improved stocking efficiencies; and percentage of food waste due to suboptimal date labelling.

However, stakeholders generally preferred to discuss and estimate the total share of food at the retail stage that is wasted. One stakeholder commented that date labels do not generate much waste at the retail stage; this issue is more applicable at the consumer stage. Another suggested that within the supply chain, the risk around date labels is often borne disproportionately by suppliers rather than retailers. In short, the distribution of date label risk across actors is important to determining overall levels of waste arising from this cause, and where this waste may arise.

Another stakeholder explicitly stated that the indicator should be combined to the total share of food waste in retail. Therefore, the indicator for this measure was changed to the percentage of

[85] WRAP (2023). Retail: Actions to support delivery of the UK Food Waste Reduction Roadmap; stakeholder comment.
[86] Horton, H., Partridge, J. (2023) Food tsar blames shortages on UK's 'weird supermarket culture'.

food at the retail stage wasted. Several interviewees emphasised the importance of retailers in influencing food waste production and prevention at other stages in the supply chain, even if the waste does not arise at the retail stage.

5.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 5 with a medium level of engagement. The stakeholders represented a small section of the food and drink sector, with discussions and voting activity from manufacturers and a redistributor. There was a mixture of medium confidence and high confidence levels in voting for levels of efficiency for this measure. There were three votes for the current level of efficiency, three for the maximum level of efficiency and three for business-as-usual. Stakeholders discussed the challenges and opportunities of reducing food waste at the retail level. Also touched on was the role of pricing strategies and redistribution charities for minimising waste. Additionally, there was acknowledgement of the difficulties faced by retailers such as damaged goods, short shelf-life products, and complex supply chains.

An additional barrier was suggested by stakeholders during the workshop:

Upcoming packaging legislative changes might reduce resource efficiency.

The level of engagement in the workshop was as follows:

- Three stakeholders across manufacturing and redistribution were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Two stakeholders actively contributed to verbal discussion, with no contribution on the Teams chat.

5.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

5.3.1 Drivers

Table 14 below shows the main drivers for Measure 5. The most significant drivers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 14: Drivers for food and drink measure 5

Description	PESTLE	COM-B
Supply chain actors working in partnership with redistribution organisations	**Social**	**Opportunity – social**

Dynamic markdown of products	**Economic**	**Motivation – reflective**
Setting a food waste reduction target	**Social**	**Motivation – reflective**
Technology	Technological	Capability – physical
Financial and other support for redistributors to increase capacity and capability	Economic	Opportunity – social
Food waste measurement and public reporting	Social	Motivation – reflective
Incentivising and training staff to take action to reduce food waste	Social	Opportunity – social
Avoided environmental impacts	Environmental	Motivation - reflective

Supply chain actors working in partnership with redistribution organisations

By developing partnerships with redistribution organisations, supply chain actors, including retailers, can ensure that surplus products that would have been destined to become food waste are diverted through other routes for human consumption, or use in animal feed or as by-products.

Dynamic markdown of products

Dynamic markdown involves progressively reducing the price of food and drink products as they near the end of their shelf-life, with the reduction amount being a function of the stock left on the shelf. Dynamic markdown helps to minimise the amount of food and drink products left on the shelves at the end of their shelf-life, thereby reducing food and drink waste.

Setting a food waste reduction target

The rationale for retailers to set a food waste reduction target is the same as outlined in Section 1.3.1.

Technology

The use of technology can help to improve stock management in food and drink retail settings, e.g., smart labelling, improved demand forecasting, and algorithm driven ordering, linked to the shelf-edge. This can help to prevent over-ordering, thereby, driving food waste reduction in

retail. It was notable that workshop attendees were relatively cautious about the potential of technology to be transformative.

Financial and other support for redistributors to increase capacity and capability

Take up of guidance from WRAP's redistribution working group will help redistributors to overcome barriers to redistribution.[87] Redistribution organisations may rely financially on private donations, the government, and/or the supply chain. Increased financial and other support could help these organisations to operate more sustainably, at scale. This would help redistribution organisations to partner with retailers, thereby helping to reduce food waste in retail.

Food waste measurement and public reporting

The rationale for retailers to measure and publicly report on food waste is the same as outlined in Section 1.3.1.

Incentivising and training staff to take action to reduce food waste

The rationale for distribution and storage providers to incentivise and train staff to take action to reduce food waste is the same as outlined in Section 2.3.1.

Avoided environmental impacts

The rationale for this driver is the same as outlined in Section 2.3.1.

5.3.2 Barriers

Table 15 below shows the main barriers for Measure 5. The most significant barriers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 15: Barriers for food and drink measure 5

Description	PESTLE	COM-B
Trade-off between availability and waste	**Economic**	**Motivation – reflective**
Poor demand forecasting	**Economic**	**Capability – psychological**
Complex ownership arrangements	Economic	Opportunity – physical
Regular replenishment of stocks	Social	Motivation – reflective

[87] WRAP (2023) Surplus food redistribution resource hub. Available at https://wrap.org.uk/taking-action/food-drink/actions/surplus-food-waste-redistribution/surplus-food-redistribution-resource-hub

Upcoming packaging legislative changes	Legal	Capability – psychological

Trade-off between availability and waste

Retailers are constantly dealing with the trade-off between (ideally) having sufficient stock to supply all consumer demand at all times and avoiding surplus stock that ends up as food and drink waste. In order to ensure that consumer demand can always be fulfilled, retailers may systematically over-supply some food and drink products, on the grounds that a stock-out may be a worse business outcome than some waste.[88]

Poor demand forecasting

Poor demand forecasting for food and drink products, which can be caused by predictable or unpredictable adjustments in consumer purchasing, coupled with unresponsive management of stock when forecasting errors occur, means that retailers can be left with unsold stock. This stock, particularly if it is products with a short shelf-life, often ends up as food and drink surplus or waste.

Complex ownership arrangements

The rationale is the same as outlined in Section 3.3.2.

Regular replenishment of stocks

When retailers replenish stocks regularly, without clearing existing stock, customers can choose from food and drink products with varying shelf lives. If given the choice, customers in the aggregate are likely to select the item with the longer shelf-life.[89] This means products with the shortest shelf-life are more likely to remain unsold and may end up as food and drink waste. Retailers can nudge consumers towards choosing shorter life options (e.g., with shelf placement or promotions),[90] but this consumer tendency persists as it makes sense in terms of optimising shelf-life and reducing the chances of waste in the household setting in some cases.

Upcoming packaging legislative changes

If changes to legislation around packaging lead to the removal of protective packaging from food and drink products, then there could be a negative knock-on impact on the amount of food waste generated in retail.

[88] Stakeholder comment.
[89] Endara et al. (2023). Consumer willingness to pay for shelf life of high-temperature, short-time-pasteurized fluid milk: Implications for smart labelling and food waste reduction. Journal of Dairy Science. 106(9), p.5940-5957.
[90] Buisman et al (2019). Discounting and dynamic shelf life to reduce fresh food waste at retailers. International Journal of Production Economics. 209, p.274-284; stakeholder comment.

5.4 Levels of efficiency

Table 16: Levels of efficiency for food and drink measure 5

Indicator: Percentage of food at the retail stage that is wasted			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	>0 – 1.5%	>0 – 0.95%	>0 – 1%
Evidence RAG	Green	Red-amber	Red-amber

5.4.1 Current level of efficiency

Data published by WRAP indicates that there is 0.2Mt of food waste in the UK food and drink retail sector per year.[91] Another source published by WRAP reports that, as a share of food handled, food waste in retail is 0.44%.[92]

A second literature source published by WRAP provides an estimate of the current level of efficiency for Measure 5, for retailers committed to WRAP's food waste reduction roadmap. Among this group, food waste as a proportion of food handled, is estimated to have been 0.44% in 2021.[93]

At the EU level, data published by the European Commission gives a combined estimate for the share of food wasted during the supply chain's distribution and retail stages. The percentage of food produced that is wasted during distribution and retail is estimated at 1.02%.[94]

Only one stakeholder directly provided a quantitative estimate for Measure 5, but another stakeholder referred us to the above estimates reported by WRAP. The quantitative estimate provided by the stakeholder for the current level of efficiency for Measure 5 was 1.5%, although this stakeholder highlighted that there would be variation across different food and drink products. Another stakeholder agreed that food and drink waste in retail is low but commented that this is at least in part because the actions of retailers push the occurrence of waste outwards through the supply chain to manufacturers and consumers.

Stakeholder workshop participants agreed with an estimated current level of efficiency of >0 – 1.5%.

A green evidence RAG rating was given to this measure because there is alignment across multiple literature sources with high quality ratings, and support for data points reported by

[91] WRAP (2023). UK Food Waste & Food Surplus – Key Facts.
[92] WRAP (2022). Food surplus and waste in the UK – key facts.
[93] WRAP (2022). The Food Waste Reduction Roadmap Progress Report 2022.
[94] European Commission's Knowledge Centre for Bioeconomy (2020). Brief on food waste in the European Union.

WRAP was communicated by more than one of the stakeholders interviewed and during the stakeholder workshop. Through the Courtauld Commitment, a voluntary agreement aimed at tackling food waste, greenhouse gases and water stress in the food system, WRAP has been collecting data on food waste directly from retailers since 2005.[95] WRAP's estimates on food waste in retail are, therefore, considered to be very reliable.

5.4.2 Maximum level of efficiency in 2035

There was almost no quantitative evidence available on the maximum level of efficiency for Measure 5. None of the literature sources reviewed provided quantitative estimates for this measure.

One stakeholder commented that the maximum level of efficiency by 2035 for Measure 3 would be less than 1%. Another stakeholder estimated that the maximum level of efficiency would be a 5–10% improvement on the current level of efficiency, resulting in an estimated maximum level of efficiency of 0.9–0.95%. The decimal places here are intended to indicate the scope for marginal reductions, not to indicate that the estimate is high precision.

Stakeholder workshop participants agreed with an estimated maximum level of efficiency of 0 – 0.95%.

The reported range for this measure is >0– 0.95%. A red-amber evidence RAG rating was given to this measure because there is limited evidence from stakeholders and no supporting evidence was gathered from the literature reviewed.

5.4.3 Business-as-usual in 2035

There was almost no quantitative evidence available on the business-as-usual level of efficiency in 2035 for Measure 3. None of the literature sources reviewed provided quantitative estimates for this measure.

One stakeholder commented that the business-as-usual level of efficiency in 2035 for Measure 5 would be less than 1%. None of the other stakeholders interviewed were able to provide quantitative estimates for this measure.

Stakeholder workshop participants agreed with an estimated business-as-usual level of efficiency of 0 – 1%.

The reported range for this measure in a business-as-usual scenario is >0 - 1%. A red-amber evidence RAG rating was given to this measure due to the lack of quantitative evidence available from the literature reviewed to support stakeholder estimates.

[95] WRAP (N.D.). History of the Courtauld Commitment. Accessed at link.

6.0 Measure 6 – Reduction of food waste amongst households

6.1 Food and drink resource efficiency measure

6.1.1 Description

Changes in consumer behaviour to reduce the amount of food and drink waste occurring in the home.

Consumers waste food and drink in the home for a variety of reasons, e.g., due to food and drink products not being used in time, personal preference, or too much being prepared, cooked or served.[96] Changing consumer behaviours around the purchasing, storage and use of food and drink products, to reduce food and drink waste in the home can, therefore, improve resource efficiency. Food and drink waste arising in households is the largest source of food waste in the supply chain. [97]

6.1.2 Measure indicator

The indicator selected was the **percentage of food purchased by consumers that is wasted in the home**. This is a relative measure with the percentage derived from the total amount of food drink waste generated by consumers in the home divided by the total amount of food and drink purchased by consumers that is brought into the home.

6.1.3 Examples in practice

Possible ways described in the literature or provided by stakeholders to reduce the amount of food and drink wasted by consumers in the home include:

- Consumer behaviours around shopping and food purchasing, e.g., pre-shop planning, only buying exactly what is needed, buying more frozen food, buying more long-life foods.[98]
- Consumer behaviours around the storage and management of food in the home, e.g., storing more food in the freezer, organisation of the fridge and freezer, checking the fridge temperature, relying on judgement to decide whether food is safe to eat.[99]
- Consumer behaviours around the preparation and use of ingredients and food products, e.g., using leftovers in place of new ingredients, batch cooking meals, optimising portion sizes.[100]

[96] WRAP (2022). Food surplus and waste in the UK – key facts.
[97] WRAP (2022). Food surplus and waste in the UK – key facts.
[98] WRAP (2023). UK Household Food Waste Tracking Survey 2022.
[99] Stakeholder comment; WRAP (2023). UK Household Food Waste Tracking Survey 2022.
[100] WRAP (2023). UK Household Food Waste Tracking Survey 2022.

- Retailer actions to alter the choice environment for consumers in store, e.g., eliminating multibuy promotions, enabling purchase of customised portions through the provision of loose fruit and vegetables and staffed deli counters.
- Manufacturer and retailer actions to alter the product offer to consumers, e.g., packaging innovations such as split packs and resealable packaging to maximise product life, removal of date labels on fresh produce, use of the fridge logo and numerical temperature statements on all fresh produce and chilled products, and the provision of tips and advice on how to store products to maximise their open life. [101]
- Government supported or retailer communications aimed at raising awareness around food waste. For example, through campaigns like 'Food Waste Action Week'[102] or through the provision of guidance, tips and advice on food product packaging.[103] Information campaigns can be particularly effective when insights from environmental psychology and behavioural economics are incorporated into their design.[104]

6.2 Available sources

6.2.1 Literature review

The literature review identified 55 sources that discussed reduction of food waste amongst consumers, with varying current levels of resource efficiency being reported across different food types and varying future levels of efficiency that could be achieved through this measure. This comprised:

- 23 academic papers;
- 24 industry reports;
- 5 technical studies;
- 2 policy documents; and
- 1 website article.

The relevant sources were considered of medium - high accessibility and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average

[101] WRAP, Food Standards Agency, Defra (2019). Labelling guidance: Best practice on food date labelling and storage advice; WRAP (2023). The Food Waste Reduction Roadmap Toolkit; Natural Resources Defense Council (2017). Wasted: How America is losing up to 40 percent of its food from farm to fork to landfill; Parfitt et al. (2010). Food waste within food supply chains: quantification and potential for change to 2050. Philosophical Transactions of the Royal Society B. 365, p. 3065-3081; WRAP (2022). Retail Survey 2021/22: Reducing household food waste through changes to the retail environment.
[102] WRAP (n.d.). Food Waste Action Week. https://wrap.org.uk/taking-action/citizen-behaviour-change/love-food-hate-waste/key-campaigns/food-waste-action-week (Accessed 25th October 2023).
[103] WRAP (2022). Retail survey 2021/22: Reducing household food waste through changes to the retail environment.
[104] Linder et al. (2018). Using Behavioural Insights to Promote Food Waste Recycling in Urban Households—Evidence From a Longitudinal Field Experiment. Frontiers in Psychology. 9.

IAS of 4.07 (out of 5), with 38 sources exhibiting a score of 4 or above. 31 literature sources were UK-specific and only 6 sources were not recent studies.

6.2.2 Interviews

All 9 stakeholders interviewed engaged in discussion of Measure 6, although some to a minimal extent. Most stakeholders did not object to the measure or indicator definition. However, one stakeholder interpreted the indicator to include consumer waste in HoReCa settings as well as the home and so the indicator was amended to clarify that this measure relates only to household food waste.

6.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 6 with a high level of engagement. The stakeholders represented a small section of the food and drink sector, with discussions and voting activity from manufacturers, a redistributor and a researcher. There was a mixture of low confidence, medium confidence and high confidence levels in voting for levels of efficiency for this measure. There were four votes for the current level of efficiency, four for the maximum level of efficiency and four for business-as-usual.

