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CIRCULAR ECONOMY
FOR LAND AND WASTE MANAGEMENT

4.- Solid Waste Streams and Material Flows

Reading: Regional waste composition data

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The composition of household waste at the kerbside in 2021-23

Methodology Overview

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1 Introduction

Zero Waste Scotland has recently completed a waste composition analysis programme, which was carried out over the period 2021-23. The programme consisted of a series of waste composition analysis projects taking place at fifteen Scottish local authorities. The aim of this programme was to use data from a consistent and high-quality set of local authority studies in order to produce both:

1. annual estimates of waste composition for each of the local authorities participating in the programme; and to subsequently
2. use this data to generate updated national waste composition estimates of household waste collected at the kerbside.

It should be highlighted at this stage that the analysis carried out to produce the most recent national composition estimates of household collected kerbside waste excludes household waste collected at non-kerbside locations, such as recycling points and household waste recycling centres (HWRC). For this reason, overall household recycling performance should not be inferred solely from the kerbside analysis presented in the summary of findings report alone. What is presented in the summary of findings report was derived to answer the following key questions:

- how much is collected at the kerbside in total?
- what is thrown away in the residual waste bin?
- what are the changes in what we throw away in the residual waste bin since 2014-15?
- how many items that could be recycled at the kerbside, are actually recycled?
- how common is it for the wrong items to end up in recycling collections?

The findings that have been produced following completion of the programme, provide a timely update on the national composition of household kerbside waste in Scotland, as the last time a similar study was conducted by Zero Waste Scotland was in 2013-15[i].

This document provides a deeper insight into the methodology that was used to obtain the updated estimates, with a focus on describing the analytical approaches adopted. In addition to this report, three accompanying documents have been created, which include: an Excel based dataset containing a selection of key programme findings; a set of frequently asked questions; and finally, a summary report outlining the actual findings from the waste composition analysis programme. All of the documents outlined above can be found at the Zero Waste Scotland website.[ii]

A summary overview of the structure of this report is presented below, including a description of the objectives established for achieving the aim of this work.

1.1 Analysis Objectives

The following objectives were identified in order to ensure the production of updated national composition estimates for household waste collected at the kerbside:

- develop a systematic approach to analyse the composition data, create local authority groupings and fill data gaps;
- identify factors and input variables influencing local authority groupings;
- design an analytical model that has functionality to incorporate sample data to calculate national composition estimates; and can import WasteDataFlow data for multiple years.

1.2 Structure of this document

An overview of the waste composition analysis programme carried in 2021-23 is provided in section 2. In addition to outlining the key benefits of the programme, further information is provided in section 2.1 that explains the key requirements of the waste composition analysis methodological guidance utilised by local authorities and waste composition analysis contractors when completing studies. The list of local authorities that participated in the programme is then provided in section 2.2, with subsequent analysis of the level of waste coverage attributed to each sampled authority.
In order to carry out the analysis necessary to produce the national waste composition estimates, datasets, in addition to the data gathered from the sampled local authorities, are required. A description of the datasets used are described in sections 3 and 5, including those for mixed food and garden waste; and for the data reported by local authorities on WasteDataFlow for the required period. Although not incorporated in the final analysis, section 4 provides an insight into further data collected during the programme in relation to food waste in packaging; and residual waste composition at household waste recycling centres (HWRC). The latter of these datasets, as stated in the introduction, was not used in producing the national composition estimates.

Following an overview of the datasets utilised, section 6 describes the methodology that was used to generate the national kerbside composition estimates. This includes information on how sampled local authority data and supporting datasets (including data reported on WasteDataFlow) were used in the final analysis.

Finally, a series of lessons learned from the programme are described in section 7. Several key areas are addressed including (but not exhaustive) the value of a waste composition analysis programme, the required consistency and quality of data used in the final analysis, and the assumptions applied when developing a methodology.

2 Waste composition analysis fund programme 2021-23

During the period 2021-23, Zero Waste Scotland delivered a funded waste composition analysis (WCA) programme, designed to support local authorities to conduct waste composition analysis of household waste collected at the kerbside. The results from individual studies provide local authorities with the opportunity to assess the current performance of their services (e.g., capture of recyclable materials, levels of contamination, etc.), evaluate the success of pilot projects, and inform the development of new kerbside services.

The programme also enabled further key benefits to be achieved, including:

- the ongoing development of the comprehensive guidance[iii] used during the previous waste composition analysis conducted in 2013-15;
- development of dedicated project management experience to oversee individual project delivery; and
- creation of a comprehensive, standardised and quality assured dataset on completion of each study.

Following an initial call for interest, a total of fifteen local authorities were supported to carry out waste composition analysis studies over the duration of the programme. Each of the authorities that completed the study in alignment with the Zero Waste Scotland waste composition analysis methodological guidance was able to claim available grant funding to commission their individual studies.

2.1 Summary of waste composition analysis methodology guidance

A key aspect of the Zero Waste Scotland waste composition analysis programme was the continued use of a standardised methodological approach for conducting waste composition analysis. Due to the scale and complexity of local authority waste collection services influencing the sampling of waste, compromise is always required between several factors that impact study costs and the variability in waste composition estimates. The nature and quantity of waste set out at the kerbside is also subject to factors such as householder participation, service provision, socio-economic demographics and materials used in the household. A comprehensively designed study, therefore, requires an approach that accounts for this range of factors influencing effectiveness and efficiency of studies; minimisation of variation in data collected; and improvement of confidence in study findings.

This approach has been outlined in the methodology guidance document

prepared for this programme by Zero Waste Scotland[iv]. As was the case during the 2013-15 waste composition analysis programme, the most recent methodology guidance identifies a minimum set of requirements that were to be followed by local authorities during each funded study. For each local authority study, the requirements were as follows:

- compositional analysis of both the residual waste and recycling bins (including co-mingled and less co-mingled services);
- use of the Office of National Statistics (ONS) output area classification, alongside local authority profile data (e.g., number of households and waste service characteristics) to create a waste sampling regime that is practicable and representative of the whole local authority area;
- development of a sampling regime that incorporates housing type (own-door or multiple occupancy properties, i.e., flats), or area type, and a socio-economic dimension;
- each stratum to be represented by a minimum street block sample on a quota basis, with a sample size of 50 households per street block. (N.B. a street block is defined as a group of households with broadly similar characteristics.);
- waste composition analysis carried out over a single phase of fieldwork during either February to June, or September to November;
- use of a standard material category list during physical sorting of all waste collected;
- sorting of all waste collected[v];
- collection of the residual waste stream first in the collection cycle; and recycling waste stream collected after the residual, according to collection cycle. recycling is only collected only from the households where residual was collected. If recycling bin was not presented by one of these households, this was marked as absent during the recording of the set-out rate of recycling bins.

