Impact of household food waste collections on household food waste arisings

This report analyses five years of food waste collections data to better understand the impact of separate food waste collections on food waste arisings.

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1.0 Executive Summary

One of the principal objectives of WRAP is to support and enable a reduction in the quantity of UK household food waste, as well as to reduce its overall environmental impact (WRAP, 2019c; WRAP, 2018c).

In order to do this, it is first essential to define and calculate the amount of food waste produced in the UK in order to quantify the scale of the problem. We also need to identify all factors that significantly influence food waste arisings, so that effective food waste reduction policies and behavioural change campaigns can be developed.

One variable that has received increasing attention in recent years is the relationship between food waste collection and food waste prevention. There is currently large uncertainty around whether the presence of targeted food waste collection schemes influence total food waste arisings, as well as conflicting theories as to whether the influence would result in food waste prevention, or food waste legitimisation if a causal relationship is at play (WRAP, 2009b; WRAP, 2011b; WRAP, 2013a).

It is essential that this relationship is better understood, as collecting food waste is important to meeting the new Resources and Waste Strategy ambitions, and Circular Economy Package targets currently going through transposition into UK law (Defra, 2018; Resource, 2018).

In this study, food waste arisings were compared among local authorities (LAs) with and without a separate food waste collection, whilst controlling for other factors that are also known to affect food waste arisings (and which might otherwise mask or exaggerate the effect of food waste scheme type). The study covered a five year period from 2012/2013 to 2016/2017 and included data from 107 local authorities, covering three nations (England, Scotland and Wales).

The methodology for this study was designed specifically to identify whether an association between food waste collections and food waste arisings exists, as oppose to earlier studies where the main aim was to generate the published UK estimates for household food waste (HHFW) (WRAP, 2013c; WRAP 2016). The differences in methodology adds strength to the conclusion presented. However, this study should not be used to infer assumptions about changes in HHFW over time.

After taking into account social deprivation, time, and other factors previously reported to influence household food waste arisings, **separate food waste collections were significantly associated with lower total food waste arisings**. These results should be treated with caution because the size of the effect cannot be quantified with a high degree of certainty (the true difference could be between 2.3 kg/hh/yr and 29.8 kg/hh/yr food waste, with 95% confidence). However, this study still shows that there is potential to reduce food waste

across the UK, with the introduction of food waste collections.This study does not prove a causal relationship between food waste arisings and food waste collections. Previous research has found that LAs with separate food waste collections have higher overall recycling rates (WRAP, 2015b) and that a direct causal relationship exists between the introduction of food waste collections and increased sorting of packaging waste (Ek and Miliute-Plepiene, 2018). Thus, it is possible that the introduction of food waste collections may have an added cascade effect to other recycling waste streams, as well as giving the opportunity to engage households in avoidable food waste prevention strategies (WRAP, 2013d).

Future studies should consider building on the current data set in order to secure a more definitive conclusion. The significance of food waste collection type in this study suggests that future work should continue to use narrow criteria to avoid noise in the data, whilst increasing the size of the data set by adding new data for future years. Ideally, a paired before and after analysis should be conducted when sufficient data is available and sample data weighted to UK data (in terms of demographics etc.) where necessary.

2.0 Background

2.1 Definition of food waste

Food waste can be defined as 'food and the inedible parts of food removed from the food supply chain (or household) to be recovered or disposed of (including - composted, anaerobic digestion, incineration, disposal to sewer or landfill). This definition excludes waste prevention activities, namely redistribution for human consumption, or diverted to feed animals.' (WRAP, 2018a, pg. 14).

It is rapidly gaining world-wide acknowledgement as a significant international issue due to the extensive environmental impact, as well as concerns regarding food security (WRAP, 2015a; Zero Waste Scotland, 2011; Schanes, Dobernig & Gozet, 2018).

2.2 Impact of food waste

The food supply chain is highly resource intensive, resulting in significant deforestation, air and water pollution, soil erosion and green-house gas emissions (Schanes, Dobernig & Gozet, 2018). Furthermore, although there is some uncertainty around the data, global food production is estimated to account for 30% total greenhouse gas emissions and approximately 1/3rd of food thought to be wasted (Government Office for Science, 2017). Thus, food wastage has a large environmental impact.

Food waste can occur at all stages of the food supply chain from food production, processing, storage, transportation and consumption (Schanes, Dobernig & Gozet, 2018).

In the UK annual food waste for 2015 (from households, food manufacturers, retail and wholesalers and hospitality and food service) was estimated to be 10.2 million tonnes, or 156kg per person, costing over £20 billion a year and producing over 25 million tonnes of greenhouse gas (GHG) emissions. 70% of this food was intended to be consumed (WRAP, 2018b; Defra, 2018).

Private household food waste currently represents the largest constituent, contributing to ~70% of the UK post-farm-gate total and thus must be a priority for change (WRAP, 2018b).

Household food sources include food that is home grown, foraged or purchased from retailers including takeaway food (WRAP, 2018a; Parfitt, 2010). It can be wasted via three routes; local authority waste collections (food waste in the residual waste, collections targeting food waste and other collections), the sewer or via home composting.
The food waste produced can be categorised as ‘‘wasted food’ (food that the UK public consider edible), ‘inedible parts’ (food that the UK public consider inedible) (WRAP, 2018a). Ideally, edible food waste should be minimised (WRAP, 2018a).

One of the principal objectives of WRAP is to support and enable a reduction in the quantity of UK household food waste, as well as reduce to the environmental impact (WRAP, 2019c; WRAP, 2018c).

In order to do this, it is first essential to define and calculate the amount of food waste produced in the UK in order to quantify the scale of the problem, as well as identifying all factors that significantly influence food waste arisings in order so that effective food waste reduction policies and behavioural change campaigns can be developed.

WRAP has been measuring and reporting on household food waste since 2007, with increasing detail over time (WRAP 2009a; WRAP 2011a; WRAP, 2011c; WRAP, 2013b; WRAP, 2013c; WRAP, 2014a; WRAP, 2014b; WRAP, 2015a; WRAP, 2016; WRAP, 2017a; WRAP, 2017b; WRAP, 2019a; WRAP, 2019b).

Total food waste estimates are available for years 2007, 2010, 2014 and 2015 (WRAP, 2018a). These reports incorporate methods of quantifying food waste including by household waste streams, detailing and defining the composition of household food waste and consideration of factors that influence food waste including structural, contextual and behavioural variables.

One variable that has received increasing attention in recent years is the relationship between food waste collection and food waste prevention. There is currently large uncertainty around whether the presence of a targeted food waste collection schemes influence total food waste arisings, as well as conflicting theories as to whether the influence would result in food waste prevention or food waste legitimisation if a causal relationship is at play (WRAP, 2009b; WRAP, 2011b; WRAP, 2013a).

It is essential that this relationship is understood as collecting food waste is important to achieve high impact in meeting the new Resources and Waste Strategy ambitions and Circular Economy Package targets currently going through transposition into UK law (Defra, 2018; Resource, 2018).

The aims are to reduce overall food waste and ensure that food waste is valued as a resource (via anaerobic digestion). Food waste collection is therefore important in ensuring households have access to good quality high frequency services that target bio-degradable elements of the waste stream (Defra, 2018; Resource, 2018).

2.3 Definition of LA collected household food waste

The definition of LA collected household food waste was taken from WRAP's most recent synthesis of food waste compositional data report. This defines LA collected household food waste as 'food waste which is likely to have been generated from within the household: i.e. from food that was purchased (or otherwise taken into the home) or home grown and then either some or all of it disposed of in a LA collection' (WRAP, 2016, p.11).

Household food waste is collected in four different LA collection streams. These include:

- Kerbside residual – 'general' household waste (usually collected in wheeled bins or black bin bags).

- Kerbside collections targeting food waste – Food waste that is collected separately in a food waste caddy within the household and then collected at kerbside as either a separate food waste collection or as a mixed food and garden waste collection. Mixing of food and garden waste can either occur at household level i.e. households put all of their food waste and garden waste into one external container to be collected at kerbside, or at LA level where the collection vehicle used collects both food and garden waste together, so waste is reported as a mixed food and garden waste.

- Kerbside dry and garden waste recycling – This includes food waste as contamination in kerbside dry recycling collections i.e. collections designed to capture plastics, cardboard, paper, tins, glass etc. (usually collected in green or pink bags). This can include food left in plastics packaging, tins, cardboard boxes etc. Food waste is also a contamination in garden waste schemes where the organic waste is not destined for APBR approved facilities.

- Household Waste Recycling Centre (HWRC) residual waste and garden waste containers

Data from all these streams is collected in the UK in a national reporting system; *Waste Dataflow (WDF)*. However, there are data limitations with recording of food waste in diverse collection systems and even several schemes within one Local Authority that WDF is not designed to record to that level of granularity. Several, but not all, Local Authorities co-collect food waste from businesses and schools during the kerbside collection rounds. Given the large variation in food captures in WDF it is clear that some food waste is not attributed to non-household sources whilst schools waste would be eligible to be included.