There were concerns about missing drivers and barriers, such as the push to reduce packaging and the dietary shift away from animal-based products. One stakeholder commented on how food waste on a household level would vary depending on food type, consumption method and storage method. Additionally, there were discussions around how public education, food price inflation and household food waste collection could reduce household food waste.

An additional driver was suggested by stakeholders during the workshop:

Shift in household consumption trends (see discussion below).

The level of engagement in the workshop was as follows:

- Five stakeholders across manufacturing, redistribution and academia were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Four stakeholders actively contributed to verbal discussion, with no contribution on the Teams chat.

6.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

6.3.1 Drivers

Table 17 below shows the main drivers for Measure 6. The most significant drivers are shown in bold.[105] However, none of these drivers are independent, and the ways in which they combine will impact significantly on the extent to which they drive reductions in household food waste.

Table 17: Drivers for food and drink measure 6

Description	PESTLE	COM-B
Food prices	**Economic**	**Capability – psychological**
Consumer choice and information environment	**Social**	**Opportunity – psychological**
Mandatory separate food waste collections	Political	Capability - physical
Increasing shelf-life available for consumers	Economic	Capability – physical
Shift in household consumption	Environmental	Motivation – automatic

Food prices

When food prices are rising disproportionately to income, pressure is applied to consumers' living costs. As a result, consumers are more likely to be looking for ways to minimise costs.[106] When consumers are made aware of the money they could save by reducing food waste, they are more likely to say that reducing food waste is a good idea.[107] Higher food prices can, therefore, be a driver of consumer behaviour change to reduce food waste. Low food prices also encourage consumers to place a lower value on the food they buy, which can result in less care being taken to reduce household food waste.[108]

Consumer choice and information environment

The environment in which consumers choose their behaviours around food and drink purchasing, storage, preparation and consumption, influences the choices they make and the impact these behaviours have on food waste generated in the home.[109] A multitude of factors

[105] Stakeholder workshop participants also voted for 'Mandatory separate food waste collections' as a priority driver. However, the evidence in the literature does not support prioritisation of this driver. Given that there was a limited number of workshop participants, the prioritisation of drivers from the workshop voting exercise has been over-ruled here, in line with the wider evidence.
[106] WRAP (2022). Food loss and waste research summary report.
[107] WRAP (2022). Food loss and waste research summary report.
[108] Stakeholder comment.
[109] Stakeholder comments.

shape the consumer choice environment, including factors that can be influenced by Government, food and drink manufacturers, and retailers, as well as deliberate behavioural changes by consumers.

Raising awareness around food waste can help to influence consumer behaviour and reduce food waste. There are a variety of possible routes through which consumers can be reached. For example, through Government supported messages or retailers can provide information on food waste prevention, aimed at encouraging consumer behaviour change. Education on sustainable food systems and food waste prevention can be included in school curricula.[110] Food and drink manufacturers and retailers can relay information to consumers via in-store communications, on product labels or through advertising campaigns. Opportunities to participate in food production may also help to improve consumers' awareness and understanding of issues in the food supply chain influencing food waste.[111]

Retailers can help consumers to reduce food waste in the home by changing the choice environment in store. This can include avoiding promotional, pricing, and product placement strategies that may encourage consumers to over-purchase food and drink products.[112] Retailers and manufacturers can also alter the choice environment through changes to their product offering. This may include changes to product formulation, product shelf-life, packaging or portion/pack size. Both the format and the food protection and preservation properties of food and drink packaging can impact on the amount of food and drink waste generated by consumers in the home. Innovations in packaging, e.g., reseal ability to increase a product's open life, or split or smaller packs that cater to individual portion sizes can, therefore, drive reductions in food and drink waste. In the case of fresh produce, removing the packaging altogether can drive reductions in household food waste. When fresh produce is sold loose, consumers have the flexibility to purchase the exact amount they need. This reduces the likelihood of buying more than they can consume, which can lead to spoilage and waste. There may however be trade-offs between packaging changes and food waste impacts, with implications across material sectors.

Retailers and manufacturers can also follow best practice guidance on food date labelling and provision of storage advice, to help consumers reduce the amount of food they throw away. Applying best practice in date labelling on food and drink products (e.g., only applying 'Use By' dates when there is a food safety reason to do so; only displaying one date label on a product) helps to ensure that consumers are given consistent and clear advice around how to manage food and drink products at home, reducing the risk of this food and drink ending up as waste. Provision of clear storage advice on all products can help consumers to store products in optimal conditions, thereby maximising product lifetime and reducing food and drink waste.

Mandatory separate food waste collections

[110] Stakeholder comments; Sodexo (2021). Appetite for Action; European Commission (2023). European Citizens' Panel on Food Waste: Final recommendations
[111] Stakeholder comment.
[112] WRAP (2023). Collaborating with Supply Chain Partners and Supporting Citizens.

Separating food waste collections encourages consumers to collect food as a separate waste stream in the home. This may provide a clearer picture for consumers of the food waste they are producing and where it is coming from, and this may in turn motivate changes. Separate food waste collections have been found to be significantly associated with lower total food waste arisings, although the size of the effect cannot be quantified with a high degree of certainty (the true difference could be between 2.3 kg/household/yr and 29.8 kg/household/yr food waste, with 95% confidence).[113]

Increasing shelf-life available for consumers

The extent of food and drink waste in the home can be influenced by practices further upstream in the supply chain. If products reach consumers with minimal shelf-life remaining, they are more likely to spoil and become waste. Therefore, increasing the shelf-life available for consumers by reducing the amount of time between production and arrival with the consumer, can drive reductions in food and drink waste. This is in addition to increasing shelf and open life through changes to the product offering (e.g. resealable packaging), which are mentioned under the consumer choice and information environment driver above.

Shift in household consumption.

The direct environmental impacts of dietary shift is out of scope for this report. However, food consumption preferences are changing all the time. Therefore, an indirect environmental benefit may be derived from reduced waste resulting from any shift in household consumption away from high impact food products, to either products that tend to generate less waste or products that have a lower environmental impact per tonne of waste generated. There may therefore be a disproportionately large per tonne environmental benefit from reductions in waste for some food groups relative to others, for example, meat and fish products.[114] [115]

6.3.2 Barriers

Table 18 below shows the main barriers for Measure 6. The most significant barriers are shown in bold.[116] However, the fact that behaviour change around food waste is complex makes it hard to prioritise factors in isolation. One significant barrier is that multiple factors may need to be aligned to realise reductions in food waste within households.

Table 18: Barriers for food and drink measure 6

Description	PESTLE	COM-B
Pricing strategies	**Economic**	**Opportunity – physical**

[113] WRAP (2019). Impact of household food waste collections on household food waste arisings.
[114] WRAP (2023). Household food and drink waste in the United Kingdom (2021/22).
[115] Poore, J., & Nemecek, T. (2018). Reducing food's environmental impacts through producers and consumers.
[116] Stakeholder workshop participants also voted for 'Lack of food management skills' as a priority driver. However, the evidence does not support prioritisation of this driver. Given that there was a limited number of workshop participants, the prioritisation of drivers from the workshop voting exercise has been over-ruled here, in line with the wider evidence.

Recursion in behaviour	Social	Capability – psychological
Lack of consumer capacity (e.g. time, space) for food management	Social	Capability – psychological
Household composition	Social	Opportunity – physical
Lack of food management skills	Social	Capability - psychological
Ineffective communications or behavioural nudges	Social	Opportunity – social
Complex consumption patterns and supply chain practices mean that prolongation of shelf-life does not always reduce food waste	Economic	Capability – physical
Complex ownership arrangements	Economic	Opportunity – physical

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Pricing strategies

Retailer pricing strategies often mean that it is cheaper for consumers to buy food and drink products in bulk or as part of a promotional offer, even if some of the product is ultimately wasted. Such pricing strategies, therefore, act as an economic disincentive to consumers over-purchasing food and drink products.

Recursion in behaviour

Consumers may adopt behavioural changes that reduce food waste generated in the home, due to factors such as financial pressures or reduced time constraints. When these driving factors are removed or cease to apply pressure to the consumer, the behavioural changes adopted may revert, resulting in a return to previous levels of food waste. Several interviewees highlighted this tendency in relation to both the pandemic, and past periods of food price inflation.

Lack of consumer capacity (e.g. time, space) for food management

Consumers who are under time pressures find it more difficult to dedicate time to food management behaviours. This can result in food waste in the home due to improper food management.

Household composition

Household characteristics such as size and age profile, influence the amount of food waste generated by the household, e.g., smaller households are more likely to generate higher levels of food waste. Demographic changes, such as the shift towards smaller household sizes, may, therefore, act as a barrier to reducing household food waste. The percentage-based nature of this indicator should mean that overall population growth does not impact performance, however, population growth does make targets couched in absolute terms harder to achieve over time.

Lack of food management skills

Consumers may lack the skills that could help them to reduce food waste at home, e.g., meal planning, buying more than is needed, organising the storage of food in the home, the ability to judge whether food is safe to eat, creativity for using up leftovers.[117]

Ineffective communications or behavioural nudges

It can be difficult to reach consumers through communication campaigns, especially when there are many other distractions in peoples' lives. This can be a barrier to achieving significant and permanent consumer behaviour change. Equally, deploying communications in isolation from other factors likely to change behaviour (see 'Drivers' above), is likely to reduce the impact.

Complex consumption patterns and supply chain practices mean that prolongation of shelf-life does not always reduce food waste

Prolongation of shelf-life usually reduces food waste. However, complex consumption patterns (e.g., when products have longer shelf-life consumers can shop in larger volumes, resulting in longer storage periods at home), as well as the impact of shelf-life on the management of products throughout the supply chain (e.g., products with longer shelf-life may be held in storage for longer), imply that shelf-life extension may not always reduce the amount of food waste generated by consumers because a product has not been consumed before reaching its "best before date".

Complex ownership arrangements

The rationale is the same as outlined in Section 3.3.2. In this case, it is specific to the extent that optimised practices in the supply chain (for example selling excess stock more cheaply) may mean waste arises with households instead.

6.4 Levels of efficiency

Table 19: Levels of efficiency for food and drink measure 6

Indicator: Percentage of food purchased by consumers that is wasted in the home

[117] Stakeholder comments.

Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	15 – 20%	5 – 13%	15 – 23%
Evidence RAG	Green	Amber	Red-amber

6.4.1 Current level of efficiency

Data published by WRAP indicates that 6.4Mt of food is wasted by UK households per year, of which 4.7Mt is edible food (i.e., excluding the inedible parts). This literature source also reports that, as a share of food purchases, food waste from households is 16%.[118] Other WRAP publications provide estimates of the share of food purchases wasted by households for specific groups of food items. The proportion of four key products - bread, milk, chicken, potatoes - wasted by households was estimated to be 19.3% in October 2021,[119] rising to 20.5% by November 2022.[120] The share of vegetables, fruits, leafy greens and baked goods purchases wasted by households are estimated to be 25%, 22%, 17% and 23%, respectively.[121]

Data published by WRAP also provides the absolute amount of food and drink wasted on a per person basis - 95 kg per person per year[122] - as well as the total amount of food wasted by UK households each year, for a range of food product groups.[123]

At the EU level, data published by the European Commission indicates that 9.36% of all food commodities available for consumption are wasted at the consumption stage, across households and food services.[124] A study by Stenmarck et al.,[125] estimates that food waste from EU households in absolute terms is 92 kg/capita/year. In contrast, a study based on data from Norway[126] provides a lower estimate of current food waste at 61.21 kg/capita/year.

One stakeholder estimated the current level of efficiency for this indicator to be 25-33%, although this stakeholder also supported the WRAP data reported above. None of the other stakeholders interviewed were able to provide a quantitative estimate for the current level of efficiency for Measure 6, but one other stakeholder also referred us to the WRAP data reported above.

[118] WRAP (2023). UK Food Waste & Food Surplus – Key Facts.
[119] WRAP (2022). The Courtauld Commitment 2030 Progress and Insights Report 2021/2022.
[120] WRAP (2023). UK Household Food Waste Tracking Survey 2022.
[121] WRAP (2022). Food loss and waste research summary report.
[122] WRAP (2023). Household Food and Drink Waste in the United Kingdom 2021/22 .
[123] WRAP (2022). Retail Survey 2021-22; WRAP (2018). Household food waste: restated data for 2007-2015.
[124] European Commission's Knowledge Centre for Bioeconomy (2020). Brief on food waste in the European Union.
[125] Stenmarck et al. (2016). Estimates of European food waste levels.
[126] de Sadeleer et al. (2020). Waste prevention, energy recovery or recycling - Directions for household food waste management in light of Circular Economy policy.

Stakeholder workshop participants agreed with an estimated current level of efficiency of 15-20%. Two participants indicated that this estimate could be slightly lower recently, given current inflation, but they did not feel they had sufficient evidence to support this suggestion.

The reported range for this measure is 15-20%. A green evidence RAG rating was given to this measure because there is quantitative evidence available from literature sources with high quality ratings and, although stakeholders did not provide quantitative estimates, the evidence gathered from the literature reviewed was supported by stakeholders during the interviews and the workshop.

6.4.2 Maximum level of efficiency in 2035

Data published by WRAP indicates that the amount of food currently wasted by UK households per year could be reduced to 2.1Mt, if none of the food that could have been eaten (i.e., the edible parts) was wasted.[127] This would equate to a reduction in the waste of Measure 6 to 5%. A study by Garvey et al.[128] suggests that 60% of current household food waste is avoidable. Applied to estimates of the current level of food waste published by WRAP,[129] this would equate to a reduction of UK household food waste to 2.6Mt or, equivalently, assuming total food purchases remained constant, a reduction in the level of efficiency of Measure 6 to 6%. However, in both of these cases it is assumed that all food waste classified as 'avoidable' by food type can *in practice* be eliminated. This would imply a scale and comprehensiveness of behavioural change that is not necessarily realistic for 2035.

Two stakeholders were able to provide quantitative estimates for the maximum level of efficiency for Measure 6 by 2035. One stakeholder estimated that a 30-40% reduction in household food waste could be achieved in a high ambition scenario. Applied to estimates of the current level of food waste published by WRAP,[130] this would equate to a reduction of UK household food waste to 4.0 – 4.6Mt or, equivalently, assuming total food purchases remained constant, a reduction in the level of efficiency of Measure 6 to 10-11%. Another stakeholder estimated that a 20-30% reduction in household food waste could be achieved in a high ambition scenario. Applied to estimates of the current level of food waste published by WRAP,[131] this would equate to a reduction of UK household food waste to 4.6 – 5.3Mt or, equivalently, assuming total food purchases remained constant, a reduction in the level of efficiency of Measure 6 to 11–13%.

Most stakeholder workshop participants agreed with an estimated maximum level of efficiency of 5-13%. One participant suggested a narrower estimated range of 5-10%.

