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D2.6 Evaluation of food-excluded residual waste streams and impact on energy balance

Lead contractor: **Veolia Environmental Services (UK) Ltd (Veolia)**

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D2.6 Evaluation of food-excluded residual waste streams and impact on energy balance

1. Introduction

The work described in this Deliverable Report presents an analysis of the effects of the introduction of separate food waste collection on the volume and characteristics of the residual waste stream. A theoretical analysis of predicted outcomes is compared to empirical results obtained in areas where separate food waste collection has been introduced. Data were gathered and compared for the following parameters:

- Composition of residual waste stream
- Effect on calorific value of the residual waste stream
- Overall quantity of residual waste

Case studies are compiled from a number of municipalities in England, Netherlands, Spain, Sweden and Portugal, to provide snapshots of the effect that the introduction of food waste collection has had in different regions. It should be noted that these are not full country-wide surveys, but rather are examinations of individual and regional cases.

2. Background

2.1. Residual waste

Traditionally throughout Europe, the predominant mode of management for municipal solid waste has been disposal in landfill. In the last two decades, however, major strides have been made in the diversion of materials from landfill, in response to scarce landfill space, rising costs and increasingly stringent regulations at national, European and international levels (Gaillochet and Chalmin, 2009).

The Waste Framework Directive, 2008/98/EC, Article 4 establishes the hierarchy for handling of waste as follows:

1) Prevention;
2) Preparing for re-use;
3) Recycling;
4) Other recovery, e.g. energy recovery; and
5) Disposal.

Recycling and composting have been the focus for specific materials such as paper and cardboard, plastics, metals, glass and organic materials. The search for alternative disposal options for the remaining residual stream - those materials not recovered by recycling or composting – has also led to an increase in thermal treatment.

2.2. Theoretical impact of food waste collections on energy value of residual waste

Although on a dry weight basis food waste has a fairly high calorific value (Magrinho and Semiao, 2008) it has a high moisture content, which means that its Lower Heat Value (LHV) is low (Tchobanoglous et al., 1993).

If food waste were to constitute a lower proportion of the residual stream, then other, higher-LHV components would therefore make up a greater proportion. The reduction of food waste in the residual stream by diversion to separate food waste collection and processing options, therefore, has the potential to increase the overall LHV of the residual waste stream.

Magrinho and Semiao (2008) showed that as food waste is removed from the residual waste stream, Higher Heat Value (HHV) decreases but LHV increases, by up to 37% in the case of a Portuguese residual stream from which 100% of food waste was theoretically recovered. They point to LHV as the more relevant parameter as it represents the energy actually available to be converted into heat and/or electricity.

For this study, a model was developed using estimated LHV of components of the waste stream, to enable the theoretical calculation of the net calorific value (net CV) of residual waste streams based on their compositions. Net CV is equivalent to LHV, while gross CV is equivalent to HHV.

To assess heating value based on composition, standard calorific values were used for each waste category, based on literature values for Lower Heat Value (LHV) (Riber et al., 2008; Williams, 2005; Tchobanoglous et al., 1993). LHV for the fraction "miscellaneous combustibles" was estimated as an average between the fractions wood, textiles and nappies, resulting in a value of 15 MJ kg^{-1} (Table 1).

Table 2.1 Net calorific values (as LHV) used in the present study.

Waste type	LHV (MJ kg^{-1})
Food waste	4
Garden waste	6
Paper	16
Plastic	36
Glass	0
Metal	0
Wood	16
Textiles	19
Nappies, hygiene articles etc.	22
Miscellaneous combustibles	15
Hazardous wastes	0
WEEE	0
Other inert	0

In the following chapters, case studies from a number of EU countries are examined to determine the impact that separate collections of food waste have had on the composition and quantity of the residual waste stream.

3. Case Studies – England

3.1. Waste quantities and treatment capacity

According to Defra, household waste generated in England from April 2010-March 2011 was 449 kg per person, of which 186 was composted, recycled or reused, with 263 kg remaining as residual waste (Defra 2012). This was a decrease from the previous year. Overall waste sent to landfill declined by 8.8 percent between the two fiscal years, to 11.4 million tonnes in total (Defra 2012).

England accounts for approximately 81% of total UK waste generation (European Environment Agency, 2010). Alternative treatment capacity for residual waste in the UK increased from approximately 2.5 million tonnes per annum (tonnes year^{-1}) in 2001/02 to 4 million tonnes year^{-1} in 2008/09, amounting to just over 10% of residual waste being treated by these means (Tolvik, 2009). The amount of landfilled waste declined from a high of 50 million tonnes year^{-1} in 2001/02 to 33 million tonnes year^{-1} in 2008/09; 1.5 million tonnes year^{-1} of this could be attributed to increased residual treatment capacity, with the balance due to increased recycling and declining overall waste volumes (Tolvik, 2009).

The past four years have seen a significant expansion in planned and operating EfW capacity in England; the country now has a total of 15.8 million tonnes year^{-1} of residual waste treatment capacity currently operating or under construction. Planning consent has been obtained for a further 17.6 million tonnes of capacity, and an additional 2.1 million tonnes is in the planning process. The current stock of operating or under-construction facilities includes 35 incineration facilities, 5 gasification facilities, 5 cement kilns and 9 Waste Incineration Directive-compliant biomass facilities (Eunomia, 2013).

3.1.1. Current waste collection and management

Figure 3.1 shows the municipal waste arisings collected by local authorities in England as of 2007/08.

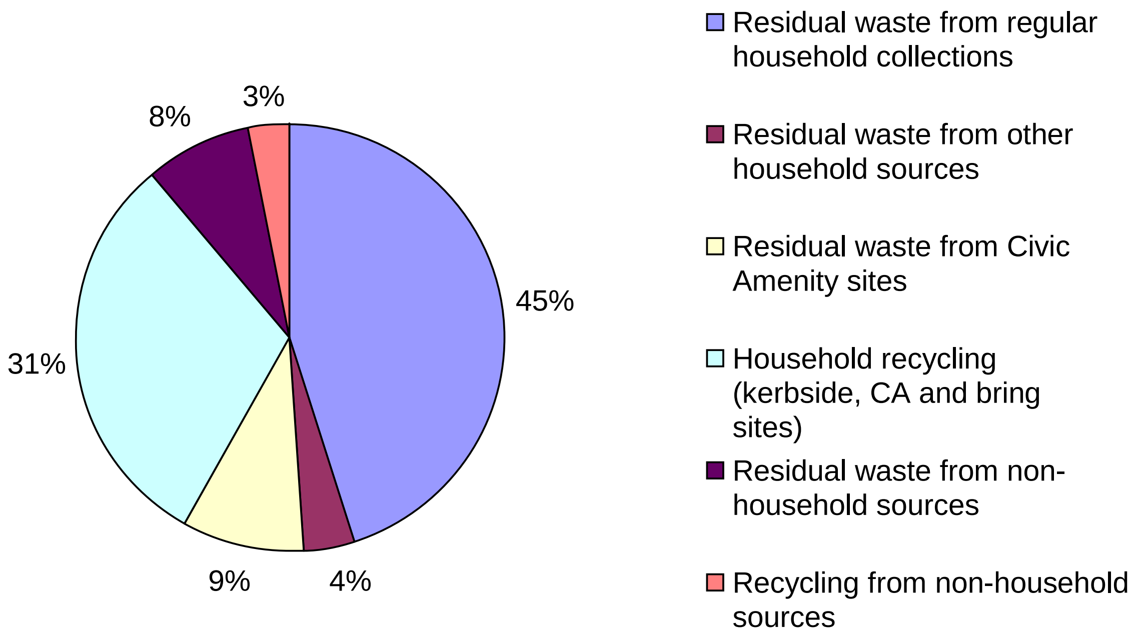


Figure 3.1 Municipal waste arisings in England by waste stream, 2007/08 (Resource Futures, 2009).

Of all waste collected, 34% was diverted to recycling and composting schemes. Residual waste, at 45%, is the largest component of waste handled by local authorities. Household waste accounted for nearly 90% of waste collected by local authorities in England in 2007/08, and residual waste accounted for 66% of collected waste. If only kerbside collections are considered, residual waste accounts for 75% of waste collected (Resource Futures, 2009). It is clear, therefore, that residual waste remains the most significant component of the municipal waste stream, and it is valuable to know how it is impacted by the introduction of new recycling initiatives.

As the figure above shows, recycling accounted for 34% of England's waste in 2007/08. As of the third quarter of 2012, this had increased to 47% (Defra, 2013).

3.1.2. Municipal Waste Composition

Figure 3.2 shows the typical composition of municipal solid waste collected by local authorities in England, in the year 2006/2007 (Defra, 2007).

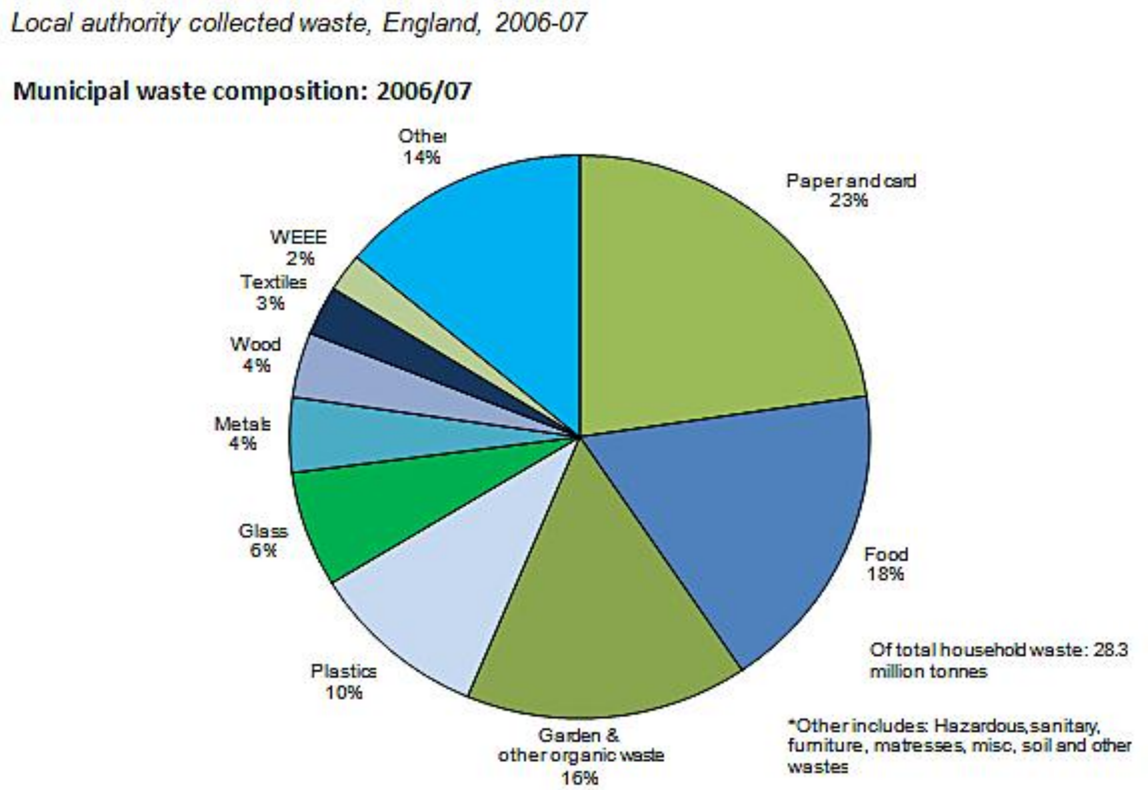


Figure 3.2 Composition of municipal waste collected by local authorities in England, 2006/07 (Defra, 2007).