Further detailed information on the specific methodological requirements, such as project management and health and safety requirements, can be found in the methodology guidance document developed for the programme. The following sections highlight at what points divergence from the guidance occurred, when deciding on the inclusion of individual datasets in final analysis.

2.2 Waste composition datasets used in final analysis

In total, datasets from fifteen local authorities participating in the programme were used in the final analysis to produce new national waste composition estimates. For each individual local authority study carried out, a raw dataset and scaled annual estimates of whole local authority kerbside composition was produced. The creation of comprehensive, standardised datasets of kerbside composition for each local authority enabled the subsequent analysis required for a

national-level study. Table 1 summarises the local authority waste composition studies, including the waste streams analysed, that were used in the final analysis.

In addition to the data collected from each of the local authority waste composition studies, additional supporting datasets were required to enable secondary analysis informing the production of updated national waste composition estimates. These included data from:

- waste composition analysis from seven studies of kerbside mixed food and garden waste collections carried out during 2011 to 2014; and
- waste tonnages reported as collected at the kerbside by all thirty-two local authorities on WasteDataFlow in 2021.

Table 1: Summary of local authority waste composition studies used in final analysis.

Local Authority	Sampling date	Waste streams sampled
Aberdeenshire Council	Jun 2022	Residual
Angus Council	Nov 2022	Residual Co-mingled recycling (with Glass)
Dumfries and Galloway Council	Jun 2022	Residual Plastics, Metals, and Cartons Paper and Card
East Dunbartonshire Council	Nov 2022	Residual Paper and Card Plastics, Metals, and Glass
East Lothian Council	Oct 2022	Residual Co-mingled Plastics, Metals, and Cartons Paper and Card
Edinburgh, City of	Nov 2022	Residual Co-mingled recycling (without Glass)
Fife Council	Mar 2022	Residual Cans and Plastics
Glasgow City Council	Feb 2022	Residual Co-mingled recycling (without Glass)
Highland Council	Nov 2022	Residual Co-mingled recycling (without Glass)

North Ayrshire Council	Jun 2022	Residual Co-mingled Plastics, Metals, and Glass Paper and Card
North Lanarkshire Council	Oct 2021	Residual Co-mingled Plastics, Metals, and Glass Paper and Card
Perth and Kinross Council (DMR)	May 2022	Residual Co-mingled recycling (without Glass)
Renfrewshire Council	Mar 2022	Residual Co-mingled Plastics, Metals, and Glass Paper and Card
Scottish Borders Council	Nov 2022	Residual Co-mingled recycling (without Glass)
South Ayrshire Council	Feb 2022	Residual Co-mingled Plastics, Metals, and Cartons

The final analysis used data from a second phase of kerbside waste composition analysis provided by Dumfries and Galloway council. This study was conducted out with the Zero Waste Scotland waste composition analysis funded programme, yet it continued to adopt the standard set of waste composition analysis requirements, as set out in the Zero Waste Scotland guidance methodology; and sampled waste from the same households identified during the first phase of Zero Waste Scotland funded waste composition analysis. The dataset produced was deemed eligible for onward use in production of local authority annual waste estimates and subsequently analysis for the national waste estimates analysis.

The following subsections provide an overview of the level of coverage provided by the fifteen kerbside composition studies used in the final analysis, broken down by several variables, including:

- the number of sampling phases;
- sampling dates;
- waste streams sampled;
- local authority national share of multiple deprivation; and
- quantity of kerbside residual waste.

2.2.1 Coverage by the number of sampling phases conducted

During the last waste composition analysis programme, a minimum of two phases of waste sampling was recommended per project, in order to account for seasonal variation shown by particular materials. These include garden and food waste, drinks containers, and waste arising from construction projects at home. Evidence gathered during the 2014-15 waste composition analysis programme was used to assess the efficacy of conducting two phases of waste composition analysis per local authority. Table 2 below presents a sample of the evidence collected, which shows that there is relatively little seasonal variation in the quantity of residual waste arisings analysed. There are several factors, apart from seasonality, that influence waste composition and variation between local authorities, such as waste collection service characteristics, and the demographics of households using the waste collection services provided.

Table 2: Quantity of residual waste analysed (kg/household/week) during two separate sampling phases of waste composition analysis conducted during the 2014-15 programme.

Local Authority	February	March	May	June	September	October	November
Angus Council		5.0					4.6
East Ayrshire Council		6.9		7.6			
Edinburgh Council, City of		5.9					6.8
Glasgow City Council		8.9					10.4
Highland Council				9.9		9.0	
Midlothian Council	9.7				9.1		
Perth & Kinross Council		7.5					7.0
South Ayrshire Council		9.1					9.6
South Lanarkshire			12.0				10.8

The most recent Zero Waste Scotland methodological guidance was updated, based on these findings, and recommended that a minimum of one phase of sampling should be carried out either in spring/ early summer or during the autumn/ early winter period. The benefits identified for adopting this approach included increased budget, which, consequently, created increased financial capacity to complete a greater number of local authority studies.

This recommended guidance was applied and met during the 2021-23 waste composition analysis programme, by all fifteen of the local authority studies included in final analysis. Throughout the programme, a key consideration when planning local authority projects was to identify key dates and particular times in the year where significant events taking place may have influenced waste arisings at the kerbside, e.g., school holidays, the Christmas and New Year period, and Halloween.
In total, seven local authority studies were carried out in the late autumn/ early winter period, with the remaining eight local authorities conducting waste composition analysis in spring/ early summer. The latest that a waste composition analysis study was completed in the spring/ early summer phase was by Dumfries and Galloway Council, in the first week in July; and during the winter phase it was at the end of the first week of December 2022 (by City of Edinburgh Council).

2.2.2 Coverage by sampling date

In terms of sampling dates, the majority of sampling (thirteen studies) was conducted during 2022, with the remaining studies completed in 2021. As mentioned in section 2.2.1, waste composition sampling for each local authority study was not developed to identify any seasonal effects, as this would have required a larger number of sampling phases over a longer term. Over the course of the 2021-23 waste composition programme there was a near equal distribution of studies conducted across the spring/ early summer and autumn/ early winter periods. Figure 1 below presents the sequencing of waste composition analysis studies carried out over the duration of the programme.

Waste composition studies are by their nature a snapshot in time, and participating local authorities were keen to conduct compositional analysis at times where they had recently implemented or were planning a service change. This was an important consideration when deciding on the WasteDataFlow reporting period used in the final analysis (further details are provided in Section 4.1).