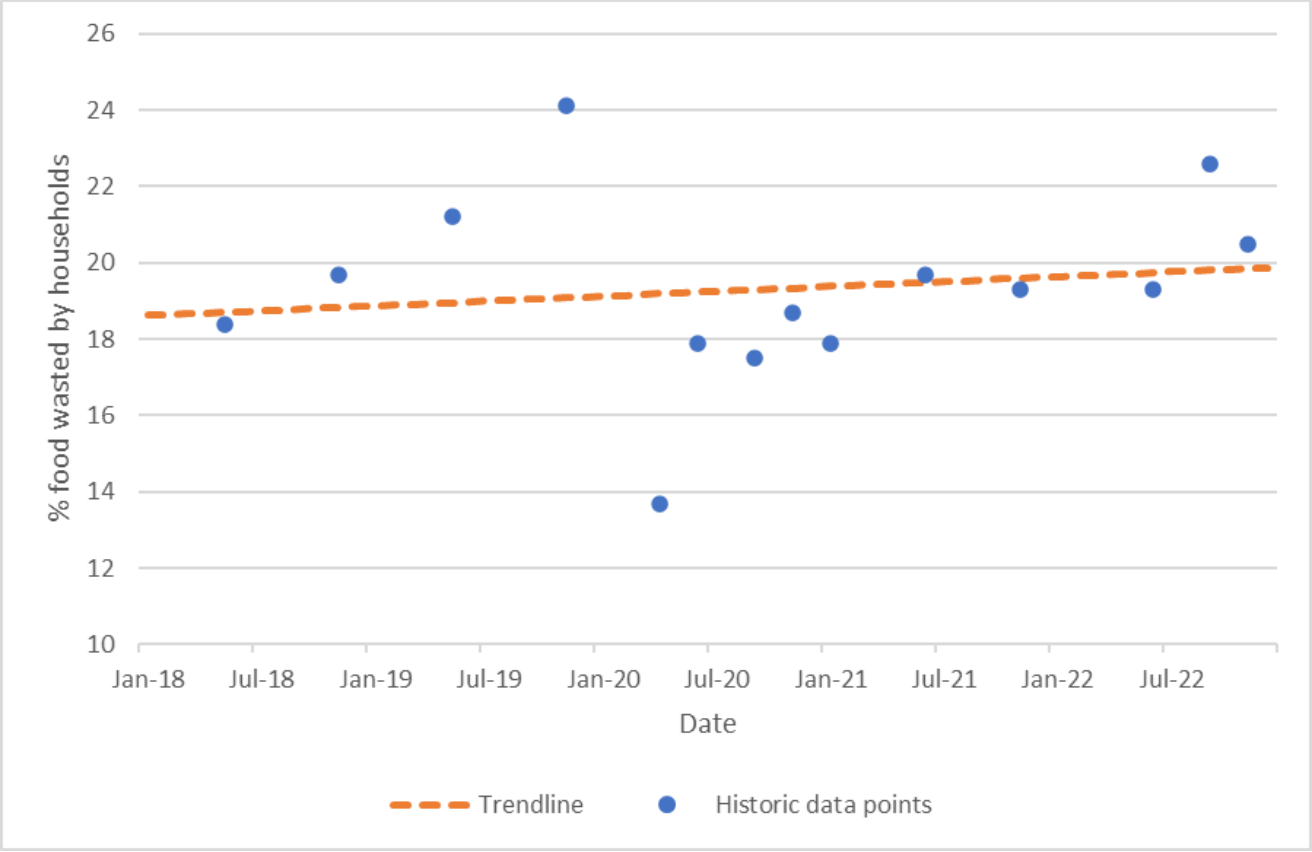
[127] WRAP (2023). Citizen Insights on Use By and Best Before Dates on Dairy Products; WRAP (2022). Food surplus and waste in the UK – key facts.
[128] Garvey et al (2021). Towards net zero nutrition: The contribution of demand-side change to mitigating UK food emissions. Journal of Cleaner Production. 290, 125672.
[129] WRAP (2023). Citizen Insights on Use By and Best Before Dates on Dairy Products; WRAP (2022). Food surplus and waste in the UK – key facts.
[130] WRAP (2023). Citizen Insights on Use By and Best Before Dates on Dairy Products; WRAP (2022). Food surplus and waste in the UK – key facts.
[131] WRAP (2023). Citizen Insights on Use By and Best Before Dates on Dairy Products; WRAP (2022). Food surplus and waste in the UK – key facts.

The reported range for this measure is 5-13%, however the lower bound of this is arguably theoretical rather than actually achievable. An amber evidence RAG rating was given to this measure because there is quantitative evidence available from literature sources with high quality ratings, and stakeholder interviews. In addition, stakeholder workshop participants confirmed the estimated range.

6.4.3 Business-as-usual in 2035

There was very limited quantitative evidence available on the business-as-usual level of efficiency in 2035 for Measure 6. None of the literature sources reviewed provided a direct quantitative estimate of the level of efficiency of Measure 6 in 2035 under a BAU scenario. However, if WRAP's historic estimates (2018 – 2022) of the share of four key food products wasted by households[132] are projected forwards, the level of efficiency of Measure 6, under a BAU scenario would reach 22.9% by 2024 (see Figure 1).

Figure 1: Estimated proportion of four key food products (bread, potatoes, milk, chicken) wasted by households[133]



Similarly, none of the stakeholders interviewed were able to give a quantitative estimate for this measure. However, two stakeholders commented that minimal changes from the current level of efficiency were likely. A reason given for this assessment was that behaviour changes from shocks (e.g., COVID-19) do not appear to be lasting. Another stakeholder suggested that

[132] WRAP (2023). UK Household Food Waste Tracking Survey 2022.
[133] Historic data points are from WRAP's UK household food waste tracking surveys.

some small gains might be possible given that consumer tastes do change over time and product offers can shift accordingly.

Most stakeholder workshop participants agreed with an estimated business-as-usual level of efficiency of 15-23%. Although, one participant suggested that the top end of the range should not be increasing.

The reported range for this measure is: 15-23%. A red-amber evidence RAG rating was given to this measure because although there was agreement across stakeholders there is a lack of quantitative evidence available from the literature reviewed or stakeholders interviewed.

7.0 Measure 7 – Reduction of food waste in HoReCa

7.1 Food and drink resource efficiency measure

7.1.1 Description

Refining the techniques and processes employed in HoReCa settings to reduce the amount of food and drink waste occurring during this stage of the supply chain.

Food and drink waste can occur in hotels, restaurants, and catering[134] (HoReCa) settings for a variety of reasons, e.g., due to over-ordering, spoilage of stock, mistakes during preparation, portion sizes being too large or consumer plate waste.[135] Optimising the techniques and processes employed in HoReCa settings, to reduce food and drink waste can, therefore, improve resource efficiency, both during preparation and in terms of consumer 'plate waste'.

7.1.2 Measure indicator

The indicator selected was the **percentage of food served in HoReCa that is wasted**. This is a relative measure with the percentage derived from the total amount of food and drink waste generated in HoReCa divided by the total amount of HoReCa food and drink throughput.

7.1.3 Examples in practice

Possible ways described in the literature or provided by stakeholders to reduce the amount of food and drink wasted in HoReCa include:

- Improving inventory management practices to reduce spoilage and damage of stock;[136]
- Improving practices to reduce food waste during food preparation.[137]
- Restructuring menus and/or reducing default portion sizes to help reduce plate waste;[138]

[134] It should be noted that catering settings include public sector canteens, in addition to provision of food and drink for events and occasions.
[135] WRAP (2023). Protecting Profits from Plate Waste: How to Reduce Waste from Customer Plates; Government of Ireland (2022). Ireland's National Food Waste Prevention Roadmap.
[136] Government of Ireland (2022). Ireland's National Food Waste Prevention Roadmap; Cristobal et al. (2018). Prioritizing and optimizing sustainable measures for food waste prevention and management. 72, p.3-16; ReFED (2018). Restaurant Food Waste Action Guide; WRAP (2023). Hospitality and Food Service: Actions to support delivery of the UK Food Waste Reduction Roadmap.
[137] Government of Ireland (2022). Ireland's National Food Waste Prevention Roadmap; WRAP (2023). Hospitality and Food Service: Actions to support delivery of the UK Food Waste Reduction Roadmap.
[138] WRAP (2023). Protecting Profits from Plate Waste: How to Reduce Waste from Customer Plates; WRAP (2023) Citizen Food Waste Attitudes and Behaviours Out of Home.

- Changing consumer expectations and behaviour to reduce and prevent plate waste, e.g., by allowing consumers to take leftovers home in hospitality settings,[139] or changes to ordering practices in catering settings like school canteens; and
- When surplus food and drink arises, diverting it from waste routes to redistribution for human consumption or use in animal feed wherever possible.[140]

7.2 Available sources

7.2.1 Literature review

The literature review identified 24 sources that discussed reduction of food waste in HoReCa. While there was some evidence on the current levels of resource efficiency, there was little evidence on the future levels of efficiency that could be achieved through this measure. This comprised:

- 13 industry reports;
- 7 academic papers;
- 2 policy documents; and
- 2 technical studies.

The relevant sources were considered of medium - high accessibility and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.79 (out of 5), with 12 sources exhibiting a score of 4 or above. 13 literature sources were UK-specific and only 4 sources were not recent studies.

7.2.2 Interviews

Only 2 of the stakeholders interviewed engaged in discussion of Measure 7. However, none of the stakeholders that did not engage in discussion of this measure objected to the measure or the indicator defined. The indicator for this measure, therefore, remained unchanged throughout the interviews.

7.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 7 with a high level of engagement. The stakeholders represented a small section of the food and drink sector, with discussions and voting activity from manufacturers and a redistributor, and so were less confident in general terms about this specific measure compared to the others discussed. There was a mixture of medium confidence and high confidence levels in voting for levels of efficiency for this measure. There were three votes for the current level of efficiency, three for the maximum level of efficiency and three for business-as-usual. Operational challenges in

[139] WRAP (2023). Protecting Profits from Plate Waste: How to Reduce Waste from Customer Plates; stakeholder comment.
[140] Defra (2023). Statutory guidance: Food and drink waste hierarchy: deal with surplus and waste.

HoReCa were discussed, alongside the fate of food not fit for human consumption. Additionally, there were discussions around how different redistribution companies target food waste at different stages of the supply chain.

The level of engagement in the workshop was as follows:

- Three stakeholders across manufacturing and redistribution were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Three stakeholders actively contributed to verbal discussion, with no contribution on the Teams chat.

7.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop.

7.3.1 Drivers

Table 20 below shows the main drivers for Measure 7. The most significant drivers, as prioritised by stakeholder workshop participants, are shown in bold. However, these drivers are inter-dependent and the ways in which they combine will impact significantly on the extent to which they drive reductions in food waste. For example, food waste tracking technology and public food waste reporting act together in that a business cannot undertake food waste reporting without a clear understanding of the food waste that is being generated.

Table 20: Drivers for food and drink measure 7

Description	PESTLE	COM-B
Incentivising and training staff to take action to reduce food waste	**Social**	**Opportunity – social**
Setting a food waste reduction target	**Social**	**Motivation – reflective**
Consumer choice and information environment	Social	Opportunity – physical
Financial and other support for redistributors to increase capacity and capability	Economic	Motivation – automatic

Food waste tracking technology	Technological	Capability – physical
Food waste measurement and public reporting	Social	Motivation – reflective
Avoided environmental impacts	Environmental	Motivation - reflective

Incentivising and training staff to take action to reduce food waste.

A range of incentives can be employed in HoReCa settings to encourage staff across the business to adopt behaviours that drive food waste reductions. For example:

- Linking financial incentives for senior management to performance on food waste reduction;
- Include food waste measurement in job descriptions and staff inductions;
- Provide opportunities for staff to improve their skills on food management and preparation to reduce waste, including through the provision of training, e.g., on the use of kitchen equipment and on ways to avoid accidents during food preparation; and
- Empower front of house staff to help customers make more informed meal choices that help to minimise food waste.

Setting a food waste reduction target

The rationale for HoReCa to set a food waste reduction target is the same as outlined in Section 1.3.1.

Consumer choice and information environment

The environment in which consumers choose their behaviours around food and drink purchasing and consumption in HoReCa settings influences the choices they make and the impact these behaviours have on food waste generated in HoReCa. A multitude of factors influence the consumer choice environment.

HoReCa providers can encourage consumers to change their behaviour in ways that reduce food waste by changing the choice environment, by for example:[141]

- Signposting about food waste at all-you-can-eat buffets;

[141] Defra (2023). Barriers and enablers to reducing plate waste in hospitality settings - FO0222; Guardians of Grub (2023). Protecting Profits From Plate Waste: How to Reduce Waste from Customer Plates; ReFED (2018). Restaurant Food Waste Action Guide.

- Implementing a policy of proactively offering a ‘doggy bag’ for consumers to takeaway leftovers;
- Providing visual ‘cues’, such as icons, on menus to convey information about portion sizing;
- Offering smaller plates in self-serve all-you-can-eat dining settings to reduce portion sizes, and food waste arising from customers taking more than they wish to eat;
- Restructuring menus to allow the customer to tailor their portion size; and
- Giving customers the option to tailor the salads and garnishes served with their meal to avoid unwanted items being left as waste.

Educating consumers around food and drink waste and raising awareness of its financial and environmental impacts can also help to influence consumer behaviour in HoReCa settings and reduce food waste. There are a variety of possible routes through which to reach consumers. HoReCa providers can relay information to consumers in their outlets, e.g., via signposting or product labelling, or via wider communication campaigns.

Financial and other support for redistributors to increase capacity and capability

The rationale is the same as outlined in Section 5.3.1.

Food waste tracking technology

Technology can be used to improve the speed and ease with which food waste can be tracked in HoReCa outlets. This could include, for example, weighing scales with integrated cameras. In future, more sophisticated technology, such as AI-powered auto-classification of food waste, may be deployed at a wider scale. Tracking food waste helps to identify food waste hotspots so that targeted measures can be implemented to reduce food waste. The capability to easily build food waste tracking into HoReCa operations can, therefore, be an important driver of food waste reductions in HoReCa, particularly for large scale organisations. However, the technology itself is only a driver to the extent that it enables process change and needs to be aligned with staff training and incentives as above.

Public food waste reporting

The rationale for HoReCa providers to measure and publicly report on food waste is the same as outlined in Section 1.3.1.

Avoided environmental impacts

The rationale for this driver is the same as outlined in Section 2.3.1.

7.3.2 Barriers

Table 21 below shows the main barriers for Measure 7. The most significant barriers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 21: Barriers for food and drink measure 7

Description	PESTLE	COM-B
Contradictory incentives	**Economic**	**Motivation - reflective**
Consumer perception	**Social**	**Capability - psychological**
Lack of food waste measurement and reporting	**Political**	**Motivation – automatic**
High staff turnover	Social	Capability – physical
Food safety	Technological	Capability – physical
Complex ownership arrangements	Economic	Opportunity – physical

Contradictory incentives

HoReCa providers usually benefit financially from selling more food and drink product. The economic incentives faced by HoReCa businesses may, therefore, contradict efforts to reduce food waste, e.g., measures to discourage consumers from over-purchasing may help to reduce food waste, but they could also reduce revenue for the provider. Similar to retail environments, HoReCa settings may also be under pressure to ensure a full range of menu choices is available throughout their service window, even if this requires over-stocking.

Consumer perception

Consumers often have a perception that the amount of food served on the plate equates to value for money. This perception can be a barrier to the implementation of food waste reduction measures such as reducing default portion size, in HoReCa settings. Concerns relating to the potential impacts on consumer experience may also discourage HoReCa providers from communicating with customers about food waste. Even where consumers do not hold this view, HoReCa businesses may be concerned that this is the case. Similarly, some reduction interventions, like ‘doggy bags’, are not culturally widespread in all HoReCa contexts.

Lack of food waste measurement and reporting

Food waste reporting and tracking of food waste in HoReCa settings is relatively rare. In particular the granularity of data collected on food waste in HoReCa (what is wasted and why in a busy kitchen environment, or the split of preparation waste and plate waste) is, therefore,

very poor. Improved measurement and reporting of food waste would enable businesses to internally track the amount of surplus and waste they are generating and where it is coming from. Based on this information, businesses can seek ways to reduce their food surplus and waste. This would be a helpful tool for more efficient management. Sharing this information externally would additionally inform customers and the public on performance, and potentially create additional pressure for improvements. As well as increased accountability, this could lead to norm creation across HoReCa, as public expectations change.