3.1.3. Residual Waste Composition and Quantity

Understanding the composition of the overall municipal waste stream is useful for understanding waste arisings overall, inclusive of recycling and composting. It is also important to know the composition of the residual waste stream remaining after the diversion of the 47% of municipal arisings that are currently recycled or composted (Defra, 2013), particularly if collection schemes are to be designed to maximise capture of specific streams or materials.

Since local authorities are seeking to decrease the amount of residual waste through reduction and diversion initiatives, the volume and composition of the residual waste stream is changing as new components are targeted for diversion.

In 2009 an effort was made to form an accurate snapshot of the composition of residual waste across England (Resource Futures, 2009). A number of local authority waste composition studies were compiled to come up with a national estimate of waste composition. There were 120 studies in total, from local authorities throughout England and dating from 2005 to 2009. From these estimates, the composition of the residual waste stream was developed, and is shown in Figure 3.3 below.

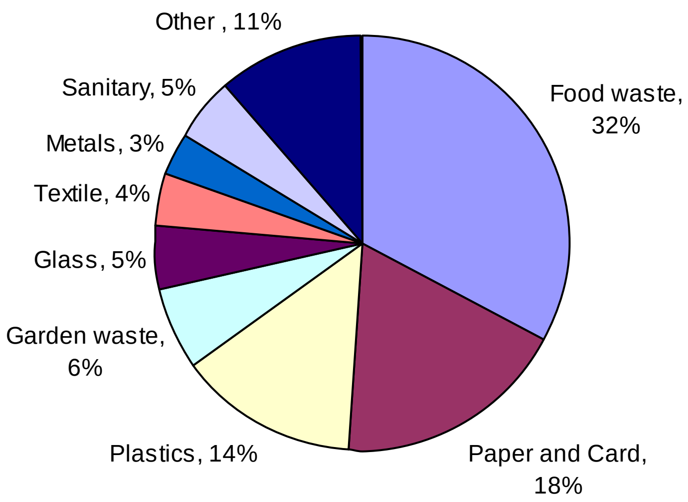


Figure 3.3 Average composition of residual waste stream, England 2005-2009 (Resource Futures, 2009).

The figure shows that food waste, at 32%, is the most significant contributor to the residual stream. Initiatives to separately collect and process food waste, therefore, should have a significant impact on residual waste arisings.

In 2005/06 separate food waste-only collections made up less than 1% of municipal organics collected for composting (WRAP, 2008); however as the landfill tax escalator has increased the cost of landfilling relative to organics processing, and as a result of major food waste campaigns from WRAP (e.g., WRAP 2008, 2009, 2012) the introduction of food waste collections has been on a sharp increase in recent years.

In England, the number of authorities providing separate food waste collection has increased from 9 in 2004/05, to 42 in 2006/07 (WRAP, 2008), to 57 in 2010/11 (VALORGAS D2.2, 2012). A further 64 authorities have a mixed organics collection of food waste and garden waste, bringing the total to 121 out of 325 local authorities (VALORGAS D2.2, 2012) or 37% of English authorities in 2010/11. This also implies that there is significant potential for further diversion of food waste from the residual stream, as more municipalities introduce separate collections for food waste or mixed organics. This number has continued to increase over the past two years.

3.1.4. Alternate weekly collections

Researchers at Bath and Hull universities compiled data from local authorities with weekly or fortnightly residual waste collections, comparing those with fortnightly collections of residuals collected on alternate weeks to recyclables, to authorities with weekly residual waste collections. They found that a local authority could expect to increase its dry recycling rate by an average of 3.8% with the introduction of alternate weekly collections (AWC) (Sloley, 2011). Williams and Cole (2013) found a recycling increase of up to 9% upon introduction of AWC in Staffordshire. AWC can also give cost savings by allowing differing waste streams to be collected without additional large investment in vehicles and staff, as the same vehicles can be used on different weeks; in Lichfield, Staffordshire, AWC saved 16,000 km of vehicle mileage and an estimated £97,000 per year over the previous system (Williams and Cole, 2013).

According to ORA (2005), householders tend to utilise as much collection capacity as is provided. By limiting weekly bin capacity, AWC or fortnightly collections encourage residents to separate recyclable and compostable material to save space in the residual bin, resulting in a decrease in residual waste arisings.

The majority of top performing recycling authorities in England and Wales use AWC, with a total of 250 authorities on the system as of 2012 (Williams and Cole, 2013). A number of the case studies examined in the following sections show decreases in residual waste tonnages after the introduction of fortnightly residual collection or in comparison to neighbouring authorities with weekly collections.

Another way in which councils have encouraged recycling and waste minimisation is through changing bin sizes, with decreased residual bin size and/or increased recycling bin size, to encourage recycling. Examples include Bristol City Council (2010), Ipswich Borough Council (2011), Dartford Borough Council (2013) and Staffordshire Moorlands District Council (2012).

3.1.5. Food waste collection

In the Waste Strategy for England 2007, food waste was identified as one of the key waste streams (Defra 2007) and since this time close to half of English authorities have been introducing collection of food waste. Elsewhere in the UK, in 2011 the Welsh government made separate collection of food waste compulsory for all Welsh authorities, and as of 2011 half of Scottish authorities had food waste collections for at least part of their areas. At the same time, the UK government has launched a strategy to encourage AD as a source of renewable energy (Defra and DECC, 2011), as a way of addressing two policy issues with one synergistic strategy.

The frequency of collection can have an impact on behaviour (Bond, 2012); when more frequent collection of organic waste is coupled with less frequent collection of residual waste, this provides a natural encouragement to dispose more organic waste in the organic waste bin, whereas if organics are only picked up on alternating weeks, people will be more likely to use the residual bin to dispose of organics in the weeks between organics pickup (WRAP, 2009).

A weekly food waste collection can not only increase the capture of food waste from the waste stream, but can also reduce the amount of food waste arisings. In one instance, quantities of food waste collected in the weekly food waste collection were lower than expected, which was originally attributed to a disappointing capture rate. When the residual stream was examined, however, there was less food waste than expected, to the extent of approximately 1 kg per household per week. This showed that the overall amount of food thrown away by residents decreased (Bond, 2012). This is thought to be related to the fact that having a separate food waste container in the kitchen shows residents more clearly that they are wasting a lot of food that they've paid for, and change their behaviour as a result (Bond, 2010).

Further evidence comes from the Greater Manchester Waste Disposal Authority, where districts that provided a kitchen caddy and separate collection of food waste (Manchester, Oldham, Stockport and Tameside) had lower quantities of food waste in the combined waste stream (including recycling streams and residual waste) than those that didn't (Bolton, Bury and Rochdale). Authorities providing food waste collection had food waste amounts in the combined stream ranging from 1.97-3.11 kg $household^{-1}$ $week^{-1}$, while those without food waste collection ranged from 3.37-3.88 kg $household^{-1}$ $week^{-1}$ (AMEC, 2012).

In the following sections, data is examined from a number of councils that have done studies on the composition of their residual waste. Although each differ somewhat in analysis methodology and waste regime, some comparison of general trends within and among the cases is possible.

These case studies are of local authorities that together represent a total population of approximately 8.5 million, or about 16% of the population of England.

3.2. South Gloucestershire Council

South Gloucestershire is a unitary district in the south west of England, east of Bristol. Its population is approximately 260,000. The council is a unitary authority responsible for collection and disposal of waste in the county, which it has contracted out to SITA South Gloucestershire Ltd. for a period of 25 years. The contract commenced in the year 2000.

In 1998, 2003 and each year since then, South Gloucestershire Council has had a study done on its kerbside residual waste, by consultants or its own staff. The Council has had kerbside dry recycling in various forms for a number of years, and introduced food waste recycling in November 2010. This was alongside an existing yard waste collection scheme.

Waste collection regime:

The recycling regimes over the time period of the analyses have been (Cummings, 2005):

- Up to 2001:
  - Weekly refuse collection;
  - Disparate recycling services among different areas with different materials collected at different frequencies;
  - Three civic amenity (CA) sites and a number of bring banks
- 2001-2004:
  - Harmonization of recycling across the council administrative area
- From January 2004:
  - Alternating week collections (AWC) of recycling and greenery/cardboard on one week, residual waste the next;
  - Continuation of CA sites (upgraded as Sort-It! Centres) and network of recycling banks;
  - Provision of bulky & clinical waste collections;
  - Chargeable collection of garden waste and household fixtures;
  - Subsidised home composting bins;

    - Waste awareness campaign to households and schools
- From November 2010:
    - As above plus introduction of weekly separate food waste collections, including a kerbside bin and kitchen caddy for indoor use plus a fortnightly alternating separate collection of plastic bottles and cardboard.

An in-vessel composting plant was built in 2006 to process organics from the council area (Cummings 2005).

Study methodology:

The annual waste audits varied in exact quantities of households surveyed, methods of categorization and weighting of households, but generally used a sample size of approximately 250 households (range from 240 to 279) with approximately equal proportions of households from five different council tax bands (about 40 hh from each).

This was a subsample of the 109,000 households serviced by South Gloucestershire. Each audit was done over a two-week period, in October of most years. Results were weighted by council tax band to more accurately represent the distribution of households across the county.

Audit results:

Figure 3.4 shows the mass and composition of residual waste from South Gloucestershire in the years 1998-2003 (before the introduction of AWC), 2004-2010 (after AWC, and before the introduction of FWC) and 2011-2012 (after introduction of FWC). The years in which AWC and FWC were introduced are shown in callouts along the X axis.