WRAP generates useful dry recycling scheme benchmarks from WDF using follow up analysis to categorise scheme profiles such as through the Local Authority Recycling Scheme Updater. However, given the variation in yield performance for food waste and uncertainty where there may be non-kerbside food sources included WRAP does not currently include food waste as a key material in benchmarking. Data on numbers of non-kerbside property collections and their relative weights are not currently reported.

The Resources and Waste Strategy for England proposes changes to how data is collected, resources tracked and will be managed in the future.

Other definitions can also incorporate food waste arisings in street sweepings and litter, food tipped down the drain and food used for home composting.

As with the four LA waste streams, food waste from street sweepings and litter is also reported in *WasteDataFlow*. However due to the negligible quantities it was not included in this study.

With regard to food waste disposed of via household drains and food used for home composting, both are rarely measured other than in small scale studies where food waste diaries are used (e.g. WRAP, 2009c), therefore are often excluded from total tonnages.

However, recent studies suggest these account for much more than previously thought. For instance, WRAP's reports suggest as much as 23% of total UK household food waste is being tipped down the drain. In 2015, this amounted to 1.6 million tonnes per kg/person/year (WRAP, 2018a).

These variables must therefore be included in total tonnage data or where data is not available, considered as part of the interpretation of study results.

2.4 Quantification of food waste within the UK

Over the last 10 years, WRAP have produced numerous estimates of food waste, with increasing detail.

The most recent estimates for the UK are from 2015 where it is estimated that the annual quantity of household food waste collected by local authorities (including food waste in targeted food waste collections, residual waste, kerbside dry recycling, discarding to the sewer and home composting) is 7.1 million tonnes which equates to 108 kg per person (WRAP, 2018a).

These estimates are based on local authority reported annual total tonnages for each waste stream and local authority waste compositional analysis of a sample of the waste with a LA, that provides a value for the percentage of food waste in each stream.

As waste compositional analyses are not conducted annually for all LAs therefore several different calculations can be used to get an average value for the percentage of food waste in the residual, dry recycling and HRWC waste streams. Further estimations based on past data for the percentage of food waste in mixed food and garden waste collections are also applied. Details can be found in *Synthesis of Food waste Compositional Data 2014 & 2015* (WRAP, 2016).

2.5 Factors influencing food waste arisings

With regard to the factors influencing food waste arisings, numerous variables have been identified (these are discussed in further detail in section 1.7).

Of particular recent interest and the focus of this study, is to ascertain the impact of food waste collection schemes on food waste arisings.

WRAP have identified several potential impacts that the introduction of food waste collections could have on the generation of food waste (WRAP, 2013a). These include:

i. *The prevention effect* - the introduction of food waste collection allows people to see the food that they throw away and influences

people to reduce the amount of food they throw away at source. This could either result in a short term behavioural change in response to the new service or a sustained long-term effect if the behavioural change becomes routine.

ii. *The diversion effect* - households that use a food waste collection are less likely to home compost, so the introduction of food waste collections could reduce the amount of food waste home composted, and increase the total food waste collected by local authorities

iii. *The legitimisation effect* - the introduction of food waste collection may cause people to legitimise the food they waste either increasing food wasting behaviour or reducing waste prevention behaviours.

iv. *Interaction of multiple effects*-interactions between the various effects above could mostly cancel each other out and result in no change.

Previous evidence suggests that food waste collections have no substantial overall effect on food waste arisings (WRAP 2011b; WRAP, 2016). However, much of the evidence discusses the difficulty in identifying the effect of food waste collections on food waste arisings 'at source', due to either lack of monitoring of all food waste disposal routes (e.g. home-composting, diversion to the residual bin), lack of consideration of other variables that may influence food waste arisings (the amount participation in the scheme, sociodemographic and variables), issues with estimating food waste values from mixed collection rounds and other waste streams or interaction effects that cause any 'real' effects to be undetectable (food waste collection schemes may have both a prevention effect and a legitimisation effect).

However, some evidence is available that indicate a legitimisation effect (WRAP, 2013a), a prevention effect (WRAP, 2011b; WRAP 2013a) and a diversion effect (WRAP, 2013a). Thus, it is possible that small net effect does occur, perhaps in certain contextual or LA conditions.

Moreover, introduction of separate food waste collections may have other additional benefits. For example, previous research has found that LAs with separate food waste collections also have higher overall recycling rates (WRAP, 2015b). Food waste recycling is considered a key element of UK Governments' recycling strategies to meet their national and International targets.

Studies show high levels of satisfaction with weekly food collections, particularly with good scheme design, addresses components such as liner supply, container design, communications and frequency (WRAP, 2009b).

Supply of free bin liners, use of leaflets for communications and kerbside containers/caddies 20-25L/5-7L in size received largely positive feedback in attitudinal surveys of around 2500 respondents (WRAP, 2009b).

Although this study does not prove a causal relationship, a recent study from Sweden found a direct causal-relationship between the introduction of food-waste collections and increased sorting of packaging waste (Ek and Miliute-Plepiene, 2018). Furthermore, introducing food waste collections has the opportunity to engage households in avoidable food waste prevention strategies (WRAP, 2013d).

Thus, further investigation into the effect of food waste collections on food waste arisings in the UK was required.

2.6 Food waste collection type

2.6.1 No effect

The most recent literature review (WRAP, 2011b) reports little evidence to indicate that the introduction of a food waste scheme results in behaviour change around food waste 'at source'.

Furthermore, the results from the Synthesis of Food waste Data 2014 & 2015 also shows no significant effect of food waste collections on food waste at kerbside (food waste in targeted food waste collections, residual, dry recycling & HWRC) or on food waste in residual collections (WRAP, 2016)., However, the results where only marginally non-significant ($p = 0.058$) with an average reduction of 6.5 (±6.7) kg / hh / yr with the introduction of a targeted food waste collection. This indicates that the presence of collections targeting food waste might be associated with slightly lower levels of food waste generated (the total of that in kerbside residual and in collections targeting food waste). This could be due to greater awareness of the amounts of food waste disposed by households that use collections targeting food waste, leading to a change in actions (e.g. shopping, food preparation) (WRAP, 2013c). However, as this factor is marginally non-significant, the result should be interpreted with caution and further analysis of the dataset and further research would be beneficial.

2.6.2 Legitimisation effect

The results of WRAP's food waste tracker indicate a legitimisation effect with 30% of participants (647 people) with a food waste collection service indicating that the food waste collection service is a hinderance to them minimising their food waste (WRAP, 2013a). It is noted that this answer may be a justification rather than a root cause.

2.6.3 Prevention effect

The Somerset Waste Partnership waste collection service (WRAP, 2011b) which involved introduction of food waste collection scheme and changes in residual and recycling collections to 160,000 households, reported a 24% reduction (kg/house/week) in food waste arisings (from the residual and food waste tonnages). However, it was difficult to ascertain a causal effect as all collection service changes were made together. Furthermore, it was not possible to ascertain whether diversion had occurred as home composting was not measured (WRAP, 2011b).

Although, the quantitative results from food waste collection trials (WRAP, 2009b) indicate a diversion effect, the attitudinal surveys suggest both attitude and behaviour changes that promote food waste reduction in sub-groups of the population with an average of 8% increasing their awareness of the importance of avoiding food waste and 4-8% of participants stating that they now pay more attention to the food that they purchase (WRAP, 2009b).

Furthermore, 63% of participants stated that the food waste scheme had not changed their composting habits and 24% stated they composted less, thus it is unlikely that diversion to home composting was an influence.

A possible prevention effect was also identified from the Community Composting Network Scotland food waste collection scheme trial (WRAP, 2011b) that ran over 12 months in an area serving 600 residents. This reported a reduction in food waste yield from a maximum of 4.1 kg/participant/week at the start of the trial to 2.9 kg/participant/week at the end. However again, it was difficult to established whether this represented a true effect as measurement of food waste in the residual waste or home composting did not occur. There is some indication that the decrease in food waste may in part be due to a food waste prevention effect as the study reports a second awareness study in which 30% of participants reported that the food waste collection service had led them to change their behaviour in relation to food waste. However, the magnitude of effect cannot be ascertained.

Other studies highlight the potential for food waste prevention behaviour change. For example, the Waste Watch project which involved 16 households participating in fortnightly waste prevention challenges (including increasing home composting) over a period of 9 months reported that food waste in the residual stream reduced by 51% (WRAP, 2011b), although the study represents

an extremely small sample size and the reduction in food waste in the residual stream could 'merely' be a diversion to other streams, rather than prevention. The Kitchen Canny project reported a short-term reduction in food waste of 52%, after participants in 49 households received campaign packs on food waste reduction and a kitchen food waste caddy and measured their food waste over a 4 day periods on initially receiving the packs and after 3 weeks. However, diversion to home composting or residual waste was not considered and the study recognises that the study population was small and already highly engaged in home compositing and waste prevention activities. Furthermore, this project aimed at preventing waste (using the caddies to increase awareness) so does not consider whether food waste collection alone leads to food waste prevention (WRAP, 2011b).