High staff turnover

In the HoReCa sector, staff turnover is high and there are many casual and shift workers. This can be a barrier to improving food preparation and customer engagement practices that help to reduce food waste because it is more difficult to provide training and development opportunities for staff to upskill in food waste reduction strategies.

Food safety

From a food safety perspective, surplus food prepared in HoReCa settings is often harder to redistribute than surplus food generated further upstream in the supply chain. This can be due to the serving format, for example, products served in a self-service dining setting may have been left out uncovered, at room temperature, for an extended period of time, and cannot then be safely redistributed for human consumption.

Complex ownership arrangements

The rationale is the same as outlined in Section 3.3.2. Uniquely to the HoReCa setting, the trade-off between preparation waste and plate waste may also manifest within an individual business, with kitchen staff focused on process savings and efficiency, but a disconnection with what the business can do to reduce plate waste on the consumer side.

7.4 Levels of efficiency

Table 22: Levels of efficiency for food and drink measure 7

Indicator: Percentage of food HoReCa that is wasted			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	18%	5 – 12.6%	15 – 17.6%
Evidence RAG	Amber-Green	Amber	Red

7.4.1 Current level of efficiency

Data published by WRAP indicates that there is 1.1Mt of food waste in the UK hospitality and food services (HaFS) sector per year, of which 0.8Mt is wasted food excluding the inedible parts. This literature source also reports that, as a share of food purchases, food waste in HaFS is 18%.[142] Two other WRAP publications also report the current level of efficiency for Measure 7 to be 18%.[143]

At the EU level, a study by Stenmarck et al.,[144] estimates that food waste from catering in absolute terms is 21kg/capita/year. Another EU study by Bryngelsson et al. provides a combined estimate of current food waste from retail, catering and households, based on data from Sweden.[145] This study estimates that food waste from retail, catering and households, as a share of food supply at wholesale level, is 19%, although the contribution of catering to this share is unknown.[146]

None of the stakeholders interviewed were able to provide a quantitative estimate for the current level of efficiency for Measure 7. Although one stakeholder referred us to the WRAP data reported above.

Stakeholder workshop participants agreed with an estimated current level of efficiency of 18%.

The reported value for this measure is 18%. An amber-green evidence RAG rating was given to this measure because although a quantitative estimate is available from a high-quality source, with support from stakeholders, this waste stream is challenging to measure, and no supporting estimates were provided by the stakeholders interviewed.

7.4.2 Maximum level of efficiency in 2035

A WRAP publication indicates that the theoretical maximum level of efficiency that could be achieved for Measure 7 is 4.5% of food in HaFS wasted, based on the estimate that 75% of the food currently wasted in HaFS could have been eaten.[147] However, it is unlikely that all avoidable food waste could be avoided by 2035 in practice, even with very aggressive measures.

The EU level study by Bryngelsson et al. provides a combined estimate of the maximum level of efficiency for Measures 5, 6 and 7 combined.[148] This study estimates that food waste from

[142] WRAP (2023). UK Food Waste & Food Surplus – Key Facts.
[143] WRAP (2023). Protecting Profits from Plate Waste: How to Reduce Waste from Customer Plates; WRAP (2023). Citizen Food Waste Attitudes and Behaviours Out of Home.
[144] Stenmarck et al. (2016). Estimates of European food waste levels.
[145] Bryngelsson et al. (2016). How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. Food Policy. 59, p.152-164.
[146] Bryngelsson et al. (2016). How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. Food Policy. 59, p.152-164.
[147] WRAP (2023). Protecting Profits from Plate Waste: How to Reduce Waste from Customer Plates.
[148] Bryngelsson et al. (2016). How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. Food Policy. 59, p.152-164.

retail, catering and households could be reduced to 12.5% of food supply at wholesale level. However, the contribution of catering alone to this share is unknown.[149]

One stakeholder estimated that food waste from HoReCa could be reduced by 30% by 2035 in a high ambition scenario. Applied to estimates of the current level of food waste published by WRAP,[150] this would equate to a reduction of UK hospitality and food services food waste to 0.77Mt or, equivalently, assuming total food purchases remained constant, a reduction in the level of efficiency of Measure 7 to 12.6%. None of the other stakeholders interviewed were able to provide a quantitative estimate for the maximum level of efficiency by 2035 for Measure 7.

Stakeholder workshop participants agreed with an estimated maximum level of efficiency of 5-12.6%. The decimal places used here indicate the scope for a marginal reduction rather than the level of precision in the estimate.

The reported value for this measure is 5 – 12.6%. An amber evidence RAG rating was given to this measure because although there was agreement across stakeholders, there was limited quantitative evidence available from the literature reviewed and the stakeholders interviewed.

7.4.3 Business-as-usual in 2035

Very limited quantitative evidence was available on the business-as-usual level of efficiency in 2035 for Measure 7. None of the literature sources reviewed provided quantitative estimates for this measure. One stakeholder estimated the BAU level of efficiency for 2035 to be 1-2% lower than the current level of efficiency. This would equate to a BAU level of efficiency of 17.6–17.8%. None of the other stakeholders interviewed were able to provide quantitative estimates.

Stakeholder workshop participants disagreed with an estimated business-as-usual level of efficiency of 17.6-17.8%, with all agreeing that the estimate should be less than 17.6%. One participant estimated 15%, with the justification that Defra's 'Simpler Recycling' policy and increased focus from large businesses will deliver greater reductions in waste in HoReCa.

The reported value for this measure is 15 - 17.6%. The decimal places used here indicate the scope for a marginal reduction rather than the level of precision in the estimate. A red evidence RAG rating was given to this measure due to the limited quantitative evidence available from the literature reviewed and inconsistency in estimates from different stakeholders.

[149] Bryngelsson et al. (2016). How can the EU climate targets be met? A combined analysis of technological and demand-side changes in food and agriculture. Food Policy. 59, p.152-164.
[150] WRAP (2022). Food surplus and waste in the UK – key facts.

8.0 Measure 8 – End-of-life practices according to the UK food and drink surplus and waste hierarchy

8.1 Food and drink resource efficiency measure

8.1.1 Description

Ensuring food and drink surplus and waste is diverted to its most efficient use, according to the UK food and drink surplus and waste hierarchy.

The UK Government publishes guidance for businesses and organisations that produce, handle, treat, or dispose of surplus or waste food and drink.[151] This guidance sets out a hierarchy of options for preventing and managing food and drink surplus and waste. The hierarchy is as follows:

- 1 - Prevent surplus and waste in businesses;
- 2 - Redistribute surplus food and drink;
- 3 - Make animal feed from former food;
- 4 - Process surplus food to make biomaterials;
- 5 - Recycle - anaerobic digestion and composting;
- 6 - Recover waste by landspreading;
- 7 - Recover energy from waste; and
- 8 - Dispose - send to sewer and landfill.

Ensuring food and drink surplus and waste is diverted to the most efficient use, according to this hierarchy, improves resource efficiency in the food and drink sector. Food that is diverted to productive uses (redistribution to humans, use as animal feed, or use for biomaterials) is classified as surplus, while food that ends up in other management routes is classified as waste. It is not just the type of food itself, but how it is managed that determines this outcome. For example, food redistributed for human consumption needs to be managed in accordance with all appropriate food regulations throughout its journey to final consumers, or it can still become waste.

In the context of this study, there is potential overlap between options 1 to 4 in the above hierarchy and measures already discussed in previous sections of this report. Prevention and redistribution are the explicit outcomes sought for Measures 2 to 7, covered in Sections 2.0 - 7.0 of this report. Additionally, and specifically, Measure 1 (covered in Section 1.0) could overlap with option 3 or option 4 in the UK food and drink surplus and waste hierarchy,

[151] Defra (2023). Statutory guidance: Food and drink waste hierarchy: deal with surplus and waste.

depending on the classification of material used in animal feed and biomaterials as by-product or not. Further, some industries might argue that landspreading, covered by option 6 in the UK food and drink surplus and waste hierarchy, is a beneficial use of their by-product. In contrasting Measures 1 and Measures 8, it is important to note that Measure 1 has a narrower scope, and is limited to food production, whereas Measure 8 relates to all post-harvest waste and surplus, including consumer food waste.

8.1.2 Measure indicator

A series of indicators was selected for this measure, reflecting the share of post-farm gate food surplus and waste diverted to each option in the UK food and drink surplus and waste hierarchy. The set of indicators looks at the distribution of surplus and waste across all the end-of-life treatment routes, and so the denominator for each of the percentages is 'food surplus and waste'. This aligns with WRAP's terminology when measuring and reporting the end-of-life destination for the material. However, it is important to note that only food that is redistributed, used in animal feed or made into biomaterials can be classified as 'surplus', while 'waste' is the material sent to anaerobic digestion, composting, landspreading, energy from waste, sewer or landfill. The indicators for this measure are however all calculated as a percentage of the combined material flow to both routes. The indicators are as follows:

- Percentage of post-farm gate food surplus and waste that is redistributed (option 2 in the UK food and drink surplus and waste hierarchy);
- Percentage of post-farm gate food surplus and waste that is made into animal feed (option 3 in the UK food and drink surplus and waste hierarchy);
- Percentage of post-farm gate food surplus and waste that is made into biomaterials (option 4 in the UK food and drink surplus and waste hierarchy);
- Percentage of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5 in the UK food and drink surplus and waste hierarchy);
- Percentage of post-farm gate food surplus and waste that is sent to composting (option 5 in the UK food and drink surplus and waste hierarchy);[152]
- Percentage of post-farm gate food surplus and waste that is used for landspreading (option 6 in the UK food and drink surplus and waste hierarchy)
- Percentage of post-farm food surplus and waste that is sent to energy from waste (option 7 in the UK food and drink surplus and waste hierarchy); and
- Percentage of post-farm food surplus and waste that is sent to sewer and landfill (option 8 in the UK food and drink surplus and waste hierarchy).

It should be noted that an indicator explicitly for option 1 in the UK food and drink surplus and waste hierarchy was excluded because food surplus and waste that never occurred (i.e. was prevented) cannot be calculated as a share of food surplus and waste. It should also be noted that two indicators for option 5 are included. This is because, although anaerobic digestion and

[152] Note that the two separate indicators for option 5 are given in no particular order – they refer to the same stage of the UK food and drink surplus and waste hierarchy.

compositing sit in the same level of the UK food and drink surplus and waste hierarchy, these two treatment routes are deemed sufficiently different for their flows to be measured separately.

It is noteworthy that because these indicators form an interlinked set, the direction of travel for a given indicator that would represent progress is not necessarily clear – it would depend on whether the material in question for any given stage was in fact moving up or down the hierarchy. In relation to this, the final indicators for energy recovery and disposal to sewer and landfill are arguably measures of resource inefficiency but may be important to understand the overall balance of progress across this indicator set which requires an understanding of the total volume of food surplus and waste.

No judgement is made here on the potential for technological differences within hierarchy stages (for example, different ways in which AD technology can be implemented).

All indicators are currently suggested as a percentage of total food surplus and waste generated across the supply chain, excluding primary production. This was questioned by some interviewees who suggested it would be beneficial to consider the above indicators for each distinct supply chain stage.

8.1.3 Examples in practice

Possible ways described in the literature or provided by stakeholders to ensure food and drink surplus and waste is diverted to its most efficient use include:

- Redistribution organisations can work with retailers to divert food and drink nearing the end of its shelf-life to human consumption, via alternative routes;[153]
- Retailers can divert more surplus products, e.g. bakery items, from their stores to be used in animal feed, instead of being sent to AD;[154]
- Diverting fruit and vegetable material such as husks, seeds and peels from disposal to use in the manufacture of biodegradable food packaging or animal feed;[155] [156]
- Redistribution organisations can work with manufacturers to re-label and redistribute food and drink products that have been incorrectly packaged and would otherwise have ended up as waste;[157] and
- Separated collections of household food waste can divert food waste from landfill to anaerobic digestion or composting.[158]

[153] Company Shop (2023). The Surplus Manual.
[154] WRAP (2016) Using surplus bakery products in animal feed – and saving money.
[155] Zhang, H., Sablani, S. (2021). Biodegradable packaging reinforced with plant-based food waste and by-products.
[156] Garcia-Garcia, G. et al., (2019). Opportunities for waste valorisation in the food industry – A case study with four UK food manufacturers. Journal of Cleaner Production. 211. p1339-1356.
[157] Company Shop (2023). The Surplus Manual.
[158] Stakeholder comment.

8.2 Available sources

8.2.1 Literature review

The literature review identified 18 sources that discussed end-of-life practices according to the UK food and drink surplus and waste hierarchy. While there was some evidence on the current levels of resource efficiency, there was little evidence on the future levels of efficiency that could be achieved through this measure. This comprised:

- 12 industry reports; and
- 6 academic papers.

The relevant sources were considered of medium - high accessibility and credibility when assessed against the data assessment framework, which recognises the relevance of the sources and the strength of the methodology within each. The sources exhibited an average IAS of 3.78 (out of 5), with only 8 sources exhibiting a score of 4 or above. 13 literature sources were UK-specific and all 18 sources were recent studies.

8.2.2 Interviews

A set of indicators of the structure presented above were discussed with stakeholders.

During discussions with stakeholders around Measure 8, it became apparent that defining progress on this measure is complex. Whether an increase in any one of the suggested indicators constitutes success depends on which other indicator the additional waste has been diverted from. Initially, indicators for options 7 and 8 in the UK food and drink surplus and waste hierarchy were excluded because the share of food waste being sent to energy from waste, sewer and landfill were judged not to indicate resource efficiency. However, the residual channels might in fact be important for understanding overall progress in this measure. Therefore, indicators for options 7 and 8 in the UK food and drink surplus and waste hierarchy have been added.

Multiple stakeholders suggested that Measure 8 should be embedded within other measures discussed in this report, rather than as a standalone measure, i.e., the indicators reported as a percentage of food waste generated at a particular supply chain stage, rather than as a percentage of total food waste generated across the supply chain. However, reporting indicators in this way would add further complexity to the interpretation of a change in any one indicator, since it would be dependent on both the other indicators for Measure 8 within that supply chain stage and the indicators for Measure 8 across other supply chain stages.

Given the challenges associated with defining interpretable indicators for Measure 8, the indicators presented in this paper were suggested as an area for further discussion with stakeholders during the workshop phase of this study.

8.2.3 Workshop

There was active discussion from stakeholders in the workshop for Measure 8 with a high level of engagement. The stakeholders represented a small section of the food and drink sector, with discussions and voting activity from manufacturers and a redistributor. There was a mixture of medium confidence and high confidence levels in voting for levels of efficiency for this measure. There were twenty votes for the current level of efficiency, nineteen for the maximum level of efficiency and nineteen for business-as-usual across the hierarchy, as votes were allocated for each level of the hierarchy. There was some discussion about uncertainty in figures found in literature, particularly the combination of different stages of the hierarchy. The discussion also touched on challenges with redistributing retailer brand products. Additionally, there was discussion of various barriers and drivers associated with Measure 8.

An additional barrier was suggested by stakeholders during the workshop:

Awareness - and the issue of complexity of possible end-of-life routes.

The level of engagement in the workshop was as follows:

- Three stakeholders across manufacturing and redistribution were active on the mural board, voting for levels of efficiency, drivers and/or barriers.
- Two stakeholders actively contributed to verbal discussion, with no contribution on the Teams chat.

