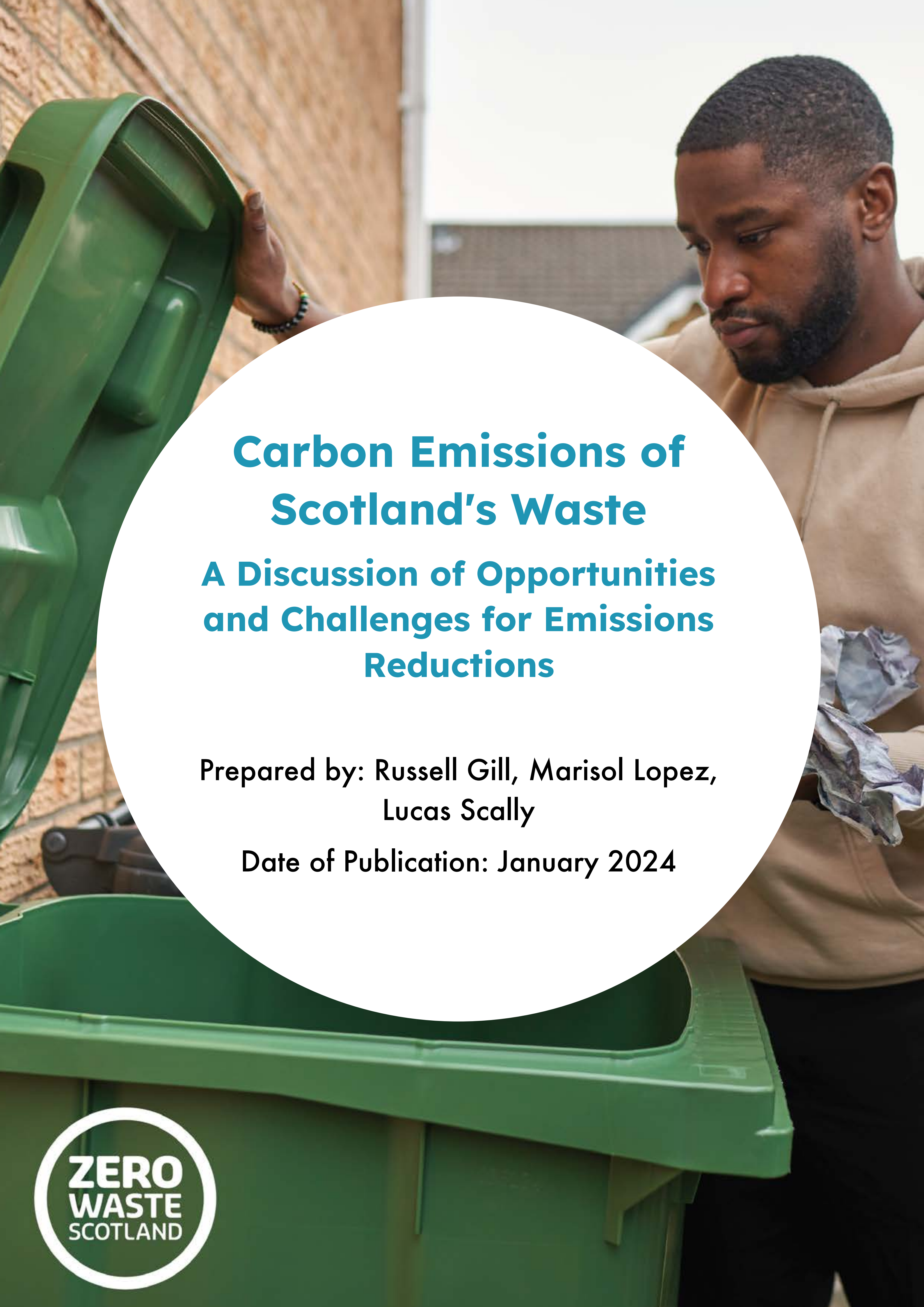

Carbon Emissions of Scotland's Waste

A Discussion of Opportunities and Challenges for Emissions Reductions

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ZERO WASTE SCOTLAND

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Glossary

AD	Anaerobic Digestion
CHP	Combined Heat and Power
DEFRA	Department for Environment, Food & Rural Affairs
DRS	Deposit Return Scheme
EPR	Extended Producer Responsibility
EWC	European Waste Catalogue
FWRAP	Food Waste Reduction Action Plan
HaFS	Hospitality and Food Service Sector
HRW	Household Residual Waste
$ktCO_2e$	Kilotonnes of carbon dioxide equivalent
LCA	Life-Cycle Analysis
MRF	Material Reprocessing Facility
PRN	Packaging Recovery Note
SEPA	Scottish Environment Protection Agency
WRAP	Waste and Resources Action Programme
ZWS	Zero Waste Scotland

1 Executive Summary

The purpose of this report is to identify Scotland's priority sectors when considering the lifecycle greenhouse gas impacts of the waste streams they generate (i.e., embodied and disposal emissions combined).

1.1 Methodology

Data for this study was sourced from the SEPA Waste from All Sources dataset (2018), the SEPA Household Waste dataset (2018), the SEPA Business Waste Tables (2018), the SEPA Data Discovery Tool (2018), the Zero Waste Scotland Carbon Metric Technical Report (2018), and the Zero Waste Scotland Carbon Metric (2018). Key assumptions made were how each waste stream from each sector was treated and how exports were treated; these assumptions may be a limitation on the accuracy of our findings. Tonnages from the waste generation datasets were divided up by treatment method based on ratios calculated from the waste treatment datasets. Thereafter, the calculated treatment tonnages were multiplied by the 2018 Carbon Metric's carbon factors to get the total impacts of greenhouse gas emissions from both treatment and the embodied production emissions.

To explore the broad sectors/waste categories identified by our initial analysis, we conducted an evidence review of primary research undertaken by Zero Waste Scotland and a broad scope of secondary sources. We engaged with Zero Waste Scotland experts on the waste categories highlighted by the analysis to identify existing research, policy, and initiatives associated with these sector/waste categories.

1.2 Priority Sectors

The lifecycle carbon impacts of sectoral waste streams in Scotland in 2018 were calculated using SEPA data on the waste generated and treated by various sectors and carbon factors drawn from the Zero Waste Scotland Carbon Metric 2018. Our analysis has identified the following sectoral waste streams as having the highest total lifecycle carbon impacts:

Table 1: Highest Lifecycle Carbon Impact Sectoral Waste Streams

Waste stream	Sector	% Total Waste Carbon Impact	% Total waste Tonnage
Animal and mixed food wastes	Household	16.1%	3.8%
Textile waste	Household	14.7%	0.8%
Animal and mixed food wastes	Manufacturing of food and beverage products	8.6%	1.6%

Animal and mixed food wastes	Commerce	7.4%	1.3%
Plastic waste	Household	5.5%	1.8%
	TOTAL	52.4%	9.3%

For each of the sectoral waste streams the relative contribution of embodied emissions and waste disposal emissions is displayed in Table 2. For textile waste, the overall impact of waste treatment is negative, meaning that the displaced emissions from use of reused/recycled textiles exceeds the emissions resulting from the treatment of waste textiles.

Table 2: Proportion of Embodied and Waste Treatment Emissions for Each Priority Sectoral Waste Stream

Waste stream	Sector	% of total carbon impact embodied	% of total carbon impact waste treatment
Animal and mixed food wastes	Household	85.8%	14.2%
Textile waste	Household	101.6%	-1.6%
Animal and mixed food wastes	Manufacturing of food and beverage products	99.8%	0.2%
Animal and mixed food wastes	Commerce	99.8%	0.2%
Plastic waste	Household	97.9%	2.1%

For each of these sectoral waste streams, we discuss the key challenges and opportunities for reducing carbon emissions, as well as action already being taken in these areas.

1.3 Sectoral Discussion

1.3.1 Animal and Mixed Food Waste – Households

16.1% of total carbon Impacts.

Household food waste is well established as a carbon emissions policy and research priority area[1], and this analysis further confirms this as the case. Household food waste is the only priority sectoral waste stream identified in this study, where waste treatment contributes significantly to the overall carbon impact. Fourteen percent of the effect is attributable to waste treatment, primarily from landfilling food waste, amounting to about

[1] Scherfauer et al., 2018, Environmental impacts of food waste in Europe

2% of the overall carbon impact of all waste. This study estimates that 63% of household food waste goes to landfill.

Studies identify various 'priority food types' in terms of tonnes wasted. From a carbon impact perspective, the comparatively high embodied carbon impact of animal products, meat and dairy are identified as priorities for carbon savings.

The factors influencing food waste are varied and include factors relating to the household, and those related to the supply chain (e.g., date labelling and packaging). Therefore, actions to address household food waste must be directed across the supply chain and within the household.

1.3.2 Animal and Mixed Food Waste – Manufacturing of Food and Beverage Products

8.6% of total carbon impacts. Over 99% of impacts from this sectoral waste stream are from embodied emissions.

The availability and consistency of data, and especially how waste is classified, presents a particular challenge for estimating the carbon impact of food waste in this sector. By-products from this sector that are not intended for human consumption (e.g., animal carcasses or 'draff' from distilling) are not consistently recorded as food waste, either in terms of waste classification or not counted as waste at all. Understanding this distinction between avoidable/unavoidable or edible/inedible waste is important as efforts to minimise carbon impacts differ for each (i.e., for avoidable or edible food waste the priority is waste minimisation whereas for unavoidable or inedible food waste, the priority is waste utilisation). The categorisation of waste in this way is further complicated by the difficulty in defining what waste is edible/inedible. This distinction may be defined cosmetically or result from improper handling of food.

The significance of the carbon assessment of food waste from this sector is subject to greater uncertainty than the other priority sectors identified. This is because the carbon factor for food used in the Carbon Metric is based on finished food products, and therefore already accounts for some of the waste generated in production. When considering interventions to reduce carbon emissions, waste utilisation measures will tend to remove material from the waste stream – however, the full carbon benefits of these interventions can only be quantified by using a consequential LCA approach, considering impacts beyond the waste system. There is an opportunity therefore for work to properly assess the carbon impact of waste and by-products produced in food manufacturing, as well as the full carbon benefits of maximising the value of these resources.

Types of food with relatively high embodied carbon emissions (i.e., animal products), also generate higher tonnages of waste in this sector, and a high proportion of this waste is considered unavoidable. The Courtauld Agreement includes sectoral plans with the meat and dairy sectors, with a focus on improving waste monitoring and reporting through the Target, Measure, Act framework. An understanding of the quantities and nature of food waste and by-products generated in this sector is vital to support the development of a circular bioeconomy in Scotland.

1.3.3 Animal and Mixed Food Waste – Commerce

7.4% of total carbon impacts.

As with the Manufacturing of Food and Beverage Products sector, over 99% of impacts from this sectoral waste stream are from embodied emissions.

Commerce is an extensive sector encompassing distribution, retail, and a variety of hospitality and food service (HaFS) settings. Studies suggest that waste from retail and distribution is lower in percentage terms than from HaFS (around 2% vs 18%), although Scotland-specific evidence relating to food waste from the latter is more than ten years old. The composition of waste from the HFaS sector is not well understood and varies between businesses. Foods with higher embodied carbon (i.e., animal products) are identified in studies as priority products in terms of the carbon impact of waste from this sector.

The retail sector is well engaged with the Courtauld Commitment, with most major retailers signed up. The retail sector has doubled the amount of unsold produce it redistributes in recent years. Actions by the retail sector can also support householders to reduce food waste, and recent actions in this area include improving date labelling on products. The HfaS sector is less well engaged with the Courtauld Commitment, although research, guidance, and initiatives (e.g., 'Guardians of Grub') targeting the sector have been developed.

1.3.4 Textile Waste - Household

14.7% of total carbon impacts

Our analysis shows that textile waste only constitutes 0.8% of waste tonnages but 14.7% of total carbon impact. In Scotland, 84% of end-of-life textiles end up in landfill or are incinerated. Waste tonnage data in Scotland generally only consider textiles which have been brought to a textile recycling centre. The analysis in this study includes estimates on textile waste in residual household waste based on Zero Waste Scotland's report on the Carbon Footprint of Scotland's Household Waste. We estimate that 89.3% of textile waste is disposed of via household residual waste in Scotland.

We have identified the following key challenges: fast fashion and overconsumption, overproduction, synthetic materials made from petrochemicals, lack of reuse or recycling options, and a lack of infrastructure and system collaboration in Scotland. Whilst textile production occurs primarily overseas, Scotland can implement measures which facilitate the consumption of sustainably produced textiles. We also discuss the potential for Scotland to integrate more sustainable practices into its textile economy and promote the move towards a circular textile economy. These include ongoing projects, such as the Johnston of Elgin's work on an everyday wool product, but also discuss the potential room for improvement, such as the lack of textile recycling facilities.

1.3.5 Plastic Wastes - Households

5.5% of total carbon impacts

In 2018, Scottish households produced a total of 202,816 tonnes of plastic waste, which will emit a total of 660 kilo-tonnes of CO_2e over the course of their lifespan. The majority of these emissions are occurring during the production phases and are embedded in the plastic products themselves. The best available waste treatment data estimates that 62% of this waste stream is being landfilled, 11% incinerated, 25% is being recycled, and the rest is treated by miscellaneous means. Assuming that recycling plastic prevents the need to consume an equivalent tonnage of virgin plastic, recycling plastics only prevents 17% of the embodied emissions that would occur if the bottle was produced with virgin plastic.

The majority of household plastic waste comes in the form of food packaging, further highlighting food products as priority products. Plastic films and dense plastics such as pots, tubs, and trays were identified as making up the largest percentages of plastic wastes, as well as being some of the most difficult to recycle. These two plastic waste categories each make up 22% of the total household plastic waste stream. The majority of household plastic waste is disposed of in residual bins. Recent household surveys suggest that drink bottles are virtually the only plastic waste category being disposed of in recycling bins, and these only had recycling rates varying from 41-74%.At the point of product design, implementing eco-design standards and improving recyclability labelling can help abate this problem; however, preventing the need for plastic consumption would be the most effective strategy given plastic's embodied impacts and the potential rebound effects of increasing recycling rates. Increasing Scotland's capacity for recycling dense plastics and plastic films is necessary to address the most problematic waste streams. This can be done by increasing local recycling capacity and facilitating the proliferation of chemical recycling processes to recycle plastic films. Bioplastics and degradable plastics may present an opportunity for better plastic consumption; however, it would be necessary to reorient our current recycling and waste management infrastructure around these products in order to make them a net carbon benefit. Also, consumer information campaigns would be necessary to ensure that these plastics were not disposed of in the natural environment. Expansion of policies such as Extended Producer Responsibility schemes, Deposit Return schemes, the Single Use Plastics Ban, and the initiatives under the UK Plastics Pact will significantly abate the impacts of this waste stream.

1.4 Conclusion

This research has attempted to use publicly available waste data in order to identify 'priority sectors' in relation to the carbon emissions from waste. In doing so we have highlighted some of the limitations of using this data for this purpose. We have replicated previous research that has identified food, textile and plastic waste as priorities, and found that a large share of impacts (36.3%) are associated with waste disposed by householders. Households are at the end of the flow of materials in the linear economy and therefore it is not surprising that impacts accumulate here. As such, efforts to reduce carbon emissions in these priority sectors cannot be focussed solely on households, and improved waste composition analysis could assist in identifying specific sectors contributing to these waste streams within households. For example, analysis of household plastic waste shows that the majority of this is associated with the food supply chain.

Our research emphasises that most emissions are embedded in the production of the goods themselves. Therefore, reducing consumption represents the biggest opportunity for mitigating carbon emissions, whilst improving recycling rates will have a limited impact. Opportunities for reducing consumption vary across the waste categories identified in this report. For food, efforts focus on efficient use of resources to minimise wastage. For textiles, reducing demand and making things last are where the biggest opportunities lie. For plastics, opportunities are limited for householders, and the challenge lies largely with food producers and retailers to reduce single use plastics. Where waste cannot be avoided, effective valorisation of this as a resource for use in a circular economy should be the focus. This research has highlighted opportunities to maximise value from waste in the bioeconomy, alongside opportunities for improving textile and plastics recycling. The goal is to reduce waste by recognising it as a valuable resource, but to fully capture the carbon benefits of these actions requires analysis that goes beyond the waste sector, to understand how waste as a resource reduces the impacts of the sector in which it is utilised.

2 Introduction

2.1 Aims and Objectives

2.1.1 Research Aims

The aims of this research are to:

1. Identify sectors and associated waste streams that contribute the most to the whole lifecycle carbon imact of waste generated in Scotland, wherever those emissions are generated in the world.
2. Review the challenges and possible opportunities for reducing these carbon impacts within identified priority waste streams, sectors, products, and industries.

2.1.2 Research Objectives

1. Identify waste streams and sectors that have the highest carbon impact in Scotland, from a lifecycle perspective.
2. Assess the identified sectors/waste streams isolated impacts to distinguish particular products or industries of interest.
3. Assess the challenge of, and opportunities for, reducing the lifcycle carbon impacts of identified waste streams, sectors, products, and industries.
4. Highlight examples of good practice in the areas of waste prevention, product innovation, policy and waste treatement from Scotland and abroad in sectors with the highest carbon impacts.
5. Identify gaps in data & knowledge to further support efforts to abate these impacts in Scotland.

2.2 Methodology

2.2.1 Objective 1: Identifying Priority Sectors

We quantified the lifecycle carbon impact of the 26 European Waste Classification for Statistics (EWC-Stat) waste categories by the sectors that produced them. Carbon impacts were calculated for the embodied emissions in the waste (from cradle to retail) and emissions from waste treatment. The list of waste categories and waste generator sectors is provided in Appendix 1.

The model uses data on waste tonnages from the Scottish Environment Protection Agency (SEPA), using 2018 data as this is the most recent year for which comprehensive data is available for both household and non-household sources. Data sources used are shown in Table 3.

Table 3: Data sources

Data source	Data Used
SEPA Waste from All Sources	Provides data on waste generated from all sources and also waste treated by recycling/composting, landfilling, incineration, and other methods. Tonnes of waste generated do not equal tonnes of waste treated for each category due to differences in data collection approaches, and that mixed waste streams generated are sorted before treatment.
SEPA Household Waste	Provides data on waste generated from households and waste treated by recycling/composting, landfilling, incineration and other. Tonnes of waste generated do not equal tonnes of waste treated for each category due to differences in data collection approaches, and that mixed waste streams generated are sorted before treating.
SEPA Business Waste Tables	This provides data on waste tonnages generated by each sector as in Appendix 1, except Households and Construction and Demolition. No data on waste treatment tonnes by sector is provided
SEPA Data Discover Tool	This provides a breakdown of 'Waste from All Sources' data into Households, Construction and Demolition and Commercial and Industrial
Zero Waste Scotland Carbon Metric Technical Report 2017 & 2018[2]	This provides waste composition estimates for 'Household and Similar wastes' waste category from Households and Commercial and Industrial sources in Scotland.
Zero Waste Scotland Carbon Metric 2018	This provides carbon factors for embodied emissions and emissions from a variety of waste treatment options. Embodied emissions are modelled from cradle to retail. Waste treatment emissions consider emissions from transport and waste treatment processes as well as the impacts of raw material substitution from recycling and/or displaced marginal energy generation.