The results show that food waste decreased in the composition from 36% to 27% after separate food waste collections (FWC) were introduced, and the overall tonnage of residual dropped from 8.5 to 6.8 kg household^{-1} week^{-1} (442 to 351 kg household^{-1} year^{-1}), a decrease of 21%. The maximum year-to-year decline in quantity previously had been 16%, from 2003 to 2004 when the alternating week collection (AWC) of residuals and recycling was first introduced. Decreases in other years varied from -16% (an actual increase in tonnage) to 13%. Average weekly household residual waste quantities declined after each new program was introduced.

The compositions shown in Figure 3.4 were also used to calculate the theoretical net calorific value (CV) of the residual waste stream each year, by assigning a lower heat value to each component, as given in Table 2.1, and weighting its contribution to heat value according to its proportion in the composition.

The highest net CV is seen in October 2011, the year FWC was introduced. It decreased in October 2012 to slightly less than in the years 2007-2009, with a lower proportion of mixed plastics.

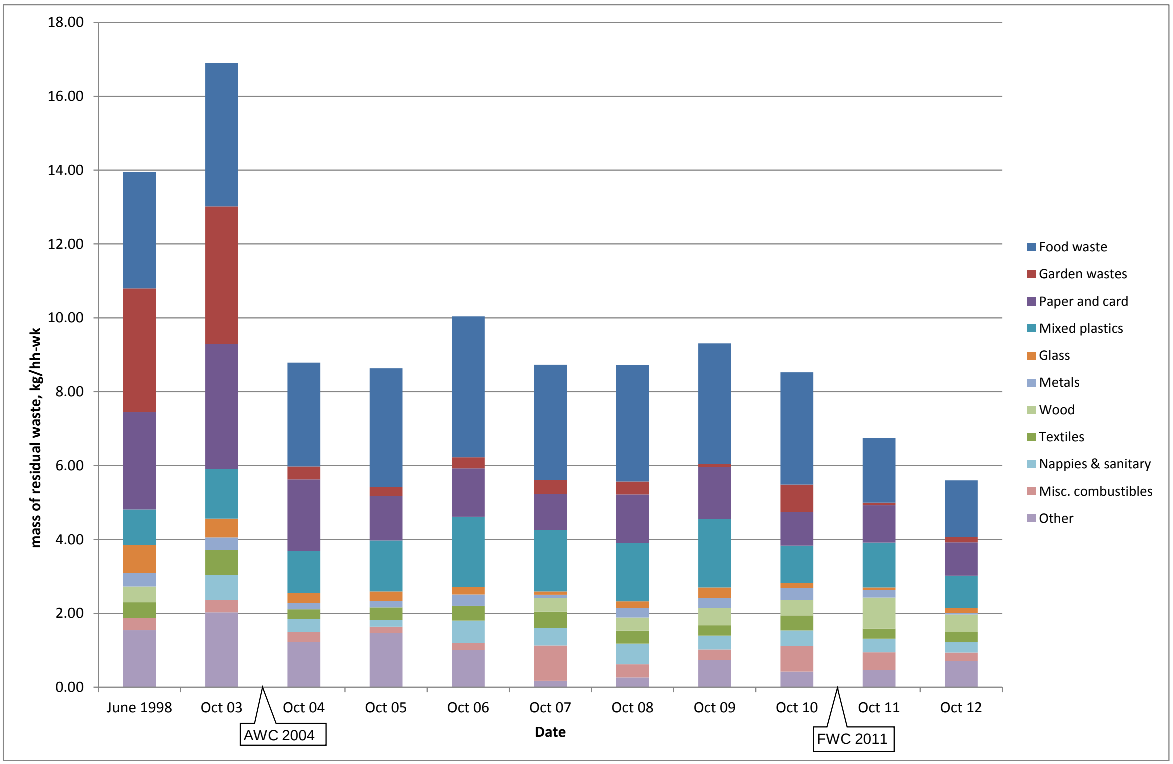


Figure 3.4 Mass and composition of residual waste stream in South Gloucestershire, years 1998-2011. 1998-2003: before introduction of AWC; 2004-2010: after introduction of AWC and before introduction of FWC; 2011-2012: after introduction of FWC. (Network Recycling, 2003a-2006; Cummings, 2005; Resource Futures, 2007d-2012a)

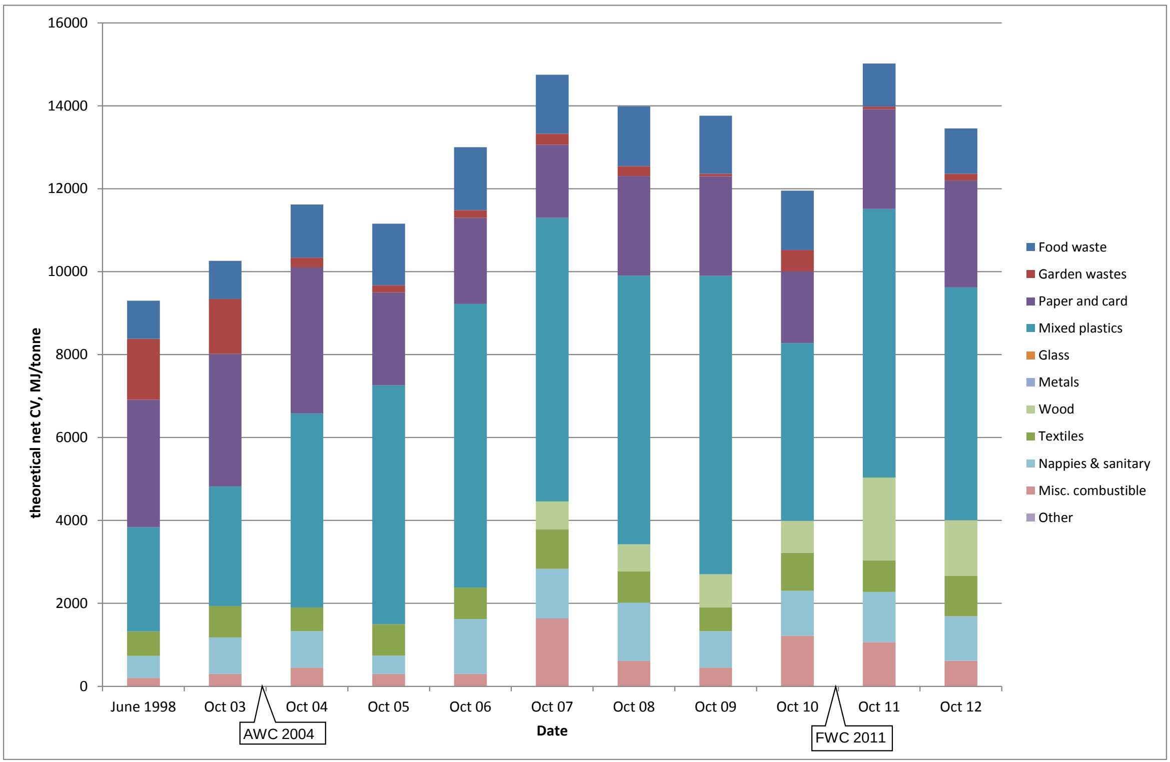


Figure 3.5 Theoretical heating value of residual waste stream in South Gloucestershire, years 1998-2011 (Network Recycling, 2003a-2006; Cummings, 2005; Resource Futures, 2007d-2012a)

Figure 3.6 shows together the percentage change in mass and theoretical net CV of the residuals for each of the years of the audit.

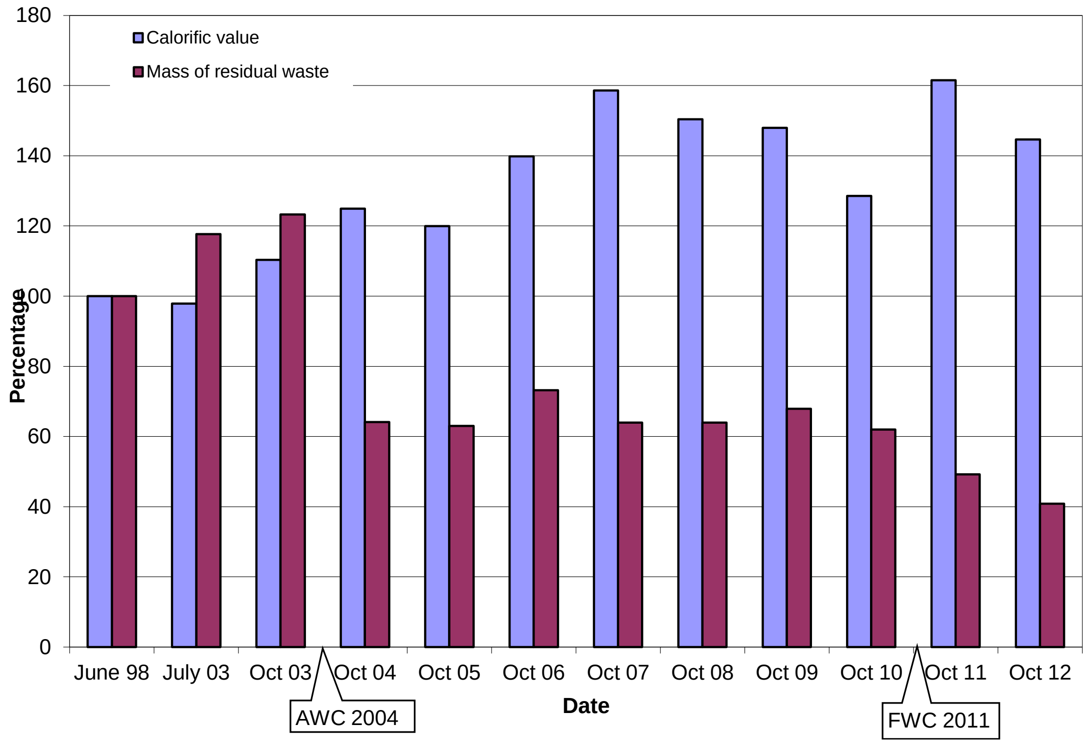


Figure 3.6 Changes in residual waste quantity and calorific value in South Gloucestershire, after change to alternating weekly collection of residuals (2004) and weekly food waste collections (2011).

3.3. Somerset Waste Partnership

Somerset Waste Partnership (SWP) is a consortium of individual district councils and the county council of Somerset, which have partnered to deliver waste collection and disposal services within the county. It is the executive arm of Somerset Waste Board, which includes two representatives from each of Somerset's six local authorities. They have contracted with May Gurney to provide waste collection services (Somerset Waste Partnership, 2012a).

The Partnership consists of Mendip, Sedgemoor, South Somerset and West Somerset District Councils, Taunton Deane Borough Council and Somerset County Council, the disposal authority. These authorities have worked together on waste services since 1992, and SWP was established as a Virtual Joint Waste Authority in 2007 (Somerset Waste Partnership, 2008).