8.3 Drivers & Barriers

The drivers and barriers influencing this measure were identified through a combination of the literature review, stakeholder interviews and sector workshop. Given that measure 8 relates to all stages of the food supply chain, the drivers and barriers discussed here are related to those discussed throughout the report, in particular recurring ones about cost, awareness, and capacity.

8.3.1 Drivers

Table 23 below shows the main drivers for Measure 8. The most significant drivers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 23: Drivers for food and drink measure 8

Description	PESTLE	COM-B
Improved redistribution of surplus food to humans and animal feed	**Technological**	**Capability – physical**

Investment in separate collection and (re)processing infrastructure	**Economic**	**Opportunity – physical**
Food waste measurement and reporting	Legal	Motivation – automatic
Research and development into biomaterials	Technological	Capability – physical

Improved options for redistribution of surplus food

Improved redistribution would help to divert surplus food products to the most efficient use (i.e., for human consumption), rather than being sent to routes further down the UK food and drink surplus and waste hierarchy. A range of actions could help to improve redistribution options.

Manufacturers, retailers and HoReCa businesses can put in place partnership agreements with food redistribution organisations for each of their sites. This helps to ensure that when food and drink surplus and waste arises, suitable systems and processes are in place to divert products to human consumption where possible. These agreements must be designed with sufficient scope to enable redistribution organisations to actually redistribute surplus for human consumption (and divert food that is not suitable for people to animal feed, or biomaterials, rather than waste routes), otherwise the surplus is simply shifted to another part of the value chain.

Improved infrastructure and logistics on a scale that enables redistribution organisations to handle high volumes of product, including bulk stock, can help to ensure that surplus food can consistently be redistributed for human consumption. Increased capacity of food redistribution programmes could be delivered in various ways and would also help them to operate consistently, and at greater scale.

Communications around the UK food and drink surplus and waste hierarchy can help to raise awareness of the issue among food industry stakeholders and ensure that businesses and organisations are aware of the redistribution options available to them. This encourages stakeholders to target, measure and act on their food waste, in accordance with the Food Waste Reduction Roadmap,[159] and to divert their food surplus to the most efficient use.

Investment in separate collection and (re)processing infrastructure

To realise options for more efficient uses of food waste, according to the UK food and drink surplus and waste hierarchy, food must be collected in separate streams that meet any input

[159] WRAP and IGD (2023). Food Waste Reduction Roadmap.

requirements (e.g., health and safety requirements for animal feed, unpackaged food waste for AD, quality and composition for bioprocessing, etc).[160] The infrastructure to handle these waste streams needs to be built where it does not already exist.

Food waste measurement and reporting

More businesses measuring and publicly reporting on their food waste, including the destination of their food waste, would ensure organisations know where to focus actions to reduce their waste and are held accountable for their food waste reduction efforts. Public reporting provides an incentive for businesses and organisations to implement food waste reduction measures.

Research and development into biomaterials

Research and development into the production of biomaterials, taking into consideration the availability and consistency of food waste feedstocks, could improve the options for diverting food waste for use in biomaterials.

8.3.2 Barriers

Table 24 below shows the main barriers for Measure 8. The most significant barriers, as prioritised by stakeholder workshop participants, are shown in bold.

Table 24: Barriers for food and drink measure 8

Description	PESTLE	COM-B
Regulation around the uses of food waste	**Legal / Political**	**Capability – psychological**
Lack of investment in separate collections and (re)processing infrastructure	**Economic / Political**	**Opportunity – physical**
UK policy environment	**Political**	**Capability – psychological**
Complex ownership arrangements	Economic	Opportunity – physical
Awareness of possible end-of-life routes	Social	Opportunity – social

[160] Stakeholder comment.

Restrictive regulation around the uses of food waste

In the UK, regulations around the use of food and drink waste in animal feeds, including feed for insects, restricts the amount of food and drink waste going to this route.[161] Similarly, there is legislation preventing the use of insect protein, in pig and poultry feed, uses which have recently been legalised in the EU. Regulation, therefore, potentially acts as a barrier to diverting food and drink waste from uses further down the UK food and drink surplus and waste hierarchy, to these more efficient uses. This is a function of health and safety regulation of animal feeds, but internationally the current trend is to increasingly enable the use of insects as animal feed in a wider range of farming applications.

Lack of investment in separate collections and (re)processing infrastructure

The rationale behind the need for investment in separate collections and (re)processing infrastructure is described in Section 8.3.1 Drivers. Market conditions that prevent investment in separate collections and (re)processing infrastructure, therefore, act as a barrier to more efficient uses of food waste.

UK policy environment

This is a complex area that generates stakeholder debate. In a perfect world each hierarchy step would be incentivised more highly than the stage below, but this may be hard to achieve in all contexts. To date, the UK policy environment provides economic incentives for sending food waste to anaerobic digestion, e.g., The Green Gas Support Scheme (GGSS) and legacy policies such as the Renewable Heat Incentive and the Feed-in-Tariff which provide income support for the generation of biogas from anaerobic digestion. A key driver for these policies was incentivising diversion of waste from landfill, at the bottom of the UK food and drink surplus and waste hierarchy.

However, despite stringent sustainability and feedstock requirements under AD incentive schemes, the overall combination of economic costs and benefits may sometimes mean that economic actors are incentivised to divert surplus from more efficient uses higher up the UK food and drink surplus and waste hierarchy (specifically from biomaterials and animal feed) to anaerobic digestion. This has been suggested as a potential conflict for distilling byproducts, though the extent to which this occurs is contested.[162] [163] There is scope for further investigation to better understand potential conflicts between the overall economic incentives for particular end-of-life routes and the UK food and drink surplus and waste hierarchy.

Complex ownership arrangements

Ownership arrangements for food and drink products as they pass between different stages of the supply chain can be complex and this can act as a barrier to diverting food and drink waste

[161] Stakeholder comment.
[162] Stakeholder comment.
[163] Scottish Government (2019). Distillery by-products, livestock feed and bio-energy use: report.

to a more efficient use. The complexity of ownership arrangements mean that when food and drink surplus or waste arises in the supply chain, it may be unclear which actor bears responsibility for dealing with the waste and who should bear the cost of doing so. Delays caused by this uncertainty may result in food and drink products no longer being suitable for human consumption.

Awareness of possible end-of-life routes

When food and drink surplus or waste arises in the supply chain, the supply chain actor responsible for the surplus/waste at that stage of the supply chain faces a complex set of end-of-life options for dealing with the surplus/waste. If the supply chain actor lacks awareness of the possible end-of-life routes, the surplus/waste may not be diverted to its most efficient use.[164]

8.4 Levels of efficiency

Table 26 gives the estimated levels of efficiency for Measure 8. It should be noted that, while the estimated current levels of efficiency sum to 100%, subsequent columns represent the spread of options for the different levels of the hierarchy, and so these columns may not sum to 100%, depending on how the different end-of-life routes ultimately end up interacting. When estimating business-as-usual and maximum levels of efficiency, stakeholders were encouraged to think about change route by route, rather than worry about summing their estimates to 100%. Additionally, the estimates for business-as-usual and maximum levels of efficiency reflect a compromise among a range of views and sources.

Table 25: Levels of efficiency for food and drink measure 8

Indicator: See Section 8.1.2			
Level of efficiency	Current	Maximum in 2035	Business-as-usual in 2035
Value	% of post-farm gate food surplus and waste that is redistributed (option 2): 1%	% of post-farm gate food surplus and waste that is redistributed (option 2): <10%	% of post-farm gate food surplus and waste that is redistributed (option 2): <5%

[164] Added during stakeholder workshop.

	% of post-farm gate food surplus and waste that is made into animal feed (option 3): 7%	% of post-farm gate food surplus and waste that is made into animal feed (option 3): 14-20%	% of post-farm gate food surplus and waste that is made into animal feed (option 3): <10%
	% of post-farm gate food surplus and waste that is made into biomaterials (option 4): 20%	% of post-farm gate food surplus and waste that is made into biomaterials (option 4): <40%	% of post-farm gate food surplus and waste that is made into biomaterials (option 4): <30%
	% of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5) and % of post-farm gate food surplus and waste that is sent to composting (option 5):[165] 14%	% of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5) and % of post-farm gate food surplus and waste that is sent to composting (option 5): <30%	% of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5) and % of post-farm gate food surplus and waste that is sent to composting (option 5): <20%
	% of post-farm gate food surplus and waste that is used for landspreading (option 6): <=19%	% of post-farm gate food surplus and waste that is used for landspreading (option 6): <=19%	% of post-farm gate food surplus and waste that is used for landspreading (option 6): <=19%
	% of post-farm gate food surplus and waste that is sent to energy from waste (option 7):<=19%	% of post-farm gate food surplus and waste that is sent to energy from waste (option 7): <=19%	% of post-farm gate food surplus and waste that is sent to energy from waste (option 7): <=19%
	% of post-farm gate food surplus and waste that is sent to sewer and landfill (option 8): 19%	% of post-farm gate food surplus and waste that is sent to sewer and landfill (option 8): 0-5%	% of post-farm gate food surplus and waste that is sent to sewer and landfill (option 8): 15-19%

[165] Unable to separate based on the data available.

Evidence RAG	Red-Amber	Red	Red

8.4.1 Current level of efficiency

Data published by WRAP shows a breakdown of the treatment routes for the 9.7Mt of post-farm gate food surplus and waste generated in the UK in 2021 and the 2.8Mt of by-products generated in the manufacturing sector.[166]

Table 26: Treatment routes for post-farm gate food surplus and waste, UK[167]

Treatment route	Tonnes	Share of post-farm gate food surplus and waste
Redistribution to humans	88,600	1%
Used in animal feed	751,000	6%
Rendering of animal by-products	2,200,000	18%
Other food by-products	600,000	5%
Anaerobic digestion and composting	1,900,000	15%
Thermal recovery and landspreading	5,100,000	41%
Disposal	1,900,000	15%
Total	**12,539,600**	**100%**

The categorisation of treatment routes in this publication does not map directly to the indicators suggested for Measure 8.

[166] WRAP (2023). UK Food Waste & Food Surplus – Key Facts.
[167] WRAP (2023).
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A study by Facchini et al.[168] also provides a breakdown of UK food flows, but the reported data is older (from 2013). However, this data shows some inconsistencies with the proportions reported in the WRAP publication, e.g., the proportion to landfill is much higher and the combined proportion to thermal recovery and landspreading is much lower. Given that the data presented in this study is older, the more recent WRAP publication is interpreted as a better reflection of current efficiency levels.

Similar breakdowns of the treatment of food surplus and waste are available for Australia and South Korea. A study by FIAL presents the following analysis for Australia (excluding primary production):[169]

Table 27: Treatment routes for post-farm gate food surplus and waste, Australia[170]

Treatment route	Tonnes	**Share of food surplus and waste**
Commercial composting	1,372,000	8.5%
Home / on-site composting	443,000	2.7%
Anaerobic digestion	40,000	0.2%
Waste to energy	28,000	0.2%
On-farm disposal	52,000	0.3%
Landfill	3,322,000	20.6%
Wastewater treatment	736,000	4.6%
Recovery (new food)	926,000	5.7%

[168] Facchini et al. (2018). Food flows in the United Kingdom: The potential of surplus food redistribution to reduce waste. Journal of the Air & Waste Management Association. 68, p.887-899.
[169] FIAL (2021). National Food Waste Strategy Feasibility Study.
[170] FIAL (2021). National Food Waste Strategy Feasibility Study.

Recovery (non-food product)	2,067,000	12.8%
Other	22,000	0.1%
Export	585,000	3.6%
Food rescue	37,000	0.2%
Animal feed	6,486,000	40.2%
Total	**16,116,000**	**100%**

There are significant differences in the treatment of food surplus and waste in Australia vs the UK, e.g., the proportion sent to anaerobic digestion is much lower than in the UK, while the proportion used in animal feed is much higher.

The following breakdown of the treatment of food waste in South Korea is presented in a study by Shurson:[171]

Table 28: Treatment routes for food waste, South Korea[172]

Treatment route	Share of food waste
Recycled into animal feeds	45%
Composted	45%
Anaerobic digestion, vermicomposting, and co-digestion with sewage sludge	10%

Given the large contextual differences between food waste treatment in Australia, South Korea and the UK, the quantitative estimates reported here for Australia and South Korea are not

[171] Shurson, G.C. (2020). "What a Waste"—Can We Improve Sustainability of Food Animal Production Systems by Recycling Food Waste Streams into Animal Feed in an Era of Health, Climate, and Economic Crises? Sustainability. 12, p.7071.
[172] Shurson, G.C. (2020). "What a Waste"—Can We Improve Sustainability of Food Animal Production Systems by Recycling Food Waste Streams into Animal Feed in an Era of Health, Climate, and Economic Crises? Sustainability. 12, p.7071.

considered when determining quantitative estimates of the current level of efficiency for Measure 8 in the UK.

Stakeholders found it difficult to provide quantitative estimates for the current level of efficiency of Measure 8 indicators. One stakeholder estimated that around 1/3 of surplus food is redistributed. However, this estimate is significantly inconsistent with the data collected in the literature review, perhaps reflecting the fact many stakeholders understand their parts of the supply chain in great detail, but may not have an overview of aggregate performance. Another stakeholder was unable to offer quantitative estimates but suggested that the proportions to animal feed and anaerobic digestion were likely the highest, with the other treatment routes receiving much smaller proportions.

Stakeholder workshop participants were presented with the following values for the current levels of efficiency of the indicators, based on the data available from WRAP at that time.[173] In examining the below, we reiterate that each indicator is calculated as a proportion of all material that ends up as either food surplus or food waste, though only material ending up at the lower stages of the hierarchy will ultimately be classed as waste.

- Percentage of post-farm gate food surplus and waste that is redistributed (option 2): 1%
- Percentage of post-farm gate food surplus and waste that is made into animal feed (option 3): 7%
- Percentage of post-farm gate food surplus and waste that is made into biomaterials (option 4): 20%
- Percentage of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5) and Percentage of food waste that is sent to composting (option 5):[174] 14%
- Percentage of post-farm gate food surplus and waste that is used for landspreading (option 6):[175] <=19%
- Percentage of food surplus and waste that is sent to energy from waste (option 7): [176] <=19%
- Percentage of post-farm gate food surplus and waste that is sent to sewer and landfill (option 8): 19%

Workshop participants did not agree on the estimates for the first two indicators. For the indicator ‘percentage of post-farm gate food surplus and waste that is redistributed (option 2)’, one participant estimated 1-3%, while 2 participants estimated <1%. For the indicator ‘percentage of post-farm gate food surplus and waste that is made into animal feed (option 3)’, two participants estimated 7-10%, while 1 participant estimated <7%.

[173] WRAP (2022). Food surplus and waste in the UK – key facts.
[174] Unable to separate based on the data available.
[175] ‘Percentage of post-farm gate food surplus and waste that is used for landspreading (option 6)’ and ‘Percentage of food waste that is sent to energy from waste (option 7)’ were combined in the source data. However, the estimate for these two very divergent categories was separated for the purposes of the workshop, in order to gather stakeholders’ views on the split between the two categories.
[176] Unable to separate based on the data available.