Furthermore, WRAP's Fresher for Longer campaign which surveyed 1015 participants reported 22% of participants exhibited food waste prevention behaviours in response to a food waste collection scheme, whilst only 1% who stated that they don't worry about throwing food away (WRAP, 2013a). This was based on an unprompted question which asked whether the food waste collection had altered their food related behaviours. In addition, the same question, asked as a closed question, answered by 1018 participants with only one response each, found that 42% reported waste prevention behaviour as opposed to 9% who don't worry about throwing food away (WRAP, 2013a). However, it is noted that the difference between results for the same question highlight the influences of framing and bias that occurs due to giving socially desirable results.

2.6.4 Diversion effect

WRAP's food waste collection trials which involved introducing a food waste collection scheme trial to 21 different areas in the UK over 50 weeks, reported a diversion of food waste from to the residual stream with the introduction of food waste collections, rather than a net reduction in food waste (WRAP, 2009b).

In addition, WRAP's Fresher for longer survey indicated a diversion effect, where the introduction of food waste collections increased home composting. For example, when 2033 participants were asked about the impact of food waste collections on home composting, 30% stated they increased their home composting by a lot or a little and an additional 5% that they have started home composting. However, these results are in contrast to the older Food waste Tracker results (WRAP, 2019d) which show clearly that those who use food waste collections were less likely to home compost and vice versa as well as WRAP's kitchen diaries 2012, report no significant difference between food waste collection scheme on the kg/hh/week of food waste that is home composted (WRAP, 2013a). Thus, it is possible that these results were

influenced by due to respondent fatigue (the survey was long and largely focused on packaging and food waste) and/or social desirability bias

2.7 Other influencing factors of food waste arisings

Various factors have previously been found to significantly influence food waste arisings (either total food waste arisings or food waste arisings in the residual collection). A summary of this evidence can be found in table 1.1, and the sections below.

Table 1.1: Summary of significant predictors of food waste arisings (total food waste at kerbside or food waste in kerbside residual)

Report	Model	food waste variable	Variables included	Significant predictors
Synthesis of Food waste Compositional Data 2014&2015	Multiple linear regression (backwards elimination)	Food waste at kerbside (food waste in targeted food waste collections, residual, dry recycling & HWRC)	❖ Level of deprivation ❖ Population density ❖ Residual collection type ❖ food waste collection targeted for treatment or not ❖ Whether the waste compositional data includes 'packaged food' or not ❖ Year ❖ Nation ❖ Quarter of the year during which the waste compositional study was carried out	❖ Residual collection frequency ❖ Deprivation level
Synthesis of Food waste Compositional Data 2014&2015	Multiple linear regression (backwards elimination)	Kerbside residual that is food waste	❖ Level of deprivation ❖ Population density ❖ Residual collection type ❖ food waste collection targeted for treatment or not	❖ Food waste targeted for treatment ❖ Nation ❖ Year ❖ Quarter of the year during which the waste

			❖ Whether the waste compositional data includes 'packaged food' or not ❖ Year ❖ Nation ❖ Quarter of the year during which the waste compositional study was carried out	compositional study was carried out
Analysis of recycling performance and waste arisings in the UK 2012/2013	ANOVA (parameter estimates)	Organic yield (garden waste, garden waste, and other compostable waste)	❖ Deprivation ❖ Collecting pots, tubs and trays (PTT) at kerbside ❖ Collecting textiles at kerbside ❖ Effectively weekly residual containment capacity ❖ Additional dry recycling collected from residual waste ❖ Garden waste collection type ❖ Food waste collection type ❖ Deprivation indicator ❖ Rural nature indicator ❖ Nation	❖ Deprivation indicator ❖ Rural nature indicator ❖ Food waste collection type ❖ Garden waste collection type ❖

Evaluation of the WRAP Separate Food waste Collections Trials	*t*-tests	Mean food waste yield (kg per household served per week)	N/A	❖ Refuse collection frequency ❖ Refuse collection type

2.7.1 Residual waste collection frequency

In 2007 to 2009 a series of food waste collection trials were run across England and Northern Ireland (WRAP, 2009). The trials found residual collection frequency to be a statistically significant predictor of mean food waste yield in the second half of the trial, with households with fortnightly refuse collections producing higher average food waste yields that households with weekly refuse collections, indicating that time for the collections to embed might be needed before a difference is seen.

The food waste collection trials (WRAP, 2009) also found significant differences between the food waste yields for the first and second half of the 50-week trial period with those with fortnightly refuse collections producing higher yields in the second half of the trial and those with weekly refuse collections producing lower yields in the second half. Furthermore, the general trend across all trials was a gradual decline in food waste yields over the entire trial period.

In addition, the synthesis of food waste compositional data report for 2014&2015 (WRAP 2016) looks at pooled UK food waste arisings from 2011&2012, 2013&2014 and 2015&2016 found that fortnightly kerbside residual collection was a significant predictor of overall kerbside food waste arisings (kg/hh/yr). A backwards stepwise multiple regression model found the that the presence of a fortnightly refuse collection was associated with lower food waste arisings of 15 kg/hh/yr. However, the authors suggest that based on WRAP research for 2012/2013 (WRAP,2015), it cannot be assumed that the reduction in food waste arisings with fortnightly collections is due lower food waste production. Instead, the 2012/2013 reported no significant relationship between effective weekly containment capacity (a composite measure of both residual collection frequency and kerbside residual bin size) and total waste arisings (residual, dry & organics), suggesting that with fortnightly collections it is possible that material is diverted elsewhere, such as the HMRC.

2.7.2 Kerbside residual bin type

The food waste collection trials (WRAP, 2009) found that for households with weekly residual collections, food waste collection yields were generally higher in households where residual was collected in sacks as opposed to wheeled bins.

Furthermore, anecdotal reports from several LAs in the trials stated that residents with residual black bag refuse collections were particularly keen on the food waste collection service due to the provisional of a solid container for food waste and thus less chance of splitting/damaged black bags.

2.7.3 Multi-occupancy dwellings and flats

The food waste collection trials (WRAP, 2009) also reported low average collection yields from flats with door-to-door food waste collections. However, the per kg per participating household per week was comparable to the kerbside trials therefore it was ascertained that lower food waste yields in flats was due to low participation rates.

2.7.4 Time

The synthesis of food waste compositional data 2014 & 2015 report (WRAP, 2016) show that a from 2007 to 2010 a substantial significant reduction in total household food waste arisings (food waste in kerbside residual and separate food waste collections) in the UK from 5577 thousand tonnes (per/hh/yr) to 4615 thousand tonnes (per/hh/yr). After which, estimates from 2012 (4040 thousand tonnes), 2014 (4198 thousand tonnes) and 2015 (4756 thousand tonnes) shows that food waste remains relatively consistent at a UK level.

2.7.5 Nation

Recent evidence reports that Wales is a significant predictor in a regression model to predict the percentage of food waste in the residual waste, where Wales is associated with lower food waste compared to other parts of the UK. However, Wales is not significant in a model to predict total waste arisings (WRAP, 2016). It is known that all LAs in Wales have targeted food waste collections (either separately collection food waste or food waste mixed in garden waste), this report highlights that although food waste *per se* is not lower in Wales, food waste is diverted away from the residual, into targeted food waste collections. Thus, the link between nation and food waste streams is important to be aware for future analysis.

2.7.6 Rurality

The analysis of recycling performance and waste arisings in the UK report (WRAP, 2015) show that rurality is a significant predictor of total organics yield (food waste, garden waste and other compostable waste) with a larger proportion of rural households associated with higher organic yields, which might indicate that the impact of rurality on food waste alone is worth exploring.

2.7.7 Social deprivation

Deprivation has been reported to be a significant predictor of food waste collection yields in several previous studies.

The synthesis of food waste compositional data 2014 & 2015 show that food waste increases by 0.94 kg/hh/yr with a 1% increase in the percentage of households as social grade D & E. Although it is noted that this effect is questionable due to the large confidence intervals.

Conversely, the Household Food and Drink Waste report (WRAP, 2014) found no significant differences between households in social grade D&E compared to those in the rest of the population after taking into account home composting and household size.

However, data from the food waste collection trials (WRAP, 2016) found trends towards lower food waste yields with higher levels of deprivation when refuse collection scheme type is taken into account. Correlations of $r^2 = 0.45$, $r^2 = 0.49$ and $r^2 = 0.41$ were found for the relationship between food waste arisings and deprivation when plotted for fortnightly refuse collections, weekly refuse collections with using sacks and weekly refuse collections using bins

respectively. Although no correlation is found with multi-occupancy properties, partly due to the smaller sample but more likely that other studies on flats have shown that infrastructural barriers relative to the site's design are more impactful than other factors.

Overall, the collection focussed studies tend to show that the degree of deprivation in a community appears to drive participation rate and therefore collected yield rather than overall arisings. A further related effect appears to be the cessation of supply of free liners and a requirement on residents to purchase their own significantly affects capture over time.