Waste collection regime:

A new recycling regime, termed 'Sort It!' was introduced in October 2004 in three Somerset authorities, with these features:

- Weekly recycling and food waste collections, with kerbside sorting for recyclables;
- Fortnightly refuse (residual) collections, in 180-litre wheeled bins;
- Optional charged garden waste collection in wheeled bins or compostable paper sacks.

This was rolled out over two years to cover 160,000 households in three councils: Mendip, South Somerset and Taunton Deane (Somerset Waste Partnership, 2008). This was the first large-scale separate collection for domestic food waste since the introduction of the Animal By-Product Regulations of 2003 (Somerset Waste Partnership, 2008). The two remaining collection authorities maintained the previous recycling regime with weekly collection of refuse, until 2009/10 when the district of Sedgemoor adopted the ‘Sort It!’ program, followed by West Somerset in 2011, making it a county-wide program.

Study methodology:

In 2003 a waste composition analysis was done on residual waste collected from households in each district in Somerset. The results were weighted to reflect the socioeconomic profile of Somerset.

A second waste composition analysis was then carried out in 2006, after the ‘Sort It!’ recycling program had been in place for two years in the three local authorities. Waste samples were taken from areas with and without the ‘Sort It!’ program, allowing comparison of the results on the basis of recycling regime. A third waste composition analysis was carried out in April 2010 (D. Mansell, pers.comm. 2012).

Audit results:

Figure 3.6 shows the results of waste composition analyses from the three study years. After the introduction of the ‘Sort It!’ program, food waste decreased to 27% of the residual, versus 33% in non-‘Sort It!’ areas. Overall residual decreased from 2003 to 2006, by a greater amount in the ‘Sort-It!’ areas than those without (to 8.6 kg household^{-1} week^{-1} versus 13.2 kg household^{-1} week^{-1}). For the year 2009/10, residual tonnage in ‘Sort It!’ areas had decreased to 7.9 kg household^{-1} week^{-1}.

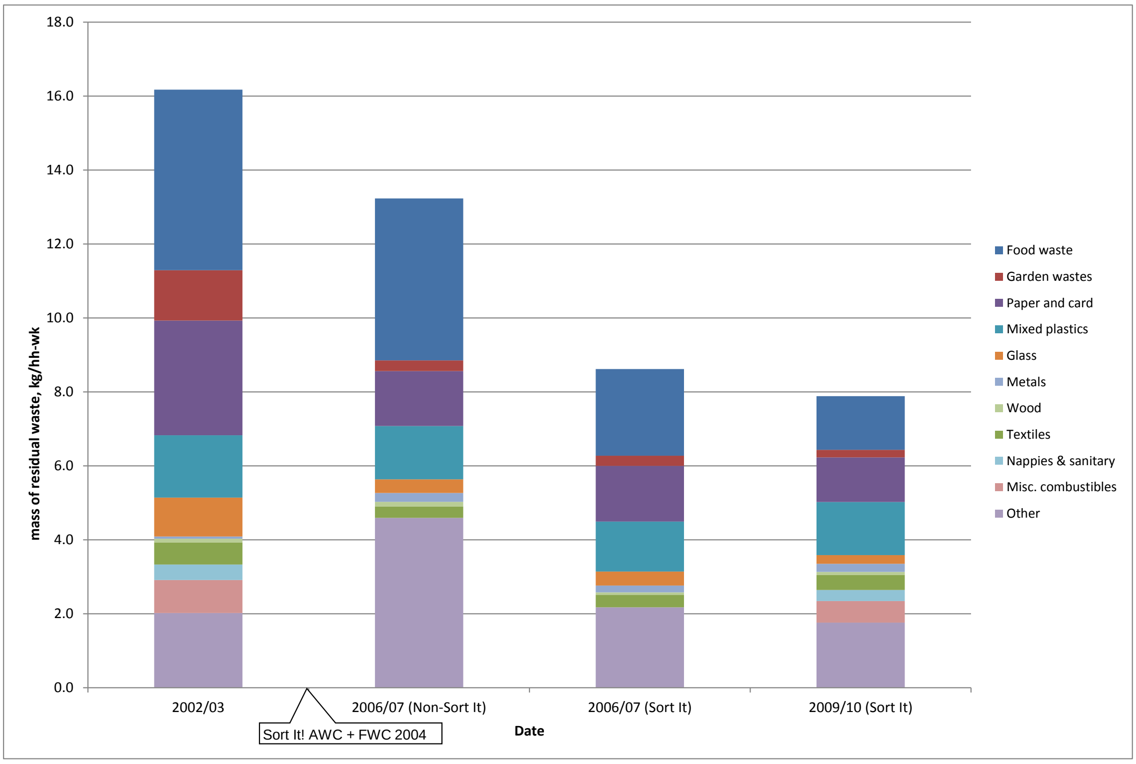


Figure 3.6 Residual waste composition in areas with and without ‘Sort It!’ recycling program, before and after implementation of the program (Data from D. Mansell, Somerset Waste Partnership 2012)

Figure 3.7 shows the theoretical net CV of the residual waste stream for those years, based on composition, using the LHV values given in Table 2.1. It shows an increase in net CV in the residual stream for areas with the 'Sort It!' program.

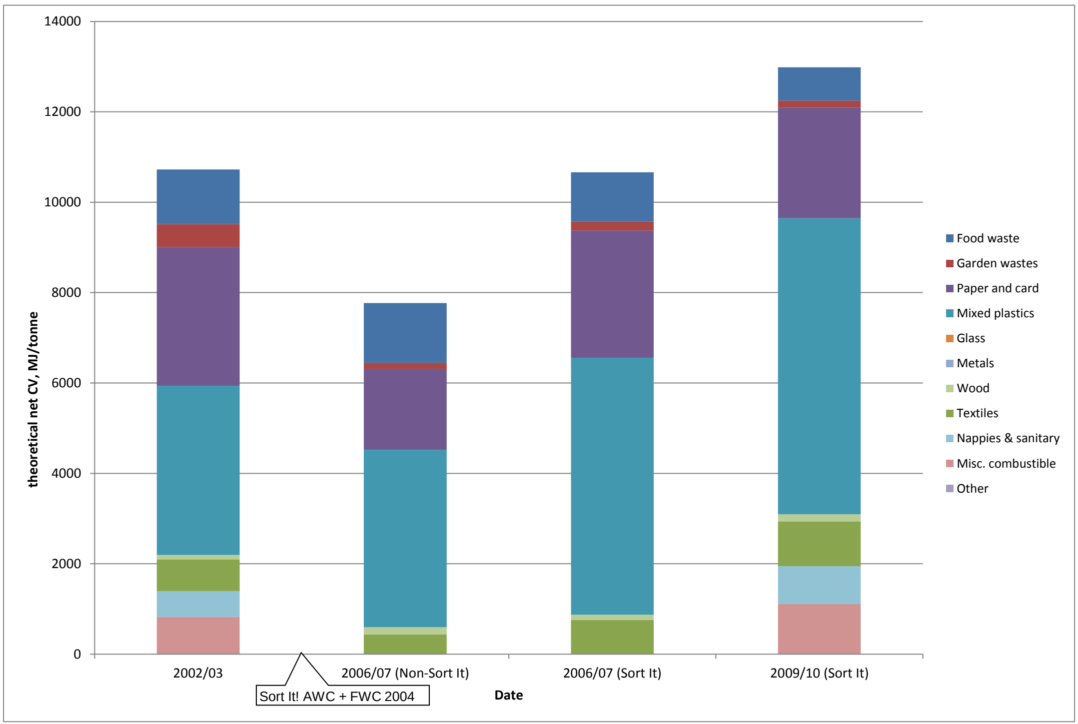


Figure 3.7 Theoretical net CV of residual waste based on composition in areas with and without 'Sort It!' recycling program, before and after implementation of the program (Data from D. Mansell, Somerset Waste Partnership 2012)

Figure 3.8 shows the relative changes in per-household amounts of residual waste, and in their theoretical net CV based on their compositions, for the years 2002/03 to 2011/12. It shows a decrease in quantity of residual waste where weekly food waste recycling was introduced, with an increase in calorific value.

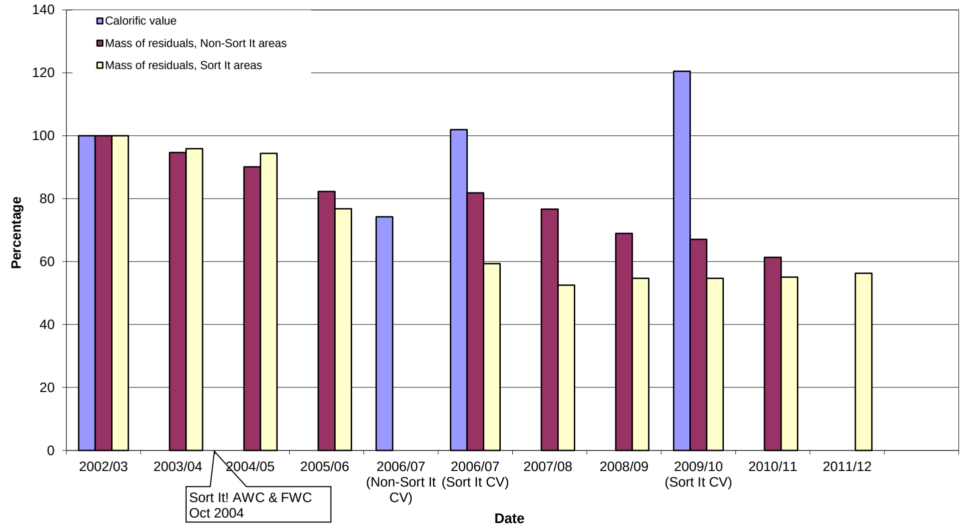


Figure 3.8 Changes in residual waste quantity and calorific value in Somerset, after introduction of comprehensive recycling services and weekly food waste collections (Data from D. Mansell, Somerset Waste Partnership 2012)

3.4. Surrey Councils

In 2010, a waste composition analysis was carried out on residual waste of all of the local authorities within Surrey (MEL, 2010). As the authorities had different collection regimes, this was useful for comparison of authorities with and without alternating week collections (AWC) and/or food waste collections (FWC). Eight of the eleven authorities had AWC of residual waste, while the other three had weekly residual waste collections. Five of the eight AWC local authorities provided separate collection of food waste, while three didn't. None of the authorities with weekly residual collection provided separate FWC.
All of the LAs had a garden waste subscription service and access to HWRCs, and provided collection of dry recyclables on a weekly or fortnightly basis.