All workshop participants agreed on the following estimated ranges for the remaining indicators, albeit with mixed levels of confidence:

- Percentage of post-farm gate food surplus and waste that is made into biomaterials (option 4): <20%
- Percentage of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5) and Percentage of food surplus and waste that is sent to composting (option 5): <14%
- Percentage of post-farm gate food surplus and waste that is used for landspreading (option 6): <=19%
- Percentage of food surplus and waste that is sent to energy from waste (option 7): <=19%
- Percentage of post-farm gate food surplus and waste that is sent to sewer and landfill (option 8): 15-19%

Given that workshop participants' estimates did not diverge strongly from the WRAP data, these estimates are taken as the starting point for the estimates reported for this measure. Since the WRAP data does not give separate estimates for the indicators 'Percentage of post-farm gate food surplus and waste that is used for landspreading (option 6)' and 'Percentage of food surplus and waste that is sent to energy from waste (option 7)', input from the stakeholder workshop was used to separate the estimate. The reported estimates for the current level of efficiency for measure 8 are as follows. As previously stated, all figures are calculated as a proportion of the total material flow that ends up as either surplus or waste, but only material ending up in lower stages of the hierarchy will ultimately be classified as waste.

- % of post-farm gate food surplus and waste that is redistributed (option 2): 1%
- % of post-farm gate food surplus and waste that is made into animal feed (option 3): 7%
- % of post-farm gate food surplus and waste that is made into biomaterials (option 4): 20%
- % of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5) and % of post-farm gate food surplus and waste that is sent to composting (option 5): 14%
- % of post-farm gate food surplus and waste that is used for landspreading (option 6): <=19%
- % of post-farm gate food surplus and waste that is sent to energy from waste (option 7): <=19%
- % of post-farm gate food surplus and waste that is sent to sewer and landfill (option 8): 19%

A red-amber evidence RAG rating was given to this measure because, while there is relevant quantitative evidence available from a trusted source, estimates were not provided in the literature for each of the individual indicators specified for Measure 8. In addition, there was some disagreement across stakeholders on the estimated range for some indicators. Finally, there may be value in considering the risk of overlap in thinking between Measure 1 and

Measure 8. While this should not really impact the figures obtained for either, some material might be considered in scope for both, but not always consistently identified as such by stakeholders without prompting.

8.4.2 Maximum level of efficiency in 2035

There was very limited quantitative evidence available on the maximum level of efficiency in 2035 for Measure 8. The literature sources reviewed only provided quantitative evidence relevant to the indicator for the percentage of post-farm gate food surplus and waste that is redistributed (option 2).

WRAP has estimated that the total additional amount of post-farm gate surplus food that might be suitable for redistribution in the UK, could be between 170,000 to 190,000 tonnes.[177] This would equate to a 105-118% increase in redistribution from the 161,500t of post-farm gate surplus food estimated to have been redistributed for human consumption in 2022.[178] Another study published by WRAP indicates that 68% of food surplus could feasibly be redistributed (i.e. readily redistributable according to criteria that reflect the practicality and suitability of using food surpluses in redistribution).[179]

However, there is likely significant variation across food product types in the potential for increased redistribution. For example, one of the stakeholders interviewed suggested that there is little scope for additional redistribution from the manufacturing and retail of ambient foods. In contrast, while there is scope for increased redistribution of fresh produce, this can also be logistically more challenging for both supply chain actors and redistribution organisations, as the window for redistribution is narrower.

Stakeholder workshop participants largely agreed with each other on the following estimated ranges for the maximum level of efficiency for this measure. As previously stated, all figures are calculated as a proportion of the total material flow that ends up as either surplus or waste, but only material ending up in lower stages of the hierarchy will ultimately be classified as waste.

- Percentage of post-farm gate food surplus and waste that is redistributed (option 2): <10%
- Percentage of post-farm gate food surplus and waste that is made into animal feed (option 3): 14-20%
- Percentage of post-farm gate food surplus and waste that is made into biomaterials (option 4): <40%
- Percentage of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5) and Percentage of food surplus and waste that is sent to composting (option 5): <30%

[177] WRAP (2022). Surplus Food Redistribution in the UK 2015 – 2021.
[178] WRAP (2023). Annual Survey of Redistribution Organisations in the UK –2022 Update: Key Findings.
[179] WRAP, Cymru (2023). Technical Appendix: Welsh Food Waste Route Map; WRAP (2016). Quantification of food surplus, waste and related materials in the grocery supply chain.

- Percentage of post-farm gate food surplus and waste that is used for landspreading (option 6): <=19%
- Percentage of food surplus and waste that is sent to energy from waste (option 7): <=19%
- Percentage of post-farm gate food surplus and waste that is sent to sewer and landfill (option 8): 0-5%

Given the limited quantitative evidence available for the maximum level of efficiency across this set of indicators, the ranges supported by workshop participants are taken as the reported estimates for measure 8. However, the reported estimates are given a red evidence RAG rating, due to the lack of supporting quantitative evidence available from the literature reviewed or stakeholder interviews. As noted previously, estimates here add up to greater than 100%, reflecting how different management routes may grow or shrink relative to the baseline, rather than necessarily reflecting the overall split between routes that will be achieved in future.

8.4.3 Business-as-usual in 2035

There was also very limited quantitative evidence available on the BAU level of efficiency in 2035 for Measure 8. The literature sources reviewed only provided minimal quantitative evidence relevant to the indicator for the percentage of post-farm gate food surplus and waste that is redistributed (option 2).

Data published by WRAP shows that the amount of surplus food (including from primary production) redistributed for human consumption has been increasing over time, from 54,439t in 2019 to 126,620 in 2022, across 7 organisations that have submitted data annually 2019 – 2022.[180]

Although none of the stakeholders interviewed were able to provide quantitative estimates for the BAU level of efficiency, one stakeholder highlighted that the most growth is being seen in the share of food waste to anaerobic digestion and composting (option 5), across many different types of food waste material. It should be noted that whether this is considered a good or a bad outcome from a resource efficiency point of view would depend on whether all this material represented movement up the hierarchy to these outcomes, or a loss of resources that could have been used for other purposes (e.g. human consumption or animal feed).

Stakeholder workshop participants largely agreed with each other on the following estimated ranges for the business-as-usual level of efficiency for this measure. As previously stated, all figures are calculated as a proportion of the total material flow that ends up as either surplus or waste, but only material ending up in lower stages of the hierarchy will ultimately be classified as waste.

- Percentage of post-farm gate food surplus and waste that is redistributed (option 2): <5%

[180] WRAP (2023). Annual Survey of Redistribution Organisations in the UK –2022 update.

- Percentage of post-farm gate food surplus and waste that is made into animal feed (option 3): <10%
- Percentage of post-farm gate food surplus and waste that is made into biomaterials (option 4): <30%
- Percentage of post-farm gate food surplus and waste that is sent to anaerobic digestion (option 5) and Percentage of food surplus and waste that is sent to composting (option 5): <20%
- Percentage of post-farm gate food surplus and waste that is used for landspreading (option 6): <=19%
- Percentage of food surplus and waste that is sent to energy from waste (option 7): <=19%
- Percentage of post-farm gate food surplus and waste that is sent to sewer and landfill (option 8): 15-19%

As for the maximum level of efficiency, the ranges supported by workshop participants are taken as the reported estimates, given the limited quantitative evidence available for the business-as-usual level of efficiency across this set of indicators. However, the reported estimates are given a red evidence RAG rating, due to the lack of supporting quantitative evidence available from the literature reviewed or stakeholder interviews. As noted previously, estimates here add up to greater than 100% reflecting how different management routes may grow or shrink relative to the baseline, rather than necessarily reflecting the overall split between routes that will be achieved in future.

9.0 Interdependencies

This report has discussed each of the measures identified for the food and drink sector and presented estimates for the maximum and BAU level of efficiency they could achieve independently, that is, not considering any interdependencies or interactions between measures.

However, in practice these measures are likely to occur in tandem, and the levels of efficiency that are reached in each will depend on progress against other measures. The precise nature of these interdependencies should be considered when using any of the level of efficiency estimates from this report in further research or modelling exercises that attempt to produce an estimate of the cumulative impact of these measures over time.

A summary of the key interactions/interdependencies between the measures in this report with other measures in the sector, and with measures in other sectors is presented below.

Note, the estimates for the current level of efficiency will by their nature reflect the interactions and interdependencies between measures as they currently occur.

9.1 Interdependencies within the sector

The food and drink sector is highly interconnected. While many of the resource efficiency measures covered throughout this paper are presented as relating to a particular stage in the food and drink supply chain, in practice the stage at which waste arises is not necessarily the stage where the decisions leading to that waste were taken. Therefore, actions required for the implementation of a measure will often sit across multiple parts of the supply chain. Further, an action taken to reduce waste at one stage of the supply chain may not reduce overall food waste, but merely shift the food waste to another part of the supply chain. Specific examples are outlined below. It is also the case that food waste prevention may require multiple drivers to be in place and multiple barriers to be eliminated for change to occur. This is true both for interactions between supply chain stages, but also within supply chain stages – in particular for complex behavioural areas such as household food waste prevention.

Measures 5 & 6

- Measure 5 – Reduction of food waste in retail
- Measure 6 – Reduction of food waste amongst consumers

Measures implemented in retail to reduce food waste can have a knock-on effect on the amount of waste generated by consumers in the home. For example, promotional offers implemented by retailers can encourage consumers to buy excessive quantities of food. This can increase consumer food waste because the consumer is not able to use the food in

time.[181] In this case, food waste may merely be shifted from the retailer to the consumer, rather than being eliminated. In some cases, this may still be a net gain, but the trade-off matters to the outcome.

Consumer behaviour can influence actions taken by retailers to reduce food waste. Retailers respond to consumer demand. Therefore, if consumer preferences relating to food waste impact on what they demand from retailers, then retailers will shift their offering accordingly, e.g. through the product standards they set or through the products they place on the market.

As outlined for Measure 6, retailers' wider practices are also significant drivers of consumer behaviours, as retailers represent the primary point of contact with the supply chain for consumers. However, this relates more to the role retailers can play in reducing food waste at household level, rather than a trade-off around where waste might arise.

Measures 4 & 5

- Measure 4 – Reduction in food waste due to relaxed standards
- Measure 5 – Reduction of food waste in retail

Relaxing standards with the aim of reducing food waste could have unintended consequences for food waste in retail. If, for example, aesthetic standards on fresh produce are relaxed by the retailer but this is not coupled with consumer acceptance of the relaxed standard, then the produce could instead end up as food waste at the retail stage. Similarly, if retailers reject consignments on quality grounds, this reduces the resulting waste at retail stage, but in the absence of an alternative route to market, will simply leave that waste to be accounted for at the logistics or processing and manufacturing stages of the supply chain, which in turn can impact on the demands of the production stage. The distribution of responsibility for action and of waste risks across the supply chain is essential to optimising overall resource efficiency outcomes.

Measures 1 & 8

- Measure 1 – Use of by-products in other products
- Measure 8 – End-of-life practices according to the UK food and drink surplus and waste hierarchy

There could be some overlap between Measure 1 and Measure 8, specifically the indicators 'percentage of post-farm gate food surplus that is made into animal feed (option 3)' and 'percentage of post-farm gate food surplus that is made into biomaterials (option 4)' for Measure 8. Measure 1 considers the use of by-products in other products, which could include both animal feed and biomaterials.

[181] Jeswani et al. (2021). The extent of food waste generation in the UK and its environmental impacts. Sustainable Production and Consumption. 26, p.532-547.

9.2 Interdependencies with other sectors

Plastic, glass, paper, aluminium and steel used in packaging

Plastic, glass, paper, aluminium and steel are all utilised as food and drink packaging materials, to varying extents. Packaging can impact on resource efficiency in the food and drink sector because it offers protection and preservation for food and drink products, which can help to extend shelf-life and reduce food waste. However, there is often a trade-off in terms of the GHG emissions associated with packaging, due to the carbon embedded in the production of packaging materials, as well as the additional emissions associated with transporting heavier products. This report assumed that resource efficiency measures considered in the plastic, glass, paper, aluminium and steel sectors would not result in deterioration of the product protection and preservation provided by food and drink packaging. It also assumes that improvements in packaging that may reduce food waste (e.g., packaging for longer life, resealable packaging, or smaller portions) will not generate significant extra packaging waste. In practice, this packaging food waste trade-off is an area of study in its own right.

Glossary and abbreviations

AD	Anaerobic digestion
AI	Artificial intelligence
BAU	Business-as-usual
EU	European Union
FIAL	Food Innovation Australia Limited
GHG	Greenhouse gases
GVA	Gross value added
HaFS	Hospitality and food services
HoReCa	Hotels, restaurants and catering
IAS	Indicative applicability score
IGD	Institute of Grocery Distribution
RAG	Red, Amber, Green
RE	Resource efficiency
RFID	Radio frequency identification
SDG	Sustainable development goals
SME	Small and medium-sized enterprises
UN	United Nations

Appendix A: IAS Scoring Parameters

Table 29: Methodology for the calculation of the IAS

Number of 'high' criteria	Number of 'low' criteria	IAS
Indifferent	3 or more	1
<= 1	2	2
>= 2	2	3
<= 2	1	3
>= 3	1	4
<= 1	None	3
2	None	4
>= 3	None	5

Table 30: IAS Scoring Parameters

Criteria	High	Medium	Low
Geography	Specific to UK	Non-UK but applicable to the UK	Non-UK and not applicable to the UK
Date of publication	< 10 years	10 to 20 years	> 20 years
Sector applicability	Sector and measure-specific, discusses RE and circularity	Sector and measure-specific, focus on decarbonisation	Cross-sector
Methodology	Research methodology well defined and deemed appropriate	Research methodology well defined but not deemed appropriate / Minor description of research methodology	No research methodology
Peer Review	Explicitly mentioned peer review	Not explicitly mentioned, but assumed to have been peer reviewed	Unknown

Appendix B: Search strings

- (food OR ingredient* OR food yield) AND resource efficiency
- (food OR ingredient* OR food yield) AND (circular economy OR circular*)
- (food OR ingredient* OR food yield) AND (circular economy OR circular*) AND business models
- (food OR ingredient*) AND (circular economy OR circular*) AND processing
- (food OR ingredient*) AND (circular economy OR circular*) AND manufact*
- (food OR ingredient*) AND (circular economy OR circular*) AND distribution
- (food OR ingredient*) AND (circular economy OR circular*) AND retail
- resource efficien* food (processing OR manufact*)
- (food OR ingredient*) AND (waste minimisation OR waste reduction OR waste prevention)
- (food OR ingredient*) AND (waste minimisation OR waste reduction OR waste prevention) AND processing
- (food OR ingredient*) AND (waste minimisation OR waste reduction OR waste prevention) AND manufact*
- (food OR ingredient*) AND (waste minimisation OR waste reduction OR waste prevention) AND distribut*
- (food OR ingredient*) AND (waste minimisation OR waste reduction OR waste prevention) AND retail*
- (food OR ingredient*) AND shelf-life extension
- (food OR ingredient*) AND waste AND smart packaging
- minim* AND overproduction AND (food OR ingredient*)
- (food OR ingredient*) AND (waste recycl* OR recycl*)
- (food OR ingredient*) AND end-of-life AND option*
- (food OR ingredient* OR food waste OR surplus food) AND redistribut*
- (food OR ingredient*) AND waste AND (composting OR AD OR anaerobic digestion)
- (food OR ingredient*) AND by-product
- (food OR ingredient*) AND by-product AND recycl*
- (food OR ingredient*) AND resource efficiency AND (barrier* OR challenge*)
- (food OR ingredient*) AND (waste minimisation OR waste reduction OR waste prevention) AND (barrier* OR challenge*)
- (food OR ingredient*) AND waste AND technolog* OR option*

- (food OR ingredient*) AND waste AND investment AND UK
- (food OR ingredient*) AND waste AND funding AND UK
- (food OR ingredient*) AND waste policy AND UK
- UK food waste statistics
- (food OR ingredient*) AND (resource efficiency OR waste minimisation OR waste reduction OR waste prevention) AND (measure OR initiative) AND UK

Appendix C: Literature sources

Table 33 below lists the literature sources for food and drink sector.