Furthermore, the analysis of recycling performance and waste arisings in the UK report (WRAP, 2015) show that deprivation is a significant predictor of total organics yield (food waste, garden waste and other compostable waste) with higher deprivation resulting in lower organics yields, which along with the research above suggest that the impact of deprivation on food waste alone is worth considering.

2.7.8 Other

There are various other factors that have been shown to influence the amount of food waste collected in separate food waste collections (e.g. the availability of free food waste bin liners), the relative percentage of food waste in the residual bin (e.g. the influence of different garden waste schemes) and total food waste arisings (e.g. public attitudes to food waste).

For instance, in LAs with targeted food waste collections, the availability of free food waste liners has been shown to improve engagement with food waste collections as it makes it easier and cleaner to use the food waste caddies (WRAP, 2009b).

Public attitudes surrounding food waste collections including concern about odour, hygiene or issues with vermin may influence participation in schemes. Surveys from the Food waste Collection Trials (2009b) found that these concerned where raised in 24% of respondents without food waste collections, although these issues were raised by only 6% of those with food waste collections.

It is possible that with the introduction of charges for garden waste collections, household divert their garden waste in the residual waste stream and thus this must be considered if using a blanket estimate of the relative percentage of food waste in residual waste streams.

Further detailed discussion of the factors effecting food waste can be found in the following reports; Quested (2013), WRAP (2014a) and WRAP (2014b).

3.0 Objective / Hypothesis

3.1 Objective

The objective of this study was to test whether the introduction of food waste collections alters household food waste arisings and, if so, by how much?

3.2 Scope and approach

The study was interested in household food waste collected in separate food waste collections and household food waste collected in the residual bin only. Food waste disposed of in dry recycling and HWRC was assumed to be negligible and food waste used in home composting, tipped down the drain or given to pets was out of the scope of this study.

The study covered a 5 year period from 2012/2013 to 2016/2017 and attempted to cover all 4 UK nations.

Ideally, we would seek to calculate and compare food waste arisings at specific LAs before and after the introduction of a separate food waste collection. However, the limited number of WCA studies meant that there was insufficient data available to conduct a before-after comparison.

Instead, food waste arisings were compared among LAs with and without a separate food waste collection, whilst controlling for other factors that are also known to affect food waste arisings (and which might otherwise mask or exaggerate the effect of food waste scheme type). Therefore, the per household change in food waste arisings in relation to food waste collection scheme could be ascertained. To facilitate a clear comparison, LAs with mixed food and garden waste collections or multiple food waste collection schemes were excluded.

4.0 Methodology

4.1 Data collation and preparation

The most recent UK estimate of the proportion of LA collected household food waste arisings in each stream (WRAP, 2016) are shown below:

84.1%	13.1%	1.6%	1.2%
Residual	Collections targeting food waste (separate collections and food mixed in garden waste)	HWRC	Dry Recycling

(WRAP, 2016, pg. 26, table 4)

Based on the data above, for the purposes of this study, LA household collected food waste was calculated from food waste in the residual stream and food waste in separate collections, with the food waste in dry recycling, HWRC as well as food waste via street sweeping, home compositing and via the sewers assumed to contain negligible quantities of food waste.

In order to consider the effect of a separate food waste collections on overall food waste arising the following process was followed:

1. The collection schemes for each authority were established;
2. The quantity of food waste per year in each LA was calculated;

3. Data quality was considered, and inclusion and exclusion criteria applied;
4. The final data was screened for any errors or anomalies;
5. All potential variables influencing food waste arisings were considered;
6. Descriptive statistics to draw on general themes were created; and
7. A regression model was used to test whether food scheme type affects food waste arisings.

These seven steps are described in more detail below.

4.1.1 Collection scheme type in each LA

In order to establish which LAs are running collections targeting food waste, data was obtained from the *Local Authority Recycling Scheme Updater (LARSU)* on organics collection scheme. The LARSU portal is a database embedded on the WRAP website, where all UK LAs submit yearly updates on the recycling and waste collection services that they are running.

This database has been running since April 2010. Previous reports have used earlier data from the beginning (WRAP, 2013c). However, this study took a different approach, using data from April 2012 onwards, in order to ensure time to embed and that the data is complete and of high quality. This database was used as the gold standard source of collection scheme data.

4.1.2 Quantification of food waste per year in each LA

As described above, this research assumes that kerbside household food waste can be found in two LA collection streams; residual waste and collections targeting food waste (separate food waste and mixed food and garden waste).

The annual residual tonnage for each LA as well as the annual food waste tonnage from collections targeting food waste (separate food waste and mixed food and garden waste are reported separately) can be obtained from the *WasteDataFlow (WDF)* database. This is an open source UK database through which all UK local authorities are required to report total yearly municipal waste arisings to government (see appendix E for further details of data extracted). Data is available from April 2006 to December 2018.

However, WDF does not provide further breakdown of the materials found in the residual waste or the amount of food waste found in the mixed food and garden waste collections therefore in order to ascertain the relative quantities of food waste, estimations must be used.

The most accurate way of estimating these quantities is to use data available from waste compositional analyses of kerbside household waste in each LA. Waste compositional analysis (WCAs) are commissioned by many LAs, in order to get a detailed understanding of the materials deposited in each of the waste streams. Usually, waste is categorised into 40-70 variables across all waste streams within the LA and includes 1-7 variables for food waste. Thus, percentage of food waste in the residual waste and mixed food and garden waste can be calculated for a specific time point. By assuming that this figure is representative of the percentage of food waste in these waste streams over

the entire year, an annual food waste tonnage in the residual waste stream and mixed food and garden stream can be calculated.

It is widely known that there are peaks in food waste in mid-summer and spikes in short holidays (e.g. Halloween and Christmas) and otherwise food waste arisings are reasonably steady. The effect of seasonality on food waste arisings has previously been explored in *Synthesis of Food waste Compositional Data 2014 & 2015* (WRAP, 2016). Although it was significantly associated with food waste arisings, with lower food waste in the April-June quarter, stratification by quarter only had a minimal impact on the overall results. Thus, the assumption above was deemed appropriate. An annual tonnage per LA can then be ascertained from the residual and organics waste streams combined. All else being equal, the annual tonnage per LA is proportional to the number of households in each LA, so the kilograms of food waste produced per household in each LA was calculated by using household projection data based on the 2011 census data (see appendix E for further details).

As WCA data is needed to produce an estimate of food waste in the residual bin, this study only looked at only those LAs with waste compositional analyses.

If all LAs commissioned an annual waste compositional analysis, 2037 data point would have been available for analysis. However, WCAs are commissioned on a need-to-do basis, some LAs may commission several waste compositional analyses within the same year, whereas others may not have commissioned one for the entire 5-year period. Where several WCA's where conducted in the same year, an average value used.

At the point of this study, WCA data was available up until the end of 2017, therefore this research focused on annual data from a 5-year period; from April 2012 (the start of the LARSU data) to March 2017.

There was not enough data available to conduct a comparison of food waste arisings before and after the introduction of a separate food waste collection within each LA. Over the 5-year period only 49 LAs had at least two WCAs, only 8 of which the food waste collection scheme had changed.

Instead, a comparison was made of food waste arisings for all LAs with separate food waste collections versus food waste arisings for all LAs without food waste collections, taking into account other variables that influence food waste.

4.1.3 Inclusion/exclusion criteria

Due to the uncertainty in the literature surrounding the impact of food waste collections on food waste arisings, this study took a conservative approach to analysis, making as few assumptions as possible, in order to reduce potential noise.

The following considerations where made when deciding what data should be used for analysis.

Food scheme types

Four scheme types were available: i) no food waste collection, ii) separate food waste collection, iii) mixed food and garden waste collection and iv) a combination of both schemes.

With regard to the mixed food and garden waste it is unlikely that the percentage of food waste in this waste stream will be consistent across the year as garden waste is likely to increase considerably during the summer months and decrease during the winter. The accuracy of the estimation is therefore highly dependent on the time of year that the waste compositional analysis was undertaken therefore LAs with both the mixed food and garden waste collection and a combination of both schemes were removed. This left 161 data points for a direct comparison between UK LAs with and without food waste collections.

Percentage of households on the food waste scheme

Annual food waste arisings will be lower for LAs with trial food waste collection schemes or where the collection scheme had not been rolled out over the entire LA. This this study sought to only include LAs where the majority of households received a food waste collection.

Data from LARSU includes the number of hh's on the food waste collection scheme, therefore the relative percentage of households on the scheme could be calculated using the LA household data. Due to the predictive nature of the LA household data, the percentage of households on the food waste scheme contained some inaccuracies with some overestimating the number of households on the scheme (values calculated where over 100%) and others potential underestimating, thus an arbitrary cut off of ≥75% was used for inclusion, leaving 150 data points.

Percentage of food waste accounted for

All LA report annual data to *WasteDataFlow*, with the majority reporting quarterly. In some cases, where the food waste scheme started part way through a financial year not all quarters are available. Rather than estimating the missing data these LAs where excluded leaving 149 data points.