Due to differences in data collection methods and the sorting of mixed waste streams before treatment, the totals in the waste generated accounts are not equal to the summarised waste treated accounts, which justifies this approach. Additionally, data on the waste treatment destination was not available for the construction & demolition sector, nor was it for the individual sectors in the business waste tables. Therefore, we based our calculated greenhouse gas impacts on the waste generated tonnages in the SEPA Business Waste Tables and the SEPA Data Discovery tool, using waste treatment data to provide an estiamte of the percentage of waste generated managed by different methods.

To compensate for these considerations, we did two things. First, we used waste composition estimates for the 'Household and Similar Wastes' waste category to redistribute the waste from this mixed category to the appropriate waste streams. We then estimated the tonnage of waste being sent to each waste treatment option for all sectors by calculating the percentage of waste sent to each treatment option in the waste treatment

[2] The Carbon Footprint of Scotland's Waste: Carbon Metric Technical Report (2017 & 2018)

accounts and then applied these percentages to the tonnages in our adjusted waste generated accounts.

This is displayed in the equation below

$$\text{Tonnes of generated waste sent for } X \text{ waste treatment} = \text{Tonnes waste generated} \times \left(\text{tonnes waste sent to } X \text{ treatment} \,/\, \text{total waste treatment tonnes} \right)$$

From here, we calculated the carbon impact of each waste stream by sector by applying the relative carbon factors to the amount of waste going to each waste treatment option. This is depicted in the equation below:

$$\text{Whole lifecycle carbon} = \left(\text{Tonnes generated} \times \text{generated carbon factor}\right) + \left(\text{Tonnes recycled} \times \text{recycled carbon factor}\right) + \left(\text{Tonnes landfilled} \times \text{landfilled carbon factor}\right) + \left(\text{Tonnes incinerated} \times \text{incinerated carbon factor}\right) + \left(\text{Tonnes other treatment} \times \text{other treatment carbon factor}\right)$$

It should be noted that, as in the Carbon Metric, the carbon impacts of recycling and incineration are often considered negative, indicating that these waste management methods lead to carbon reductions that outweigh the carbon emissions of managing the waste. For recycling these reductions are achieved through the displacement of raw materials. In the case of incineration carbon reductions are realised where electricity is generated at a lower carbon intensity than the intensity of the grid.

2.2.2 Objective 2 – 5: Discussion of Key Challenges and Opportunities

In order to explore the broad sectors/waste categories identified by our initial analysis, we conducted an evidence review of primary research conducted by Zero Waste Scotland and a wide scope of secondary sources. We engaged with Zero Waste Scotland experts on the waste categories highlighted by the analysis to identify existing research, policy, and initiatives associated with these sector/waste categories. The following experts have informed our report:

- Colleagues working on the Circular Textiles Fund, who in developing the fund interviewed stakeholders from across the sector in Scotland and the wider UK,
- Colleagues who worked on the development of the Scottish Government's Food Waste Reduction Action Plan and delivery of food waste reduciton initiatives,
- Colleagues who have been involved in the development of policy such as Scotland's Deposit Return Scheme, Extended Producer Resposnibility for packaging and the UK Plastics Pact,

- Colleagues with experience in resource management and engagement with waste collectors, and
- Colleagues who are working on parallel research into waste commercial waste composition.

We reviewed secondary material available online, such as:

- Research into the composition of waste categories and/or sectors identified as priorities
- Research into the carbon impacts of identified waste categories across their lifecycle
- Existing policy targeting waste categories and/or sectors identified as priorities
- Existing voluntary agreements or initiatives in the sectors identified as priorities in relation to the relevant waste categories

2.3 Results

2.3.1 Objective 1: Identifying Priority Sectors

Table 4 shows the sectors and associated waste categories with the largest contribution to the total carbon impact of waste based on our analysis. This represents the entire lifecycle of the waste, considering embodied carbon and the varying carbon impacts of waste disposal.

Table 4: Top 5 Carbon impacts of Waste, by Waste Stream and Category

Waste stream	Sector	% Total Waste Carbon Impact	% Total waste Tonnage
Animal and mixed food wastes	Household	16.1%	3.8%
Textile waste	Household	14.7%	0.8%
Animal and mixed food wastes	Manufacturing of food and beverage products	8.6%	1.6%
Animal and mixed food wastes	Commerce	7.4	1.3%
Plastic waste	Household	5.5%	1.8%
	Total	52.4%	9.3%

Of the 330 waste streams/sectors, these five represent 52% of the total carbon impact of waste, but only 9% of waste generated by weight. Animal and mixed food waste accounts for 32.7% of all climate change impacts (vs 6.8% of waste tonnes), highlighting the particularly high carbon impact of this waste category. 26.3% of all climate change impacts (vs. 6.4% of waste tonnes) are associated with waste produced by households.

2.3.2 Objectives 2 - 5: Discussion of Key Challenges and Opportunities

For each of the above identified waste categories/sectors the following will be discussed:

- Analysis of embodied vs. disposal emissions
- Identification of particular product streams/industries
- Discussion of problems/challenges
- Possible solutions – examples of good practice/initiatives
- Gaps in knowledge/areas for further work

3 Animal and Mixed Food Waste

'Animal and Mixed Food waste' accounts for 32.7% of all climate change impacts associated with waste (vs 6.8% of waste tonnes). Virtually all (98%) of this is attributed to the three sectors from the top 5 identified in our analysis:

- Households (16.1% of carbon impacts and 3.8% of total tonnage)
- Manufacture of food and beverage products (8.6% of carbon impacts and 1.6% of total tonnage)
- Commerce (7.4% of carbon impacts and 1.3% of total tonnage)

The disproportionate climate change impact of food waste is well documented[3], as is that the majority of this arises from households, followed by food and drink manufacturing[4].

The 'Animal and mixed food waste' category includes the following EWC codes:

[3] Scherfauer et al., 2018, Environmental impacts of food waste in Europe
[4] Food Waste Reduction Action Plan

Table 5: EWC Codes for 'Animal and Mixed Food Waste Category'

EWC	Description	Sectors
02 01 02	Wastes from agriculture – horticulture – aquaculture – forestry – hunting and fishing; animal-tissue waste	Agriculture, forestry, fishing
02 02 01	Wastes from the preparation and processing of meat, fish and other foods of animal origin - sludges from washing and cleaning	Manufacture of food and beverage products
02 02 02	Wastes from the preparation and processing of meat, fish and other foods of animal origin - animal-tissue waste	Manufacture of food and beverage products
02 02 03	Wastes from the preparation and processing of meat, fish and other foods of animal origin - materials unsuitable for consumption or processing	Manufacture of food and beverage products
02 05 01	Wastes from the dairy products industry - materials unsuitable for consumption or processing	Manufacture of food and beverage products
02 03 02	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation – wastes from preserving agents	Manufacture of food and beverage products
02 06 02	Wastes from baking and confectionary industry – wases from preserving agents	Manufacture of food and beverage products
19 08 09	Materials from waste and water treatment – grease and oil mixture/water separation containing edible oil and fats	Manufacture of food and beverage products OR Commerce
20 01 08	Municipal waste and similar materials from commerce and industry - Biodegradable kitchen and canteen waste	All sectors
20 01 25	Municipal waste and similar materials from commerce and industry - Edible Oil and fat	Commerce
20 03 01	Mixed municipal waste – the animal and mixed food waste fraction of this is estimated based on composition estimates	All sectors

In the 2016 Making Things Last: a circular economy strategy for Scotland[5], Scottish Government set a target of a 33% reduction in per capita food waste by 2025. In 2019, Scottish Government published the Food Waste Reduction Action Plan (FWRAP)[6] which detailed the actions required to achieve the 33% target. In establishing a baseline for the

[5] https://www.gov.scot/publications/making-things-last-circular-economy-strategy-scotland/documents/
[6] https://cdn.zerowastescotland.org.uk/managed-downloads/mf-wte3m9ey-1678806645d

target, Zero Waste Scotland aligned with the EU fusions definition of food waste which takes a more comprehensive position:

> **"any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)"[7]**

This definition does not include some material that is not legally classified as waste but might be considered part of the food supply chain; for example, food removed from the food supply chain for use as animal food or for other non-food purposes. In current reporting, any food waste or by-products that are diverted for use as a resource before entering the waste sector are not being captured here. The estimate includes food composted at home and liquid food waste disposed of down the drain. Table 6 below shows the EWC codes included in the 33% food waste reduction target baseline that are additional to those covered in the 'Animal and mixed food waste category' in this analysis.

Table 6: Additional EWC Codes Considered in the 33% food waste reduction target baseline of Food Waste in Scotland.

EWC	Description	Sectors
02 07 02	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa) - wastes from spirits distillation	Manufacture of food and beverage products
02 07 04	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa) - materials unsuitable for consumption or processing	Manufacture of food and beverage products
02 03 04	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation - materials unsuitable for consumption or processing	Manufacture of food and beverage products
02 02 04	Wastes from the preparation and processing of meat, fish and other foods of animal origin - sludges from on-site effluent treatment	Manufacture of food and beverage products
02 03 99	Wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation - wastes not otherwise specified	Manufacture of food and beverage products
02 07 01	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa) - wastes from washing, cleaning and mechanical reduction of raw materials	Manufacture of food and beverage products

[7] FUSIONS,2016

02 07 05	Wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa) - sludges from on-site effluent treatment	Manufacture of food and beverage products
N/A	Household food waste composted	Households
N/A	Household liquid food waste disposed of down the sink	Households

Overall, the FWRAP estimates food waste to be higher than our analysis based on waste data from SEPA alone. Table 7 below compares waste tonnes and estimated whole lifecycle carbon impacts from our analysis based on the tonnes of waste estimated in the Scottish Food Waste baseline (2013)8 against which the FWRAP targets are measured.

Table 7: Tonnes of Food Waste and Carbon Impacts from 33% food waste reduction target baseline and this Analysis

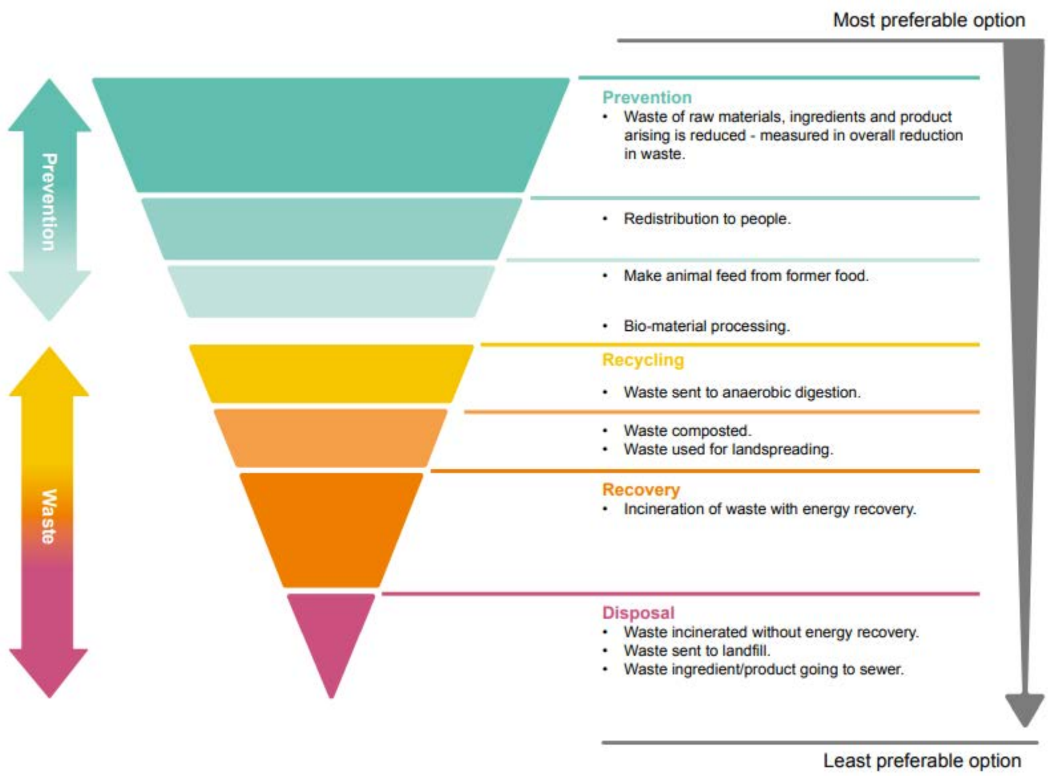
	Food and Drink Manufacturing	Households	Other sectors
33% food waste reduction target baseline total tonnes (2013)	248,230t	598,946t	140,714t
This analysis total tonnes (2018)	178,975t	439,786t	164,133t
FWRAP carbon impact $ktCO_2e$ (2013)	1426 $ktCO_2e$	2614 $ktCO_2e$	808 $ktCO_2e$
This analysis carbon impact $ktCO_2e$ (2018)	1026 $ktCO_2e$	1920 $ktCO_2e$	943 $ktCO_2e$

The 33% food waste reduction target baseline puts food waste and associated carbon emissions 20% higher than the figures generated in this analysis, likely due to the inclusion of the additional waste categories outlined in Table 6. The relative contribution of each category to the overall total is largely similar, however.

The hierarchy for tackling the impact of food waste (Figure 1) applies to all the sectors to be discussed below.

[8] Zero Waste Scotland, Update Scottish Baseline – Technical Note

Figure 1: Food Waste Hierarchy definition from Scottish FWRAP



The FWRAP highlighted that maximising waste prevention requires actions across the supply chain. Four key areas for action were identified:

1. Improved monitoring and infrastructure: including an action to consult on a mandatory national food waste reduction target and mandatory reporting of Scotland's food surplus and waste by businesses.
2. Sector leadership: Supporting action across public, private, and hospitality sectors.
3. Public engagement and communications: raising awareness of the problem of food waste with the public and engaging them with activities to address it.
4. Supporting the delivery of a new approach to food waste: a new Food Waste Hub to drive change throughout the supply chain with a co-ordinated approach.

A review of the FWRAP is intended to be published in 2023.

The Courtauld Commitment 2030[9] is a UK-wide voluntary commitment working across the food supply and value chain to deliver farm-to-fork reductions in food waste, greenhouse gas emissions, and water stress. The Courtauld 2030 targets are for a 50% reduction in per capita food waste and associated carbon emissions by 2030 against the 2007 baseline. The commitment has over 170 signatories and has created several initiatives and activities:

[9] WRAP, Courtauld Commitment 2030

- The Food Waste Reduction Roadmap which highlights the 'Target, Measure, Act' approach to food waste reduction, to which in 2022 there were 300 businesses committed to using.
- Sector specific action plans – for example, for the Hospitality and food service sector and for the dairy sector.
- Best practice and guidance – for example, on labelling and the use of best before dates and on redistribution of surplus food
- Campaigns and engagement – for example, the 'Guardians of Grub' campaign targeting the hospitality sector.

This is the current phase of a long-running voluntary agreement, and reports against the 2025 targets are also considered below.

Research and initiatives from both the FWRAP and the Courtauld Commitment are drawn on heavily in the sections below, highlighting information relevant to each of the sectors but also seeking to address the specific concern of carbon emissions from food waste rather than a focus on overall tonnes.

4 Animal and Mixed Food Waste from Households

16.1% of Carbon Impact; 3.8% of Waste Tonnes

Whole lifecycle impacts of food waste from households are estimated at 1920 ktCO_2e by our analysis. A study by Zero Waste Scotland in 2017, examining the carbon impact of the FWRAP targets, estimated the carbon impact of food waste from households in 2013 to be considerably higher at 2652 ktCO_2e[10]. The 2017 analysis combined waste data with information about food purchases to estimate the composition of food waste and therefore apply food-type specific carbon factors, in addition to using a higher figure for overall tonnes of food wasted by households drawn from the original 33% food waste reduction target baseline.

The 33% food waste reduction target baseline (2018 update)[11] estimates household food waste tonnes to be 598,946 tonnes (approx. 160,000 tonnes higher than in this analysis). This is partly because the 33% food waste reduction target baseline includes an estimate of food waste composted or disposed of down the drain.

4.1 Analysis of Embodied vs. Disposal Emissions

Embodied emissions account for 86% of carbon impacts from household food waste, with waste treatment impacts accounting for 14%. Household food waste has a larger proportion of impacts arising from waste treatment than other waste streams identified here – accounting for 2% of all waste impacts – as household food waste that is sent to landfill produces methane. This analysis has estimated food waste that is disposed of in household 'black bag' waste rather than just segregated food waste collections.

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[10] Zero Waste Scotland, 2017, internal dataset
[11] Zero Waste Scotland, Update Scottish Baseline – Technical Note

4.1.1 Identification of Particular Product Streams/Industries

WRAP research from 2012 estimated the following breakdown of food categories wasted by UK households[12]:

Fresh fruit vegetables and salads	19%
Drink	17%
Bakery	11%
Meals	10%
Dairy and eggs	10%
Fresh fruit	8%
Meat and fish	7%
All other	18%

However, the same study highlighted the following top ten individual food types thrown away:

1. Standard bread
2. Fresh potatoes
3. Milk
4. Meals (home-made and pre-prepared)
5. Carbonated soft drinks
6. Fruit juice and smoothies
7. Poultry meat
8. Pork meat
9. Cakes
10. Processed potatoes (e.g. chips)

WRAP is repeating this 'kitchen diary' study and Scottish specific data will be available in 2024.

In the most recent report from WRAP on progress against Courtauld 2025 targets it is estimated that 68% of food waste from households would be classed as avoidable/edible, and 32% unavoidable/inedible[13].

[12] WRAP 2012, Household food and drink waste in the United Kingdom 2012
[13] WRAP, UK progress against Courtauld 2025 targets and UN Sustainable Development Goal 12.3

4.1.2 Carbon Impacts

Zero Waste Scotland 2017 analysis[14] identified the following five items (refer to Table 8) as most significant by tonnages created and by global carbon impact from households in 2013:

Table 8: Top 5 Food Types by Tonnes of Waste Generated and Global Carbon Impact for Households.