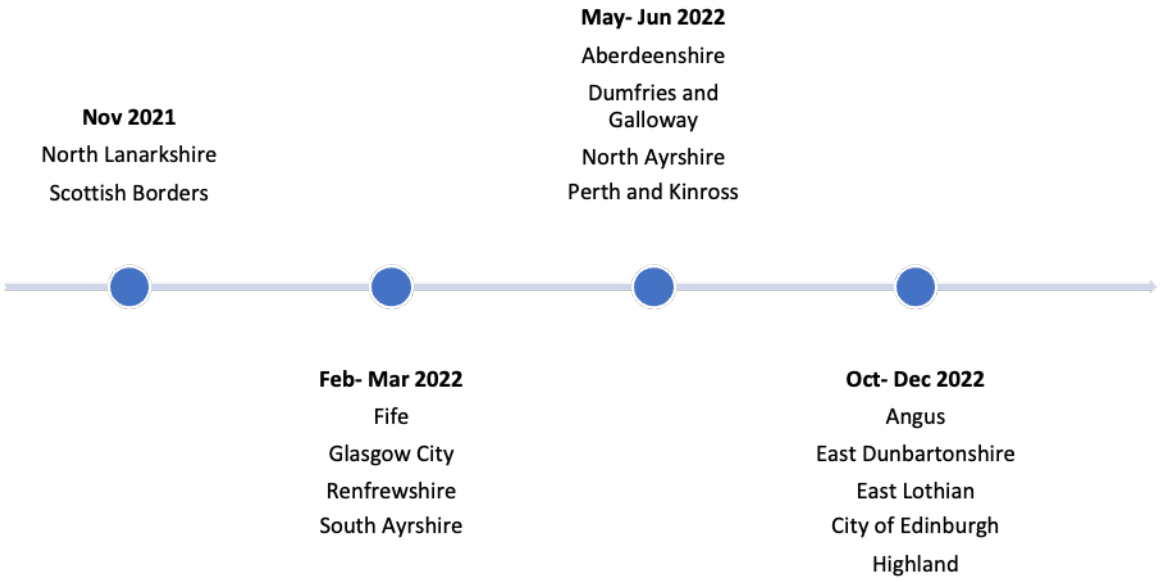

Figure 1: Sequencing of waste composition analysis studies conducted between 2021-23

2.2.3 Coverage by waste streams sampled

All fifteen of the local authorities that took part in the waste composition analysis programme undertook sampling of their residual waste service. All but one of the local authorities that took part also sampled their mixed recycling streams, which were comprised of both co-mingled collections, and services with further segregated collection of recycling streams.

2.2.4 Coverage by local authority national share of multiple deprivation

The individual local authority waste composition studies conducted during the programme were designed to be as representative as possible of households in a local authority area. Further details of the stratification requirements are set out in the accompanying guidance document[vi].

In terms of the degree to which individual local authority studies used in final analysis were representative of Scotland as a whole, one useful measure is the local authority's national share of the most deprived areas of Scotland.

The Scottish Index of multiple deprivation[vii] provides a rank for all the 6,976 data zones in Scotland, where a rank of 1 is the most deprived and a rank of 6,976 is the least deprived. The ranks cannot be averaged to obtain a deprivation score for local authority areas. However, the concept of national share of the most deprived data zones is useful for the current study, in order to describe levels of deprivation in sampled and non-sampled local authorities. To find a local authority's national share, the most deprived data zones in Scotland were firstly identified by applying a threshold (15% most deprived is typically used), and then calculating the proportion of the data zones identified as 'most deprived' belonging to that area. For example: there are 1046 data zones that fall in the 15% most deprived in Scotland, of which North Lanarkshire has 113 data zones, which equates to approximately 11% of the national share.

The coverage, by levels of deprivation of participating and non-participating local authorities is provided in Figure 2 below. Local authorities that were used in our final analysis represented just under 70% of the national share of the 15% most deprived Scottish Index of Multiple Deprivation (SIMD) data zones, suggesting that the local authorities with composition data – the sampled authorities - are broadly representative of Scotland in terms of levels of multiple deprivation.

The following section outlines the level of coverage of kerbside residual waste provided by the local authorities sampled during the programme.