Assumes that LAs that only report yearly data have reported 100% of the data

Disparity between databases

On occasions the collection scheme listed in the LARSU data set did not match up with the data reported in the WDF data. For example, LASRU may have reported a separate food waste scheme but no food waste was recorded in WDF; alternatively, food waste may have been reported in WDF but no scheme involving food waste collection was listed in LARSU. Where disparities occurred, these LAs where excluded. After applying this criterion, 144 data points where left.

4.1.4 Data screening

Finally, all data was screened to ensure the data set was complete and any outliers were legitimate and not due to reporting errors. This process resulted in the removal of one LA due to unavailable waste data.

Furthermore, several high (over 300 kg/hh/yr) food waste data points were identified, both from the same LA. The original data was sourced and there was no reason to assume this was not an error therefore these were included in analysis.

The final data set included 143 data points, from 107 different local authorities (75 of the LAs had data from only one year, 28 of the LAs had data from two different years, and 4 of the LAs had data from three different years). 76 had no food waste collection scheme and 67 food that had a separate food waste collection scheme.

4.1.5 Selection of independent variables

The choice of independent variables was based on previous literature (section 1.7) as well as data availability.

For all categorical variables, the number of data points in each category was considered and, where appropriate, categories were combined to ensure a reasonable minimum sample size in each category. Furthermore, variables that could be constructed as continuous or categorical where graphed in order to assess data trends and therefore appropriate labelling.

A description of all independent variables, coding and description of the reason for inclusion is included in table 3.1.

Relationships between pairs independent variables were assessed using Chi-squared tests to test for collinearity. Although some pairs of variables were significantly correlated, this correlation was not strong enough to justify excluding variables from the analysis.

Table 3.1: All independent variables used in the multiple linear regression model

Independent variables	Type (number of categories/ value range)	Coding	Data obtained from	Reason for inclusion
Food waste collection scheme type	Categorical (2)	• Separate food waste collection scheme • No food waste collection scheme	LARSU	Study focus (see section 1.6)
Year	Categorical (5)	• April 2012-March 2013 • April 2013-March 2014 • April 2014-March 2015 • April 2015-March 2016 • April 2016-March 2017	WDF	Food waste arisings are known to vary over time (see section 1.7.4) Year was considered as both a continuous and categorical variable. Exploratory analysis showed no clear, linear relationship between year and mean food waste arisings, and so Year was used a categorical variable to avoid the possibly false assumption of a linear change in mean food waste arisings over time. Year was compiled annually from April to April, therefore 5 categories were used: i) 2012-2013, ii) 2013-2014, iii) 2014-2015, iv) 2015-2016 and v) 2016-2017.
Nation	Categorical (3)	• England • Scotland • Wales	WDF	Nation is known to be associated with food waste collection schemes (see section 1.7.5) but no clear link has been shown with total food waste arisings. However, each nation has devolved responsibility for setting its own food waste targets and recycling schemes. Many of these factors are difficult to measure and quantify (e.g. food waste prevention strategies, behaviour change campaigns, public attitudes to food waste) but could influence total food waste arisings therefore

				Nation was included as an independent variable in the model. Whilst the study attempted to account for all nations, lack of WCAs meant that data for only 3 nations was used; England, Scotland and Wales.
Rurality	Categorical (3)	• Predominantly urban • Mixed Urban/Rural • Predominantly Rural	Office of National Statistics (see appendix E for further details)	Rurality has been shown to influence total organics yield (see section 1.7.6) and therefore it seems plausible that an association between rurality and food waste arisings may also exist. Rurality was defined as the 'proportion of an LAs population living in rural areas and was taken from the population densities of the LAs Lower Super Output Areas (LSOAs) for England and Wales, Data zones in Scotland and Super Output Areas for Northern Ireland' (WRAP, 2008). This definition divides rurality into 3 categories; i) Predominantly urban, ii) Mixed urban/rural and iii) Predominantly rural.
Social grade (Proportion of people in social grade D&E)	Categorical (3)	• ≤ 20% • 20 <> 30% • ≥ 30%	Office of National Statistics (see appendix E for further details)	Social deprivation has been previously shown to influence food waste arisings (see section 1.7.7). Social deprivation was defined as the percentage of households in social grade banding D&E (where A&E is the most deprived banding) therefore values ranged from 0% to 100%. A scatter plot of social deprivation showed curvilinear relationship between social grade as continuous variable and total food waste arisings therefore was spilt into three approximately equal categories; i) ≤ 20%, ii) 20% <> 30% and iii) ≥ 30% or more.
Residual collection frequency	Categorical (2)	• At least weekly (More than weekly or weekly)	LARSU	Residual waste collection scheme has been previously shown to influence food waste arisings (see section 1.7.1). Residual waste can either be collected more than weekly, weekly, fortnightly or 3-weekly. In some LAs different collection frequency occurred depending on

		• More than weekly (Fortnightly or 3-weekly)		whether the collection served households or flats therefore this study used the collection frequency that served the majority of dwellings. Most LAs ran weekly or fortnightly collections the data was sorted into two categories: i) At least weekly (More than weekly or weekly), ii) More than weekly (Fortnightly or 3-weekly).
Kerbside residual bin size/type	Categorical (4)	• Household provides • Non-reusable sacks • Household wheeled bin • Mixed/unable to identify	LARSU	Kerbside residual bin type has been previously shown to influence food waste arisings (see section 1.7.2). Kerbside residual bin types included: i) bins that are provided by the household, ii) Non-reusable sacks and iii) Household wheeled bins. Other options were also available however similarly to residual collection frequency, different bin types where often used within the same LA. The data was therefore sorted into the majority bin type and if where this was not clear an additional category 'Mixed/unable to identify' was used.
Percentage of the food waste scheme that serves flats	Continuous (75-100%)	• % of the food waste scheme that serves flats (data range in the final dataset: 75%-100%)	LARSU	Multi-occupancy dwellings and flats has been previously shown to influence food waste arisings (see section 1.7.3). The percentage of households on the food waste scheme that are flats was calculated as the number of households on the food waste scheme that are flats (LARSU data) as a percentage of the total households in the LA (ONS data). As the household data is often projected and therefore not completely accurate, on occasions the newly calculated 'percentage households on the food waste scheme that are flats' figure was greater than 100%. In these cases, the data was adjusted to '100%', creating a continuous variable between 0-100%.

4.1.6 Multiple regression model

A multiple linear regression model was used to model total food waste arisings as a function of the independent variables listed in table 3.1. All the independent variables were initially included, and then variables were eliminated one at a time using a backward selection approach to produce a final, parsimonious model containing only those variables that had a statistically significant association with food waste arisings.

Finally, the model assumptions where checked and sensitivity analysis performed to explore the robustness of the results.

4.1.7 Descriptive statistics

Food waste arisings data were initially plotted against food waste collection type and food waste scheme type by year in order to visualise trends in the data. *t*-tests were then conducted to ascertain potential differences between food waste arisings between food scheme collection type for the entire 5 year period, as well as by year.

5.0 Results

5.1 Descriptive statistics

Data was analysed from 143 LAs; 76 with no food waste collection scheme and 67 with a separate food waste collection scheme.

The distribution of LAs over time was skewed, with more data captured in more recent years due to the increasing national traction to reduce waste and thus LA interest in commissioning waste compositional studies. Within each year, approximately half of LAs had a separate food waste collection, and half didn't (table 4.1).

Table 4.1: Year by food waste collection scheme type

Year	Total	No food waste collection scheme		Separate food waste collection scheme	
	n	n	%	n	%
2012-2013	12	9	11.8	3	4.5
2013-2014	22	9	11.8	13	19.4
2014-2015	41	24	31.6	17	25.4
2015-2016	32	14	18.4	18	26.9
2016-2017	36	20	26.3	16	23.9
Total	**143**	**76**	**100.0**	**67**	**100.0**

In addition, the distribution of LAs by nation also showed differences between food waste collection schemes, from 100% of LAs in Wales to only 38% of LAs in England having a separate food waste collection (table 4.2). This was also a difference between food waste collection schemes in the percentage of LAs categorised as 'predominantly urban' (table 4.3), as most LAs in Wales are likely to more rural.

Table 4.2: Nation by food waste collection scheme

Nation	Total	No food waste collection scheme		Separate food waste collection scheme	
	n	n	%	n	%
England	115	71	93.4	44	65.7
Scotland	10	5	6.6	5	7.5
Wales	18	0	0.0	18	26.9
Total	**143**	**76**	**100.0**	**67**	**100.0**

Table 4.3: Rurality by food waste collection scheme

Rurality category	Total	No food waste collection scheme		Separate food waste collection scheme	
	n	n	%	n	%
Predominantly urban	29	22	28.9	7	10.4
Mixed urban/rural	61	31	40.8	30	44.8
Predominantly rural	53	23	30.3	30	44.8
Total	**143**	**76**	**100.0**	**67**	**100.0**

LAs with a separate food waste collection tended to have less frequent residual waste collections (table 4.4); this is expected, particularly in areas where residual waste is collected in sacks.