Top 5 by tonnes generated		Top 5 by carbon impact
1	Fresh Vegetables	Meat
2	Drinks (Non-Alcoholic)	Pre-prepared meals and snacks
3	Fresh Fruit	Fresh Vegetables
4	Bakery	Diary (excluding milk)
5	Meat	Bakery

Meat represents the biggest carbon impact by a large margin (more than three times the impact of the 2nd placed item), due to its significantly higher embodied carbon. Other studies have found similar. For example, an academic study of the environment impacts of food waste in the UK which comparted the relative climate change impact of food waste in the UK across all sectors, found that meat had by far the most significant carbon impact, accounting for around 40% of all impacts, followed by cereals at 20%[15]. An assessment by WRAP of the carbon impact of household food waste identified meat as the biggest contributor, followed by milk, and then wheat[16].

4.2 Discussion of Problems/Challenges

According to WRAP's Food Waste Trends Survey 2021, household factors affecting food waste generation include[17]:

- Younger adults (under 44)
- Children in home
- Prevalence of eating meals out/takeaways
- Lack of confidence in cooking/preparing food
- Householders following a diet

[14] Zero Waste Scotland, 2017, internal dataset
[15] Jeswani, et al. 2020, The extent of food waste generation in the UK and its environmental impacts
[16] WRAP, 2011, The water and carbon footprint of household food and drink waste in the UK
[17] WRAP, 2021, Returning to normality after Covid-19: Food waste attitudes and behaviours in 2021

- Householders having an allergy/experiencing food poisoning
- Ordering ready-made food boxes
- Ordering fruit/veg boxes

The study also identifies some key 'food management behaviours' that enable reduced food waste in the home, such as meal planning, storing food correctly, portion sizing, using up leftovers, and batch cooking. The same study showed that food waste was seen to reduce during the COVID 19 lockdown, from 24% to 14%, then return to 20% post-lockdown. Key reasons identified for the increase in food waste were a return of 'time pressures' and an increase in eating meals out/takeaways post-lockdown.

Household waste is influenced not only by characteristics of the household and behaviours of individuals within it. A range of factors from the retail supply chain have an impact including[18]:

- The shelf life of products
- Production methods and location
- Functionality of packaging
- Product labelling,
- Portioning in pre-packaged foods
- Marketing
- Price promotions

55% of households (albeit self-reported) use local authority food waste collection, up 26% since 2012 but representing an opportunity for improvement[19].

Public awareness of food waste's impact on the planet also presents a significant challenge in terms of meeting our 33% reduction target. Evidence from a recent Zero Waste Scotland survey suggests that 86% of people in Scotland are unaware that food waste can be an even bigger contributor to climate change than plastic waste[20]. Conversely, 78% of people in Scotland also reported in 2023 that they actively try to reduce their food waste most or all of the time[21], with those over 65 and those without children most likely to always reduce food waste. At a UK level, awareness of food waste as an important issue was very high and increasing in 2022, with 81% of people agreeing that food waste is an important national issue, and 92% of people agreeing that everyone has a responsibility to reduce their food waste. However, there is still a gap between awareness, intention, and action, with 76% of individuals agreeing that food waste was a top priority for them, and 66% making more of an effort to reduce food waste[22].

[18] Quested et al., 2013, Spaghetti soup: The complex world of food waste behaviours
[19] Scottish Government, Food Waste Reduction Action Plan
[20] Food waste vs. plastic waste | Which is worse? (zerowastescotland.org.uk)
[21] See section 7.3 of https://www.foodstandards.gov.scot/downloads/Consumer_attitudes_towards_the_diet_and_food_environment_in_Scotland_research_report_-_June_2023.pdf
[22] https://wrap.org.uk/sites/default/files/2023-03/20230309%20Food%20Trends%202022.pdf

Focussing on meat as a priority waste stream from a carbon emissions perspective, WRAP's 'Meat in a Net-Zero World' report identifies several reasons for wasting three types of meat[23]:

Table 9: Reasons for Wasting Three Types of Meat Product

Reason for not using	Poultry	Pork	Beef
Not used in time (date code)	20%	31%	23%
Not used in time (not date code)	9%	17%	6%
Cooked/served too much	43%	31%	35%
Fussy eating	11%	9%	15%
Accidents	6%	6%	19%
Other	11%	7%	2%

4.3 Solutions – Examples of Good Practice/Initiatives

Under the Courtauld Commitment, guidance on food labelling for manufacturers and retailers to promote consistent advice to householders on managing and storing food at home and avoiding food waste[24].

A recent study by WRAP (2022) looked at the impact of packaging on uncut fruit and vegetables in terms of shelf life and the ability of households to only buy what they needed[25]. It found little benefit in terms of shelf life in the home for pre-packaged fruit and vegetables if stored correctly at home. The study concludes that across the UK-wide, if all apples, bananas and potatoes were sold loose, 60,000 tonnes of food waste and 8,800 tonnes of plastic could be avoided. It is important to note that this study only considers shelf life in the home and does not consider the impact of packaging on shelf life from the farm gate. In January 2022 France introduced a plastic packaging ban for most uncut, fresh fruit and vegetables. Spain is due to introduce a similar ban from 2023.

Date labels on food are a driver for householders to dispose of food[26]. The variety of date labels (e.g., display until, best before, use by) can confuse and lead householders to dispose of edible food. In response, guidance on the application of date labels has been produced by WRAP in collaboration with Food Standards agencies across the UK[27]. This

[23] WRAP, 2021, Meat in a Net Zero World – A UK meat industry commitment to action
[24] WRAP, 2019, Best practice on food date labelling and storage advice
[25] WRAP, 2022, Reducing food waste and plastic packaging
[26] WRAP 2015, Helping consumers reduce food waste – retail survey 2015
[27] WRAP, 2019, Labelling guidance – best practice on food date labelling and storage advice.

has seen manufacturers and retailers remove use by labels from some products – for example, Morrisons has removed them from milk from 31st Jan 2022[28].

The upcoming ban on landfilling biodegradable municipal waste (BMW) in Scotland, if implemented fully, would impact the 14% of emissions (273 ktCO_2e) that arise from waste treatment – emissions from landfilling food waste are estimated at 274 ktCO_2e. Savings will be maximised by ensuring this waste is disposed of as far up the waste hierarchy as possible. In our analysis, approximately 79% of the total food waste from households is disposed of in residual waste and therefore segregating this represents a significant challenge for realising maximum potential savings.

The FWRAP identifies 'sustained and large-scale public communications activity on food waste as a key area of activity to target food waste from households. An example of such activity was Zero Waste Scotland's 'Rankin COP26 Campaign', which aimed to raise awareness of the impact of food waste on climate change. The campaign highlighted the issue of food waste through comparison with plastic waste – something that has high levels of public awareness following the 'Blue Planet effect'. The campaign used traditional media, a public art trail in Glasgow during COP26 featuring photographs by Rankin, and the use of social media influencers to spread campaign messages. Before and after surveys asking the question, "In your opinion, which ONE of the following contributes the most to climate change: A) Food waste, B) Plastic waste, C) Don't know" saw an overall increase of 5% in awareness of food waste as more significant.

A lack of confidence and skills in cooking a preparing food is identified above as a factor that can lead to increased food waste. Love Food Hate Waste training run by Zero Waste Scotland targeted at individuals seeks to address this, and a new phase will include trainer-the-trainer modules to cascade skills within communities. Community food initiatives also often focus on building food skills and confidence. For example, the Lang Spoon Community Kitchen, run by community-led charity and development trust Greener Kirkcaldy, offers training and volunteer opportunities to build basic cooking skills[29].

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[28] Morrison scrapping 'use by' dates from milk to help customers reduce waste
[29] Greener Kirkcaldy, Lang Spoon Community Kitchen

5 Animal and Mixed Food Waste from the Manufacture of Food and Beverage Products

8.7% of Carbon Impact: 1.6% of Waste Tonnes

Whole lifecycle impacts of food waste from food and drink manufacturing are estimated at 1028 ktCO_2e in this analysis. This compares to 2,824 ktCO_2e as estimated by the Zero Waste Scotland 2017 analysis of the carbon impact of the FWRAP, based on 2013 figures[30] – although overall tonnes of waste for the food and drink manufacturing sector have since been revised down by about 50% in a technical update carried out in 2018[31]. There is a relatively high degree of uncertainty over the estimate produced for this research arising from the lack of distinction between avoidable and unavoidable food waste in the data. This is explained further in the 'problems and challenges' section below.

5.1 Analysis of Embodied vs. Disposal Emissions

SEPA data shows that 97% of food waste from all commercial and industrial sources is recycled/composted (with a net carbon benefit). Virtually 100% of impacts are attributable to the embodied emissions of the waste.

5.2 Identification of Particular Product Streams/Industries

5.2.1 Waste Classifications

The following is a breakdown of food waste from food and drink (F&D) manufacturing in Scotland in 2013, produced as part of the 'Technical update' to the 33% food waste reduction target baseline in 2018 by EWC codes, which is aligned to the FUSION definition of food waste[32], outlined in Section 3 above. Rows highlighted in blue are EWC codes that come under the 'Mixed animal and food waste' category and have been included in our analysis.

[30] Zero Waste Scotland, 2017, Unpublished
[31] Zero Waste Scotland, 2018, Updated Scottish Baseline - Technical Note
[32] FUSIONS, 2016, Estimates of European Food Waste Levels

Table 10: Food and Drink Manufacturing Waste Tonnes

EWC Description	EWC code	Scottish Food & Drink manufacturing (tonnes)
wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)-- wastes from spirits distillation	02 07 02	86,120
wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)-- materials unsuitable for consumption or processing	02 07 04	52,711
Municipal wastes (Household waste and similar commercial, industrial and institutional wastes separately collected fractions-- biodegradable kitchen and canteen waste	20 01 08	33,419
wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation-- materials unsuitable for consumption or processing	02 03 04	24,493
wastes from the preparation and processing of meat, fish and other foods of animal origin-- materials unsuitable for consumption or processing	02 02 03	21,253
wastes from the dairy products industry-- materials unsuitable for consumption or processing	02 05 01	14,624
wastes from the preparation and processing of meat, fish and other foods of animal origin-- sludges from washing and cleaning	02 02 01	10,312
wastes from the baking and confectionary industry-- materials unsuitable for consumption or processing	02 06 01	2,240
wastes from fruit, vegetables, cereals, edible oils, cocoa, coffee, tea and tobacco preparation and processing; conserve production; yeast and yeast extract production, molasses preparation and fermentation-- sludges from washing, cleaning, peeling, centrifuging and separation	02 03 01	1,427
wastes from the preparation and processing of meat, fish and other foods of animal origin-- sludges from on-site effluent treatment	02 02 04	1,352
wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa) -- wastes from washing, cleaning and mechanical reduction of raw materials	02 07 01	162

wastes from the baking and confectionery industry-- sludges from on-site effluent treatment	02 06 03	80
wastes from the production of alcoholic and non-alcoholic beverages (except coffee, tea and cocoa)-- sludges from on-site effluent treatment	02 07 05	37

Notably the 33% food waste reduction target baseline includes 'wastes from the production of alcoholic and non-alcoholic beverages' which amount to a significant 138,831 tonnes. This compares with 178,975 tonnes total for the 'Manufacture of food and beverage products' sector, from which this waste arises, but that is categorised as 'vegetal waste' in the SEPA data. In Zero Waste Scotland's Carbon Metric model used in this analysis, 'vegetal waste' is considered to have zero embodied carbon impacts.

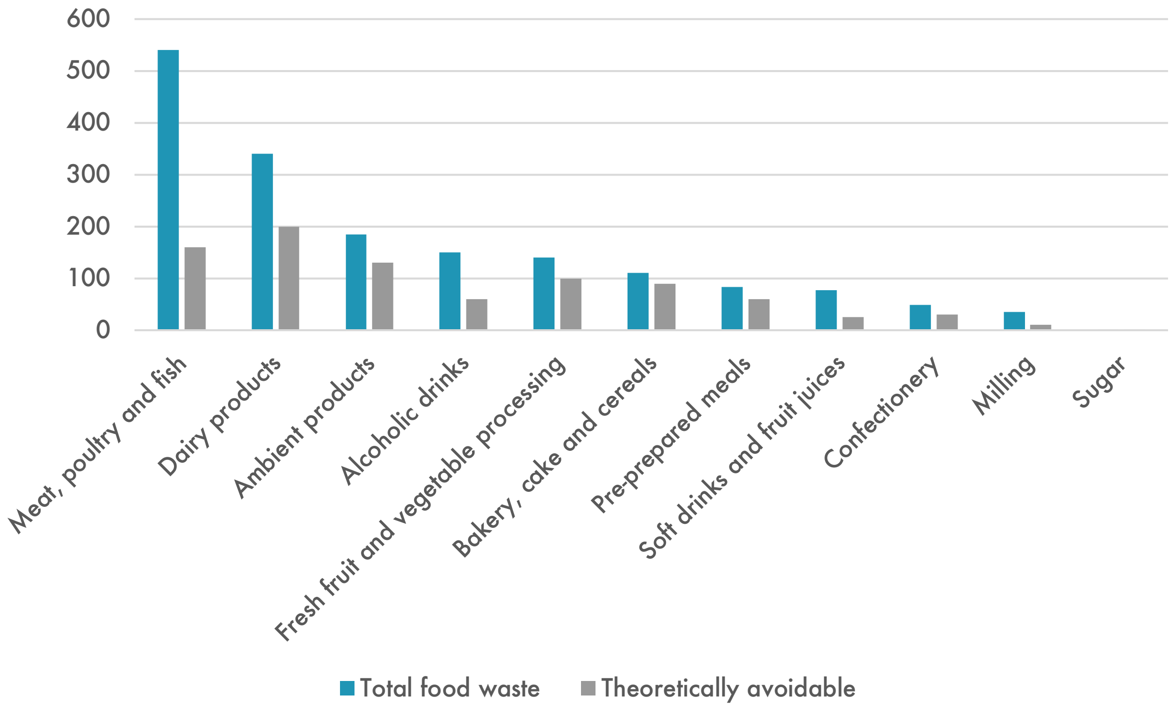
The SEPA waste data does not differentiate between avoidable and unavoidable food waste. Research by WRAP suggests that in the manufacturing sector, about 51% of waste is theoretically avoidable, and 21% 'practically' (either technically or economically) avoidable[33].

[33] WRAP, 2016, Quantification of food surplus, waste and related materials in the grocery supply chain

5.2.2 Subsectors

WRAP research[34] also provides the following breakdown of manufacturing sectors considering total food waste (following the FUISON definition) and theoretically avoidable waste:

Figure 2: Food Waste by Manufacturing Sector in the UK (000's of tonnes)



The above suggests that both the meat and dairy processing industries are priorities from a tonnage perspective both in terms of total food waste and theoretically avoidable waste. A large proportion of meat, poultry, and fish waste is categorised as 'unavoidable' at 70%. There are some uncertainties in quantifying carbon impacts from these types of wastes using the method applied in this study, which are explored below.

The 'UK Dairy Roadmap' produced by Dairy UK (2018) states that in 2016 37% of produce not destined for the final consumer could be defined as 'food waste' under the FUSION definition and that 63% of this was sent to anaerobic digestion and 37% landfilled or sent to the sewer. The 63% of produce not sent to the consumer was either sent to animal feed (61%), redistribution (25%) or 'other by-products' (14%)[35].

WRAP's 'Meat in a Net Zero World' report[36] quantifies waste in the waste processing sector, indicating that an average of 23% of the animal is not used to produce meat products. 15% is captured as a 'surplus' for high-value valorisation (e.g., pet food,

[34] Ibid.
[35] Dairy UK, 2018, The UK Dairy Roadmap
[36] WRAP, 2021, Meat in a Net Zero World – A UK meat industry commitment to action

cosmetics) and does not fit the FUSION definition of food waste. 6% is considered inedible and only 1% categorised as avoidable food waste. This translates to an average of 14% of all 'food waste' categorised as avoidable and 86% as unavoidable.

Wastes arising from the production of alcoholic beverages are significant in Scotland (see Table 10 above) but are not included under this total for 'animal and mixed food wastes' – instead, they are classed as 'vegetal wastes' in the SEPA data and ascribed zero embodied carbon impact according to the Carbon Metric. There is an established practice of using products from distilling and brewing for animal feed and soil improver[37], but a recent report suggests that increasingly material is being diverted away from animal feed to use in bio-energy production (via Anaerobic Digestion [AD] or Combined Heat and Power [CHP]), partly because financial incentives are encouraging it[38]. Often these AD or CHP plants are located on the distillery site and so the material used for this purpose may not be fully recorded in the waste statistics. The SRUC report estimates that total by-products from distilleries used for feed fell by 57% between 2012 and 2019. This represents a significant shift of by-product use down the food waste hierarchy – from use as feed to use as bioenergy, driven by incentives for renewable energy.

5.2.3 Carbon Impacts

Analysis carried out in 2017 by Zero Waste Scotland into the carbon impacts of the FWRAP actions showed the following top 5 waste types from food manufacturing by tonnes and by global carbon impact[39].

Table 11: Top 5 Waste Food Types by Weight and by Carbon Impact from manufacturing

	Top 5 by tonnes generated	Top 5 by carbon impact
1	Meat	Meat
2	Fresh vegetables	Dairy (excl. milk)
3	Fresh fruit	Fish
4	Milk	Milk
5	Fish	Fresh vegetables

An assessment of the environmental impacts of food waste in the UK across all stages of the supply chain also found meat and fish to be the largest contributor to carbon emissions

[37] Zero Waste Scotland, 2015, Sector study on beer, whisky and fish
[38] SRUC, 2019, Distillery by-products, live-stock feed and bio-energy use in Scotland.
[39] Zero Waste Scotland, 2017, internal dataset

at around 60%. However, cereals are highlighted as the second most impactful at almost 20%, with dairy and eggs, and vegetables and roots similar at about 5% each[40].

5.3 Discussion of Problems/Challenges

5.3.1 Quantifying the Problem

A major barrier to addressing food waste from manufacturing is a lack of clarity of the definition of food waste and associated terms such as by-products vs co-products, and avoidable vs unavoidable waste. The lack of clear definitions means that consistent and accessible data relating to these is not available. The FWRAP 2019 highlighted improved monitoring and reporting of food waste within the sector as a priority, promoting the 'Target, Measure, Act' initiative from the Courtauld Agreement. A report mapping potential 'bioresources' in Scotland highlighted this as an issue in identifying geographical 'hotspots' where concentrations of bioresources are available[41]. Most of that report's recommendations relate to improving data and information on the composition and quantity of biological waste arisings to better understand the bioresource available in Scotland.

Additional methodological uncertainty arises as a result of the lack of distinction in the data between unavoidable and avoidable food waste, when estimating carbon impacts. The carbon factor for 'generated' food waste is based on a 'cradle to retail' analysis of food, with a functional unit of kg of finished food product. Unavoidable food waste/by-product from food manufacture (and perhaps some of the avoidable food waste) would be already accounted for in this carbon factor. There is a risk of double counting, therefore, where carbon impacts of food waste from households (or from retail/commercial catering) have already accounted for some of the associated unavoidable food waste arising from manufacturing.