The list of local authorities and their collection regimes are shown below:

Table 3.1 Kerbside collection regimes for Surrey councils (MEL, 2010)

Authority	Refuse Collection	Food waste Collection
Elmbridge	AWC	Yes
Epsom & Ewell	AWC	Yes
Guildford	AWC	Yes
Surrey Heath	AWC	Yes
Woking	AWC	Yes
Mole Valley	AWC	No
Spelthorne	AWC	No
Waverley	AWC	No
Reigate & Banstead	Weekly	No
Runnymede	Weekly	No
Tandridge	Weekly	No

Audit results:

Figure 3.9 below shows relative household residual waste tonnage and theoretical net CV for each authority. Figures 3.10 through 3.13 show the breakdown of mass and CV in absolute amounts, by local authority and grouped according to waste regime. The analysis showed that authorities with AWC of residual waste combined with weekly FWC had the lowest average residual waste, at 5.14 kg household^{-1} week^{-1}, while the average was highest for areas with weekly residual collections and no food waste collections, at 8.62 kg household^{-1} week^{-1}. The average for authorities with AWC but no FWC fell between these, at 6.99 kg household^{-1} week^{-1}.

They also found that across the county overall, an average of 1.86 kg household^{-1} week^{-1} of residual waste consisted of potentially recyclable food waste; this ranged from 1.18 kg household^{-1} week^{-1} for areas with FWC, up to 2.71 kg household^{-1} week^{-1} in areas where no FWC was provided and residual waste is collected on a weekly basis. Once again the authorities with AWC but no FWC fell between these, with an average of 2.16 kg household^{-1} week^{-1}.

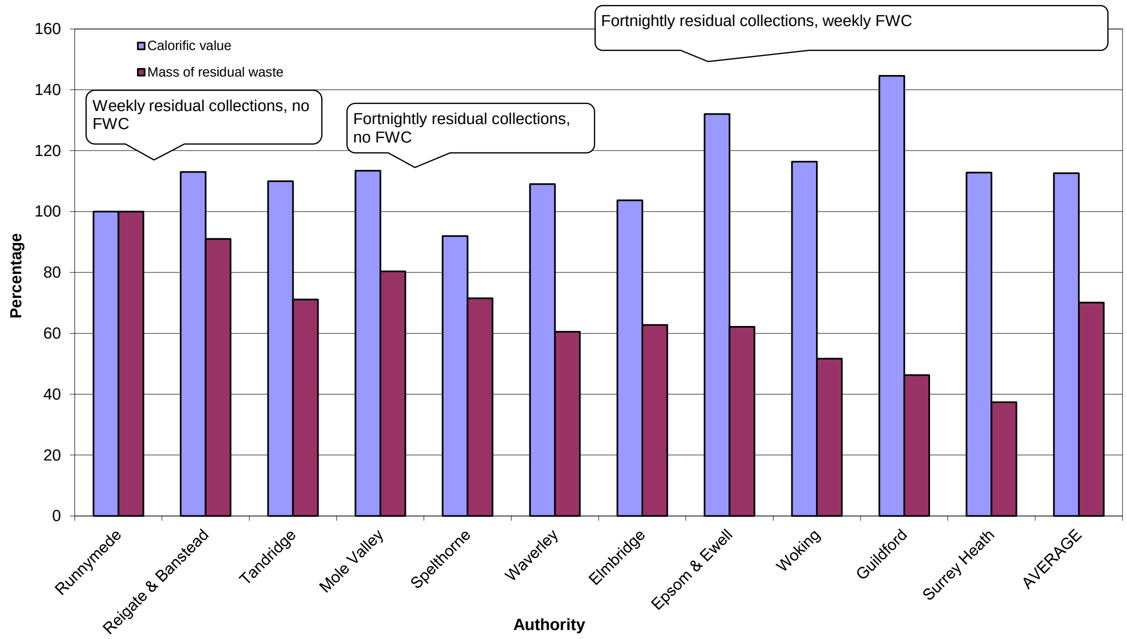


Figure 3.9 Comparison of relative quantities and calorific value for local authorities in Surrey (data from MEL, 2010).

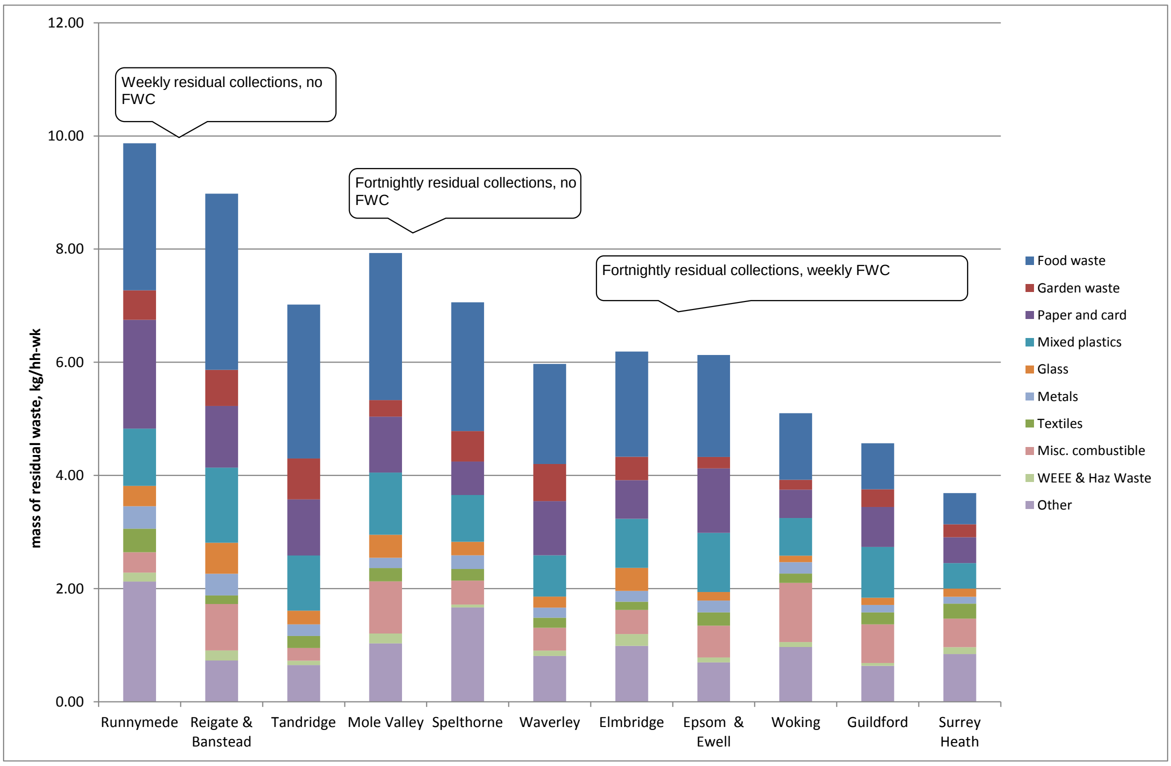


Figure 3.10 Comparison of household residual mass by composition for local authorities in Surrey (data from MEL, 2010).

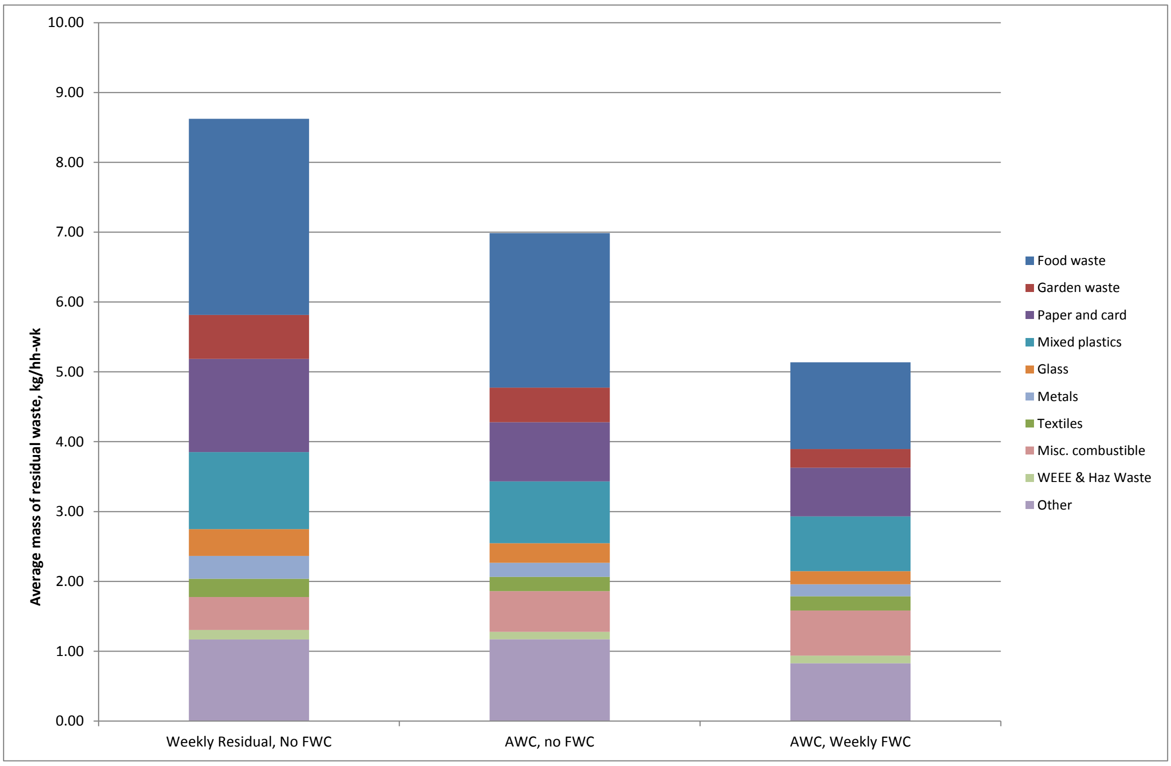


Figure 3.11 Comparison of household residual mass by composition for local authorities in Surrey, grouped by waste regime (data from MEL, 2010).