Table 4.4: Majority residual waste collection scheme by food waste collection scheme

Majority residual waste collection scheme	Total	No food waste collection scheme		Separate food waste collection scheme	
	n	n	%	n	%
At least weekly	36	28	36.8	8	11.9
Less than weekly	107	48	63.2	59	88.1
Total	**143**	**76**	**100.0**	**67**	**100.0**

LAs with separate food waste collections tended to have less deprived households, with a lower percentage of households classed as social grade D&E (table 4.5).

Table 4.5: Social grade by food waste collection scheme

% Social grade D&E	Total	No food waste collection scheme		Separate food waste collection scheme	
	n	n	%	n	%
≤20%	51	17	22.4	34	50.7
20% <> 30%	49	30	39.5	19	28.4
≥ 30% or more	43	29	38.2	14	20.9
Total	**143**	**76**	**100.0**	**67**	**100.0**

5.1.1 Food waste scheme type

Over the entire 5 year period, LAs with a separate food waste collection scheme had lower food waste arisings than those without (173.1 ± 21.9 kg/hh/year, compared to 194.9 ± 50.5; two-sample t-test: t =3.405, p < 0.001) (figure 4.1 and table 4.6). Significant differences were also found between the two scheme types for years 2013-2014 (t=2.231, p = 0.037), 2014-2015 (t =3.655, p = 0.001) and 2016-2017 (t =2.233, p=0.033) (figure 4.2).

Figure 4.1: Household food waste by food waste collection scheme (mean ± SE)

Table 4.6: Descriptive statistics of total food waste and total food waste arisings by food waste collection scheme

		All LAs	**No** food waste **collection**	**Separate** food waste **collection**
Mean		184.7	194.8	173.1
Standard Deviation		41.1	50.5	21.8
Max		404.5	404.5	263.4
Min		95.9	95.9	137.9
Interquartile range		37.7	46.6	28.4
Standard Error		3.4	5.8	2.7
95% confidence intervals	Lower bound	177.9	183.3	167.8
	Upper bound	191.5	206.4	178.5

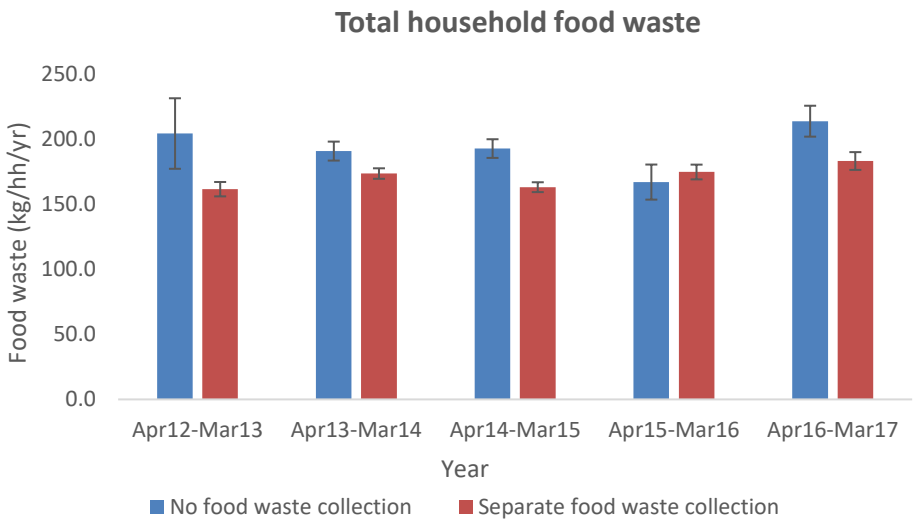

Figure 4.2: Household food waste by food waste collection scheme and year (mean ± SE)

Without using a regression model to account for other factors known to influence food waste arisings, it is not possible to conclude from this descriptive analysis whether the differences observed are due to food scheme type or other, correlated factors.

5.2 Regression model results

The final model explained 17% of the variation in food waste arisings (kg/hh/yr). Three of the independent variables (year, food scheme type and social grade) where found to be significantly associated with food waste arisings (table 4.7). Other variables such as nation, residual collection frequency, household food waste bin type/size, kerbside food waste bin size/type and percentage of the food waste scheme that serves flats showed no statistically significant association with food waste arisings and were excluded from the final model.

Food waste arisings peaked in 2016-2017 and were significantly higher in this year than in 2014-2015 (difference = 22.6 ± 17.7 kg/hh/yr) and in 2015-2016 (difference = 30.5 ± 19.5 kg/hh/yr).

LAs with lower deprivation (a lower percentage of households categorised as social grade D&E) were associated with lower food waste arisings. LAs with 20% or less of the households categorised as social grade D or E and LAs with between 20% and 30% of the households categorised as social grade D or E are associated with a reduction in food waste arisings of 20.4 ± 17.6 and 18.5 ± 16.2 respectively, in relation to LAs with 30% or more to the households categorised as social grade D or E.

After controlling for the effect of time and deprivation, food waste arisings were 16.1 ± 13.9 kg/hh/yr lower in LAs that had a separate food waste collection than in those that didn't (table 4.7).

Table 4.7: Multiple regression model for total food waste arisings (kg/hh/year)

Explanatory variable	Relative to	Standardised regression coefficient (B)	Standard Error	t	Sig.	95% Confidence Interval	
						Lower	Upper
Intercept		206.129	9.899	20.822	.000	186.551	225.707
Year 2012-2013	Year 2016-2017	-6.678	12.951	-.516	.607	-32.292	18.936
Year 2013-2014	Year 2016-2017	-16.444	10.506	-1.565	.120	-37.222	4.333
Year 2014-2015	Year 2016-2017	-22.664	8.841	-2.563	.011	-40.149	-5.179
Year 2015-2016	Year 2016-2017	-30.460	9.731	-3.130	.002	-49.705	-11.214
Separate food waste collection scheme	No food waste collection scheme	-16.070	6.943	2.315	.022	2.339	29.801
Social grade D&E ≤ 20%	Social grade D&E ≥ 30%	-20.380	8.776	-2.322	.022	-37.736	-3.023
Social grade D&E 20% <>30%	Social grade D&E ≥ 30%	-18.455	8.141	-2.267	.025	-34.556	-2.355

5.2.1 Model assumptions and sensitivity analysis

The model residuals were plotted to check the assumptions of normally distributed errors and homogenous variances (appendix C).

Sensitivity analysis was conducted to explore how robust the results were to data processing decisions and outliers. Specifically, variations on the main model were produced that (i) represented year as a continuous rather than a categorical variable (thereby assuming a linear change in food waste over time), and (ii) excluded one LA with unusually high food waste (which Cooks Distance diagnostic suggested was highly influential on the model).

The following models were produced:

- *Model 1: All data (n=143) and Year(continuous)*
- *Model 2: All data (n=143) and Year (categorical)**
- *Model 3: High data point removed (n=142) and Year(continuous)*
- *Model 4a: High data point removed (n=142) and Year(categorical)*
- *Model 4b: High data point removed (n=142) and Year(categorical). This is a previous iteration of model 4a, that includes food waste collection scheme type which was not significant*

**final model (see table 4.7)*

Table 4.8: A comparison of all models

	Explanatory variable	Relative to	Standardised regression coefficient (B)	Standard Error	Significance
Model 1	Separate food waste collection scheme	No food waste collection scheme	-21.719	6.661	.001
Model 2*			-16.070	6.943	.022
Model 3			-16.197	6.134	0.009
Model 4b			-8.683	6.281	0.169

**final model (see table 4.7)*

Table 4.8 shows that the direction of the effect was the same in all four models, but the magnitude of the effect, and its statistical significance, did vary, especially in model 4.

Both models using year as a continuous variable (model 1 and 3) showed food waste scheme type to be a significant predictor of food waste arisings, regardless of the inclusion/exclusion of the high data point. With the inclusion of the high data point, total food waste arisings decreased by 21.7 ± 13.3 kg/hh/yr (model 1). When excluding the high data point, after taking into account social grade and year, total food waste arisings decreased by 16.2 ± 12.3 kg/hh/yr with the introduction of a food waste collection (model 3).

After removing the high data point but leaving year as a categorical variable, food scheme type was no longer a significant variable, however the direction of effect was the same as the other models.

As there was no clear theoretical or empirical justification for assuming a linear relationship between food waste arisings and time, year was used as a categorical variable. Furthermore, the LA with the high data point had a consistently high percentage of food waste in the residual waste in two different years, therefore there was no reason to assume the value was not legitimate. It was therefore concluded that model 2 was the most accurate representation of the relationship between food waste arisings and food waste collection scheme.