5.3.2 Meat Processing

WRAP's Meat in a Net Zero World report[42] (2021) highlights the following causes for why the maximum value is not always realised from meat products:

- Limited access to available markets for co-products or to waste collection services
- Human error – e.g., misclassification or floor waste
- Machine waste
- Wash downs leading to a lack of visibility of food waste lost to sewer

To maximise value and reduce carbon emissions, food waste and by-products should be dealt with according to the hierarchy above, however, there are legislative barriers to doing this. The hierarchy shows 'use as animal feed' as the next stage down from redistribution for human consumption. Legislation limits the use of 'Animal by-products' to

[40] Jeswani, et al. 2020, The extent of food waste generation in the UK and its environmental impacts
[41] Zero Waste Scotland, 2017, Biorefining Potential for Scotland
[42] WRAP, 2021, Meat in a Net Zero World – A UK meat industry commitment to action

be used as animal feed to a short list of 'category 3 ABPs', and there is a complete ban on using household or catering kitchen waste[43]. This is to prevent outbreaks of animal diseases and limits the value that can be extracted from one of the biggest sources of by-product in the meat, poultry and fish and dairy sectors. Bakery products can be used to produce animal feed if they meet certain conditions. Feeding municipal food waste to livestock is common practice in many parts of the world (e.g., South Korea) where heat treatment is used to render it safe for use but to be utilised food waste needs to be collected separately and be relatively fresh[44]. Whilst technically possible to use food waste as feed therefore, there would be practical challenges to doing so safely.

5.4 Solutions – Examples of Good Practice/Initiatives

The distinction between avoidable and unavoidable food waste is important when considering what actions and targets are relevant. Avoidable food waste refers to waste that is disposed of before it reaches its intended use. In this case, carbon impact is minimised by focussing on waste prevention.

Unavoidable food waste refers largely to by-products of food production and preparation and so minimising generation is less relevant and the opportunities for carbon reduction come from opportunities to maximise the use of this by-product as a resource to substitute raw material inputs to another process.

As discussed above, improving information and data on waste and by-products from this sector is key to reducing waste and minimising carbon impacts.

The 2019 FWRAP committed to consult on mandatory public reporting of Scotland's food waste and surplus by food businesses. Scottish Government consulted on this issue through its 2019 and 2022 consultations on proposals for a Circular Economy (Scotland) Bill, and the Circular Economy and Waste Route Map consultation in 2022. All three consultations generated strong overall support for the introduction of mandatory public reporting of food waste. As part of the consultations, stakeholders have expressed a range of opinions on how public reporting of food waste should be implemented. Key considerations that were identified include the potential burden of reporting on small and medium enterprises, alignment across the four nations, and how food waste is defined and classified.

The Circular Economy (Scotland) Bill was introduced to Scottish Parliament on 13 June 2023. It includes powers for Scottish Ministers to require mandatory public reporting of waste and surplus. Subject to the Circular Economy (Scotland) Bill completing its Parliamentary passage, it is likely that food waste and surplus will be one of the first areas to be subject to mandatory public reporting, which would be implemented through secondary legislation, in order to enable businesses to take targeted action and promote transparency about the amount of food waste and surplus.

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[43] UK Government – Guidance on supplying and using animal by-products as farm animal feed.
[44] Salemdeeb et al., 2017, Environmental and health impacts of using food waste as animal feed: a comparative analysis of food waste management options.

WRAP have produced sector-specific guidance for this for two of the priority subsectors highlighted above, meat[45] and dairy[46]. The guidance for meat includes support to categorise wastes and by-products to ensure that the highest value is extracted from them, either from valorisation (whereby by-products are diverted from the waste stream) or from energy recovery.

The WRAP report on progress against the Courtauld 2025 targets notes progress in improved monitoring and reporting of food waste:

> "21 UK food manufacturers have publicly reported 2018 and historical data, and collectively reported a 6% reduction in food waste, saving over £47 million of food (40,000 tonnes)…This average 6% reduction over ca 12 months compares with a 9.8% reduction over three years for the sector."[47]

Between 2017 and 2021, the amount of food surplus redistributed from manufacturers to charities almost doubled with the total redistributed in 2021 being 42,013 tonnes.

The UK dairy sector has produced 'The Dairy Roadmap' 2018 which showcases '10 years of environmental commitment' in the sector. It highlights that sector has pledged under the Courtauld Commitment to reduce food waste by 20% between 2015 and 2025 and is reviewing how to measure and report food waste. It also has an action to improve packaging to help prevent consumer food waste[48]. Research by WRAP into waste in the milk supply chain has highlighted significant loses in the process that separates cream from milk, and further research aims to investigate ways to utilise the waste created in the process into food or feed applications[49]. It is estimated this could reduce waste in milk processing in the UK by 10,000 tonnes.

WRAP's 'Meat in a Net Zero World' outlines benchmarks for a yield of products from animal carcasses and provides a hierarchy to guide actions to maximise yield[50]. As noted above, current legislation means that 'category 3' animal by-products are very limited and so most are destined for anaerobic digestion (AD) or other energy recovery.

Where food waste is unavoidable and, therefore, more accurately defined as 'by-product', then waste prevention is not viable. The above sections highlight that this comprises a large proportion of some subsectors. However, carbon benefits could still be realised by utilising this bioresource and ensuring it is utilised as far up the waste hierarchy as possible. If the by-product enters the waste stream, then value can be realised through energy recovery. Removing by-product from the waste system all together results in

[45] WRAP, 2018, Food surplus and waste measurement guidelines: Meat processing
[46] WRAP, 2021, Food surplus and waste measurement and reporting guidelines: Dairy processing.
[47] WRAP, 2020, UK progress against Courtauld 2025 targets and UN Sustainable Development Goal 12.3
[48] Dairy UK, 2018, The UK Dairy Roadmap
[49] WRAP, 2018, Opportunities to Reduce Waste along the Journey of Milk, from Dairy to Home
[50] WRAP, 2021, Meat in a Net Zero World – A UK meat industry commitment to action

apparent waste prevention (as it disappears from waste tonnages reported) but in reality it is used as a resource in another system where it displaces virgin material requirement. In the waste system, carbon impacts are reduced, and this will be captured in the kind of analysis carried out in this research. However, to understand the full potential of carbon benefits from these actions, monitoring by-product diversion and understanding what raw materials they displace would be necessary. Consequential LCA approaches have been used to consider the full carbon impacts of using food waste for animal feed, demonstrating that there are potential savings compared to sending food waste to AD[51], but that omitting to take consideration of all impacts in other sectors can lead to different conclusions[52].

There are several Scottish examples of work in this area to examine the potential for extracting maximum value from food waste, co and by-products:

- A Zero Waste Scotland report mapping potential 'bioresources' in Scotland estimated the potential resources available for circular bioeconomy activities but identified a lack of data as a challenge[53]. Potential products from 'biorefining' include biofuels, fatty acids, carboxylic acid and olefins[54].
- The 'Serial Utilisation of Whisky Co-products' (2022) report sought to investigate the potential for maximising value from whisky co-products by 'cascading' by-products from one process to another, each extracting value. This project required a high degree of collaboration between the whisky industry, academic partners and innovative bio-refining businesses in Scotland. The focus of the research has been on establishing viability, and no assessment of the carbon-reducing potential has been made yet[55].
- A report by Zero Waste Scotland (2018) into the potential of insect farming demonstrates that moving food waste up the hierarchy can translate to carbon benefits. An LCA-modelled food waste used for anaerobic digestion against insect farming to produce protein feed to displace fish meal in aquaculture, the research suggested that an approximately 10% carbon benefit would be realised in the insect farming scenario[56].

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[51] Salemdeeb et al., 2017, Environmental and health impacts of using food waste as animal feed: a comparative analysis of food waste management options.
[52] Van Zanten, 2014, Assessing environmental consequences of using co-products in animal feed
[53] Zero Waste Scotland, 2017, Biorefining Potential for Scotland
[54] Isah and Ozbay, 2020, Valorization of Food Loss and Wastes: Feedstocks for Biofuels and Valuable Chemicals
[55] IBioIC, 2022. Serial Utilisation of Whisky Co-Products
[56] Zero Waste Scotland, 2018, Black Soldier Fly A Circular Economy Solution for Scotland

6 Animal and Mixed Food Waste from Commerce

7.5% of Carbon Impacts; 1.4% of Waste Tonnes

6.1 Analysis of Embodied vs. Disposal Emissions

The modelling in this study assumes that 97% of food waste from all commercial and industrial sources is recycled/composted (with a net carbon benefit). Virtually 100% of impacts are attributable to the embodied emissions of the waste.

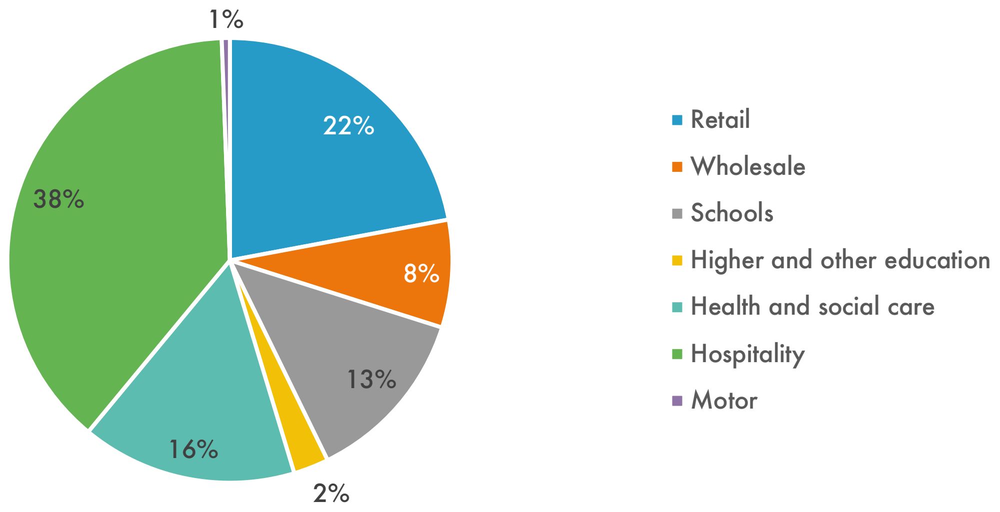
6.2 Identification of Particular Product Streams/Industries

'Commerce' as a sector is very broad, covering retail, hospitality, offices, education and healthcare settings.

Several specific sector studies in 2011 provided compositional analysis data on mixed waste from several subsectors that are counted as 'commerce' in the SEPA waste data. These reports were based on visiting selected sites, measuring waste amounts and types, and then scaling these estimates to Scotland as a whole. These studies only covered "mixed waste", but it is expected that this includes most food waste thrown away in 2011 before separate commercial food waste collections became widespread. The proportions of waste from each sector are shown below[57].

[57] Zero Waste Scotland, 2016, Report - Detailing the scope of Scotland's food and drink waste prevention targets

Figure 3: Food Waste by Subsector in Scotland



Whilst there are a diversity of subsectors, hospitality, education and health and social care all represent catering contexts and these account for 70% of total food waste – WRAP refers to such as 'Hospitality and Food Service Sector'. Retail and wholesale account for the other 30%, with retail the most significant of these at 22%.

In the most recent report from WRAP (2016) on progress against Courtauld 2025 targets, the split between 'Retail' and 'Hospitality and Food Sector' was 21% and 79%, respectively. One hundred percent of food waste from retail could be classed as 'avoidable' (i.e., intended to be eaten), whereas in catering contexts, it is estimated that 83% of food waste would be classed as avoidable/intended to be eaten[58].

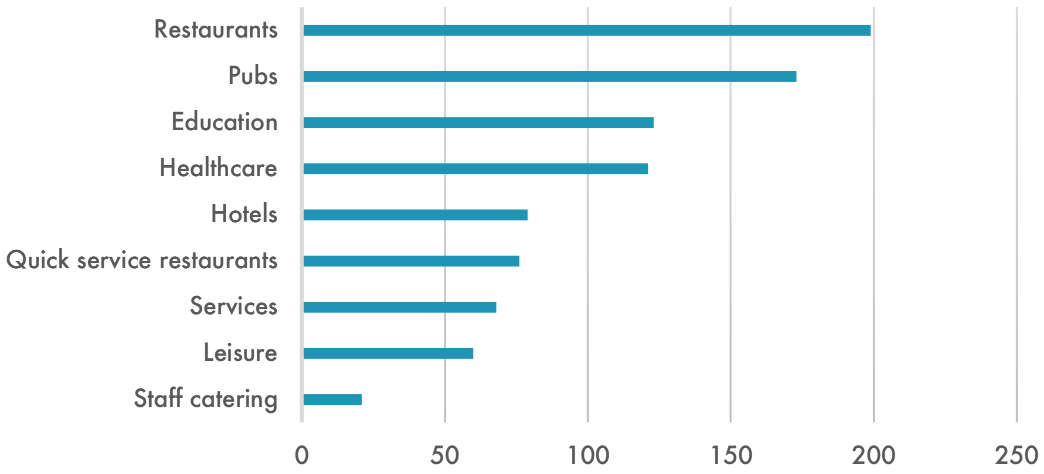
6.2.1 Hospitality and Food Service Sector

A 2013 WRAP study into food waste in the hospitality and food service sector estimated the following tonnes of food waste per subsector[59].

[58] WRAP, 2021, UK progress against Courtauld 2025 targets and UN Sustainable Development Goal 12.3

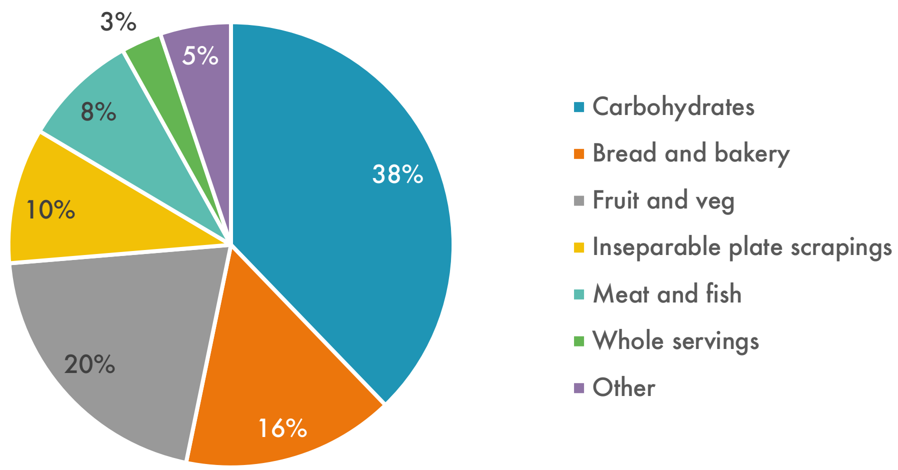
[59] WRAP, 2013, Overview of Waste in the UK Hospitality and Food Service Sector

Figure 4: Food Waste by Subsector in the UK (000's of tonnes)



Although SEPA data states that 97% of food waste is being recycled/composted, this assumption is applied across all commercial and industrial sources, the specific recycling rate for the commerce sector not being available. The findings of the 2013 WRAP study put the recycling rate at 46%, although rates have likely improved in the intervening decade given the introduction of mandatory food waste separation for businesses in Scotland. The same study also suggests that 75% of food waste is avoidable. In terms of composition, the study found the following breakdown of avoidable food waste:

Figure 5: Composition of Avoidable Food Waste in the UK Hospitality and Food Service sector 2012[60]



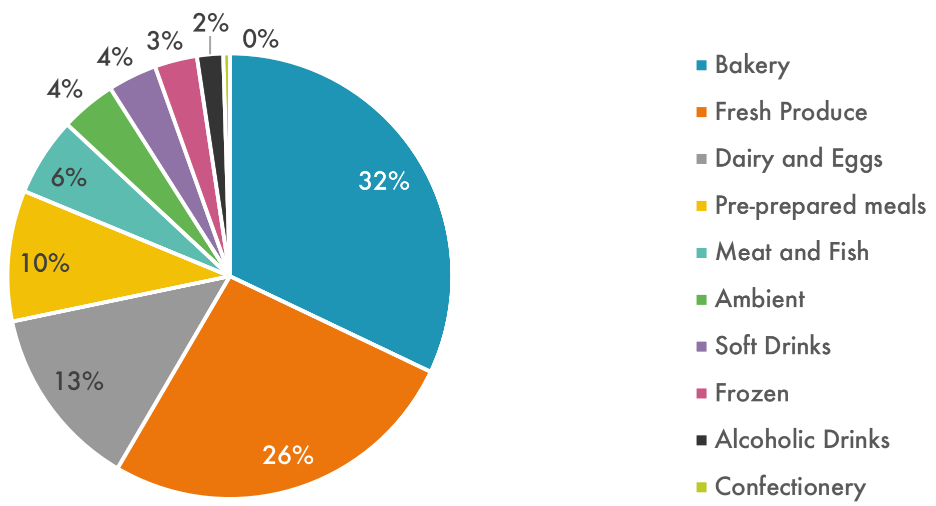
[60] Potato and pasta and rice categories combined as "carbohydrate" category

6.2.2 Retail and Wholesale

UK retailers that have published relevant data report food waste as a percentage of sales of between 0.02% and 1.25%[61]. In 2013, WRAP estimated that food waste in the hospitality and food sector was about 18% of purchased food (by weight)[62].

Data is very limited on the nature of food waste from catering contexts, and the FWRAP identifies improved monitoring and reporting as a priority, promoting the Target, Measure, Act framework from the Courtauld agreement. WRAP research provides a breakdown of food waste from UK retail as illustrated below[63]:

Figure 6: Types of Food Waste Generated from UK Retail (2014/2015)



A report by Tesco in 2022 states that prepared foods were their most wasted item at 25%; followed by dairy (18%); meat, fish and poultry (11%) and bakery (10%)[64]. Lidl (2020) however reported fruit and vegetable to be their most wasted item at 46%; followed by bakery (20%); chilled (17%) and meat, poultry, fish and eggs (7%)[65]. There is variation in how these three examples categorise food wastes, therefore, comparison is difficult.