Table 31: List of literature sources for the food and drink sector

Title	URL	Author	Year	IAS
European Citizens' Panel on Food Waste: Final recommendations	https://food.ec.europa.eu/system/files/2023-02/flw_eu-actions_fwrt_20230210_recom-cit_0.pdf	European Commission	2023	3
Protecting Profits From Plate Waste: How to Reduce Waste from Customer Plates	https://guardiansofgrub.com/resources/downloads/plate-waste-toolkit/	Guardians of Grub	2023	3
Building a Food System That Works for Everyone: A Look at the Intersection of Food Waste with Justice, Equity, Diversity, and Inclusion	https://refed.org/uploads/buildingafoodsystem-jediassessment.pdf	ReFED	2023	1
Collaborating with Supply Chain Partners and Supporting Citizens	https://wrap.org.uk/sites/default/files/2023-02/WRAP-Food-Waste-Reduction-Roadmap-Collaborating-with-supply-chain-partners-and-supporting-citizens.pdf	WRAP	2023	3
Retail: Actions to support delivery of the UK Food Waste Reduction Roadmap	https://wrap.org.uk/sites/default/files/2023-02/WRAP-Food-Waste-Reduction-Roadmap-Quickstart-Guide-Retail.pdf	WRAP	2023	3
Manufacturers: Actions to support delivery of the UK Food Waste Reduction Roadmap	https://wrap.org.uk/sites/default/files/2023-02/WRAP-Food-Waste-Reduction-Roadmap-Quickstart-Guide-Manufacturers.pdf	WRAP	2023	3

Hospitality and Food Service: Actions to support delivery of the UK Food Waste Reduction Roadmap	https://wrap.org.uk/sites/default/files/2023-02/WRAP-Food-Waste-Reduction-Roadmap-Quickstart-Guide-Hospitality-and-Food-Service.pdf	WRAP	2023	3
UK Household Food Waste Tracking Survey 2022	https://wrap.org.uk/sites/default/files/2023-03/20230309%20Food%20Trends%202022.pdf	WRAP	2023	4
The Food Waste Reduction Roadmap Toolkit	https://wrap.org.uk/sites/default/files/2023-03/WRAP-Food-Waste-Measurement-Roadmap-Toolkit.pdf	WRAP	2023	4
Citizen Food Waste Attitudes and Behaviours Out of Home	https://wrap.org.uk/sites/default/files/2023-02/WRAP_Citizen_food_waste_attitudes_and_behaviours_out_of_home.pdf	WRAP	2023	4
Citizen insights on 'Use By' and 'Best Before' dates on dairy products	https://wrap.org.uk/sites/default/files/2023-02/WRAP-Citizen-insights-on-Use-By-and-Best-Before-dates-on-dairy-products.pdf	WRAP	2023	4
Ireland's National Food Waste Prevention Roadmap: 2023 - 2025	https://www.gov.ie/pdf/?file=https://assets.gov.ie/240909/35f9082e-d734-4c55-b31b-83670f92aeda.pdf#page=null	Department of the Environment, Climate and Communications	2022	3
2022 Annual Impact Report	https://refed.org/uploads/refed-2022-annualreport-digital-final.pdf	ReFED	2022	3

The Food Waste Reduction Roadmap Progress Report 2022	https://wrap.org.uk/sites/default/files/2022-12/WRAP_Food_Waste_Reduction_Roadmap_Progress_Report_2022.pdf	WRAP	2022	3
Evidence & Insights: Reducing household food waste and plastic packaging	https://wrap.org.uk/sites/default/files/2022-02/WRAP-Reducing-household-food-waste-and-plastic-packaging-Full-report.pdf	WRAP	2022	4
Surplus Food Redistribution in the UK 2015 - 2021	https://wrap.org.uk/sites/default/files/2022-07/WRAP-Surplus-food-redistribution-in-the-UK-2015-to-2021_0.pdf	WRAP	2022	4
The Courtauld Commitment 2030: Progress and Insights Report 2021/2022	https://wrap.org.uk/sites/default/files/2022-11/WRAP_The_Courtauld_Commitment_2030_Progress_and_Insights_Report_2022.pdf	WRAP	2022	3
Food loss and waste research summary report	https://wrap.org.uk/sites/default/files/2022-09/WRAP%20food%20loss%20and%20waste%20research%20summary%20report_Sept%202022.pdf	WRAP	2022	4
Food surplus and waste in the UK – key facts	https://wrap.org.uk/sites/default/files/2023-01/Food%20Surplus%20and%20Waste%20in%20the%20UK%20Key%20Facts%20December%202022.pdf	WRAP	2022	3
Evaluation of Project Implementation: LIFE-FOODWASTEPREV	https://webgate.ec.europa.eu/life/publicWebsite/index.cf	European Commission	2021	3

	m?fuseaction=search.dspPage&n_proj_id=5823			
Maximising food surplus redistribution: a guide for food manufacturing businesses	https://igdwebfiles.blob.core.windows.net/websiteassets/Portals/0/downloads/Content/Maximising_food_surplus_redistribution.pdf	Institute of Grocery Distribution	2021	3
Hospitality and Food Service Action Plan - UK Food Waste Reduction Roadmap	https://wrap.org.uk/sites/default/files/2022-03/WRAP_hospitality_and_food_action_plan.pdf	WRAP	2021	3
Best Practice on Redistributing Own-Label Products Within the Supply Chain	https://wrap.org.uk/sites/default/files/2022-03/202202~1_0.PDF	WRAP	2021	3
Updated BFFF Guidance on Freezing Down of Chilled and Ambient Product to Preserve Life (V4)	https://bfff.co.uk/covid-19-news/updated-bfff-guidance-on-freezing-down-of-chilled-and-ambient-product-to-preserve-life-v4/	British Frozen Food Federation	2020	3
No time to waste: assessing the performance of food waste prevention actions	https://www.sciencedirect.com/science/article/pii/S0921344920302640	De Laurentiis, V., Patinha Caldeira, C. and Sala, S.	2020	5
Farm to Fork Strategy	https://food.ec.europa.eu/system/files/2020-05/f2f_action-plan_2020_strategy-info_en.pdf	European Commission	2020	3
Brief on food waste in the European Union	https://knowledge4policy.ec.europa.eu/sites/default/files/KCB-Food%20waste%20brief_print_HQ.pdf	European Commission's Knowledge Centre for Bioeconomy	2020	4

Sustainability of food waste biorefinery: A review on valorisation pathways, techno-economic constraints, and environmental assessment	https://www.sciencedirect.com/science/article/pii/S0960852420308476?via%253Dihub	Patinha Caldeira, C., Vlysidis, A., Fiore, G., De Laurentiis, V., Vignali, G. and Sala, S.	2020	5
Recommendations for Action in Food Waste Prevention	https://food.ec.europa.eu/system/files/2021-05/fs_eu-actions_action_platform_key-rcmnd_en.pdf	EU Platform on Food Losses and Food Waste	2019	3
Assessment of food waste prevention actions	https://publications.jrc.ec.europa.eu/repository/handle/JRC118276	Patinha Caldeira, C., De Laurentiis, V. and Sala, S.	2019	5
Quantification of food waste per product group along the food supply chain in the European Union: a mass flow analysis	https://www.sciencedirect.com/science/article/pii/S0921344919302721?via%253Dihub#sec0105	Patinha Caldeira, C., De Laurentiis, V., Corrado, S., Holsteijn, F. and Sala, S.	2019	5
Food waste accounting methodologies: Challenges, opportunities, and further advancements	https://www.sciencedirect.com/science/article/pii/S2211912417301530	Sara Corrado, Carla Caldeira, Mattias Eriksson, Ole Jørgen Hanssen, Hans-Eduard Hauser, Freija van Holsteijn, Gang Liu, Karin Östergren, Andrew Parry, Luca Secondi, Åsa Stenmarck, Serenella Sala	2019	5

Food Waste Reduction Action Plan	https://cdn.zerowastescotland.org.uk/managed-downloads/mf-wte3m9ey-1678806645d	Scottish Government	2019	3
Labelling guidance: Best practice on food date labelling and storage advice	https://wrap.org.uk/sites/default/files/2020-07/WRAP-Food-labelling-guidance.pdf	WRAP, Food Standards Agency, Defra	2019	3
Quantifying household waste of fresh fruit and vegetables in the EU	https://www.sciencedirect.com/science/article/pii/S0956053X18301946?via%253Dihub	De Laurentiis, V., Corrado, S. and Sala, S.	2018	5
Prioritizing and optimizing sustainable measures for food waste prevention and management	https://www.sciencedirect.com/science/article/pii/S0956053X17308061	Jorge Cristóbal, Valentina Castellani, Simone Manfredi, Serenella Sala,	2018	5
Portugal National Strategy and Action Plan to Combat Food Waste	https://food.ec.europa.eu/system/files/2020-05/fw_lib_fwp-strat_national-strategy_prt_en.pdf	National Commission for Combating Food Waste	2018	4
Restaurant Food Waste Action Guide	https://refed.org/downloads/Restaurant_Guide_Web.pdf	ReFED	2018	3
Foodservice Food Waste Action Guide	https://refed.org/downloads/Foodservice_Guide_Web.pdf	ReFED	2018	3
Bio-Economy Contribution to Circular Economy	https://link.springer.com/chapter/10.1007/978-3-319-66981-6_6	Sara Corrado, Serenella Sala	2018	5

Opportunities to Reduce Waste along the Journey of Milk, from Dairy to Home	https://wrap.org.uk/sites/default/files/2020-10/WRAP-Report%20-%20Opportunities%20to%20reduce%20waste%20along%20the%20journey%20of%20milk%20PUB%2011.2018.pdf	WRAP	2018	5
Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill	https://www.nrdc.org/sites/default/files/wasted-2017-report.pdf	Natural Resources Defense Council	2017	3
Measuring food waste: manual and smart meter based approaches	https://wrap.org.uk/sites/default/files/2020-10/WRAP-Sodexo%20smart%20and%20manual%20monitoring%20Case%20Study.pdf	WRAP	2015	3
Current options for the valorization of food manufacturing waste: a review	https://www.sciencedirect.com/science/article/abs/pii/S0959652613007440	Mirabella N., Castellani V., Sala S.	2014	5
Large buffet savings at Crieff Hydro	https://wrap.org.uk/sites/default/files/2020-10/WRAP-Crieff%20Hydro%20case%20study.pdf	WRAP	2014	3
The Surplus Manual	https://www.companyshopgroup.co.uk/content/files/companyshop/Surplus%20Solutions.pdf	Company Shop	2023	3
Food System Transformation - The Courtauld Commitment 2030	https://wrap.org.uk/resources/guide/food-system-transformation-courtauld-commitment-2030	WRAP	2023	3
Love Food Hate Food Waste	https://wrap.org.uk/taking-action/citizen-behaviour-	WRAP	2023	3

	change/love-food-hate-waste			
Surplus Food Redistribution Labelling Guidance	https://wrap.org.uk/resources/guide/surplus-food-redistribution-labelling-guidance	WRAP	2020	3
Redistribution of Food Beyond its 'Best Before' Date - Implementation resource	https://wrap.org.uk/resources/guide/redistribution-food-beyond-its-best-date-implementation-resource	WRAP	2022	3
Label better, less waste: Uncut fruit and vegetables	https://wrap.org.uk/resources/guide/label-better-less-waste-uncut-fruit-and-vegetables	WRAP	2023	3
The pathway to selling more uncut fruit and veg loose	https://wrap.org.uk/resources/report/pathway-selling-more-uncut-fruit-and-veg-loose	WRAP	2023	3
Retail Survey 2021-22	https://wrap.org.uk/resources/report/retail-survey-2021-22	WRAP	2022	4
Guardians of Grub	https://wrap.org.uk/taking-action/food-drink/initiatives/guardians-grub	WRAP	2019	3
The Courtauld Commitment 2030	https://wrap.org.uk/taking-action/food-drink/initiatives/courtauld-commitment	WRAP	2023	5
Food Waste Reduction Roadmap	https://wrap.org.uk/sites/default/files/2023-02/WRAP-Food-Waste-Reduction-	WRAP	2023	3

	Roadmap-Executive-Summary.pdf			
Best Available Technologies (BAT) Reference Document for the Food, Drink and Milk Industries	https://eippcb.jrc.ec.europa.eu/sites/default/files/2020-01/JRC118627_FDM_Bref_2019_published.pdf	European Commission (JRC)	2019	4
Food and Drink Federation Publications	https://www.fdf.org.uk/fdf/resources/	FDF	2023	3
Zero Carbon Forum Website	https://zerocarbonforum.com/	Zero Carbon Forum	2023	3
Towards net zero nutrition: The contribution of demand-side change to mitigating UK food emissions	https://www.sciencedirect.com/science/article/pii/S0959652620357188	Alice Garvey, Jonathan B. Norman, Anne Owen, John Barrett	2021	5
UK food surplus and waste measurement and reporting guidelines	https://wrap.org.uk/sites/default/files/2020-10/Food-surplus-and-waste-measurement-and-reporting-UK-guidelines.pdf	WRAP	2020	4
Estimates of European Food Waste Levels	https://www.eu-fusions.org/phocadownload/Publications/Estimates%20of%20European%20food%20waste%20levels.pdf	FUSIONS	2016	5
Household Food and Drink Waste in the United Kingdom	https://wrap.org.uk/sites/default/files/2020-12/Household-Food-and-Drink-Waste-in-the-United-Kingdom-2012.pdf	WRAP	2013	5
How can the EU climate targets be met? A combined analysis of technological and	https://www.sciencedirect.com/science/article/pii/S0306919216000129	David Bryngelsson, Stefan Wirsenius,	2016	5

demand-side changes in food and agriculture		Fredrik Hedenus, Ulf Sonesson		
Our Journey to Net Zero	https://uk.sodexo.com/files/live/sites/com-uk/files/Positive%20Impact/Planet/Net-Zero-Report.pdf	Sodexo	2023	3
Appetite for Action	https://uk.sodexo.com/files/live/sites/com-uk/files/Social%20Impact/Sodexo_Appetite_For_Action_Report_Food.pdf	Sodexo	2021	3
Technical Appendix: Welsh Food Waste Route Map	https://wrapcymru.org.uk/sites/default/files/2023-05/Welsh%20Food%20Waste%20Routemap%20-%20Technical%20Report_0.pdf	Wrap, Cymru	2023	4
National Food Waste Strategy Feasibility Study	https://workdrive.zohopublic.com.au/external/06152b9ff5971843391f39fc4d32a847e56fb907c167a4a645887b0a4bc43000	FIAL	2021	5
Uncovering New Ways to Improve Yield in Food & Beverage Production	https://www.manufacturing.net/operations/article/13183554/uncovering-new-ways-to-improve-yield-in-food-beverage-production	Manufacturing.net	2014	3
10 ways manufacturers waste food	https://www.thegrocer.co.uk/food-waste/10-ways-manufacturers-waste-food/547633.article	The Grocer	2017	3