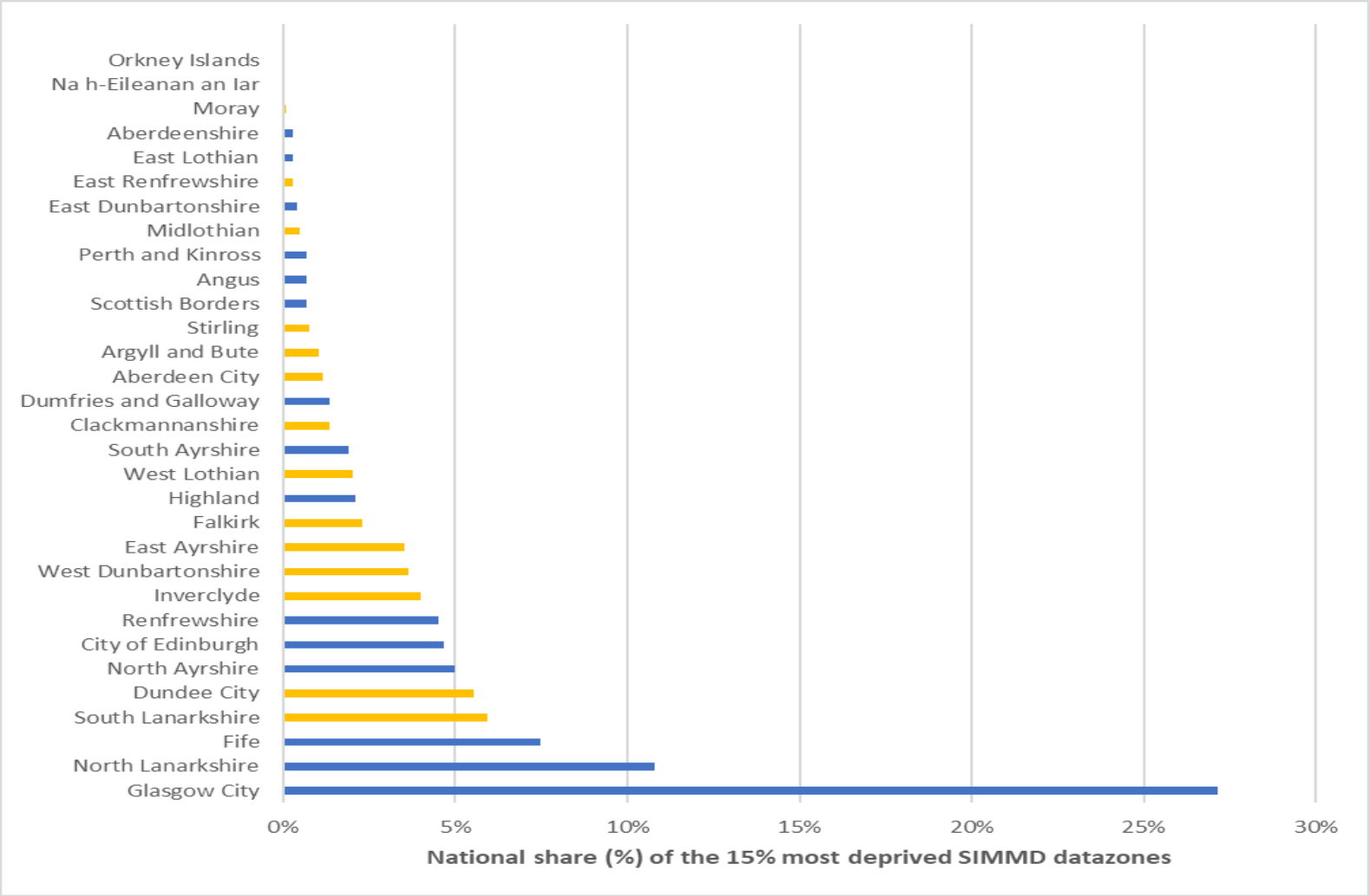

Figure 2: Local authority national share of the 15% most deprived data zones for SIMD 2021. BLUE shading denotes those local authorities where waste composition data was used in final analysis.

2.2.5 Coverage by quantity of kerbside residual waste

A useful measure of the degree to which local authority waste composition data was broadly representative of a national picture is the overall quantities of residual waste used in the final analysis. As shown in Table 3, approximately 67% of the total kerbside residual waste used in the final analysis was from local authorities where residual waste composition data had been collected.

Table 3:Total kerbside residual waste used in final analysis, split by whether residual waste composition data was available for the local authority.

	Total residual waste arising (tonnes)	% of all residual waste used in analysis
Local authorities where residual waste composition analysis was conducted (sampled authorities)	715,214	67%
Local authorities where residual waste composition analysis (non-sampled authorities	354,805	33%
Total kerbside residual waste used in final analysis	1,070,019	

3 Waste composition analysis studies of mixed food and garden waste

Prioritisation of available budget and time to carry out fieldwork contributing towards the compositional analysis of residual waste and dry recycling required seeking opportunities to reduce the quantities and streams of waste needing to be sampled over the course of the programme. One of the streams not sampled was the mixed food and garden waste. For this reason, previous compositional data from seven studies of kerbside mixed food and garden waste conducted during the periods 2011 and 2014 was used in the final analysis. It was possible to use this data alongside that gathered through the Zero Waste Scotland funded studies.

As was outlined during the 2013-15 waste composition analysis programme reporting, this mixed food and garden waste data was produced from five local authority studies supported by Zero Waste Scotland. Following a review of the methodologies employed (in terms of the guidance summarised in Section 2.1 and the material categories used during analysis), these studies were

all deemed suitable for use in a national study. To supplement these studies, a further two local authorities conducted composition analysis of their mixed food and garden waste services during 2014, as part of the 2014-15 waste composition analysis funded programme.

Table 4 provides a summary reminder of the mixed food and garden waste studies used in the current analysis. In total, there were seven local authority studies available to use as standard compositions when transposing the "Mixed food and garden waste", "Green garden waste only" and "Waste food only" reporting categories from WasteDataFlow, into our final analysis (see Section 5.3). The waste composition analysis methodology implemented for each of the mixed food and garden waste studies used a single phase of spring sampling, with five of the seven studies operating a fortnightly kerbside collection service for these streams. The number of sampling phases and the frequency of collection are recognised as factors that could have potentially impacted on the observed quantities of food and garden waste. For example, food waste yields in mixed food and garden waste collections have previously been found to be significantly different for weekly and fortnightly collections.[viii]

Table 4: Summary of mixed food and garden waste composition studies used in final analysis, unless indicated all studies conducted prior to establishing the funded waste composition analysis programme.

Local Authority	Collection frequency (food and garden)	Sampling period
Aberdeen City Council	Fortnightly	Feb- March 2011
East Renfrewshire Council	Weekly	Feb-March 2012
North Lanarkshire Council	Fortnightly	Feb-March 2013
Perth and Kinross Council	Fortnightly	March 2012
West Dunbartonshire Council	Fortnightly	April 2012
Moray Council*	Fortnightly	March 2014
North Ayrshire Council*	Weekly	May-June 2014

The case for conducting future studies to produce more recent estimates of the split in waste in mixed food and garden collections if mixed collections has been highlighted during this most recent analysis. Food waste proportions in areas with mixed collections may be influenced by contextual factors (such as a legacy effects of historical services), or by changes in food waste collection patterns over time.

The seasonal nature of the garden waste stream would also need to be considered in any future study, so as to reduce the uncertainty when applying composition profiles for this waste type. This raises the issue over the number of sampling phases to use. This would be pertinent when making comparison between local authorities that operate chargeable and free garden waste collection services, respectively. In the current programme, it was found that there

was a higher garden waste composition in the residual stream for authorities operating a chargeable service, when compared to authorities offering a free collection service. The caveat to consider, however, is that comparison in this context is being made between rural and non-rural authorities, which does not provide an accurate enough indication into direct causes of this increase, e.g., service characteristics, service coverage, bin capacity. The current programme has shown that adopting a two phased sampling approach would help to provide evidence on the seasonal impact on arisings and enable the influencing factors outlined above to be considered in more detail when carrying out analysis.

4 Further waste composition analysis studies

4.1 Waste composition data for food waste in packaging

During the most recent waste composition analysis programme, an additional bespoke study was carried out at three of the local authorities already carrying out waste sampling. This study was designed to provide an estimate of the disaggregated weight of food and drink waste in packaging, whereby individual weights would be estimated for the food, drink, and packaging components of these items in the residual and non-residual streams. This process would inform understanding of the contribution that packaging makes to food and drink waste estimates.

Following an initial sort of food and drink waste according to the standard protocol, a secondary sort was carried out, involving the separation of food and drink waste from its packaging and weighing of the separated items individually.

The sorting methodology differed at one of the studies, which resulted in the quantities of food in packaging and drink in packaging corresponding to unseparated or unopened packaging categories. These outputs were subsequently used to calculate the split of unseparated or unopened packaging at the other two local authorities participating in this bespoke study, for instances where the food and/ or drink was not weight separately to its packaging.