[61] WRAP, 2021, UK progress against Courtauld 2025 targets and UN Sustainable Development Goal 12.3
[62] WRAP, 2013, The true cost of food waste within hospitality and food service
[63] WRAP 2016, Quantification of food surplus, waste and related materials in the grocery supply chain
[64] Tesco, 2022 Food Waste and Distribution Fact Sheet
[65] Lidl, Food waste data

6.2.3 Carbon Impacts

An assessment of the environmental impacts of food waste in the UK looked at the relative climate change impact of food wasted in the UK across all sectors[66]. In the consumption stage (which would include both hospitality and food service and households) meat and fish had the biggest impact, accounting for around 40% of all impacts, followed by cereals at 20%. For the distribution stage (including retail and wholesale) meat and fish accounted for over 60% of carbon impacts (vs 19% of total tonnes), with fruits and vegetables accounting for about 20% (vs 34% of total tonnes). Analysis carried out in 2017 by Zero Waste Scotland into the carbon impacts of reducing food waste by 33% shows the following top 5 waste types from all commercial and industrial sources except food and drink manufacturing by tonnes and by global carbon impact[67]. Commerce accounts for 93% of this.

Table 12: Top 5 Wasted Food from Commercial and Industrial Sector

	Top 5 by tonnes generated	Top 5 by carbon impact
1	Fresh vegetables	Meat
2	Drinks (non-alcoholic)	Pre-prepared meals and snacks
3	Fresh fruit	Fresh vegetables
4	Bakery	Dairy (excluding milk)
5	Meat	Other

6.3 Discussion of Problems/Challenges

6.3.1 Quantifying the problem

Whilst the above section demonstrates there is some information about food waste from commerce, the data is not up to date, and better detail on subsector sources and specific food waste types would allow for better identification of specific problems or challenges. As with food waste from the food and drink manufacturing sector, a lack of a common understanding and definition of food waste, co-products, by-products, and unavoidable and avoidable food waste all hamper efforts to properly identify and reduce food waste. The FWRAP proposed stakeholder engagement with businesses to understand the barriers to food waste recycling and reuse in the sector and proposes to work to identify 'hotspots' across all sectors[68].

[66] Jeswani, et al. 2020, The extent of food waste generation in the UK and its environmental impacts
[67] Zero Waste Scotland, 2017, internal dataset
[68] Scottish Government, Food Waste Reduction Action Plan

6.3.2 Hospitality and Food Service Sector

A study by WRAP (2013) found that, on average, in catering contexts, 21% of food is wasted because of spoilage, 45% from food preparation and 34% from customer plates. In more formal catering contexts (e.g., restaurants), plate waste was less, and preparation waste was a higher proportion. In contrast, in less formal contexts (e.g., canteens and quick service restaurants), the proportion of waste from plates was as high as 46%[69].

WRAP's overview of waste in the hospitality and food sector identifies a variety of factors that contribute to food waste, influenced by clients, suppliers, staff, budgets and customers[70]. Changing menus and difficulty in predicting demand for certain items can lead to preparing food that is not required – caterers do not want to over-prepare but are also wary of not having food available when required. The types of ingredients used and food produced also influence food waste – quick-service restaurants use more pre-prepared and frozen ingredients and tend to have less waste in-house. Skilled and aware catering staff are critical in ensuring good stock management and storage, good food preparation practices and appropriate portioning.

6.3.3 Retail and Wholesale

A variety of factors cause food waste in retail and wholesale, and many are specific to certain types of products; for example, driver behaviour damaging certain fruit and vegetables[71]. Food waste in retail varies greatly between businesses and individual products (e.g., see the example above where two major UK supermarkets report very different products in their most wasted items). Whilst retailers have greatly increased the amount of surplus stock they redistribute (see below), it is not clear how much of this is eventually consumed.

6.4 Solutions – Examples of Good Practice/Initiatives

As noted above, the 2019 FWRAP committed to consult on mandatory public reporting of Scotland's food waste and surplus by food businesses. Scottish Government consulted on this issue through its 2019 and 2022 consultations on proposals for a Circular Economy (Scotland) Bill, and the Circular Economy and Waste Route Map consultation in 2022. All three consultations generated strong overall support for the introduction of mandatory public reporting of food waste.

The Food Waste Reduction Roadmap (from the Courtauld Agreement) was developed by WRAP and the IGD (Institute of Grocery Distribution) and suggests that businesses are

[69] WRAP, 2013, Where food waste arises within the UK hospitality and food service sector: spoilage, preparation and plate waste
[70] WRAP, 2013, Overview of Waste in the UK Hospitality and Food Service Sector
[71] Li and Thomas, 2014, Quantitative evaluation of mechanical damage to fresh fruits

willing to participate. Retailers are well represented in the Courtauld Agreement, but the hospitality and food service (HaFS) sector is less well engaged.

A 2013 WRAP study into the HaFS sector provides a list of 10 waste prevention opportunities for caterers, along with some brief case study examples of how these have been implemented. For example, a school switched from a staff-served to a self-serve system, and monitoring was carried out as to what pupils chose to eat. This allowed menus to be adapted to match what pupils ate and led to a 50% reduction in food waste overall[72].

There are a number of sector-specific targeted initiatives that can be highlighted to demonstrate action in this area:

- Schools: The Small Change, Big Difference programme focussed on healthy eating, reducing food waste and increasing food waste recycling in schools and at home. Pupil-led classroom-based interventions, in tandem with catering measuring and monitoring efforts, reduced waste within schools in the London area[73]. A Zero Waste Scotland study in 2020 demonstrated how 'nudge' techniques could lead to food waste reductions in schools[74].
- NHS Scotland: Zero Waste Scotland has developed a guide for NHS hospitals to support management of food waste, including waste prevention and reuse[75]. In 2019, the NHS produced the NHS Scotland Food Waste Reduction Strategy, which outlines its plan to reduce food waste by a third by 2025 (compared to the 2013 baseline). Food Waste Action Plans are in development which will describe the steps that each Health Board will take to deliver the strategy.
- WRAP published the 'Hospitality and Food Service Action Plan' in March 2021, outlining actions within the sector to deliver on the Courtauld 2025 commitments. This sets a range of targets and actions covering tracking, staff, supplier and consumer engagement, redistribution of surplus and working with waste management contractors[76].
- The FWRAP highlighted that the hospitality sector is very diverse and challenging to provide generic solutions for because of this. It highlights an analysis that demonstrates the business case for food waste reduction in the sector[77]. The Good to Go campaign is an initiative targeting 'plate waste' to support customers to take uneaten food home. Where customers were proactively offered 'doggy bags', average food waste was reduced by 42%[78].

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72 WRAP, 2013, Overview of Waste in the UK Hospitality and Food Service Sector
73 Small Change Big Difference
74 Zero Waste Scotland, 2020, How to systematically trial behavioural interventions to change the common behaviours which contribute to the climate crisis, a case study on using the nudge technique to reduce food waste in a Scottish school
75 Zero Waste Scotland, Manging NHSS food waste
76 WRAP, Hospitality and Food Service Action Plan
77 Scottish Food Waste Reduction Action Plan
78 Zero Waste Scotland 2014, Good to Go, estimating the impact of a formal take-home service on restaurant food waste

- Guardians of Grub is a campaign led by WRAP to support Hospitality and Food Service businesses to reduce food waste[79].
- The FWRAP set out an action area to promote community food redistribution and includes a case study on the impact of the Scottish Government Fair Food Transformation Fund. Community fridges and an increasing number of mobile apps that facilitate food sharing are also highlighted as examples of success in this area. According to the Courtauld 2025 progress report, between 2015 and 2018, the amount of food surplus redistributed from retail to charities increased by over 14,000 tonnes, and the total redistributed from retail via charitable and commercial routes in 2018 amounted to almost 25,000 tonnes[80].
- In retail, actions can help to reduce both food waste in the sector, but also at home for consumers. The Coop reported that new packaging for steaks had reduced waste by 8%. Providing a range of pack sizes to allow consumers to buy the right amount and clear labelling on packaging to advise on storing, freezing and cooking are recommended areas for focus from the Meat in a Net Zero World report[81].

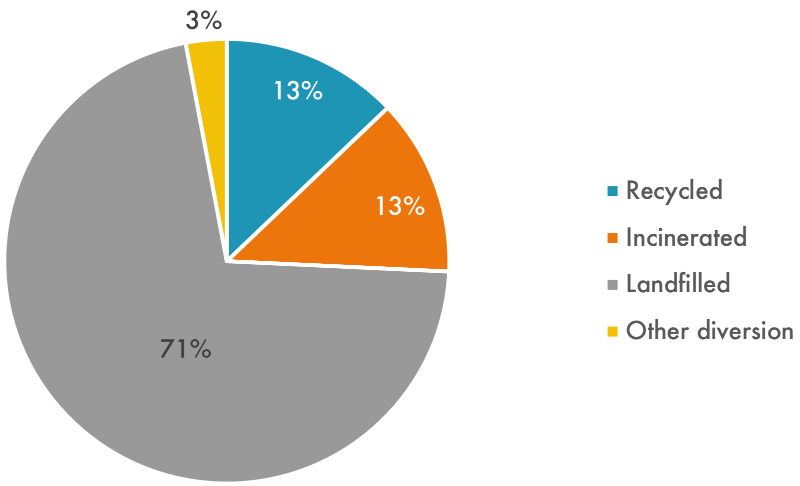
[79] Guardians of Grub
[80] WRAP, 2021, UK progress against Courtauld 2025 targets and UN Sustainable Development Goal 12.3
[81] WRAP, 2021, Meat in a Net Zero world Annual Progress Summary 2020-21

7 Textile Waste from Households

14.7% of Carbon Impact, 0.8% of Waste Tonnes

The analysis in this study shows that textile waste only constitutes 0.8% of waste tonnages but 14.7% of total carbon impact. In Scotland, 84% of end-of-life textiles end up in landfill or are incinerated (see Figure 7). Waste tonnage data in Scotland generally only consider textiles which have been brought to a textile recycling centre. The analysis includes estimates of textile waste in residual household waste based on Zero Waste Scotland's report on the Carbon Footprint of Scotland's Household Waste. We estimate that 89.3% of textile waste is disposed of via household residual waste (HRW) in Scotland[82]. Waste management and textile industry experts indicated that textiles in household waste bins had increased throughout the pandemic due to a lack of alternative donation or collection options, indicating that this amount could be considerably larger.

Figure 7: Destination of Household Textile Waste in Scotland (based on the data within this study)



7.1 Analysis of Embodied vs. Disposal Emissions

The textile industry is under intense scrutiny over its environmental impacts. It is a significant polluter and accounts for about 10% of global carbon emissions, more than aviation and maritime shipping combined[83]. This impact is exacerbated by the overconsumption of clothing, as the global population produces 92 million tonnes of

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[82] This analysis does not include carpets, mattresses, or soft furnishings, which are classified as bulky waste in Scotland.

[83] European Parliament. The impact of textile production and waste on the environment (infographic). Published April 26, 2022. Accessed August 12, 2022.

clothing waste annually[84]. Over 5% of carbon and water emissions in the UK originate from the fashion industry[85].

This study shows that Scotland's households produce 87,157 tonnes of textile waste annually. The lifecycle greenhouse gas (GHG) impact of this waste stream (sector and waste stream combination) is around 1.8 million tonnes of CO_2 equivalent. This analysis has found that 97% of this impact is embodied. These findings are in line with international research. A study by the Carbon Trust (2011) on the global impact of textiles found that 97% of carbon emissions are embodied, while the remaining 3% are attributable to disposal. Fibre production, particularly polymer extrusion, creates the most significant emissions during the production process at around 9 million tonnes of CO_2e per year globally[86]. These figures highlight that low-carbon manufacturing processes are a priority.

7.2 Identification of Product Streams/Industries

7.2.1 Clothing vs. Non-Clothing Textiles

A UK-wide study by WRAP (2017) found that 921,000 tonnes of textile products were in household residual waste destined for landfill and incineration. Of this, 36% was clothing; 21% shoes, bags, & belts; and the remaining 42% was non-clothing textiles[87]. However, this analysis also counted what Scottish waste data currently considers bulky household waste (i.e., mattresses, carpets, soft furnishings), meaning that this breakdown may not be comparable to this report's current data.

In 2014, the UK was the third largest producer of textile waste in the EU. The generation of textile waste per capita in the UK was 19kg in 2012, compared to the EU average of 6 kg per capita[88]. Based on the data from this study, Scotland produces about 16kg per capita. Globally, less than 1% of textile waste (incl. non-clothing textiles) is recycled into new garments[89].

7.2.2 Clothing Types

The WRAP (2017) report "Valuing our clothes: the cost of UK Fashion" identified the following items of clothing as priority products for reducing environmental impact:

- Women's dresses have the most significant potential for reducing carbon emissions and supply chain waste
- Women's jumpers have the most considerable potential for reducing carbon emissions
- Men's t-shirts have the greatest potential for supply chain waste

[84] Fashion Revolution
[85] Love your Clothes. Why love your clothes? Published 2022. Accessed August 11, 2022.
[86] WRAP. Valuing Our Clothes: The Cost of UK Fashion. 2017.
[87] WRAP. Textiles Market Situation Report 2019. 2019.
[88] Koszewska, Małgorzata. "Circular Economy – Challenges for the Textile and Clothing Industry" Autex Research Journal, vol.18, no.4, 2018, pp.337-347.
[89] Common Objective. The Issues: Waste. 2022.

- Women's jeans have the largest potential water savings

These items were identified as priority areas due to their high sales volume. However, the type of material used to create clothing items may be a more valuable measure for determining priority sectors for reducing carbon emissions than the type of clothing, as the differences in emissions between types of materials are higher than the differences between clothing items or producers.

Table 13: Representative Lifetime Value of Textiles[90]

Textile	Lifetime value CO_2 eq / kilogram weight of textile
Average	29.96kg
Polyester t-shirt	67.5kg
Wool sweater	7.35kg

A polyester t-shirt has more than double the carbon footprint of a cotton t-shirt (5.5kg CO_2e vs. 21 kg CO_2e)[91].

7.2.3 Fibre Types

As discussed, the production of synthetic fibres is repeatedly found to create higher emissions than natural fibres, such as cotton and hemp (see Table 14). The production of fibre through polymer extrusion is the highest contributor to carbon emissions in the fashion industry[92].

Table 14: Kilogram of CO_2 Emissions per Tonne of Spun Fibre[93]

	Crop cultivation (CO_2 emissions per tonne)	Fibre production (CO_2 emissions per tonne)	Total
Polyester (USA)	0.00	9.52	9.52

[90] Muthu SS. Handbook of Life Cycle Assessment (LCA) of Textiles and Clothing. Woodhead Publishing; 2015.
[91] House of Commons Environmental Audit Committee. Fixing Fashion: Clothing Consumption and Sustainability Sixteenth Report of Session 2017-19.; 2019.
[92] WRAP. Textiles Market Situation Report 2019. 2019.
[93] Rana S, Pichandi S, Moorthy S, Parveen S, Fangueiro R. Carbon Footprint of Textile and Clothing Products. In: Handbook of Sustainable Apparel Production. CRC Press; 2015:128-155. doi:10.1201/b18428-10

Cotton, conventional (USA)	4.20	1.70	5.90
Cotton, organic (USA)	0.90	1.45	2.35
Cotton, organic (India)	2.00	1.80	3.80
Hemp, conventional	1.90	2.15	4.05

7.3 Discussion of Key Challenges

7.3.1 Fast Fashion and Overconsumption

UK citizens consumed 1.04m tonnes of new clothing in 2017. Spending on apparel has almost quadrupled since 1998[94]. UK citizens buy more clothes per person than any other European country. The number of times a garment is worn decreased by 36% between 1993 and 2018[95]. The average UK citizen has not worn 30% of the clothing in their wardrobe for over a year as it no longer fits, and only wears 44% of their wardrobe regularly[96]. This highlights that the majority of clothing items lay unused for long periods when they could be in circulation in the second-hand economy.

7.3.2 Overproduction

Only 30% of the clothing produced today is sold at the recommended retail price, another 30% goes into sales, and 40% remains unsold or even fails to reach the shops. About 60% of clothing manufactured reaches landfill a year after production[97]. If the solid waste generated by textile production processes and end-of-use continue at the current growth rate (an additional 57 million tons globally per year), it will increase by 60% between 2015 to 2030[98]. This means that the total level of fashion waste will rise to 148 million tons by 2030 (or 17.5 kg per capita globally) annually across the planet[99].

7.3.3 Synthetic Fibres Made from Petrochemicals

Synthetic fibres from petrochemicals pose multiple climate challenges, including:

- High emissions during production
- Difficult or not yet established recycling processes
- The incineration of complex materials (e.g., carpets) creates high levels of carbon emissions and releases toxic materials into the atmosphere

[94] WRAP. Textiles Market Situation Report 2019. 2019.
[95] TRAID. The Impacts of Clothing Fact Sheets. 2018.
[96] Ibid.
[97] The price of fast fashion. Nat Clim Chang. 2018;8(1):1. doi:10.1038/s41558-017-0058-9
[98] Lehmann M, Arici G, Boger S, et al. Pulse of the Fashion Industry - 2019 Updates. 2019.
[99] Tidswell E. Less is more: fixing overproduction in the fashion industry. 2022.

Still, 88% of fast fashion contains new plastics[100] and 49% of clothing on fast-fashion websites is made from virgin plastics[101]. Recycled polyester production creates 37% fewer carbon emissions than virgin polyester, although it currently primarily uses non-textile plastic waste[102]. Without an established textile recycling process, this is linear, as it is only recycled once before ending up in a landfill or incinerated. A circular economy would ideally facilitate closed-loop recycling, meaning that plastic bottles would be recycled into bottles and fabrics into fabrics.

7.3.4 Lack of Reuse or Recycling Options

A lack of durability (i.e., a short lifespan), usually present within low-quality fast-fashion items, means that an increasing amount of donated second-hand clothing cannot be resold or reused, further contributing to over-consumption[103]. There are also challenges at the end-of-life stages. Current textile recycling technology is not yet developed enough to mass produce fully recycled garments. While mechanical tearing of the textiles allows fibres to be re-spun into new threads, this process shortens fibre lengths, affecting fibre spinnability and the strength of recycled fibre threads[104]. An additional barrier is posed by a lack of knowledge about the materials used in a garment. Recycling for cotton and wool is the most established, and techniques allow recycled wool to have the same quality as virgin wool. However, there are very few synthetic fibre recycling options, and fibre blends (e.g., cotton and polyester blends) are difficult to separate successfully[105].

Whilst some clothing in Scotland is collected for reuse (less than 3%) or recycling (13%), there are no fibre-to-fibre processing units within the country. Textiles are generally downcycled rather than upcycled and used as a new resource, as only 1% of textiles are recycled into new garments[106]. For instance, they are shredded to be used as mattress filling or underlay. As fewer than 1% of mattresses are collected for recycling in Scotland[107], this results in only a single further use before being landfilled or incinerated.