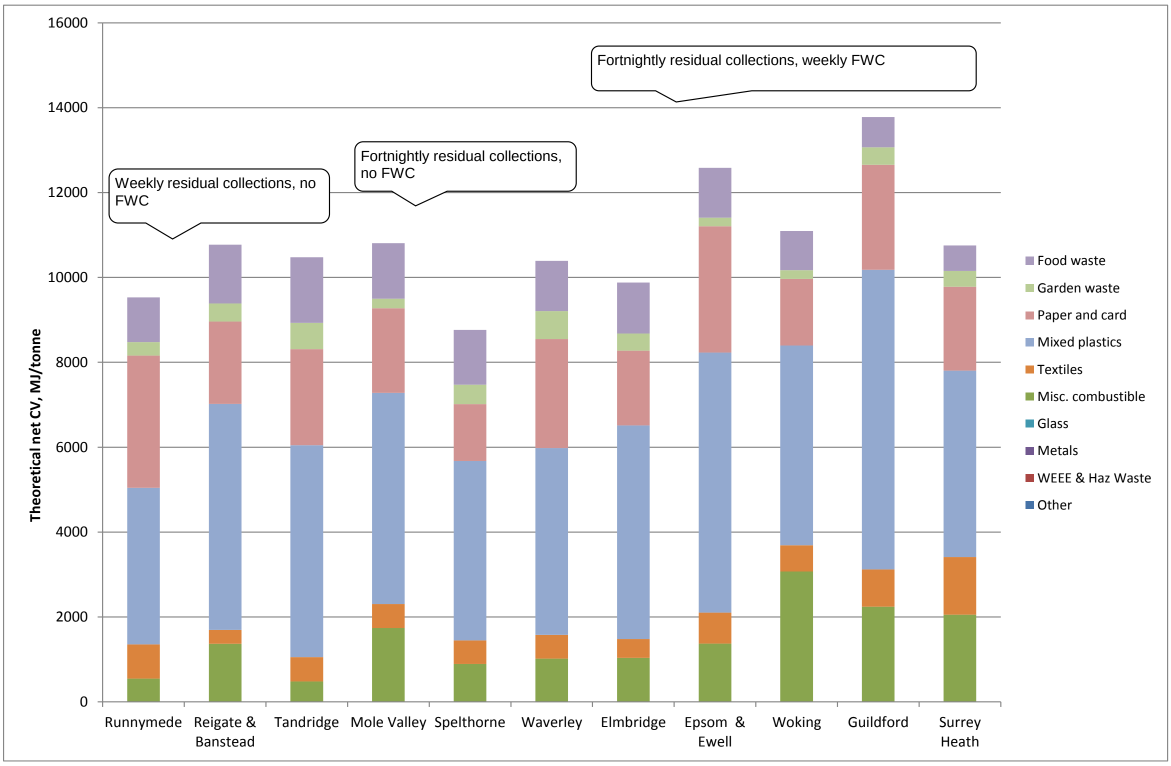


Figure 3.12. Comparison of calorific value by composition for local authorities in Surrey (data from MEL, 2010).

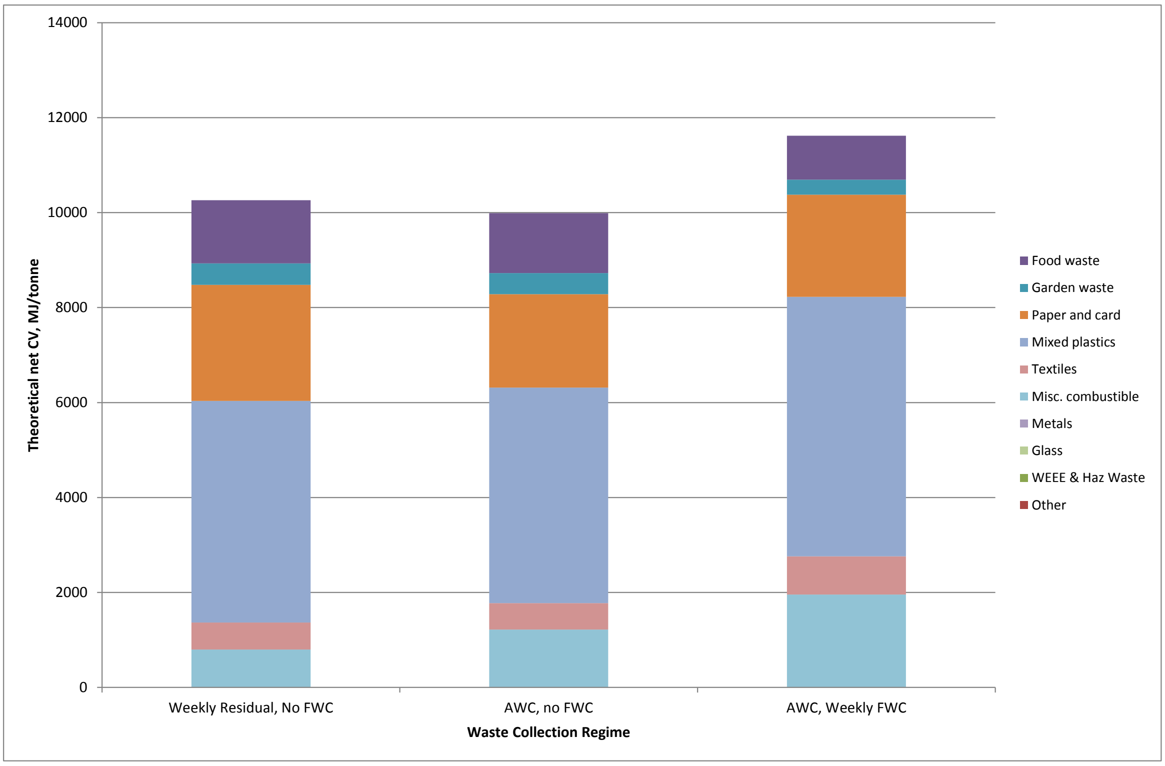


Figure 3.13 Comparison of average contributions to calorific value for local authorities in Surrey, grouped by waste regime (data from MEL, 2010).

3.5. Kent Waste Partnership

In December 2008, a waste composition analysis was carried out on residual waste of eleven of the twelve districts making up the Kent Waste Partnership (KWP) (WastesWork, 2009). Dartford was the only Kent council that did not participate in the study.

As the authorities had different collection regimes, this was another useful comparison of authorities with and without alternating week collections (AWC). Five of the eleven participating authorities collected residual waste weekly, while the other six collected it on an AWC basis. With respect to food waste collections, none of the councils provided separate FWC. Two of the councils provided collection of food waste as part of a fortnightly organics collection with garden waste, while the balance of councils collected garden waste only, either as a free or Pay-as-you-throw (PAYT) service.

Table 3.2 shows the collection regimes for each of the councils within the KWP.

Table 3.2 Kerbside collection regimes for Kent Waste Partnership councils (WastesWork, 2009)

Authority	Refuse Collection	Organics Collection
Gravesham	Weekly, sacks	PAYT garden waste
Maidstone	Weekly, wheelie bin	PAYT garden waste
Ashford	Weekly, sacks	Fortnightly garden waste
Dartford	Weekly, wheelie bin	None
Dover	Weekly, sacks	Fortnightly garden waste
Sevenoaks	Weekly, sacks	Fortnightly garden waste
Thanet	AWC	PAYT garden waste
Canterbury	AWC	Fortnightly garden waste
Shepway	AWC	Fortnightly garden waste
Swale	AWC	Fortnightly garden waste
Tonbridge and Malling	AWC	Fortnightly organics
Tunbridge Wells	AWC	Fortnightly organics

Study methodology:

The waste composition analysis was carried out over a 3-week period in December 2008, on residual waste collected from households. A total of 2146 households were surveyed, with an average of 195 households sampled in each district.

Audit Results:

Figures 3.14 through 3.17 show the results for the Kent authorities. The councils have been grouped into five sets, according to their residual waste collection frequency and organics collection regime. Only two of the councils, Tonbridge & Malling and Tunbridge Wells, collect food waste - this is part of a fortnightly organics collection.

In all councils, food waste makes up from 30-39% of the composition. Tonbridge & Malling and Tunbridge Wells, the two councils providing organics collection are among the lowest at 32 and 30% respectively, but Ashford also has a low food waste percentage at 30%, along with Maidstone at 32%.
Figure 3.14 shows that the two highest values for mass of RW per household are from two of the authorities with weekly residual collection, although two of these councils with this same collection regime also have tonnages below the average.

The two municipalities providing collection of food waste (Tonbridge and Malling, and Tunbridge Wells) were among the lowest at 9.3 kg household^{-1} week^{-1} and 8.5 kg household^{-1} week^{-1}, respectively, although Canterbury was the council with the lowest residual quantity, at 7.8 kg household^{-1} week^{-1}.

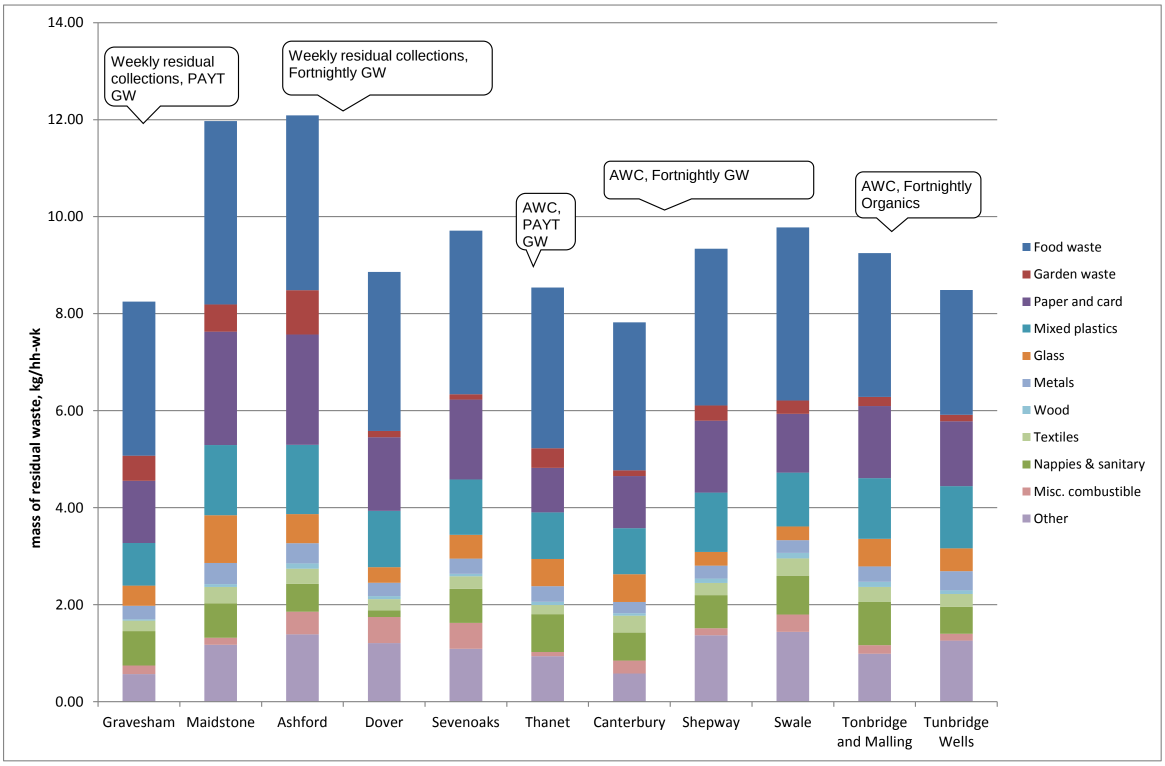


Figure 3.14 Comparison of household residual mass by composition for local authorities in Kent (data from WastesWork, 2009).