There results showed approximately a 5% reduction in the total food waste arisings in the national estimate (or approximately a decrease of 18,000 tonnes). The results for the non-residual stream, however, showed more variation, due to the uncertainty over the level of food and drink waste arisings presented in the recycling stream. It was agreed that the accuracy of this analysis would benefit from future studies being carried out at a greater number of authorities with different kerbside recycling services; and a standardised sorting protocol agreed with waste composition analysis contractors that accounts for variability in health and safety procedures.

5 WasteData Flow datasets used in this study

The WasteDataFlow (WDF) system is used by Scottish local authorities to report the collection and management of household wastes. For the current study, the quantities of waste reported as collected by local authorities at the kerbside in questions 10 (kerbside recycling) and 23 (kerbside residual waste & other bulky) were used. The following sections provide insight into how this data was reviewed and applied in the final analysis.

5.1 Reporting years used in final analysis

As highlighted in the summary of findings report, over the course of the waste composition analysis programme, local authority kerbside waste services continue to undergo change. During the sampling design phase for individual local authorities, issues surrounding upcoming and completed service changes were reviewed and considered when selecting households for sampling that may have started receiving a new service or had been identified as targeted households prior to a wider service roll out. Reviewing these service changes enabled sense checking of reported tonnages against what was known about changes in service over the WasteDataFlow reporting period; and supported matching of the most relevant waste composition data to WasteDataFlow reported tonnages.

As mentioned in section 2.2, WasteDataFlow reported data from the 2021 period was used for all thirty-two local authorities. The results presented are therefore representative of the 2021-22 period. In some cases, certain local authorities came forward and provided bespoke waste datasets that were more representative of the period in which sampling had taken place. There is scope within the functionality of the analytical model that has been developed for calculating the national waste composition estimates to integrate further datasets that cover multiple years. With WasteDataFlow data soon to become available for the 2022 period, there is potential to use this data and carry out the analysis for local authorities that conducted waste composition analysis studies during the 2022-23 period. The main benefit of using this data will be that the reported data is reflective of the year in which sampling was carried out.

5.2 Review of local authority data prior to use in final analysis

For the reasons described in section 5.1, the methodology for calculating national waste estimates is highly dependent on the quantities of waste data reported by local authorities on WasteDataFlow.

The household kerbside residual waste tonnages reported on question 23 were reviewed using yield estimates (kg/household/week) and commercial and household splits for all thirty-two local authorities. Review of this data indicated relatively small variation between local authorities, or where there was divergence from averages the underlying cause was well

understood (e.g., it was recognised that island local authorities would tend to have a higher proportion of commercial waste, due to a lack of private sector waste management companies).

5.3 Estimating the composition of all recycling reported on WasteDataFlow

The calculation of national kerbside composition estimates relies on summing all of the recycling components reported on question 10 of WasteDataFlow (WDF). To do this, there is a requirement to transpose the WasteDataFlow reporting categories into the waste composition categories used in our analysis (see Appendix for a detailed list of waste composition categories). For some WasteDataFlow reporting categories the summing process is straightforward. For example, the tonnage of "steel cans" directly transposes to the category "Steel drink cans" in the current waste composition material categories being used for the final analysis.

For the WasteDataFlow reporting categories listed in Table 4 below, the transposition of data is more complex and relies on the use of either:

- the local authorities own waste composition data (e.g., physical analysis of a co-mingled recycling collection, in order to define the composition). In this case the local authority's own composition profile for co-mingled recycling was applied to the reported tonnages of "Co-mingled materials" on WasteDataFlow; or
- when local authority-specific composition analysis data of a recycling stream was limited or lacking, a set of standard composition profiles were identified that could be applied to reported tonnages and used to transpose data to the waste composition material categories used in the final analysis. For example, in the case of a local authority reporting "Mixed garden and food waste" on WasteDataFlow, but waste composition data for their service is unavailable, an average overall composition from the seven waste composition studies of mixed food and garden waste outlined in section 3 was used.

Table 5 below details the WasteDataFlow recycling categories that required transposition and provides an overview of the standard composition data sources used in the final analysis. As was the case in the 2014-15 programme, it was possible to quality assure the application of any standard compositions to WasteDataFlow tonnages for all thirty-two local authorities. This process enabled a more accurate correlation between WasteDataFlow reporting categories and the compositional profiles developed from the analysis.

Certain reported material categories remained sources of uncertainty. As with the previous programme, the "Co-mingled materials" reporting category on WasteDataFlow was the main source of this uncertainty, as the specific nature of local authority kerbside collection services has transitioned over this time, in part due to a move towards Household Recycling Charter compliance[ix]. These changes create uncertainty on how kerbside recycling waste data is being reported to reflect the changes in service.

Table 5. WasteDataFlow (WDF) reporting categories that required transposition to the waste categories used in the current study, including sources of standard composition data.

WasteDataFlow category	Source of standard composition data (where there was a lack of specific data for the local authority)
Co-mingled materials	Average composition taken from a standard DMR (6 studies); DMR with Glass (3 studies); DMR with Film (2 studies); Containers (8 studies); Containers with Glass (4 studies); Containers with Film (1 study); Fibres and Containers (2 studies); Fibres and Containers and Glass (1 study).
Mixed paper and card	Average composition taken from Fibres of 14 studies; and communal Fibres taken from 1 study).
Green garden waste only	Average composition of the garden waste component of seven waste composition studies of mixed food and garden waste
Mixed garden and food waste	Average composition of the garden waste component of seven waste composition studies of mixed food and garden waste.
Mixed glass	Average composition taken from Mixed glass (12 studies).
Mixed plastic bottles	Average composition taken from Mixed Plastic stream for two studies.
Paper	Average composition taken from Paper stream for 1 communal study.
Waste food only	Average composition taken from Food waste for 19 studies
Card	A single local authority reported under this category, which was treated as Card.

WasteDataFlow category	Source of standard composition data (where there was a lack of specific data for the local authority)
Aluminium cans	Average composition taken from two local authorities reporting under this category, which was treated as Aluminium cans.
Steel cans	Directly transposes to Steel cans in waste composition analysis programme.
Textiles only	Limited compositional data reported by one local authority. 100% of WasteDataFlow data applied to Clothing category.

6 Methodology for national kerbside composition estimates

The following sections describe the methodologies employed to calculate national kerbside composition estimates from individual local authority data, using waste composition analysis and WasteDataFlow data. The methodologies can broadly be split according to whether or not a given local authority participated in the kerbside waste composition analysis programme during the 2021-23 period (see Table 1 in Section 2.2). For the local authorities that did participate, compositional analysis data for a given waste stream was made available, enabling bespoke data to be used when calculating overall kerbside composition for the local authority.

If a composition profile for a given local authority and waste stream was not available, i.e., for a non-sampled local authority, a proxy local authority waste composition profile was identified, using a combination of kerbside waste service characteristics and local authority "nearest neighbour" analysis. Further detail on this process is provided in subsection 6.2.1.