7.3.5 Lack of Infrastructure and System Collaboration in Scotland

Within Scotland, there is a disconnect between organisations involved in the lifecycle of textiles (i.e., manufacturers, designers, retailers, and recyclers). Textile production generally occurs outside of Scotland, limiting the ability to communicate and share information. This highlights a significant gap in the potential of a circular textile industry, as

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[100] WRAP. Valuing Our Clothes: The Cost of UK Fashion. 2017.
[101] RSA. FAST FASHION'S PLASTIC PROBLEM Sustainability and Material Usage in Online Fashion. 2021.
[102] Textile Exchange. Preferred Fiber & Materials (PFM) Market Report. 2017.
[103] TRAID. The Impacts of Clothing Fact Sheets. 2018. and RSA. FAST FASHION'S PLASTIC PROBLEM Sustainability and Material Usage in Online Fashion.; 2021.
[104] Lindström K, Sjöblom T, Persson A, Kadi N. Improving mechanical textile recycling by lubricant pre-treatment to mitigate length loss of fibers. Sustainability (Switzerland). 2020;12(20):1-13. doi:10.3390/su12208706
[105] Textile Exchange. Preferred Fiber & Materials (PFM) Market Report. 2017.
[106] Common Objective. The Issues: Waste. 2022.
[107] Zero Waste Scotland. Research Partnership aims to put mattress waste to bed. 2019.

knowledge sharing between these different lifecycle stages of textiles would be vital to ensuring products are produced sustainably and recyclable at the end-of-life stage.

7.4 Solutions – Examples of Good Practice/Initiatives

Zero Waste Scotland implemented the Circular Textile Fund in 2022. The fund will provide £2 million to Scottish organisations in the textile industry and support the implementation of innovative circular projects. The fund identifies the following priority areas to make the transition to a circular textile economy:

1. Reduce consumption
2. Design for circularity
3. Implement reduce, reuse and repair models
4. Support clothing care and chemical management
5. Help manage end-of-life processing[108]

We have grouped our solutions within these categories below.

7.4.1 Reduce Consumption

Reducing consumption, particularly of fast fashion, should lie at the forefront of a textile waste intervention. To reduce consumption, we must:

- Drive collective action and educate the public on the impact of textiles
- Develop repurposing, upcycling, repair, leasing, and sharing services
- Invest in mainstream reuse services

7.4.1.1 Second-hand Clothing

Two-thirds of UK citizens buy or receive used clothing. By donating clothes in our wardrobe, we no longer wear, we could significantly increase the availability of good quality clothing in second-hand shops[109]. The Love your Clothes campaign estimates that if every UK citizen were to donate unworn clothing, this could bring £30 billion worth of clothing into circulation[110].

Table 15: Reduction in carbon emissions for repair, hire, and second-hand clothing

	Increase in average lifespan (years)	Reduction in lifetime carbon emissions if it constituted *5%* of total sales	Reduction in lifetime carbon emissions if it constituted *10%* of total sales
Repair	1.2	1%	3%

[108] Zero Waste Scotland. Circular Textiles Fund. 2022.
[109] TRAID. The Impacts of Clothing Fact Sheets.; 2018.
[110] Love your Clothes. Why love your clothes? 2022.

Hire	1.2	1%	3%
Second-hand	1.6	1%	3%

Increasing demand for second-hand, upcycled, and recycled fashion and furniture can positively contribute to a reduction in carbon emissions and extend the lifespan of textile items. Online marketplaces, such as eBay and Depop, can assist in popularising second-hand goods. Whilst online marketplaces support circular economy principles, they pose a challenge to charity shops. So, alternative solutions may need to be implemented to ensure these businesses maintain an income stream. The European Clothing Action Plan (ECAP) introduced consumer interventions designed to instigate behavioural change through various interventions and campaigns. One of these interventions included pop-up stalls exhibiting second-hand fashion in London, accompanied by the provision of information on the environmental impact of the fashion industry. The Love your Clothes campaign also collaborated with major retailers to highlight the importance of reuse and recycling models to consumers. These campaigns led to an increase in clothing donations, second-hand purchases, and an increase in clothing longevity. In Germany, for instance, clothing longevity increased from 3.8 to 4.4 years, and the percentage of second-hand purchases increased from 5-8%[111].

7.4.1.2 Clothing Hire and Repair Services

Hire and repair services could significantly increase clothing lifespan. According to WRAP (2017), increasing sales via hire and repair services to 5-10% of total clothing sales could reduce the UK's carbon footprint by 80,000-160,000 tonnes of CO_2e annually and increase the average clothing lifespan from 3.3 to 4.5 years[112].

Some large-scale retailers have already implemented these types of services. For instance, Patagonia offers free repair of virtually all Patagonia items other than those deemed unsafe or unsanitary to repair (e.g., wetsuits and underwear). However, as these result in raised costs and a loss of income to businesses, incentivisation or legal guidelines may be required to encourage this to become mainstream.

Hire services are not yet as mainstream but are a developing economy. Activists have been pushing for the removal of VAT from clothing repair and hiring services to incentivise the use of these services, and this has been recognised in a report by the House of Commons in 2019[113]. For example, Sioda is a Stirling-based company which allows the customer to rent high-fashion, either per item or by subscription[114]. These types of services could especially reduce the carbon footprint of special occasion clothing items or specialist workwear.

[111] WRAP. Valuing Our Clothes: The Cost of UK Fashion. 2017
[112] WRAP. Valuing Our Clothes: The Cost of UK Fashion. 2017.
[113] House of Commons – Fixing Fashion: Clothing Consumption and Sustainability
[114] Sioda. 2022.

7.4.1.3 Promoting "Slow Fashion"

Increasing the lifespan of textiles is essential to reducing consumption and would significantly reduce emissions. An increase of nine months (extending the total lifespan by 33.3% to three years) would reduce carbon emissions by 20-30%. Increasing the lifespan only by three months could lead to a 5-10% reduction[115]. Creating textiles that are designed to last is the primary strategy to ensure circularity. Around 80% of a product's environmental impact is decided at the design and production stage[116], highlighting the need to create clothing which is of high quality and durable. Increasing durability could extend the average lifespan by 50% and reduce carbon emissions by 8%[117]. Whilst Scotland currently has limited control over imported goods, establishing a solid production base within the country could ensure that sustainable production methods are implemented and reduce the country's carbon footprint.

7.4.1.4 Education and Public Awareness

In addition to repair services, it could be useful to provide education to the public to repair or upcycle clothing. ReMode in Paisley, Reboutique in Dundee, and ApparelXchange in Glasgow (specialising in children's wear) are social enterprises promoting sustainable fashion and offering textile repair and upcycling courses at low prices. The Save your Wardrobe app, developed in London, allows users to catalogue the clothing items in their wardrobe, with the intention of maximising use of already owned clothing and reducing the need for new purchases. Public awareness interventions were successful in WRAP's ECAP campaign (see impacts discussed above), so implementing these types of educational services across Scotland could have a positive impact on increasing sustainable clothing choices.

7.4.2 Design for Circularity

7.4.2.1 Promoting Circular Pathways

Scotland's Circular Economy strategy recognises that textile waste is problematic, however, it has not yet set out guidelines for how to tackle the issue. The EU's New Circular Economy Action Plan was published in 2020[118]. Priority sectors at the European level include a textiles strategy, which was published in March 2022. It is expected to cover the following areas of work:

- Establishing eco-design for textiles and incentivising circular business models
- Enabling better recycling of materials and improved production processes
- Ensuring increased transparency for consumers across the value chain
- Managing value chain risks through due diligence on social impacts, including labour conditions

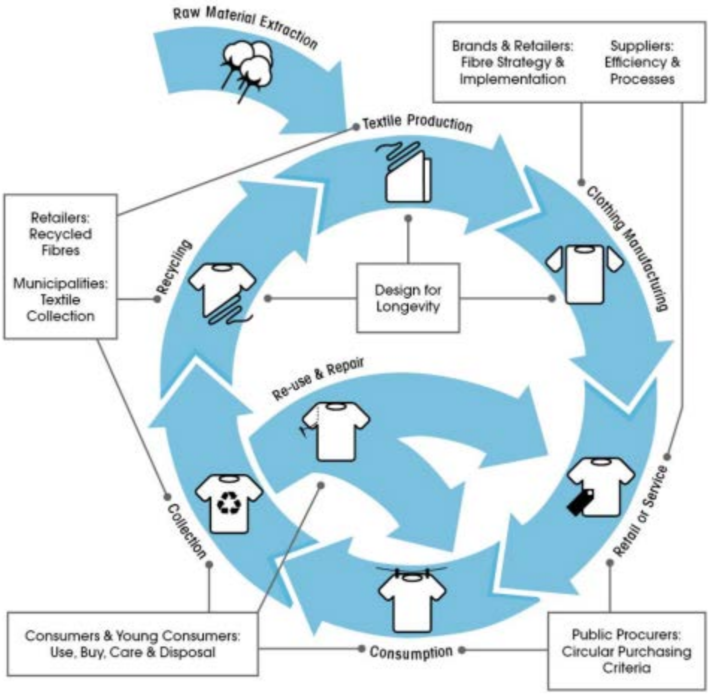
[115] Love your Clothes. Why love your clothes? 2022.
[116] WRAP. Textiles 2030 Circularity Pathway. 2021.
[117] WRAP. Valuing Our Clothes: The Cost of UK Fashion. 2017.
[118] European Commission - Circular Economy Action Plan

- Better management of production and post-consumer textile waste

In 2012, WRAP implemented the Sustainable Clothes Action Plan (SCAP), a collaborative effort between producers, retailers, and recycling managers to create collaborative plans for production, use and disposal. Ninety organisations participated, amounting to 48% of the total UK sales volume. SCAP led to a 21.6% reduction in lifetime carbon emissions and an 18.2% reduction in water use (both exceeding the 15% goal) over eight years in the participating businesses. However, the plan did not meet the waste targets. It aimed for a 15% reduction of clothing in household waste, only achieving 4%, and a 3.5% reduction in waste footprint, yet only achieving 2.1%[119].

[119] WRAP. Textiles 2030 Circularity Pathway. 2021.

Figure 8: Circular Clothing System



The WRAP Textiles 2030 Circularity Pathway has estimated that the 2030 carbon emission reductions target of 50% could be achieved by businesses taking the following actions:

- Utilising low carbon energy within the UK (8% reduction)

- Utilising low carbon energy within the supply chain (10% reduction)

- Selecting more sustainable fibres (4% reduction)

- Low-impact production processes (2% reduction)

- Using recycled fibres (12% reduction)

- Implementing reuse business models (7% reduction) } Circularity Pathway Actions

- Design products for longer lifespans (7% reduction) (Provisional estimates: - 26%)[120]

The Kalopsia Collective in Edinburgh is an example of a business promoting circular pathways. It encourages closed-loop production processes, upcycling surplus fabrics and offcuts, sustainable packaging, and many more sustainable textile practices[121].

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120 WRAP. Textiles 2030 Circularity Pathway. 2021.
121 Kalopsia Collective. Sustainability. 2022.

Embedding circular design must become in policy. Taking a full systems approach could provide best practice solutions to a sustainable textiles industry (e.g., designing materials to be circular from the outset and facilitating collaboration between different sectors involved in the lifecycle of textiles). With barriers in place which hinder control over methods of production, reshoring production of textiles to Scotland could reduce carbon emissions through reduction of transport emissions.

7.4.2.2 Extended Producer Responsibility (EPR)

Implementing EPR for textiles would make producers responsible for post-consumption processes. The EU Strategy for Sustainable and Circular Textiles was introduced in March 2022 and will introduce schemes on EPR for textiles[122]. France implemented Extended Producer Responsibility for textile waste in 2007. It mandates that producers finance a repair fund (no guidelines for the amount) and a reuse fund (5% of budgets). It also introduces modulations to the eco-contributions paid by producers (up to 20% of retail price depending on various factors, including durability, repairability, and amount of recycled material used)[123]. The UK Government is discussing a textiles EPR with Defra.

In addition to making clothing sustainable and recyclable, retailers can implement takeback schemes, allowing customers to bring unused/unwanted clothing to the store. There are models for commercial partnerships, charity partnerships, and own programmes. Clothes are generally sorted into clothes than can be resold, reused (e.g., as mops or cloths), or shredded and recycled (e.g., for mattress filling or underlay)[124]. Rapanui is a clothing business on the Isle of Wight which implements a fully circular production process. It only produces ordered clothing, thereby eliminating waste, and it takes back clothes for recycling at the end-of-life stage[125].

7.4.2.3 Reduce Virgin Plastics and Increase Sustainable Fibre Options

Reducing the amount of virgin plastic could significantly reduce carbon emissions. Production of fibres made from rPET (recycled polyethylene terephthalate) creates 79% fewer carbon emissions than virgin polyester but are still problematic as they cannot be recycled into new textiles[126]. The RSA, amongst others, has advocated for a ban on textiles derived from virgin plastics and a plastics tax on imports or production of clothing with virgin plastics[127].

There is a global drive to create more sustainable fibre options. The Herewear project is a collaboration of EU organisations, including the Centre for Circular Design in London, working on developing sustainable fabrics local to each participating country[128]. There is

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[122] European Commission – EU Strategy for Sustainable Textiles
[123] Jacques Vernier, "Extended producer responsibility (EPR) in France", Field Actions Science Reports [Online], Special Issue 23 | 2021.
[124] WRAP. Retailer Clothing Take-Back Guide. 2020.
[125] Rapanui Clothing – Our Story
[126] Common Objective - Is Recycled Polyester Green or Greenwashing?
[127] RSA – Turning the Tide, 2021
[128] Herewear EU

currently no established production of regenerative textiles within Scotland, although some industries or start-ups have potential.

Johnston's of Elgin and Prickly Thistle are currently working on developing fibre from wool that can be used for everyday clothing as a means of providing biodegradable fibre options. Although wool is a highly produced textile in Scotland, it is most likely to be used for carpeting or upholstery than clothing, and much of it is disposed of on the farm site[129].

Internationally, many start-ups have developed fibre types made from food waste, which accounts for 32% of lifecycle carbon emissions from waste[130]. Many of these start-ups use waste from crops not native to the UK, such as oranges and pineapples. However, there are opportunities for creating fabric directly from hemp and flax or from their by-products (if main products are primarily used for food and cosmetic production). Flax was once grown widely in Scotland for linen production but halted in the 1950s for more profitable crops. Currently, there is only one linen mill remaining: Peter Greig & Co in Kirkcaldy[131]. Linen is one of the most sustainable fabric types. Safilin in France has established a process for creating fibres from flax by-products[132]. In Kinghorn, Fife, Fibrerevolution is working with the Soil Association and Homegrown Homespun on projects looking at developing local and zero-waste production of textiles from flax and nettles[133]. Investing in these types of crops could allow Scotland to develop a sustainable textile industry.

However, Mistra Future Fashions' Outlook Report has found that the differences in carbon emissions between producers can be more significant than differences between fibre types, highlighting the importance of implementing sustainable practices throughout the entire supply chain[134].

7.4.3 Supply Chain Management

7.4.3.1 Procurement and Investment

Organisations that procure textiles at a large-scale (e.g., uniforms) can support the move towards a circular textile industry by identifying materials and designs that can be easily reused, repaired, and have a reduced impact. The EU Strategy for Circular Textiles is currently developing a set of mandatory guidelines for green public procurement[135].

[129] UKFT Johnstons of Elgin explores new treatment for coarse Scottish wool
[130] Todeschini BV, Cortimiglia MN, Callegaro-de-Menezes D, Ghezzi A. Innovative and sustainable business models in the fashion industry: Entrepreneurial drivers, opportunities, and challenges. Bus Horiz. 2017;60(6):759-770. doi:10.1016/j.bushor.2017.07.003
[131] Creative Dundee. Flax. 2022.
[132] Safilin. Flax fibre, a fibre that is ecologically responsible by nature. 2021.
[133] Our Linen Stories. Towards a Fibreshed for Scotland. 2022.
[134] Mistra Future Fashion. The Outlook Report 2011-2019. 2019.
[135] European Commission – EU Strategy for Sustainable Textiles

7.4.4 Help Manage End-of-Life Processing

7.4.4.1 Established Textile Recycling Markets

Mature markets for end-of-life materials include using fibre shreds in car and mattress manufacturing processes. However, waste statistics on mattresses in Scotland (fewer than 1% of mattresses are collected for recycling[136]) demonstrate that this type of recycling would be a linear process. Therefore, fibre-to-fibre recycling would be preferable. Currently, technology allows for the efficient recycling of wool and cotton. Although wool is a large market in Scotland, there are currently no wool recycling facilities. In Prato, Italy, a well-established cashmere recycling facility separates wool by colour, to remove the need for recolouration, and spins them into new yarns and fabric[137]. This is a process that could potentially be integrated into existing wool production markets within Scotland.

7.4.4.2 Fibre-to-Fibre Processing

Used textiles could provide a useful resource in future. Whilst some start-ups have developed recycling techniques for fibre blends, these are not yet widely implemented. In Scotland, there are no currently operating fibre-to-fibre recycling plants. Without adequate recycling facilities in place, full circularity cannot be achieved.

Other countries' promising fibre-to-fibre processing facilities tackle common barriers to end-of-life textile recycling. Blend: Rewind in Sweden has developed technology to separate blended fibres and produce high-quality cotton, viscose, and polyester monomer fibres[138]. Swedish technology, which uses infrared to sort fabric by fibre type and colour, tackles barriers posed by a lack of knowledge of the types of materials[139]. Swedish scientists have developed techniques to overcome the barriers posed by shortened fibres by pre-treating garments with lubricant[140]. It could be worth considering whether there is scope to implement these types of facilities in Scotland.

7.4.4.3 Digital Product Passports and Recyclability

Introducing Digital Product Passports for textiles could assist with ensuring that products are designed sustainably as they provide transparency on the full life-cycle of a product, including manufacturing, transportation, and material content[141]. They will also allow recyclers to easily identify fibre types and sort them appropriately for recycling. Designing textiles to be recyclable at the end-of-life phase could divert an amount of waste from

[136] Zero Waste Scotland. Research Partnership aims to put mattress waste to bed. 2019.
[137] Asket. The Cashmere Recycling Facility. 2022.
[138] Mistra Future Fashion - Blend Re:wind, a new process that recycles both cotton and polyester is now demonstrated in Sweden
[139] SIPTex. How SIPTex functions. 2022.
[140] Lindström K, Sjöblom T, Persson A, Kadi N. Improving mechanical textile recycling by lubricant pre-treatment to mitigate length loss of fibers. Sustainability (Switzerland). 2020;12(20):1-13. doi:10.3390/su12208706
[141] Just Style Week in review: Digital product passport uptake soars as EU fine-tunes eco-fashion legislation

landfill. Whilst textile recycling facilities are not yet fully established, these passports could ease the process in future.

7.4.4.4 Household Textile Waste Collection

EU members have agreed to offer additional collection services for textile waste to households by 2025. Once this is implemented within Scotland, this could avoid textiles unnecessarily ending up in HRW, as currently, 89.3% of textile waste ends up in HRW.