Theoretical net CV was similar among many of the councils. The two councils with AWC and fortnightly organics collection were among the highest, but Maidstone, Sevenoaks, Canterbury and Shepway also had high net CV values.

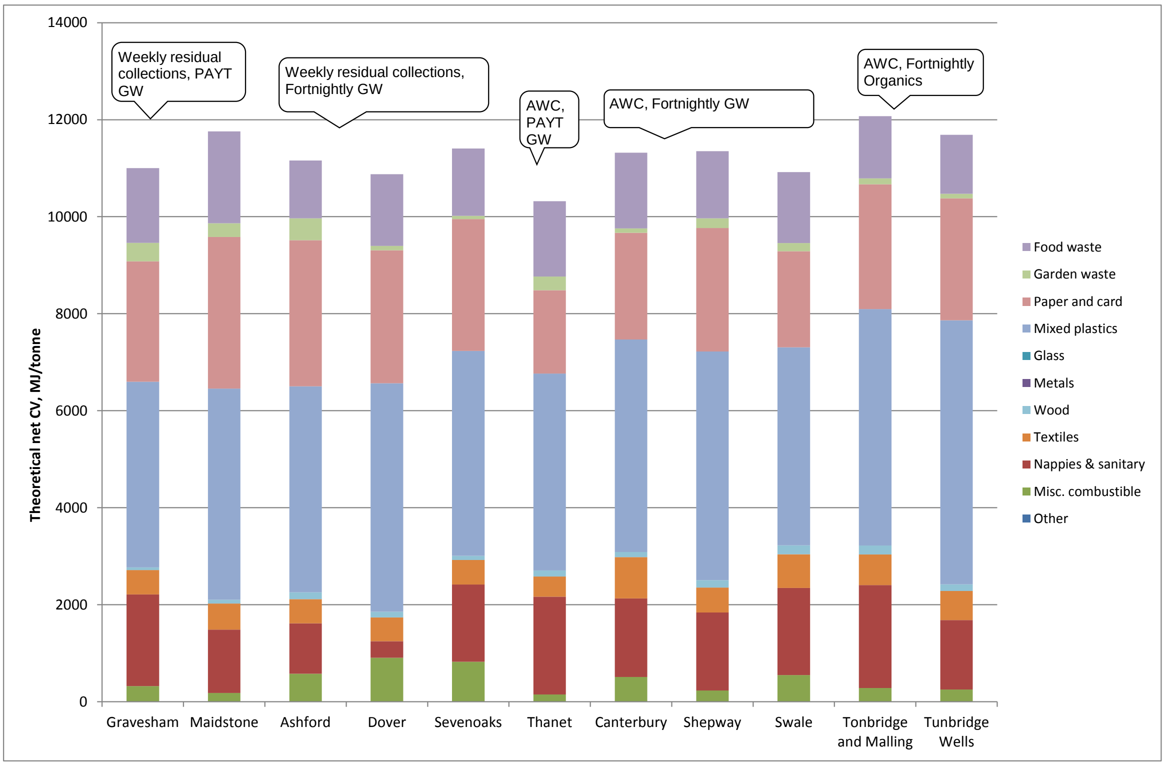


Figure 3.15 Comparison of calorific value by composition for local authorities in Kent (data from WastesWork, 2009).

Figure 3.16 below shows the authorities grouped by collection regime. The average value for theoretical net CV is highest for the AWC/fortnightly organics group, but similar to that for three other groups. The average household RW tonnage value is lowest for the AWC/fortnightly organics group, but this is again similar to that for the AWC/fortnightly GW group.

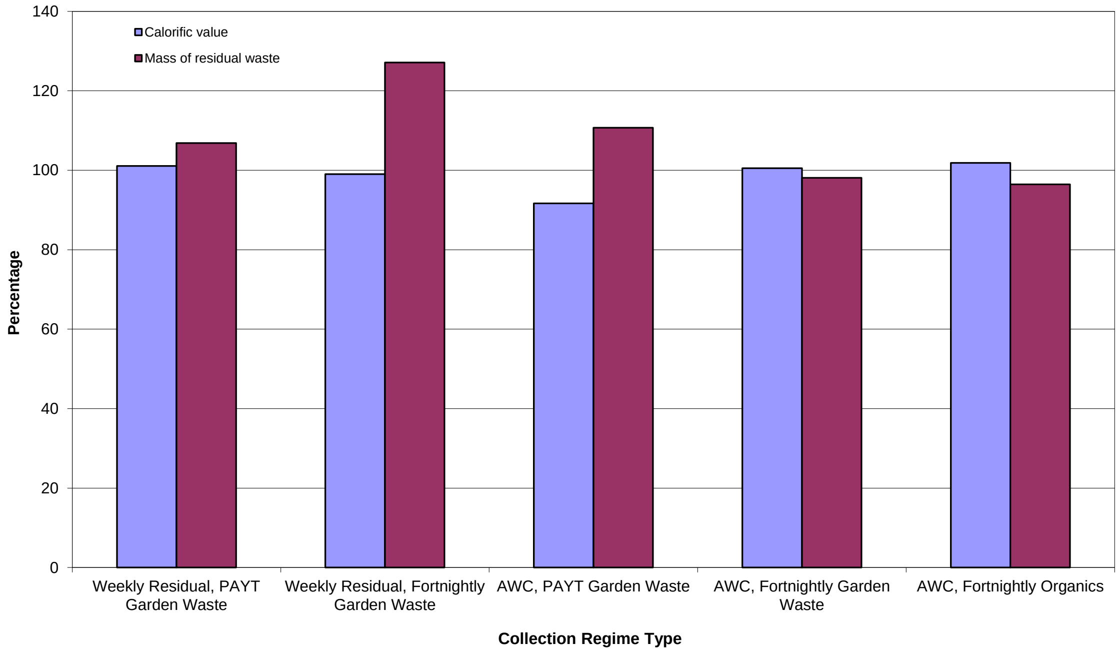


Figure 3.16 Comparison of average figures for relative quantities and calorific value for local authorities in Kent, grouped by waste regime (data from WastesWork,2009).

According to these results, providing food waste as part of a fortnightly service has a less significant impact on residual waste quantity and net CV than a weekly separate food waste collection. A significant portion of food waste has stayed in the RW stream and residual waste quantity shows less of a decrease than in previous case studies with weekly FWC.

Further Actions:

Two of the councils, Maidstone and Shepway, have since introduced weekly separate collections of food waste. Maidstone commenced FWC in January 2011 along with AWC of residuals, while Shepway introduced it alongside the existing AWC of residual.

3.6. Greater Manchester Waste Disposal Authority

The Greater Manchester Waste Disposal Authority (GMWDA) is responsible for collection, processing and disposal of waste from the geographical area of Greater Manchester, which is a large sub-region comprised of the districts listed in the table below. With 973,000 households in the catchment area, the GMWDA is responsible for 5% of the UK's waste. In 2009 the GMWDA signed a 25-year Private Finance Initiative (PFI) contract with Viridor Laing to provide waste collection and disposal services (Dunn and Jenkinson, 2012).

This includes development of a network of recycling and waste management facilities; as of 2012 there are four MBT-AD plants and four IVC facilities (P. Davies, GMWDA, pers.comm. 7/11/12), and an energy from waste plant at Ineos Chlor that will treat 850,000 tonnes year^{-1} of the RDF produced by the MBT plants, producing heat for the Ineos Chlor plastics production facility and exporting up to about 70 MWe to the national grid.

Table 3.3 shows the waste collection regimes for each of the districts.

Table 3.3 Kerbside collection regimes for GMWDA councils (AMEC, 2012)

Authority	Refuse Collection	Organics Collection
Bolton	Weekly, 240 L	Fortnightly garden waste
Bury	Weekly, 240 L	Fortnightly garden waste
Manchester	Weekly (Ph 1), AWC (Ph 2), 240 L	Fortnightly organics (120k hh); Weekly FWC (42k hh)
Oldham	AWC, 240 L	Weekly organics
Rochdale	AWC, 240 L	Fortnightly organics
Salford	Weekly, 240 L	Fortnightly garden waste
Stockport	AWC, 140 L	Weekly organics
Tameside	AWC, 240 L	Fortnightly organics
Trafford	Weekly, 180 L	Fortnightly garden waste (Ph 1), Fortnightly organics (Ph 2)

Study Methodology:

The waste audit and composition analysis was carried out during two distinct time phases of 2011: Phase 1 in February/March 2011, and Phase 2 in September 2011. Four sample areas were chosen to represent each district, for a total of 36 sample areas. An average of 25 households per sample area were used, for a total of 100 per district and 900 for all of the GMWDA.

Audit Results:

The results of the composition study are shown in Figures 3.17 and 3.18. The average of the two phases is shown for each district, except for the two districts which changed their collection regime between phases of the study: Manchester, which changed from weekly to fortnightly collection of residuals, and Trafford, which changed from fortnightly GW only collection to fortnightly organics.

The lowest residual waste quantities and highest net CV were seen for authorities with AWC and weekly organics collection.