6.1 Local authorities with waste composition data

6.1.1 The composition of kerbside residual waste

To estimate the composition of kerbside residual waste for each local authority that participated in the waste composition analysis, the raw percentage values (from raw kg observations) from each sampling phase and group (or strata) were weighted according to the number of households represented by each group. For the one local authority where two phases of sampled data was made available, the weighted values for each phase were then combined to give an estimated annual composition of residual waste (by percentage for each material category). This compositional profile was then multiplied by the annual kerbside residual waste (tonnes) reported on WasteDataFlow by the local authority, to estimate the annual residual waste composition (tonnes).

6.1.2 The composition of all kerbside recycling

To estimate the composition of all kerbside recycling for each local authority that participated in the waste composition analysis programme, we summed:

- the quantity (tonnes) of each material reported as separately collected recycling on WasteDataFlow (i.e., that not requiring transposition to our waste composition categories, see Section 5.3).

- the quantity (tonnes) of each material estimated to be in mixed recycling collections (including co-mingled and less co-mingled services) sampled during compositional analysis, using the authorities own compositional analysis data (weighted as per residual waste above), which was then applied to the corresponding WasteDataFlow tonnages.
- the quantity (tonnes) of each material estimated to be in mixed recycling collections not sampled during waste composition analysis, using standard compositions (see Section 5.3) from other studies, which was applied to the corresponding WasteDataFlow tonnages.

6.1.3 The overall tonnage and composition of kerbside waste

To estimate an overall kerbside composition for each local authority with waste composition analysis data, the kerbside recycling and residual tonnage estimates were combined to give an overall kerbside tonnage and percentage composition.

6.2 Local authorities without waste composition data

The methodology for estimating the overall kerbside composition (residual waste and recycling) for local authorities that did not have waste composition data consisted of the following steps:

- identifying a suitable proxy local authority who had participated in the kerbside waste composition analysis programme;
- applying the proxy residual waste composition profile to the non-sampled local authority's own data from WasteDataFlow, in order to estimate the overall composition of kerbside waste;
- applying the standard recycling waste composition profile to the non-sampled

Further details of each step of the analysis are provided in the following subsections.

6.2.1 Allocating a proxy kerbside composition

The process for selecting a suitable proxy local authority kerbside composition for a local authority that did not have waste composition data consisted of using a combination of information on kerbside waste service characteristics and local authority "nearest neighbour" analysis, which was also the case in the waste composition analysis programme in 2014-15. During the last programme, kerbside service was found to be as important as the socio-economic characteristics of the local authority in deriving accurate kerbside estimates. The reason for this being that where materials were not collected at the kerbside (glass or garden waste only collected at bring sites) a significant amount of material will not arise in the kerbside composition or will appear in greater quantity in the residual waste stream.

For the current programme, residual waste composition was derived using a combination of nearest neighbour analysis and the residual up method. The nearest neighbour analysis consisted of using data sourced from the Office

for National Statistics (ONS) for each local authority in Scotland, based on a wide range of socio-demographic data from the 2011 census[x], but also a wider set of guiding principles, which included:

- matching the exact local authority classification group;
- matching garden and glass waste coverage;
- approximate matching of kerbside performance;
- using data from sampled authorities for no more than two gap (non-sampled) authorities; and
- where the option existed, matching garden waste permit status.

The degree of similarity between two local authorities, which can be expressed as the Squared Euclidean Distance (SED) - a dissimilarity measure, meaning the larger the value between two local authorities, the more dissimilar they are – was also referenced in the analysis when identifying suitable proxy local authorities. Although considered, the squared Euclidean distance values were not the primary indicator used to group local authorities. Further grouping analysis of a wide range of inputs, including by local authority classification, residual waste capacity, kerbside service type, materials collected, etc., implied significant clustering and interrelatedness existed between numerous variables.

Although residual waste output estimates showed that the grouping and nearest neighbour approaches produced similar results, the nearest neighbour approach was selected as it:

- avoided the use of data from sampled authorities more than once;
- did not rely on engineered performance groupings; and
- ensured similarity between the current and previous waste composition analysis programme.

Table 6 summarises how using information from both waste service and socio-demographic characteristics in combination would provide a more accurate proxy kerbside composition, where composition analysis data was lacking.

Table 6: Summary of local authorities without waste composition analysis, including the proxy local authority compositions used to estimate overall kerbside composition. Comments are provided to highlight the individual assessments made.

Local Authority requiring a proxy kerbside composition	Local authority kerbside waste composition applied in final analysis	Comments on individual decision for final analysis
Aberdeen City Council	Edinburgh, City of	Similar local authority type according to classification[xi]; and by service provision
Argyll and Bute Council	Scottish Borders	Similar local authority type according to classification except for Glass waste service coverage.
Clackmannanshire Council	Fife	Similar local authority type according to classification except for Glass service coverage and Garden Waste service permitting.
Dundee City Council	Glasgow	Similar local authority type according to classification except for Garden waste service coverage
East Ayrshire Council	East Lothian	Similar local authority type according to classification except for Garden waste permitting.
East Renfrewshire Council	East Dunbartonshire	Similar local authority type according to classification except for Garden waste permitting.
Eilean Sar	South Ayrshire	Similar local authority type according to classification[xii]; and by service provision
Falkirk Council	North Ayrshire	Similar local authority type according to classification except for Garden waste permitting
Inverclyde Council	Highland	Similar Garden waste and Glass coverage fit but Food coverage not an exact match. Match for Garden waste permit. May overestimate Garden waste but compensates for potential underestimation in other nearest neighbours.
Midlothian Council	East Lothian	Similar local authority type according to classification except for Garden waste permitting.
Moray Council	Perth & Kinross	Similar local authority type according to classification except for Glass service coverage

Local Authority requiring a proxy kerbside composition	Local authority kerbside waste composition applied in final analysis	Comments on individual decision for final analysis
Orkney Islands Council	Dumfries &Galloway	Similar local authority type according to classification except for Glass service coverage.
Shetland Islands Council	Aberdeenshire	Similar local authority type according to classification except for Food service coverage.
South Lanarkshire Council	North Lanarkshire	Good fit but uncertainty over high paper arisings at North Lanarkshire Council. Renfrewshire Council could be used, either as replacement or swap in representing WDC where there is less tonnage.
Stirling Council	Angus	Similar local authority type according to classification; and by service provision
West Dunbartonshire Council	Renfrewshire	Very similar nearest neighbour, although less than fair match in terms of Glass service coverage
West Lothian Council	Fife	Similar local authority type according to classification; and by service provision.