8 Plastics Waste from Households

5.5% of Carbon Impact; 1.8% of Waste Tonnes

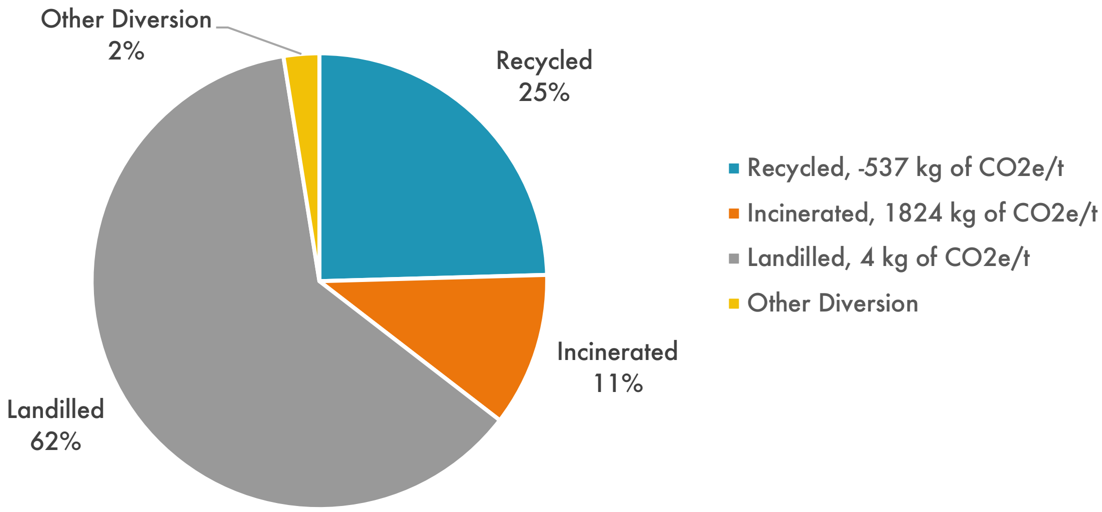
8.1 Analysis of Embodied vs. Disposal Emissions

As with most waste streams, the emissions embedded in the production of the products themselves by far outweigh the emissions resulting from waste treatment. The production of plastics consumed by households emits, on average, 3,185 kilogram (kg) of carbon dioxide equivalent (CO_2e) per tonne of material. The 202,816 tonnes of plastic waste generated by households in 2018 translates into roughly 646 million kg of CO_2e or 646 kilo-tonnes (kt) of CO_2e[142]. Multiple studies have suggested that the main driver of these impacts is the emissions caused by energy consumption in the production process[143][144][145].

The treatment of household plastics presents an interesting case study. Household plastic waste has been the focus of recycling initiatives since the 1980s. Incalculable resources have been mobilized to encourage the recycling of this specific waste stream. According to the best available 2018 SEPA data, only about 25% of this waste stream was recycled; the other 62% were landfilled, 11% incinerated, and 2% were treated by other means in 2018[146]. Ignoring the other well-known impacts, the carbon impacts of landfilling this waste are relatively small, emitting only 4 kg of CO_2e per tonne of waste. Incinerating these plastics, however, has one of the highest treatment impacts of any waste and treatment category, emitting 1,824 kg of CO_2e per tonne of waste. The recent Incineration Review has highlighted the need to divert plastic waste away from incineration facilities[147].

[142] Zero Waste Scotland- Carbon Metric 2018
[143] Agarski et al., 2019 Evaluation of the environmental impact of plastic cap production, packaging, and disposal
[144] Plastics Europe- The impact of plastics on life cycle energy consumption and greenhouse gas emissions in Europe
[145] Harding et al., 2007 Environmental analysis of plastic production processes: Comparing petroleum-based polypropylene and polyethylene with biologically-based poly–hydroxybutyric acid using life cycle analysis
[146] SEPA Waste From All Sources 2018
[147] Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review

Figure 9: Household Plastic Waste Treatment in Scotland



The modelling in this study finds the recycling of plastics to be a net carbon negative, as it offsets the need to produce more virgin plastic materials. Rebound effects are not considered by this approach, however, the emissions from the recovery and the recycling process are. In total, roughly 17% of the emissions from production are offset by the recycling process[148]. This balance between landfilling & incineration emissions and the offsets caused by recycling results in a net treatment impact of -14kt of CO_2e in 2018.

Taken together, Scotland's household plastic waste is estimated to be emitting 660 kt of CO_2e, 5.5% of Scotland's waste's total lifecycle carbon impacts. Hypothetically, if 100% of the plastic waste stream was recycled, the consumption of household plastics would still emit roughly 537 kt of CO_2e, which is only 19% less than is currently being emitted. This would reduce its proportion of total waste impacts down to 4.6%, leaving its rank of 6th biggest source of emissions unchanged. These results suggest solutions that reduce the consumption of any plastic products need to take priority over material recycling, especially given that the model does not incorporate the rebound effects of increased recycling.

8.2 Identification of Particular Product Streams/Industries

According to an upcoming waste composition report being undertaken by Zero Waste Scotland[149], plastic wastes account for approximately 12% of the household waste stream. Of this, two categories stand out: 1) pots, tubs, and trays made of dense plastics and 2) plastic film packaging. Each of these waste streams makes up 22% of the plastic waste being generated by households. Figure 10 shows the composition of household plastic

[148] Zero Waste Scotland- Carbon Metric 2018
[149] Zero Waste Scotland, Household Waste Composition Analysis 2023

wastes, and Figure 11 shows the amount of each waste category going to the correct recycling bin.

Figure 10: Kerbside Plastic Waste Composition

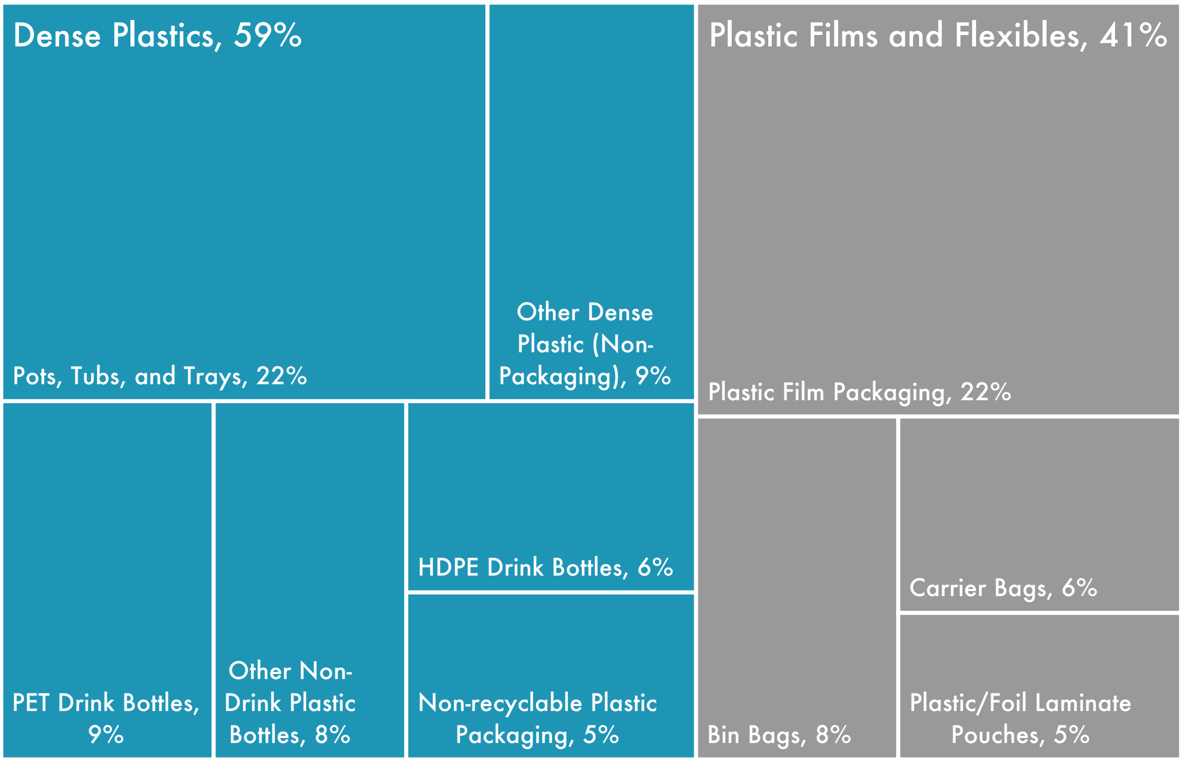
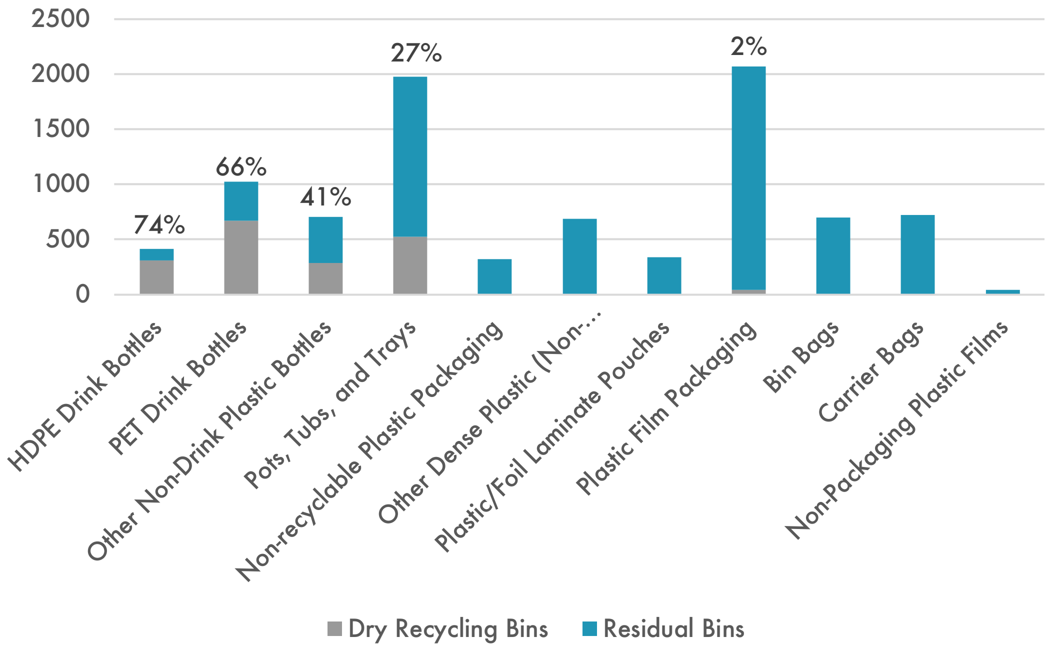


Figure 11: Kerbside Plastic Waste Tonnages



Of the two largest plastic waste streams, it is clear there is still a deficit in what actually makes it into the recycling bin. Only 27% of pots, tubs, & trays and 2% of plastic film packaging are being correctly recycled.

One-third of all plastic waste arisings are not going to recycling bins at all; and most of these are dense plastics. These numbers could partially reflect the difficulties in sorting and the recyclability of plastic films over dense plastic products. The high sorting rates for HDPE and PET bottles is encouraging, but these constitute only one-quarter of dense plastic waste and 15% of the total plastic waste stream.

The majority of these wastes – dense plastic pots, tubs, and trays – result from food packaging. for products like meats, mushrooms, tofu, yoghurts, and soft cheeses. Plastic films are commonly found on produce, cheeses, meats, bread, and grains, and mixed into cardboard boxes. Plastic films may be slightly overestimated in the data here because they are commonly contaminated with food waste, thus increasing their weight. However, this bias is not estimated to be large enough to undermine that this is a major waste stream that is disproportionately placed in residual waste bins.

It should be noted that the overall recycling rate reflected in this data is roughly 10% lower than what was applied in the core model of this study. We recognise that both our estimates and SEPA's estimates are based on limited sample sizes and, regardless, the discrepancy only results in a 3.3% difference in the overall carbon impact.

8.3 Discussion of Problems and Solutions

8.3.1 Eco-Design

At the point of design, producers of these products can minimize the amount of plastic needed, avoid difficult to recycle polymers, design packaging in a way that uses only one kind of plastic or so the different plastics are easily separable, avoid coloured plastics, and more accurately label their products. Some particularly difficult-to-recycle products are expanded polystyrene trays, dense plastic tubs, and plastic films for meat & dairy packaging. There are multiple eco-design guidance documents and tools available for producers to consult. The non-profit organization RECOUP partnered with the British Plastics Federation (a plastics trade association) to produce an eco-design guidance document, 'Recyclability by Design'[150], as well as an eco-design tool called PackScore[151]. The international waste management company Suez has also released eco-design guidance in the Suez Circpack Design for Recycling Guidelines[152].

[150] Recyclability by Design
[151] PackScore
[152] Suez Circpack Design for Recycling Guidelines

8.3.2 Improved Labelling

Recyclability labelling is currently voluntary in the UK[153]. Because of this, a variety of labelling schemes are used, many of which can be described as vague and misleading[154]. One of the most commonly used schemes is the on-pack recycling label scheme. This scheme generally only specifies if the product is widely recyclable in a local area, not often recyclable in a local area, and labels that appear as recyclable but in fine print specify that the consumer needs to take the waste to a certified collection point or search a database to check if the product can be recycled kerbside in their area (which can vary widely)[155]. In practice, this can result in resident uncertainty about if a product or plastic-type is recyclable within their municipality. Furthermore, even if these databases were commonly used, the databases often have vague product descriptions that do not easily match up with reality[156]. If a product cannot be recycled kerbside, recycling depends on consumers individually collecting, storing, and transporting their plastic waste to a specific collection point or recycling centre.

It would be valuable to waste managers if the labelling of plastic products was standardized and made universal since the current voluntary labelling schemes vary in design and the information provided to consumers is often confusing[157][158]. Future labelling should include plastic resin codes to assist material reprocessing facilities (MRF). In addition, the distinction between what can be recycled kerbside and what needs to go to a recycling centre should be made clearer for consumers[159]. Relying on individuals to take action like searching databases and collecting & transporting waste to collection centres is not sufficient to meet national targets. Therefore, these would be unreliable long-term solutions.

8.3.3 Recycling Capacity

Interviews with waste management experts have revealed that the wide variations in recycling capacity across municipalities are not only attributable to the increased collection costs in rural areas but also widespread underinvestment, as there are large differences across urban and suburban areas as well[160]. Data on collection and treatment is scarce in Scotland; while comprehensive data collection is starting to be implemented by the largest commercial waste managers, smaller firms see it as unnecessary and only collect what they are legally required to report[161].

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153 GWP Group – Recycling Symbols on Packaging
154 WRAP- On-pack labelling and citizen recycling behaviour
155 Ibid.
156 Recycle Now
157 WRAP- On-pack labelling and citizen recycling behavior
158 Ibid.
159 Oskamp et al., 1991 - Factors Influencing Household Recycling Behavior
160 ZWS confidential interviews with waste management representatives. 2021/2022
161 Ibid.

In 2018 Scotland was a net exporter of plastic waste, exporting a total of 73,968 tonnes in 2018[162]. Subtracting imports, Scotland had an overall trade balance of 36,113 tonnes in that same year. Roughly 89% of this waste was exported south to the rest of the United Kingdom[163]. While it is economical for municipalities along the central belt to export south of the border, since their waste is not helping centrally located waste managers reach the economies of scale they need for profitability, this dependence on cross-border reprocessing is exacerbating logistics issues for the waste management in the north of Scotland[164].

Partially due to this infrastructure deficit between the north and south of Scotland, the recent Incineration Review undertaken by the Scottish government has revealed that much of the potentially recyclable plastics are being landfilled or sent to incineration facilities instead of being recycled[165][166]. Along with this, energy-from-waste facilities has an incentive to burn plastic wastes because of their high calorific value[167][168]. Separating and diverting these waste streams towards recycling centres could help Scotland lower the carbon footprint associated with these wastes. For municipalities looking to increase their recycling capacity, consulting guidance given by the International Standards Organization[169] and the Code of Practice for the Scottish Charter for Household Recycling[170] would be good first steps.

8.3.4 Soft Plastics, Films, and Chemical Recycling

One of the largest plastic waste streams, plastic film packaging, is almost never recyclable in Scotland. There is virtually no capacity for the recycling of 'soft plastics' domestically, and even if there was, these films are often too contaminated with food waste and other waste to be treated[171][172]. The composition of plastic products is the main determinant of their recyclability. If polystyrene, expanded polystyrene, coloured plastics, or multiple plastics on the same product are used; it can be difficult or impractical to recycle these waste streams.

In waste processing facilities, mechanical recycling is by far the most prevalent recycling method; however, this technology has difficulty recycling waste streams like plastic films and other soft plastics as these are not easily separable and cannot be melted for reuse. To overcome this recycling gap, the development and adoption of chemical recycling technologies such as Purification, Depolymerisation, Pyrolysis, and Gasification may offer

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162 SEPA Waste from All Sources 2018
163 Ibid.
164 ZWS confidential interviews with waste management representatives. 2021/2022
165 Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review
166 SEPA Official Statistics Publication for Scotland - Household waste summary, waste landfilled, waste incinerated (Jan-Dec 2018)
167 ZWS confidential interviews with waste management representatives. 2021/2022
168 Stop, Sort, Burn, Bury - incineration in the waste hierarchy: independent review
169 ISO/TR 23891:2020 Plastics — Recycling and recovery — Necessity of standards
170 Charter for Household Recycling
171 British Plastics Federation- Plastics Recycling
172 ZWS The composition of household waste at the kerbside in 2014-15 (2017)

a valuable approach[173]. However, there are implications for adopting or changing the approach. First, mechanical recycling methods are currently the more cost-effective option for recyclers, meaning there could be challenges in meeting capacity[174]. Second, there is evidence that chemical recycling methods are much more carbon-intensive than mechanical recycling methods[175]. Current recommendations, therefore, advise ongoing use of mechanical methods over chemical ones[176][177].

8.3.5 Bioplastics and Degradable Plastics

Bio-based plastics are made from renewable resources like vegetable oils, wood cellulose, sugars and starches. Sometimes chemical treatment is needed to turn natural resources into useable plastics polymers; these should be referred to as synthetic bio-based plastics. As these plastics are made from renewable resources, it is often assumed that they have a smaller environmental footprint than fossil fuel-based plastics[178]; however, there are conflicting opinions on this[179][180][181]. There is also a misconception that bio-based plastics are inherently biodegradable, which is often conflated with being compostable[182]. This is not necessarily true for bioplastics and even if it was, current waste management infrastructure is poorly suited to handle degradable plastic materials[183].