Biogas as a resource-efficient vehicle fuel	https://www.globalbioenergy.org/uploads/media/0711_Boerjesson_Mathiasson_-_Biogas_as_a_resource-efficient_vehicle_fuel.pdf	Pa˚l Bo¨rjesson and Bo Mattiasson	2007	3
The biogas yield, climate impact, energy balance, nutrient recovery, and resource cost of biogas production from household food waste—A comparison of multiple cases from Sweden	https://www.sciencedirect.com/science/article/pii/S0959652622041087	Feiz et al.	2022	5
Waste prevention, energy recovery or recycling - Directions for household food waste management in light of Circular Economy policy	https://ntnuopen.ntnu.no/ntnu-xmlui/bitstream/handle/11250/2731260/Sadeleer_et_al_RC%26C_2020_preprint.pdf?sequence=1	Sadeleer, Brattebø, Callewaert	2020	5
Household Food Waste: Restated Data for 2007-2015	https://wrap.org.uk/sites/default/files/2021-03/WRAP-Household-food-waste-restated-data-2007-2015_0.pdf	Gillick and Quested	2018	5
Drivers and barriers towards circular economy in agri-food supply chain: A review	https://onlinelibrary.wiley.com/doi/full/10.1002/bsd2.171	Mehmood et al.	2021	5
How to innovate business models for a circular bio-economy?	https://onlinelibrary.wiley.com/doi/pdfdirect/10.1002/bse.2725	Donner and de Vries	2021	4
Industry-retail symbiosis: What we should know to reduce perishable processed food disposal for a wider circular economy	https://eprints.lincoln.ac.uk/id/eprint/46237/1/Industry-retail%20symbiosis%20clean%20version%20R2.pdf	Trento et al.	2021	4

The food waste hierarchy as a framework for the management of food surplus and food waste	https://eprints.whiterose.ac.uk/79194/1/accepted%2520manuscript.pdf	Papargyropoulou et al	2014	5
Patterns and Causes of Food Waste in the Hospitality and Food Service Sector: Food Waste Prevention Insights from Malaysia	https://www.mdpi.com/2071-1050/11/21/6016	Papargyropoulou et al	2019	4
Food waste generation and industrial uses: A review	https://www.researchgate.net/profile/Luca-Alibardi/publication/279733410_Food_waste_generation_and_industrial_uses_A_review/links/56adc3bd08ae28588c6080e6/Food-waste-generation-and-industrial-uses-A-review.pdf	Girotto et al	2015	5
Spaghetti soup: The complex world of food waste behaviours	https://www.sciencedirect.com/science/article/abs/pii/S0921344913000980	Quested et al	2013	5
The environmental food crisis: the environment's role in averting future food crises: a UNEP rapid response assessment	https://books.google.co.uk/books?hl=en&lr=&id=BO6d5mBc42cC&oi=fnd&pg=PP104&ots=_CQaaQ8yHy&sig=vwGvCA6fUKSl5r2sskMmtb5dWbY&redir_esc=y#v=onepage&q&f=false	Nellman et al	2009	3
Overview of Waste in the UK Hospitality and Food Service Sector	https://bfff.co.uk/wp-content/uploads/2014/01/WRAP-Waste-in-the-UK-Hospitality-and-Food-Service-Sector-2012-Report.pdf	WRAP	2013	5

Review: Consumption-stage food waste reduction interventions – What works and how to design better interventions	https://www.sciencedirect.com/science/article/pii/S030691921830318X	Reynolds et al	2019	5
Food Loss and Waste Prevention Strategies from Farm to Fork	https://www.mdpi.com/2071-1050/13/10/5443#B39-sustainability-13-05443	Nicastro and Carillo	2021	5
An exploratory study of food waste management practices in the UK grocery retail sector	https://eprints.bournemouth.ac.uk/29570/3/R1.pdf	Filimonau and Gherbin	2017	5
Food waste matters - A systematic review of household food waste practices and their policy implications	https://www.sciencedirect.com/science/article/pii/S0959652618303366	Schanes et al	2018	5
Food Industry Wastes: Assessment and Recuperation of Commodities	https://books.google.co.uk/books?hl=en&lr=&id=CeXEDwAAQBAJ&oi=fnd&pg=PP1&dq=(food+OR+ingredient*)+AND+waste+AND+technolog*+OR+option*&ots=m_yfTEhKYm&sig=eYamZmAtk1z_4wxK4uYaEozGROY&redir_esc=y#v=onepage&q&f=false	Kosseva and Webb	2020	5
Current options for the valorization of food manufacturing waste: a review	https://boa.unimib.it/bitstream/10281/70698/1/1-s2.0-S0959652613007440-main.pdf	Mirabella et al.	2013	4
Anaerobic digestion of source segregated domestic food waste: performance assessment by mass and energy balance	https://eprints.soton.ac.uk/184679/1/Banks_et_al_Biocycle_digester_-_scholar_text.pdf	Banks et al.	2011	5

Preventing Food Waste CASE STUDIES OF JAPAN AND THE UNITED KINGDOM	https://www.oecd-ilibrary.org/preventing-food-waste_5js4w29cf0f7.pdf?itemId=%2Fcontent%2Fpaper%2F5js4w29cf0f7-en&mimeType=pdf	Parry et al	2015	5
A comparative study of food waste management in full service restaurants of the United Kingdom and the Netherlands	https://eprints.bournemouth.ac.uk/33739/1/Filimonau%20et%20al.%202020%20JCLEP%20UK%20and%20NL.pdf	Filimonau et al	2020	5
The extent of food waste generation in the UK and its environmental impacts	https://www.sciencedirect.com/science/article/pii/S2352550920314202	Jeswani et al.	2021	5
Food flows in the United Kingdom: The potential of surplus food redistribution to reduce waste	https://www.tandfonline.com/doi/pdf/10.1080/10962247.2017.1405854	Facchini et al.	2018	5
A comparison of the drivers influencing adoption of on-farm anaerobic digestion in Germany and Australia	https://www.sciencedirect.com/science/article/abs/pii/S0961953411000146	Wilkinson	2011	4
Food Waste Drivers in Europe, from Identification to Possible Interventions	https://www.mdpi.com/2071-1050/9/1/37	Canali et al	2016	5
Processing- and product-related causes for food waste and implications for the food supply chain	https://www.researchgate.net/profile/Norbert-Raak/publication/327139420_Processing-_and_product-related_causes_for_food_waste_and_implications_for_the_food_supply_chain/links/5c694bd5299bf1e3a5adb72f/Processing-and-product-related-causes-for-food-	Raak et al	2016	5

	waste-and-implications-for-the-food-supply-chain.pdf			
Brewers' spent grain: a review with an emphasis on food and health	https://onlinelibrary.wiley.com/doi/full/10.1002/jib.363	Lynch et al	2016	5
Upcycled by-product use in agri-food systems from a consumer perspective: A review of what we know, and what is missing	https://www.sciencedirect.com/science/article/pii/S0040162521001815	Aschemann-Witzel et al	2021	5
A nutritional analysis on the byproduct coffee husk and its potential utilization in food production	https://stud.epsilon.slu.se/8486/7/bondesson_e_150922.pdf	Bondesson	2015	5
The recycling of brewer's processing by-product into ready-to-eat snacks using extrusion technology	https://www.sciencedirect.com/science/article/abs/pii/S0733521007001075	Stojceska et al	2007	5
Recycling bread waste into chemical building blocks using a circular biorefining approach	https://pubs.rsc.org/en/content/articlehtml/2021/se/d1se00575h	Narisetty et al	2021	5
Strategies for recycling and valorization of grape marc	https://jdguez.webs.uvigo.es/wp-content/uploads/2019/08/Strategies%20for%20recycling%20and%20valorization%20of%20grape%20marc.pdf	Gomez-Brandon et al.	2019	4
Food waste recovery pathways: challenges and opportunities for an emerging bio-based circular economy. A systematic review and an assessment.	https://eprints.whiterose.ac.uk/168992/3/Santagata%20et%20al_0412.pdf	Santagata et al	2021	5
From seafood waste to active seafood packaging:	https://cora.ucc.ie/server/api/core/bitstreams/a5d5fafd-	de la Caba et al	2018	5

An emerging opportunity of the circular economy	4dd5-47d3-be2f-fb2f73b47c02/content			
Analytical methods for waste minimisation in the convenience food industry	https://www.centreforsmart.co.uk/system/publications/attachments/000/000/118/original/Analytical_Methods_for_Waste_Minimisation_in_the_Convenience_Food_Industry.pdf	Darlington et al	2008	5
Quantifying food losses and the potential for reduction in Switzerland	https://www.sciencedirect.com/science/article/pii/S0956053X12005302	Beretta et al	2013	5
Food loss and waste in food supply chains. A systematic literature review and framework development approach	https://www.sciencedirect.com/science/article/pii/S0959652621006582	Chauhan et al	2021	4
Consumer-Related Food Waste: Causes and Potential for Action	https://www.mdpi.com/2071-1050/7/6/6457	Aschemann-Witzel et al	2015	5
Food loss and Waste Reduction as an Integral Part of a Circular Economy	https://www.frontiersin.org/articles/10.3389/fenvs.2017.00021/full	Vilarino et al	2017	4
Consumers' Perspective on Circular Economy Strategy for Reducing Food Waste	https://www.mdpi.com/2071-1050/9/1/141	Borello et al	2017	5
Shelf life extension and food waste reduction	https://ageconsearch.umn.edu/record/206209/	Amani & Gadde	2015	4
Research on Shelf-Life Extension Technologies for Food Sustainability: An Assessment of Scientific Activities and Networks	https://www.hindawi.com/journals/tswj/2022/7120662/	Thavorn et al	2022	5

The role of smart packaging system in food supply chain	https://ift.onlinelibrary.wiley.com/doi/full/10.1111/1750-3841.15046	Chen et al	2020	5
“What a Waste”—Can We Improve Sustainability of Food Animal Production Systems by Recycling Food Waste Streams into Animal Feed in an Era of Health, Climate, and Economic Crises?	https://www.mdpi.com/2071-1050/12/17/7071	Shurson, G.C.	2020	5
Using Behavioural Insights to Promote Food Waste Recycling in Urban Households—Evidence From a Longitudinal Field Experiment	https://www.frontiersin.org/articles/10.3389/fpsyg.2018.00352/full	Linder et al	2018	5
Environmental sustainability of anaerobic digestion of household food waste	https://www.sciencedirect.com/science/article/pii/S0301479719301422	Slorach et al	2019	5
The Challenge of Food Waste	https://www.gs1.org/sites/gs1/files/case_study_library_item/gs1_uk_the_challenge_of_food_waste.pdf	Weber et al	2011	2
Funding for Small Scale Anaerobic Digesters in England	https://www.permaculturenews.org/2013/10/23/funding-small-scale-anaerobic-digesters-england/	Mae Wan Ho	2013	3
Food waste within food supply chains: quantification and potential for change to 2050	https://royalsocietypublishing.org/doi/full/10.1098/rstb.2010.0126	Parfitt et al	2010	5
Food Trends & KPI Survey 2021	https://wrap.org.uk/sites/default/files/2021-08/food-trends-report-summary.pdf	WRAP	2021	4

Avoidable food losses and associated production-phase greenhouse gas emissions arising from application of cosmetic standards to fresh fruit and vegetables in Europe and the UK	https://www.sciencedirect.com/science/article/abs/pii/S0959652618324168	Porter et al	2018	5
Food tsar blames shortages on UK's 'weird supermarket culture'	https://www.theguardian.com/environment/2023/mar/04/food-tsar-blames-shortages-on-uks-weird-supermarket-culture	The Guardian	2023	3
Effects of Metal Packaging on Energy and Food Waste	Not available online	Gue and Hoober	2015	3
Impact of household food waste collections on household food waste arisings	https://wrap.org.uk/sites/default/files/2020-08/WRAP-Food-waste-collections-2020-report.pdf	WRAP	2019	4
Opportunities for waste valorisation in the food industry – A case study with four UK food manufacturers	https://www.sciencedirect.com/science/article/pii/S0959652618336722	Garcia-Garcia et al.	2019	5
Quantity and quality of food losses along the Swiss potato supply chain: Stepwise investigation and the influence of quality standards on losses	https://www.sciencedirect.com/science/article/abs/pii/S0956053X15301008	Willersinn et al.	2015	5
Policy recommendations to improve food waste prevention and valorisation in the EU	https://library.wur.nl/WebQuery/wurpubs/fulltext/517005	Refresh	2020	4
Barriers to circular food supply chains in China	https://repository.essex.ac.uk/27963/1/Barriers_CE_SCM_authorscopy.pdf	Farooque et al.	2019	4

Household Food and Drink Waste in the United Kingdom 2021-22	https://wrap.org.uk/sites/default/files/2023-11/Household%20Food%20and%20Drink%20Waste%20in%20the%20United%20Kingdom%202021-22.pdf	WRAP	2023	4
Tracking UK Food System Greenhouse Gas Emissions: 2022 Update	https://wrap.org.uk/sites/default/files/2022-11/WRAP_Tracking_UK_Food_System_Greenhouse_Gas_Emissions_2022_Update.pdf	WRAP	2022	4
UK Food Waste & Food Surplus – Key Facts	https://wrap.org.uk/sites/default/files/2023-11/WRAP-Food-Surplus-and-Waste-in-the-UK-Key-Facts-Nov-2023.pdf	WRAP	2023	3
The Food Waste Reduction Roadmap Progress Update 2023	https://wrap.org.uk/sites/default/files/2023-11/WRAP-Food-Waste-Reduction-Roadmap-Progress-Update-report-2023-V1.0_0.pdf	WRAP	2023	3
Barriers and enablers to reducing plate waste in hospitality settings - FO0222	https://randd.defra.gov.uk/ProjectDetails?ProjectId=21323	Defra	2023	5

Appendix D: List of discarded resource efficiency measures in the food & drink sector

Food and drink are organic materials, representing a bioeconomy resource loop, which makes them different in nature to other products under examination using the common study methodology. This meant matching to some of the measure terms used in the wider programme of work did not always make sense.

During the literature review, several measures were discarded due to reasons such as overlaps in the definition, or being outside of the agreed scope (e.g., relating to primary production or energy efficiency). These discarded measures are listed below alongside the reason for exclusion.

Table 32: List of discarded resource efficiency measures for the food and drink sector

Theme	Sub-theme	Measure name	Reason for de-prioritisation
Consumer	**Material substitution**	**Changing diet composition**	**Out of scope for this study**
Consumer	**Light-weighting**	**Reducing consumer overconsumption**	**Out of scope for this study**
Primary production	Production efficiencies	Plant breeding to increase yield	Farm processes out of scope for this study
Primary production	Production efficiencies	Plant breeding to increase resistance to diseases and pests	Farm processes out of scope for this study
Primary production	Production efficiencies	Plant breeding to increase the efficiency of the use of nutrients	Farm processes out of scope for this study
Primary production	Material substitution	Reducing synthetic fertiliser inputs	Farm processes out of scope for this study
Manufacturing	Light-weighting	Packaging material choice	Being addressed in glass / paper / plastic

Manufacturing	Light-weighting	Reducing size/ volume of packaging	Being addressed in glass / paper / plastic
Manufacturing	Recycled content	Increasing recycled content in packaging	Being addressed in glass / paper / plastic
Manufacturing	Production efficiencies	Improving the energy efficiency of processing equipment	Energy efficiency is out of scope of this study
Distribution and storage	Material substitution	Using less harmful refrigerants	Refrigerants are part of the chemicals value chain, not food
Distribution and storage	Logistics	Filling of distribution vehicles	Would be part of logistics processes, not food processes
Distribution and storage	Logistics	Distribution mode of transport	Modal shift is out of scope of this study
Distribution and storage	Logistics	Reducing distribution distance	Would be part of logistics processes, not food processes
Consumer/post-consumer	Logistics	Consumer mode of transport	Modal shift is out of scope of this study
Consumer/post-consumer	Logistics	Reducing consumer travel distance	Would be part of logistics processes, not food processes
Consumer/post-consumer	Recycled content	Reuse of N and P, recovered from food production and consumption, as fertiliser	Farm processes out of scope for this study

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