6.2.2 The overall composition of kerbside waste

To estimate the overall composition of kerbside waste for each local authority where waste composition data was lacking, the overall kerbside composition from the selected proxy local authority (percentage composition of each material category, as indicated above) was multiplied by the total kerbside residual tonnage reported by the local authority in question 23 of WasteDataFlow.

6.2.3 The composition of all kerbside recycling

To estimate the composition of all kerbside recycling for each local authority where we lacked waste composition data, we summed:

- the quantity (tonnes) of each material reported as separately collected on WasteDataFlow (i.e., those not requiring transposition to our waste composition categories)
- the quantity (tonnes) of each material estimated to be in mixed recycling collections, using standard compositions (see Section 4.3) from other studies, which were applied to WasteDataFlow annual tonnages.

6.3 What we throw away at the kerbside that could be recycled

To estimate the portion of the kerbside residual waste comprising materials that are typically collected at the kerbside for recycling, analysis of "Typically recycled at the kerbside" material categorisation was carried out. The analysis is a gross national estimate to highlight the scale of what is currently thrown away in the residual waste that could be collected at the kerbside for recycling, using typical kerbside services. Variation in the coverage of kerbside services for individual local authorities is not considered, meaning materials such as textiles, small electrical equipment, and other similar streams that are typically collected at bring banks and household waste recycling centres (HWRC) are excluded. This is notwithstanding that some individual local authorities target these particular waste streams at the kerbside.

Conversely, there may be cases where an authority, or some households in an authority would not have a kerbside collection for materials on our "typical" list. For example, a local authority may not collect glass at the kerbside, or only a percentage of households in a local authority area might be provided with a particular recycling service (e.g., garden waste recycling in rural authority cases).

The current study was not designed to individually assess additional kerbside recycling potential on an individual local authority basis for each of Scotland's thirty-two local authorities. There is the option with data that has been produced at individual local authority compositional fieldwork studies to be used for this purpose at the local level, where appropriate. Detail of the material categorisation is presented in the appendix for all thirty-two local authorities.

6.4 The biodegradable content of residual waste at the kerbside

To estimate the biodegradable content of kerbside residual household waste, a set of biodegradability assumptions was applied to the material category list

used during this waste composition analysis programme. A full list of the assumptions can be found in the appendix. The biodegradability assumptions used were cross checked with those used in similar previous studies. It is important to highlight that the estimates produced relate only to residual waste collected at the kerbside, and not to all household wastes managed by local authorities.

6.5 Correct recycling at the kerbside

Correct recycling is defined as the proportion of the overall kerbside tonnage estimated to be found in the correct kerbside recycling service. The calculation combines data on the composition of kerbside residual waste, with mixed and segregated recycling, in order to estimate the proportion of correct recycling at the kerbside. In the current programme, analysis focuses on the fifteen local authorities that took part in waste composition analysis studies. When considering Contamination in this calculation is defined as materials that are not targeted within a given recycling service.

In the summary of findings report, an average, maximum and minimum percentage of correct recycling for waste types typically recycled at the kerbside is presented. Data points where a local authority did not target a given waste type for recycling at the kerbside are excluded from this analysis, as was the case in the previous waste composition analysis programme. The analysis is therefore reflective of correct recycling when targeted at the kerbside.

Our analysis is a whole local authority assessment of what was collected for recycling at the kerbside (in both target and non-target recycling collections), as a proportion of what we estimate is found at the kerbside in total (from compositional analysis of what is thrown away in the residual waste). We do not make any adjustment for kerbside recycling service coverage, where a recycling service was provided to only a percentage of the households in a local authority area – i.e., we assume the households we sampled (and the service they receive) are representative of the whole local authority.

6.6 Contamination in mixed recycling collections

As part of the work described in section 2, waste composition analysis was conducted on six local authority dry mixed recycling services (“co-mingled recycling”), and a further five mixed recycling collections where less co-mingling and more material segregation took place.

The correct destination for each waste type used in composition analysis was defined for each local authority, with input from the local authority at the time of waste composition analysis.

The analysis used correct destination information to classify waste types into one of three groups:

- target - wastes targeted for collection at kerbside by the local authority e.g., recyclable paper and card.
- non-target – wastes not targeted at kerbside but were targeted elsewhere by the local authority service e.g., recyclable glass might be targeted using a separate

kerbside glass collection, or via bring banks.

- non-recyclable – wastes not typically recycled anywhere within a local authority service e.g., non-recyclable paper and disposable nappies.

The term “non-recyclable” waste within mixed recycling collections is used to define waste streams not typically recycled anywhere within a local authority service, e.g., disposable nappies. Further information on this analysis can be found in the summary of findings report, which includes the average, maximum and minimum values for target, non-target and non-recyclable waste streams.

6.7 Household estimates used in final analysis

Local authority household estimates used in the final analysis were taken from the national records of Scotland. Household estimates for the 2021 period (show below) were used in order to match up with the corresponding local authority WasteDataFlow datasets used in final analysis.

- national household estimates for Scotland 2021[xiii] = 2,528,823

6.8 Population numbers used in final analysis

Local authority population estimates used in the final analysis were taken from the national records of Scotland[xiv]. Population estimates for the 2021 period (shown below) were used in order to match up with the corresponding local authority WasteDataFlow datasets used in the final analysis.

- population estimates for Scotland 2014 = 5,479,900

7 Lessons learned from this programme

From completion of the current waste composition analysis programme, a series of lessons learned have been produced, which reflect upon the experience of having supported and coordinated a long term and complex programme of work.

7.1 The value of a dedicated waste composition analysis programme

Supporting and coordinating a structured programme of waste composition analysis has continued to provide a number of key benefits to both local authorities and towards the delivery of a national study of kerbside waste composition.

- development of comprehensive guidance for waste composition analysis, which has been used to inform other waste composition analysis studies being delivered looking at food waste composition;
- dedicated project management from Zero Waste Scotland to oversee individual local authority project delivery, with the provision of supporting procurement and reporting templates;
- dedicated waste compositional analysis framework established with Scotland Excel[xv], with a cohort of five waste composition analysis contractors available to deliver studies. Over the course of the most recent waste composition analysis programme, four of the five contractors were involved in project delivery at different times. It is accepted that capacity and availability of contractors will be factors influencing procurement outcomes.
- standardisation of the material sorting methodology and data recording procedure has enhanced the consistency and quality of the waste composition studies. Important to highlight is that the sorting methodology used in the current programme is different to that used in the previous programme, with sorted categories now provided for food and drink in packaging. Within the updated material category list, the definition of 'loose food' and 'food in packaging' may also differ by contractor. Other potential material categorises where subjectivity may influence outputs include 'Non-recyclable paper' and 'Heavily contaminated card & other composite card'.
- as with the previous programme, contracting of a dedicated analytical resource has enabled the creation of a comprehensive, standardised and quality assured dataset on completion of each local authority study, and in delivery of the national waste composition estimates. This resource provided great benefit during the data verification stage of each project, helping to identify inconsistencies and anomalies in the raw datasets provided by waste composition analysis contractors.
- standardised outputs from the analysis have supported reporting of the findings in the supporting documents for the current

programme. In addition, the findings will help to inform development of government priorities, e.g., delivering Scotland's route to map to a circular economy by 2025[xvi], and the technical support that Zero Waste Scotland provides to local authorities through programmes such as the Recycling Improvement Fund[xvii].