6.0 Evidence Gaps and Further Work

The approach taken in this study was to use very narrow parameters for data inclusion. Thus, several assumptions were made and recommendations for future work are listed below:

Assumption 1: Food waste occurs in separate food waste collections and in residual waste only

This study looked at the two largest sources of food waste, accounting for >95% of food waste produced in the home. Future work should aim to include all food waste streams including food waste in dry recyclate, in HWRC, tipped down the drain, fed to pets and food that is home composted.

Assumption 2: LAs with waste compositional analyses are a representative sample of all LAs in the UK

In previous LA syntheses (WRAP, 2016) weighting was carried out if there was a considerable mismatch between the LAs in the sample (in terms of nation, region, socio-economic factors, rurality, presence and type of collection targeting food waste, frequency of residual collection, season) and the population which has not been incorporated in this study. However, this was mitigated to a large degree by modelling the effect of social grade, rurality and nation.

Assumption 3: Only two food scheme types are available (separate food waste collections and no food waste collections)

It may be logistically unfeasible for some LAs to implement a separate food waste collection, therefore the impact of mixed food and garden schemes must be considered in future work.

Assumption 4: 100% of households participated in the food waste collection scheme if there was one

The data in this study was screened so that for LAs with a food waste collection scheme, the scheme had to cater for at least 75% of households in order to be included in the study. This inherently means there may be small inaccuracies in the figure for food waste arisings per household for the LAs closer to the 75% roll out, as is the case for LAs with a large number of flats that are more difficult to provide a food waste collection scheme for.

In addition, it was assumed that participation rate was 100% for all households that received a collection. However, actual participation in the food waste collection is currently not measured in national databases. In WRAP's food waste collection trials participation rate ranged from ~44% to ~73% (excluding those that severed multi-occupancy properties only), therefore this variation could create considerable noise in the data and is an important factor to consider in future work.

Assumption 5: All LAs received the same communication about food waste and food recycling

This study has not been able to look at the potential difference between LAs that have separate collections who actively communicate to residents about participation and prevention versus those that only communicate on participation. It is likely that any 'prevention' effect of collections could be enhanced through more integrated communications. This should be explored in more detail.

Assumption 6: All data points were independent

In the current data set, although the majority of data points are fully independent, 32 LAs out of the 107 different LAs had data in at least two different years and therefore these local authorities had a greater influence on the results that the others.

Assumption 7: The percentage of edible and inedible components of the food waste were the same across all LAs

Whilst the subcomponents of the food waste were out of the scope of this study, these are important components in understanding the causes of food waste and for developing campaigns to raise awareness and promote behavioural change. Future studies should consider quantifying these components and including in the analysis.

7.0 Conclusions

After taking into account social deprivation, time and other factors previously reported to influence household food waste arisings, separate food waste collections were significantly associated with lower total food waste arisings. Specifically, LAs with a separate food waste collection produced an average of 16.1 kg/hh/yr less food waste than those without.

The margin of error around this estimate was large, suggesting that the true difference could be between 2.3 kg/hh/yr and 29.8 kg/hh/yr food waste (with 95% confidence). Furthermore, sensitivity analysis indicated that the magnitude and significance of the food waste scheme effect was sensitive to one outlier in the dataset. Thus, the results should be treated with caution because the size of the effect cannot be quantified with a high degree of certainty.

However, this study still reveals the potential for reducing food waste by rolling out food waste collections across the UK.

In addition, this study does not prove a causal relationship between food waste arisings and food waste collections, previous research has found that LAs with separate food waste collections have higher overall recycling rates (WRAP, 2015b) and that a direct causal-relationship exists between the introduction of food-waste collections and increased sorting of packaging waste (Ek and Miliute-Plepiene, 2018). Thus, it is possible that the introduction of food waste collections may have an added cascade effect to other recycling waste streams, as well as giving the opportunity to engage households in avoidable food waste prevention strategies (WRAP, 2013d).

These findings build on previous work (WRAP, 2016) which reported a marginally non-significant association between food waste collections and food waste arisings. Thus, it is possible that the narrowing of parameters which aimed to improve the accuracy of the data has resulted in a significant result.

The methodology for this study was designed specifically to identify whether an association between food waste collections and food waste arisings exists, as oppose to earlier studies where the main aim was to generate the published UK estimates for HHFW (WRAP, 2013c; WRAP 2016). The differences in methodology adds strength to the conclusion presented, however, at the same time, this study should not be used to infer anything about changes in HHFW over time.

As with previous studies, due to lack of available data on home composting or food tipped down the drain, it is not possible to be certain that the apparent reduction in food waste is due to a reduction in food waste 'at source'. With regard to home composting which is likely to be the largest source of food waste diversion of the three, the literature provides arguments both for and against the likelihood that the presence of food waste collections influence home composting (see section 1.6.4).

8.0 Recommendations

Future studies should consider building on the current data set in order to secure a more definitive conclusion. The significance of food waste collection type in this study as opposed to studies that use larger data sets but more assumptions, suggests that future work should continue to use narrow criteria for inclusion to avoid noise in the data whilst increasing the size of the data set by adding new data for future years.

Ideally, a paired before and after analysis should be conducted when sufficient data is available and sample data weighted to UK data (in terms of demographics etc.) where necessary.

In addition, total food waste figures should include food waste in dry recyclate and in HWRC and where possible, empirical data should be collected on home composting, food fed to pets and food tipped down the drain and these incorporated into calculations.

Inclusion of LAs with mixed food and garden waste schemes can also be considered if more accurate figures on the percentage of garden waste become available.

Furthermore, additional variables such as liner supply, the influence of commercial waste, garden waste schemes, behavioural change campaigns should be considered.

Finally, data should be collected, or estimates calculated, on food scheme participation rate and used as a variable in analysis and subcomponents of food waste (edible and inedible parts) should be incorporated.

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10.0 Appendices

10.1 Appendix A: Independent variables: data not included in main text

Kerbside residual bin type by food waste collection scheme

	Total	No food waste collection scheme		Separate food waste collection scheme		
		n	**n**	**%**	**n**	**%**
Household provides	7	4	5.3	3	4.5	
Non-reusable sacks	11	7	9.2	4	6.0	
Household wheeled bin	57	29	38.2	28	41.8	
Mixed/no majority	68	36	47.4	32	47.8	
Total		143	76	100.0	67	100.0

Percentage of food waste scheme serving flats by food waste collection scheme

	Total	No food waste collection scheme	Separate food waste collection scheme

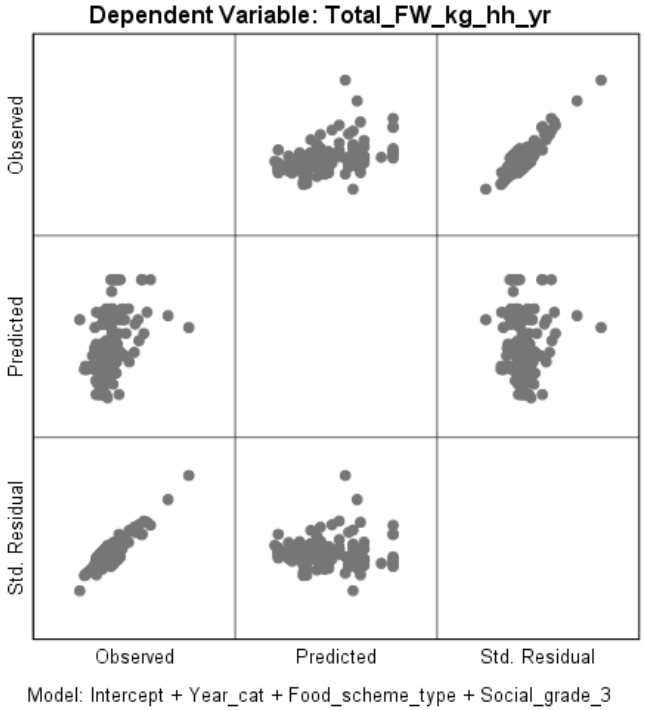
Mean (%)	1.8	0.0	3.8
Standard deviation (%)	6.6	0.0	9.3
Minimum (%)	0.0	0.0	0.0
Maximum (%)	51.3	0.0	51.3
	100.0	0.0	100.0

10.2 Appendix B: Collinearity statistics

Chi-squared	Food_scheme_type_ categorical	
	Value	(Asymptotic 2-sided)
Year_categorical	5.321	0.256
Social_grade_ categorical	12.853	0.002

Chi-squared	Year_categorical	
	Value	(Asymptotic 2-sided)
Social_grade_ categorical	20.592	0.008

10.3 Appendix C: Distribution of the residuals



10.4 Appendix D: Sensitivity analysis

Model 1: All data (n=143) & Year(continuous)

Explanatory variable	Relative to	Standardised regression coefficient (B)	Standard Error	t	Sig.	95% Confidence Interval	
						Lower	Upper
Intercept		173.130	4.856	35.652	.000	163.530	182.730
Separate food waste collection scheme	No food waste collection scheme	-21.719	6.661	3.261	.001	8.551	34.888

Model 3: High data point removed (n=142) & Year(continuous)