Biodegradability is defined as the ability to be broken down into water, biomass, and carbon dioxide[184]. Compostability refers to the ability to break down to a certain level while mixed with other biomass while producing limited toxins in the compost pile[185]. Most biodegradable products will not properly break down if disposed of into the environment or added to a home compost pile. Many require specific industrial and chemical treatment processes to degrade, and if landfilled or incinerated, as is common, they will have a greater carbon impact than fossil fuel-based plastics[186]. Compostables are similar; and often will only decompose if under certain conditions, only available in treatment facilities.

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173 British Plastics Federation: Chemical Recycling Processes
174 Achieving net-zero greenhouse gas emission plastics by a circular carbon economy (Raoul Meys et al., 2021)
175 Zero Waste Europe - Climate impact of pyrolysis of waste plastic packaging in comparison with reuse and mechanical recycling
176 CE Delft- Exploration of chemical recycling. Update 2019
177 CE Delft- Chemical recycling and its CO_2 reduction potential
178 WRAP UK Plastics Pact- Considerations for Compostable Plastic Packaging
179 Plastics Europe- The impact of plastics on life cycle energy consumption and greenhouse gas emissions in Europe
180 Narodoslawsky et al., 2015 LCA of PHA Production – Identifying the Ecological Potential of Bio-plastic
181 Harding et al., 2007 Environmental analysis of plastic production processes: Comparing petroleum-based polypropylene and polyethylene with biologically-based poly–hydroxybutyric acid using life cycle analysis
182 Zero Waste Scotland - What's the problem with plastic? The answer is more complicated than you think…
183 WRAP UK Plastics Pact- Considerations for Compostable Plastic Packaging
184 Ibid.
185 British Plastics Federation- Polymer: Bio-Based/Degradables
186 WRAP UK Plastics Pact- Considerations for Compostable Plastic Packaging

There is currently no UK, EU, or international standard for what can be defined as compostable at home[187]; independent certification schemes exist but have not been widely adopted[188][189]. If these bio-degradable and compostable plastics are landfilled, they often release methane and other greenhouse gasses, giving them a worse carbon impact than fossil fuel-based plastics[190]. Labelling these plastics as biodegradable and compostable will also likely lead consumers to believe that these plastics can be disposed of in the natural environment.

The last of the degradable plastics are referred to as oxo-degradable plastics. These are a fossil fuel-based subset of degradable plastics that, if treated with chemical additives, are also capable of breaking down. This treatment process also requires a specialized industrial facility, so separation of these oxo-degradable plastics at recycling facilities is also required.

The need to separate out the degradable plastics and treat them separately in specialized ways is a problem for waste managers[191]. If they are mixed in with recyclable plastics, they can ruin the structural integrity of long-lasting products made with recycled plastics[192]. These degradable plastics are often indistinguishable from other plastics, and suspicion that a batch of recyclable plastics contains degradable materials is enough for waste managers to dispose of an entire batch of potentially recyclable waste[193]. The capacity for waste managers to identify, separate, treat, and store these different degradable plastics is currently not in place in the UK recycling system.

Aside from these considerations, it is currently unclear the degree to which these plastics break down and the effects they can have on the environment[194]. There is concern that these degradable plastics are introducing more microplastics into the environment. It is for these reasons that eco-design guides generally recommend avoiding the use of degradable plastics altogether[195][196][197].

8.3.6 Extended Producer Responsibility

Extended producer responsibility (EPR) schemes are one solution to incentivising better eco-design in products and packaging. EPR schemes attempt to transfer the costs of waste collection and treatment to the producers to incentivise them to design products with these end-of-life stages in mind. The United Kingdom has had a packaging EPR scheme since

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[187] British Plastics Federation- Packaging Waste Directive & Compostable Packaging
[188] Vincotte
[189] Renewable Energy Assurance Ltd.
[190] WRAP- Compostable Plastic Packaging Guidance
[191] British Plastics Federation- Biobased, biodegradable and degradable plastics (as a solution for littering)
[192] Ibid.
[193] WRAP UK Plastics Pact- Considerations for Compostable Plastic Packaging
[194] European Commission- The impact of the use of "oxo-degradable" plastic on the environment
[195] British Plastics Federation- Recyclability by Design
[196] WRAP UK Plastics Pact- Considerations for Compostable Plastic Packaging
[197] Suez Circpack Design for Recycling Guidelines

1997[198]. The modern iteration of this scheme is known as the Producer Responsibility Obligations (Packaging Waste) Regulations[199].

The EPR scheme in the UK is operated through a system of plastic packaging manufacturers purchasing what is called a packaging recovery note (PRN) from plastic recyclers as proof that they are meeting their recycling obligations. While this marketized system provides some incentive for both manufacturers and recyclers to invent and adopt new technologies, the equilibrium prices of this market are ultimately determined by the technology currently available, the price of fossil fuels, and the current recycling obligations imposed on manufacturers. Therefore, the equilibrium prices may not be enough to meet national targets or provide enough incentive for companies to invest in new technologies if the price of fossil fuels inputs and the recycling obligations imposed on manufacturers are too low. Manufacturers also have a counterincentive to wait for other firms to invest in new technologies and increase their recycled content, thus lowering the prices in the overall PRN market.

Of all the PRN markets, the market for plastics PRNs has been the most volatile. In 2018 prices more than tripled before nearly halving in the following year. Before this, prices had been rising more steadily for the preceding decade[200]. The degree to which these higher prices will affect technology development remains to be seen. However, this volatility makes it difficult for manufacturers and recyclers to plan ahead and make efficient investment decisions. Regulating this market with price ceilings and price floors in a way similar to carbon markets may lead to more socially optimal outcomes[201].

While there is a market mechanism in place, the market equilibrium recycling rates are exogenously determined by policymakers. If recycling rates are inadequately progressing to meet national targets, it is recommended that policymakers explore options to alter: manufacturers recycling obligations, the price of fossil fuel inputs to manufacturers, or the cost of developing and deploying new manufacturing & waste management technologies.

8.3.7 Deposit Return Schemes

Deposit Return Schemes (DRS) are one form EPR schemes can take. DRS entails charging an additional fee/deposit upon the purchase of a product that will be returned to the consumer when the product's associated waste is returned at a certified collection point. This provides a monetary incentive for consumers to properly dispose of their waste. These schemes are most commonly applied to plastic bottles. In 2020, the Scottish parliament passed legislation laying the framework for a future deposit return scheme to be applied to plastic drink bottles[202]. The scheme is expected to begin on a voluntary basis in August

[198] UK packaging producer responsibility system reform: partial equality impact assessment
[199] The Producer Responsibility Obligations (Packaging Waste) Regulations 2007
[200] DEFRA Impact Assessment on Packaging EPR
[201] Richstein, J.C., Chappin, E.J. and de Vries, L.J., 2014. Cross-border electricity market effects due to price caps in an emission trading system: An agent-based approach. Energy Policy, 71, pp.139-158.
[202] The Deposit and Return Scheme for Scotland Regulations 2020

2023. Upon implementation, it will be the first DRS scheme in the UK[203]. Zero Waste Scotland's Ditching Disposables projects are currently promoting the adoption of deposit return schemes for single use plastics in Scottish businesses[204].

As of April 2022, UK Plastic Packaging manufacturers and importers will be subject to a tax on any products that do not contain at least 30% recycled plastics. This tax is expected to increase the use of recycled plastic in packaging by about 40%, equating to around 200,000 tonnes of carbon savings in 2022 across the UK[205].

8.3.8 Single Use Plastics Ban

In Scotland, the single-use plastic ban came into force in June 2022. The list of products this applies to includes: "plastic cutlery, plates, straws, beverage stirrers and balloon sticks; food containers made of expanded polystyrene; and cups and other beverage containers made of expanded polystyrene, including their covers and lids."[206]. This ban keeps Scotland aligned with EU policy, as they also have a similar single-use plastics ban applied to similar products [207]. The EU Single Use Plastics Directive included a ban on oxo-degradable plastics, whereas these were not included in the final version of the Scottish single-use plastics ban.

8.3.9 UK Plastics Pact

Voluntary commitments to support plastic recycling have been made by various private sector organizations and local authorities. The UK Plastics Pact has over 120 private sector member organizations with a goal to reach the following targets by 2025[208]:

1. Eliminate problematic or unnecessary single-use packaging through redesign, innovation or alternative (reuse) delivery model
2. 100% of plastic packaging to be reusable, recyclable or compostable
3. 70% of plastics packaging effectively recycled or composted
4. 30% average recycled content across all plastic packaging

While these voluntary commitments are admirable, 2018 halfway point progress reports indicate that efforts will need to significantly increase if they are to meet these goals[209].

8.3.10 Consumption Reduction

To address the emissions caused by plastic food packaging products, consumption reduction will be an important contributor. There are many challenges to reducing plastic

[203] Zero Waste Scotland- Deposit Return Scheme
[204] Zero Waste Scotland - Ground-breaking 'Ditching Disposables' pilot will see Scottish businesses break up with single-use items for good
[205] Introduction of Plastic Packaging Tax from April 2022
[206] Scottish Government- Single Use Plastics Ban
[207] EU Single-Use Plastics Directive
[208] UK Plastics Pact
[209] UK Plastics Pact Progress Against Targets

consumption in Scotland. These materials are virtually omnipresent and fill many roles that cannot easily substituted. At the consumer level, there are relatively few opportunities for consumers to avoid plastic films and plastic packaging in food products. While fruits and vegetables can be sold loose, most products are sold in packaging made of dense plastics, plastic films, or a combination of paper and plastic. Few stores accommodate the use of reusable containers for products other than the occasional dispenser of nuts and cereals. France has recently introduced an outright ban on the use of plastic packaging for 30 fruit and vegetable products (put citation here as it refers to France's example)[210].

[210] BBC- French ban on plastic packaging for fruit and vegetables begins

9 Areas for Further Work

9.1 General

This analysis has considered the whole-lifecycle carbon impacts of five key waste streams generated in Scotland. In each of the five highest carbon impact sectoral waste categories, the embodied impacts of the waste far outweigh the impacts of waste disposal. Therefore, the carbon impacts outlined in this report largely represent the emissions caused in the production and transportation of the products we consume. This analysis has attempted to identify 'priority sectors' in terms of carbon emissions from waste, however, limitations in the resolution of the data available have meant that the sectors identified have been very broad, as have the waste categories associated with them. The 'Household' sector is responsible for three of the top five sector/waste category combinations and almost half of all carbon impacts associated with waste, reflective of households being at the end of the 'linear economy' material flows. Reducing these impacts cannot be achieved solely by the actions of households/consumers. Rather, it requires actions across the supply chain and the development of circular economy practices that would design out waste. The analysis of plastic waste from the household sector in this report shows that the majority of this arises from food packaging, and therefore, efforts to reduce this requires action from packaging producers, food manufacturers, retailers, as well as householders.

A full assessment of how various sectors in the economy can contribute to addressing the carbon emissions challenge would need to look beyond where waste is generated. Instead, consideration of how each sector can reduce resource demand and facilitate reduced resource demand downstream through the adoption of circular economy principles would be valuable. The development of a circular economy will require symbiosis across sectors, as demonstrated in the Serial Utilisation of Whisky Co-Products project highlighted in this study[211]. Therefore, a fuller understanding of how each sector can contribute requires consideration of interactions between and across sectors rather than each in isolation. Taking a systems approach by facilitating collaboration across sectors involved in product lifecycles could allow for the most effective reduction in emissions across the different sectors. To ensure a smooth and just transition, various impact assessments need to be undertaken for the solutions proposed above.

9.2 Food Waste

A priority for this area, as already outlined by initiatives such as Courtauld 2030 and the Scottish Government Food Waste Reduction Action Plan, is better monitoring and reporting of food waste. This report has identified three key reasons why this is important in addressing carbon emissions from this sector:

1. Data is required to help support the development of a circular economy. The issue of food waste is part of the 'biological cycle' in the Ellen MacArthur Foundation's

[211] IBioIC, 2022. Serial Utilisation of Whisky Co-Products

butterfly diagram[212]. Maximum value and carbon emissions benefit from the utilisation of food waste is achieved through 'cascades' in this model - which refers to the use of food waste to produce other materials, new food products or animal feed. The development of processes and businesses to do this requires a good understanding of the quantities, quality, and composition of food waste.

2. Data is required to identify opportunities for waste reduction. For all stakeholders (i.e., householders, manufacturers, retailers, caterers) to minimise avoidable food waste, an essential starting point is monitoring what is wasted and why.
3. Data is required to support accurate carbon impact assessments. To properly assess the carbon impacts of 'food waste', a proper understanding of quantity, composition and whether it is considered avoidable or unavoidable (i.e., co or by-product) is needed.

Zero Waste Scotland carried out unpublished research in 2017 the carbon impacts of the actions set out in the FWRAP required to reduce food waste by 33% by 2025. Since then, the baseline has been updated, and therefore it would be beneficial to carry out a renewed analysis, taking into account the issues highlighted in this study in quantifying the carbon impacts of unavoidable food wastes in the food and drink manufacturing sector based on carbon factors for finished food products. In addition, where initiatives are already underway to develop products that utilise food waste or by-products as raw materials, consequential LCA studies would help to understand potential carbon benefits.

9.3 Textile Waste

9.3.1 Impact of Reshoring Textile Production and Recycling Processes

The technology to create sustainable textiles and textile recycling technology is still in its infancy. Whilst several fibres have the potential of becoming circular within Scotland (e.g., wool, linen), further research is required on the scalability of these sectors and the potential carbon impact of reshoring production. Comparing the carbon impacts of sustainable fabric types in Scotland could provide the basis for priority investment areas. Linen and wool production are already established industries, but the other fabric types mentioned within this report also have potential. There is also the possibility of researching opportunities for integrating the technology discussed within this paper in Scotland or collaborating with international facilities to establish circular processes.

9.3.2 Waste Data within Scotland

More data is needed to understand the full extent of textile waste in Scotland. The figures within this study use an estimate based on WRAP's composition of HRW from a report in 2017 using data from 2012. Anecdotal evidence indicates that the amount of textile waste in HRW increased significantly throughout the pandemic. Additionally, evidence suggests that clothing consumption has increased over the past few years, indicating that this could subsequently drive higher levels of waste without established recycling and reuse processes in place.

[212] Ellen Macarthur Foundation – The butterfly diagram: visualising the circular economy

Further research on the specific use of end-of-life textiles and fibre types in Scotland is essential to understanding the potential for reuse. The data used for this study also does not include textile waste considered "bulky waste" in Scotland (i.e., mattresses, carpets, and soft furnishings), which significantly contributes to levels of textile waste and have meagre rates of recycling. ZWS has conducted research on the recycling of mattresses. Classifying the textile components from these more complex items alongside other textile waste would create a more realistic picture of the true extent of textile waste in Scotland and, thus, the potential material resources for recycled textiles.

9.3.3 Reducing Consumption

Interventions are required to increase public awareness of consumption reduction of textiles. Many of the interventions discussed within this study occurred in Europe or Southern England. Whilst encouraging second-hand use is vital to reducing carbon impacts, it would be valuable to understand how public interventions could facilitate overall consumption reduction of textiles and lessen the requirement for frequent purchases.

9.4 Household Plastic Waste

Given the prevalence of plastic packaging in so many consumer products, it is likely that any added costs associated with this product have the potential to contribute to inflation. More research needs to be done on the extent to which degradable plastics break down into the environment and their effects on human health and ecosystem functioning. Much of the use of degradable plastics has been proposed for the agriculture and food sectors, so these considerations are especially important for preventing microplastics from contaminating our food and water.

More research needs to be done into the scalability of chemical recycling processes to address plastic film waste in Scotland. These technologies are in the primordial stages and have yet to meet the economies of scale required for mass proliferation. For these recycling technologies, defining what quality of plastic material inputs are needed, the quality of the recycled plastics produced, and what production levels are needed for profitability is essential for the further development of these technologies.

9.5 Conclusion

This research used publicly available waste data to identify 'priority sectors' based upon carbon emissions from waste. In doing so, we have highlighted some of the limitations of using this data for this purpose. We have replicated previous research that has identified food, textile and plastic waste as priorities, and found that a large share of impacts (36.3%) are associated with waste disposed by households. Households are at the end of the flow of materials in the linear economy and, therefore, it is not surprising that impacts accumulate here. As such, efforts to reduce carbon emissions in these priority sectors cannot be focussed solely on households, and improved waste composition analysis could assist in identifying specific products contributing to these waste streams within households.

For example, analysis of household plastic waste shows that the majority of this is associated with the food supply chain.

Our research emphasises the fact that the majority of emissions are embedded in the production of the goods themselves. Therefore, reducing consumption represents the biggest opportunity for mitigating carbon emissions, whilst improving recycling rates will have a limited impact. Opportunities for reducing consumption vary across the waste categories identified in this report. For food, efforts focus on efficient use of resources to minimise wastage. For textiles, reducing demand and making things last are where the biggest opportunities lie. For plastics, opportunities are limited for householders, and the challenge lies largely with food producers and retailers to reduce single use plastics.

Where waste cannot be avoided, effective valorisation of this as a resource for use in a circular economy should be the focus. This research has highlighted opportunities to maximise value from waste in the bioeconomy, alongside opportunities for improving textile and plastics recycling. The goal of this is to reduce waste by recognising it as a valuable resource, but to fully capture the carbon benefits of these actions requires analysis that goes beyond the waste sector, to understand how waste as a resource reduces the impacts of the sector in which it is utilised.

10 Appendices

10.1 Appendix 1. SEPA Waste Generator SIC Concordance

NACE	SIC 2007
Agriculture Forestry Fishing	A
Mining & quarrying (includes oil & gas extraction)	B
Food & drink manufacture	C10-C12
Manufacturing of wood products	C16
Chemical manufacture	C20-C22
Other manufacturing	C13-15, C17-19, C23-C33
Power industry	D
Water industry	E36_E37_E39
Waste management	E38
Construction	F
Commerce	G-X

10.2 Appendix 2. EWC-Stat Categories

Waste category
Acid, alkaline or saline wastes
Animal and mixed food waste
Animal faeces, urine and manure
Batteries and accumulators wastes
Chemical wastes
Combustion wastes
Common sludges
Discarded equipment (excluding discarded vehicles, batteries and accumulators wastes)
Discarded vehicles
Dredging spoils
Glass wastes
Health care and biological wastes
Household and similar wastes
Industrial effluent sludges
Metallic wastes, ferrous
Metallic wastes, mixed ferrous and non-ferrous
Metallic wastes, non-ferrous
Mineral waste from construction and demolition
Mineral wastes from waste treatment and stabilised wastes
Mixed and undifferentiated materials
Other mineral wastes
Paper and cardboard wastes
Plastic wastes
Rubber wastes
Sludges and liquid wastes from waste treatment
Soils
Sorting residues
Spent solvents
Textile wastes
Used oils
Vegetal wastes
Waste containing PCB
Wood wastes


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