As with the previous programme, the most recent set of studies has delivered an extensive and consistent dataset on kerbside composition in Scotland. As well as this report, and the data provided to individual local authorities, the information will be used to inform estimates of Scottish household food waste arisings and is likely to inform future studies focused on specific material flows.

7.2 Methodology of defining a household sample in each local authority area

For all of the studies delivered during the most recent programme, publicly available data, based on the 2011 census[xviii], was used to derive the household sampling profiles for each participating local authority. In addition to the guidance document created by Zero Waste Scotland based on this method, this option has increased the sampling options available at local authority level and has resulted in a decrease in the costs associated with fieldwork. Following the recently released Scotland 2021 census data[xix], there is scope to use more current data regarding Scotland's household and population demographics.

7.3 Methodology of estimating waste composition where data was lacking

Any national-scale waste composition study will rely on using the findings from waste composition analysis from sample local authorities and applying those findings to local authorities where we do not have waste composition data. A systematic approach was taken to analyse the data, match sampled authorities with non-sampled authorities, and address data gaps. A large number of factors were considered during this process, in order to identify the most appropriate composition to apply, utilise the most suitable matching process, and incorporate reported WasteDataFlow data accurately. In addition to these factors, a there were also a number of variables that could cause variation within and between studies, which had to be considered.

The overall quantity of waste at the kerbside per capita was also calculated for the sampled authorities. It was found that:

- the overall quantities of food waste (residual and separately collected) tended to be lower where a kerbside service is provided. The causes of this are not clear.

- the overall quantities of garden waste tended to be higher where a kerbside service is provided. However, where no separate kerbside service is provided a higher percentage 23 is generally observed in the residual waste. We assume that some households are more likely to home compost or allow material to decompose naturally where no collection is available.

- the quantities of glass tended to be higher where a kerbside service is

provided. As this study does not consider non-kerbside routes, these may account for the difference in these cases.

Regardless of what the findings tell us about service characteristics, analytically, this led us to conclude that overall kerbside service characteristics are at least equally important as the original groupings above in transferring findings to non-sampled local authorities.

The final analysis used in the current study used a combination of information on kerbside services and nearest neighbour analysis, which is described in Section 5.3. It's likely the principal benefit of this approach is the application of a single local authority kerbside profile (using a service and demographic component), to a matched local authority. However, the methodology is relatively time consuming and less repeatable, both as a qualitative judgement and as the "best" match may change over time. Further, it was only practical given the relatively small number of local authorities where we did not have waste composition data.

7.4 Composition data for mixed food and garden waste collections

Our review of mixed food and garden waste composition studies used in the current analysis highlighted a reliance on a relatively small number of historical compositional analysis studies conducted as a single phase in spring, between 2011 and 2014. This approach was taken during the previous programme, however, as local authorities continue to adapt their service to a mixed food and garden waste service, there may be a need to generate new composition profiles using an increased number of sampling studies in order to improve the accuracy of any standard assumptions being applied to mixed food and garden waste. This is significant for a number of related issues, including ongoing monitoring of Scotland's food waste reduction target.

7.5 Composition data for food waste in packaging

In a select number of waste composition studies carried out during the current programme, an additional sorting protocol was introduced whereby food and drink waste was separated from its packaging component and then weighed. The final analysis showed that a small reduction in the overall food waste estimate was achieved when packaging was removed from the sorted waste. However, due to the relatively low number of studies carried out, and standard assumptions needing to be applied to the composition percentages (due to material sorting variation), there is potential to improve the analysis by conducting future studies of this bespoke nature in order to improve overall accuracy.

It is also challenging to draw comparison with the previous programme (in 2014-15) due to inconsistencies in the sorting protocol and subjective interpretation of the methodology; and as a result of the material category list differing between the two programmes, which raises uncertainty over data comparison.

7.6 The use of WasteDataFlow datasets in national composition estimates

As already highlighted, the methodology described in this document is highly dependent on the data reported by local authorities on WasteDataFlow. The quality and content of the WasteDataFlow dataset therefore has a direct impact on the quality of any national scale waste composition study.

From review of the WasteDataFlow datasets, certain inconsistencies were identified, and were as follows:

- with no obligation to report bring site and household waste recycling centre (HWRC) site recyclates in questions 16 and 17, it is estimated that some bring site material is reported as kerbside collected in question 10. It is assumed that this will inflate figures for materials collected at the kerbside and, hence, estimates for kerbside arisings.
- non-kerbside co-mingled material was reported by 21 authorities in 2014, 24 authorities in 2015 and 19 authorities in 2021, suggesting the potential for practices to vary over reporting years.
- not all authorities report household waste recycling centre (HWRC) residual waste under question 23 'Civic amenity sites waste: Household', with non-kerbside tonnage reported in question 23 household collections.

Due to the above, caution should be used when considering the terms 'kerbside arisings' and 'kerbside capture' and when reporting changes over consecutive reporting years.

Endnotes

[i] https://cdn.zerowastescotland.org.uk/managed-downloads/mf-jk1pxc2e-1677510625d
[i] Waste composition analysis programme 2021-23

[ii] A Standard Methodology for Household Sampling in Waste Composition Analysis
[iii] Guidance on the methodology for waste composition analysis
iv All waste collected was sorted according to the material category list developed for the programme. As mentioned in the summary of findings report, the category list has changed since the 2013-15 programme, but this has not affected the scope and objectives of the study.
V Guidance on the methodology for waste composition analysis
Vi Scottish Index of Multiple Deprivation 2020
Vii Household food waste collections guide
Viii Charter for Household Recycling
Ix 2011 Census
X About the area classifications
Xi About the area classifications
Xii National Records of Scotland – Household and dwellings in Scotland 2021
Xii National Records of Scotland – Mid-2021 Population estimates Scotland
Xiii Scotland Excel Contract Register – Waste Composition Analysis 1520
Xiv Delivering Scotland's Circular Economy – route map to 2025 and beyond
Xv Zero Waste Scotland: Recycling improvement Fund
Xvi 2011 Census
Xvii Scotland's Census 2022