Explanatory variable	Relative to	Standardised regression coefficient (B)	Standard Error	t	Sig.	95% Confidence Interval	
						Lower	Upper
Intercept		169.598	10.962	15.472	0.000	147.922	191.274
Separate food waste collection scheme	No food waste collection scheme	-16.197	6.134	2.640	0.009	4.067	28.327
Social grade D&E ≤ 20%	Social grade D&E ≥ 30%	-17.004	7.560	-2.249	0.026	-31.953	-2.055
Social grade D&E 20% <>30%	Social grade D&E ≥ 30%	-16.360	7.247	-2.257	0.026	-30.691	-2.029
Year		4.852	2.366	2.051	0.042	0.173	9.530

Model 4a: All data (n=142) & Year(categorical)

Explanatory variable	Relative to	Standardised regression coefficient (B)	Standard Error	t	Sig.	95% Confidence Interval	
						Lower	Upper
Intercept		216.314	7.324	29.534	0.000	201.828	230.801
Year 2012-2013	Year 2016-2017	-27.770	11.595	-2.395	0.018	-50.704	-4.837
Year 2013-2014	Year 2016-2017	-14.462	9.095	-1.590	0.114	-32.450	3.527
Year 2014-2015	Year 2016-2017	-25.520	7.659	-3.332	0.001	-40.668	-10.373
Year 2015-2016	Year 2016-2017	-36.302	8.291	-4.379	0.000	-52.700	-19.904
Social grade D&E ≤ 20%	Social grade D&E ≥ 30%	-31.538	7.222	-4.367	0.000	-45.821	-17.255
Social grade D&E 20% <>30%	Social grade D&E ≥ 30%	-19.111	7.030	-2.718	0.007	-33.016	-5.206
Majority refuse collection	Majority refuse collection frequency: More than weekly	17.559	6.558	2.678	0.008	4.589	30.529

frequency: At least weekly		
Majority refuse collection frequency: More than weekly	0	7.324

Model 4b: All data (n=142) & Year(categorical), previous iteration of the model that includes food waste collection scheme type which is not significant

Explanatory variable	Relative to	Standardised regression coefficient (B)	Standard Error	t	Sig.	95% Confidence Interval	
						Lower	Upper
Intercept		210.199	8.536	24.626	0.000	193.316	227.082
Separate food waste collection scheme	No food waste collection scheme	-8.683	6.281	1.382	0.169	-3.741	21.107
Year 2012-2013	Year 2016-2017	-28.530	11.569	-2.466	0.015	-51.413	-5.646
Year 2013-2014	Year 2016-2017	-14.111	9.068	-1.556	0.122	-32.046	3.825
Year 2014-2015	Year 2016-2017	-24.985	7.643	-3.269	0.001	-40.102	-9.869
Year 2015-2016	Year 2016-2017	-34.175	8.405	-4.066	0.000	-50.799	-17.550
Majority refuse collection: At least weekly	Majority refuse collection: More than weekly	14.725	6.850	2.150	0.033	1.176	28.273

Social grade D&E ≤ 20%	Social grade D&E ≥ 30%	-27.857	7.674	-3.630	0.000	-43.036	-12.678
Social grade D&E 20% <>30%	Social grade D&E ≥ 30%	-18.177	7.039	-2.582	0.011	-32.100	-4.253

10.5 Appendix E: Data descriptions

Data variable	Description
Waste comp data	**Included:** • All fully packaged & unopened Home Compostable food waste • All fully packaged & unopened Non-Home Compostable food waste • All Loose Home Compostable food waste - Unused • All Loose Non-Home Compostable food waste - Unused • All Mixed unsortable Food waste • Consumable Liquids • Fats & Oils • All unavoidable food waste • Avoidable food waste - loose • Avoidable food waste – part used in open packaging • Avoidable food waste – fully unopened & packaged • Consumable liquids, fats & oils

	• Avoidable food waste (unpackaged) • Unavoidable food waste • Possibly avoidable food waste • Avoidable food waste (packaged) • Raw Fruit & Vegetable Waste - Avoidable • Raw Fruit & Vegetable Waste - Unavoidable • Raw meat and fish - Avoidable • Raw meat and fish - Unavoidable • All Cooked and prepared food waste • All Food whole still in packaging • Consumable Liquids, Fats & Oils • All unavoidable food waste • Avoidable food waste - loose • Avoidable food waste – within packaging • All Food waste • Cooking Oils and Other Liquid Foodstuff • Avoidable Food • Non-Avoidable Food • Raw fruit and veg • Cooked and prepared food • Raw meat, fish • Packaged food • Bread based foods including rolls • Consumable liquids, fats & oils

	• Home Compostable - Prepared • Home Compostable – Unprepared / Unopened • Non-Home Compostable - Prepared • Non-Home Compostable – Unprepared / Unopened • Home compostable Kitchen Waste • Non-home compostable Kitchen waste • Consumable Liquids **Excluded:** • Herbivorous Pet Straw & Sawdust Bedding • Compostable Liners • All Other Organics • Garden Waste • Soil • Other organic inc pet bedding & waste
Number of households in each LA	England Table 406: Household projections, mid-2001 to mid-2041 • Data from 2012 used for Apr12-Mar13 • Data from 2013 used for Apr13-Mar14 • Data from 2014 used for Apr14-Mar15 • Data from 2015 used for Apr15-Mar16 • Data from 2016 used for Apr16-Mar17 Scotland Table 6: Household projections for Scotland, by Council area, 2012 - 2037, all households

	• Data from 2012 used for Apr12-Mar13 • Data from 2013 used for Apr13-Mar14 • Data from 2014 used for Apr14-Mar15 • Data from 2015 used for Apr15-Mar16 • Data from 2016 used for Apr16-Mar17 Wales Household projections by local authority and year 2011+ • Data from 2012 used for Apr12-Mar13 • Data from 2013 used for Apr13-Mar14 Household projections by local authority and year 2014+ • Data from 2014 used for Apr14-Mar15 • Data from 2015 used for Apr15-Mar16 • Data from 2016 used for Apr16-Mar17 NI Household Projections and Average Household Size for Local Government Districts (LGD1992), 2012-2027 • Data from 2012 used for Apr12-Mar13 • Data from 2013 used for Apr13-Mar14 • Data from 2014 used for Apr14-Mar15 https://www.nisra.gov.uk/sites/nisra.gov.uk/files/publications/HHP12-LGD1992.xls Household Projections and Average Household Size for Local Government Districts, 2012-2037 • Data from 2015 used for Apr15-Mar16

	• Data from 2016 used for Apr16-Mar17
Rurality match	Rurality match is a 6-point scale based on both the rurality and deprivation of an LA. The scale was developed by WRAP to be used in the 'Kerbside recycling: Indicative Cost and Performance' model (2008) http://laportal.wrap.org.uk/ICPToolHome.aspx Rurality data: The proportion of an LAs population living in rural areas was taken from the population densities of the LAs Lower Super Output Areas (LSOAs) for England and Wales, Data zones in Scotland and Super Output Areas for Northern Ireland. Each LSOA was classified as rural or not rural based on population density. • Rural: Population density < 750 inhabitants* • Not rural: Population density ≥ 750 inhabitants* *There is no accepted definition of rurality therefore a threshold was defined for the model The proportion of a population of each local authority living in a rural LSOA was calculated for each LA and each LA was classified into: • Predominantly urban: < 6% of the population was rural • Mixed Urban/Rural: Between 6% and 30% of the population was rural • Predominantly Rural: > 30% of the population was rural
Social grade	2011 Census: Approximated social grade, local authorities in England and Wales (Table QS611EW) % of population approximated social grade DE

10.6 Appendix F: Peer review statement

Technical peer review of POS011-007: The impact of household food waste collections on household food waste arisings

An independent peer review was undertaken of *Impact of household food waste collections on household food waste arisings* study, with the goal of ensuring that the methodology is statistically valid and that the results stand up to technical scrutiny.

WRc reviewed WRAP's proposed analysis strategy during a series of teleconference meetings between September and November 2018 and potential issues raised by the review were discussed with WRAP to identify and agree appropriate changes. Interim regression modelling results were reviewed in January 2019, focusing on the coding of predictor variables and use of sensitivity analysis to gauge the robustness of the results. Interim and draft final versions of the report were reviewed on 20 February and 25 March, respectively, and suggestions made for clarifying the description of the methodology and the presentation of the results.

In this study, the author has made clear efforts to select and apply appropriate statistical techniques and provide a detailed and transparent justification for the methods used. Notably, the process for screening the data prior to analysis has been well documented, and the influence of possible confounding variable has been taken into account to reduce the risk that they act to mask or exaggerate the effect of food scheme type. The regression models have been evaluated and assumptions made during the study have been clearly presented and discussed. The report provides an accessible account of the study's findings and the conclusions are supported by the available evidence.
In summary, I am satisfied that the research presented in this report provides a fair and reliable assessment of the impact of household food waste collections on household food waste arisings.

Dr Andrew Davey, WRc plc
Peer Reviewer, 25 March 2019