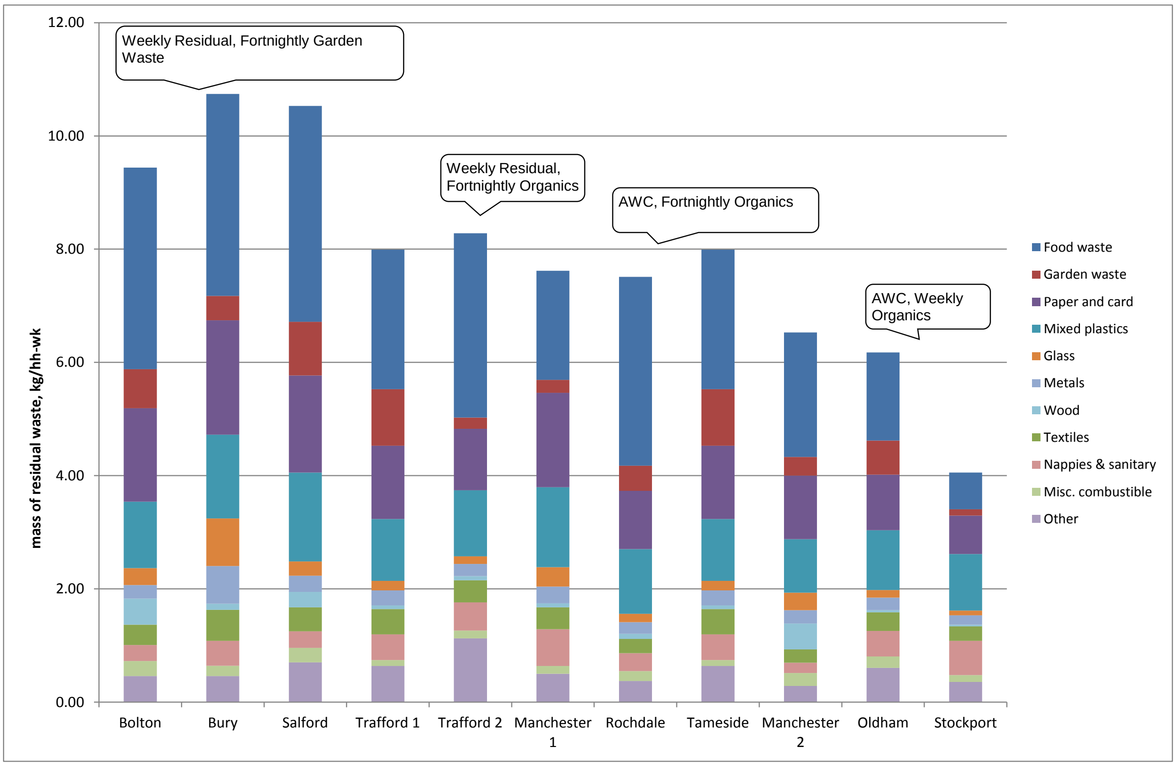


Figure 3.17 Comparison of residual waste quantity for GMWDA districts (data from AMEC, 2012).

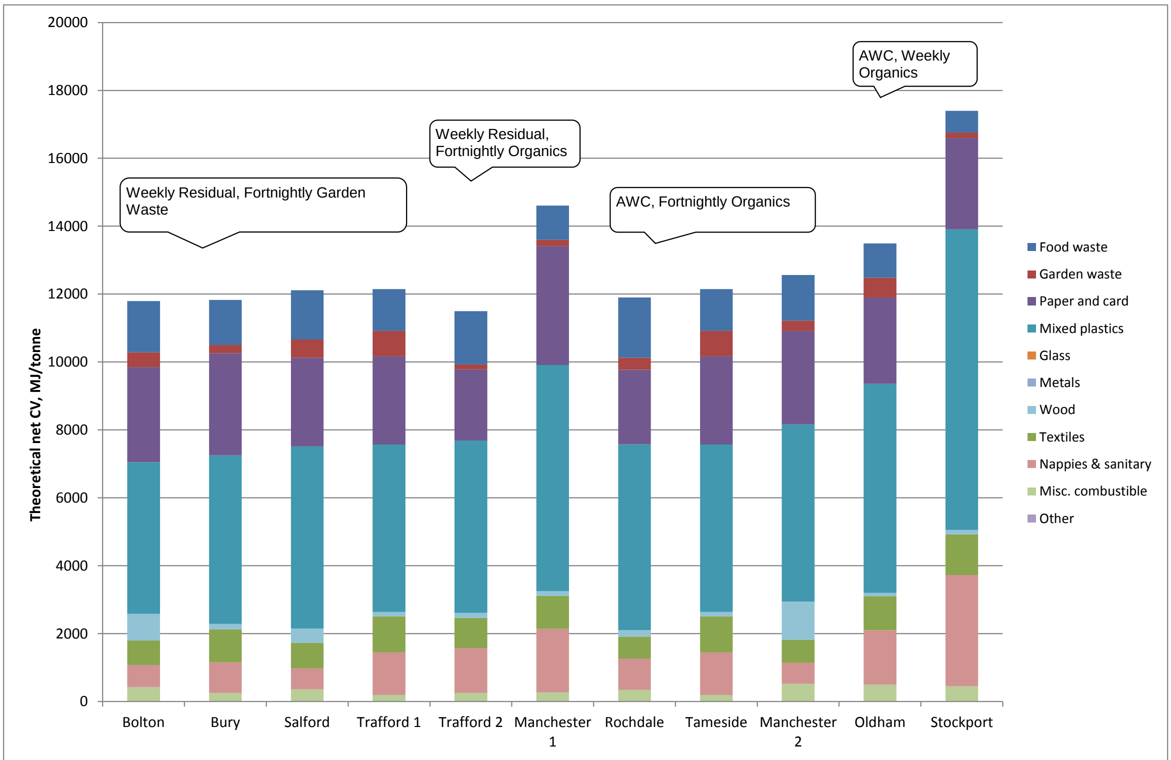


Figure 3.18 Comparison of theoretical net CV for GMWDA districts (data from AMEC, 2012).

Further Actions:

Bolton and Bury began accepting food waste with the fortnightly garden waste collection in October 2011, immediately after the waste composition study. As of November 2012, the authorities with weekly collection of food waste are Manchester, Oldham, Tameside and Stockport, whereas fortnightly collection of food waste is provided by Bolton, Bury, Rochdale, Trafford and Salford (Davies, 2012 pers.comm.).

3.7. North London Waste Authority

The North London Waste Authority (NLWA) manages waste from seven north London boroughs: Barnet, Camden, Enfield, Hackney, Haringey, Islington and Waltham Forest. Together the boroughs encompass a population of 1.7 million residents, with waste management responsibility for approximately 1 million tonnes of waste per year (NLWA, 2013).

An analysis of waste streams from the seven boroughs of the NLWA was carried out over two seasons in 2009 and 2010 by Entec, reflecting differences among the boroughs in residual waste quantity and composition.

Table 3.4 shows the collection regimes for each of the councils within the NLWA. Almost all of the councils had weekly collection of food waste for houses, with the exception of Waltham Forest, which had fortnightly collection, and Camden, which had none at the time. Barnet provided weekly collection of food waste mixed with garden waste.

Table 3.4 Kerbside collection regimes for NLWA councils (Entec, 2010)

Authority	Refuse Collection	Organics Collection Houses	Organics Collection Flats
Barnet	Weekly, sacks or wheelie bin	Weekly mixed garden & food waste	On request
Camden	Twice weekly, sacks	None – commenced after study	None
Enfield	Weekly, sacks or wheelie bin		Weekly - caddy and communal bin
Hackney	Weekly, sacks	Weekly food waste, fortnightly garden waste	Weekly - caddy for 13,000 hh
Haringey	Weekly, wheelie bin	Weekly food waste – 25 L bin, separate free garden waste (low-rise hhs)	None
Islington	Weekly, sacks	Weekly food waste, separate free garden waste (low-rise hhs – 44,000 properties)	None
Waltham Forest	Weekly, sacks or wheelie bin	Fortnightly mixed garden & food waste – 50,000 hhs	Fortnightly mixed garden & food waste

Study methodology:

Two waste sampling and analysis events were conducted, the first in September – October 2009, and the second in April – May 2010. Sample sizes of approximately 25 households from different housing categories were used, with four to five housing categories representative of each borough.

Audit Results:

Figure 3.19 shows the results for the NLWA authorities. The compositions are an average of the two sampling events. Household mass of residual waste is from WasteDataFlow data.

Two councils were not providing weekly food waste collection to any residents at the time of the audit. Waltham Forest, which had fortnightly collection of organics, had the highest residual waste mass, followed by Barnet and Haringey. Camden, however, which had no food waste collection at the time of the audit, had one of the lowest figures for weekly household residual mass. The average waste mass across the NLWA was 11.6 kg household^{-1} week^{-1}, of which 26% was food waste.

Figure 3.20 shows the theoretical net CV of residual waste from each of the boroughs, based on their compositions. This is highest for Islington and Camden, the two boroughs with the lowest mass of residual waste per household.

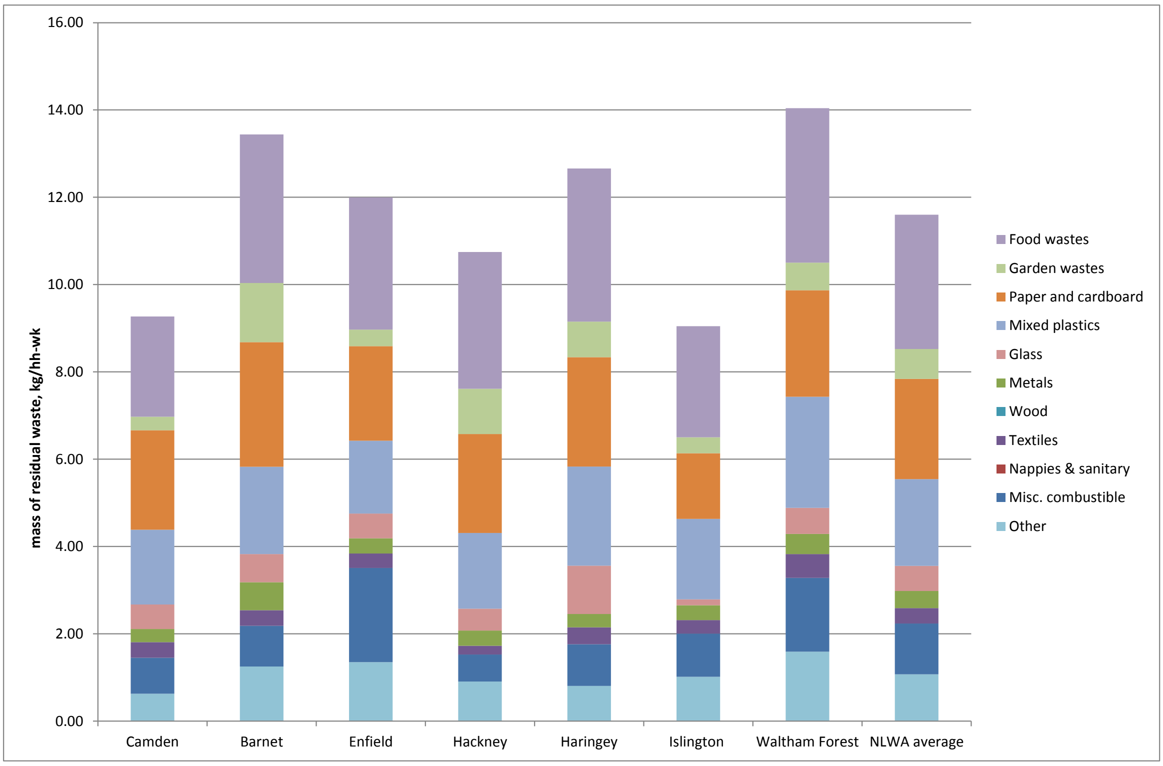


Figure 3.19 Comparison of household residual mass by composition for the boroughs of the NLWA (composition data from Entec, 2010; mass data from WasteDataFlow).

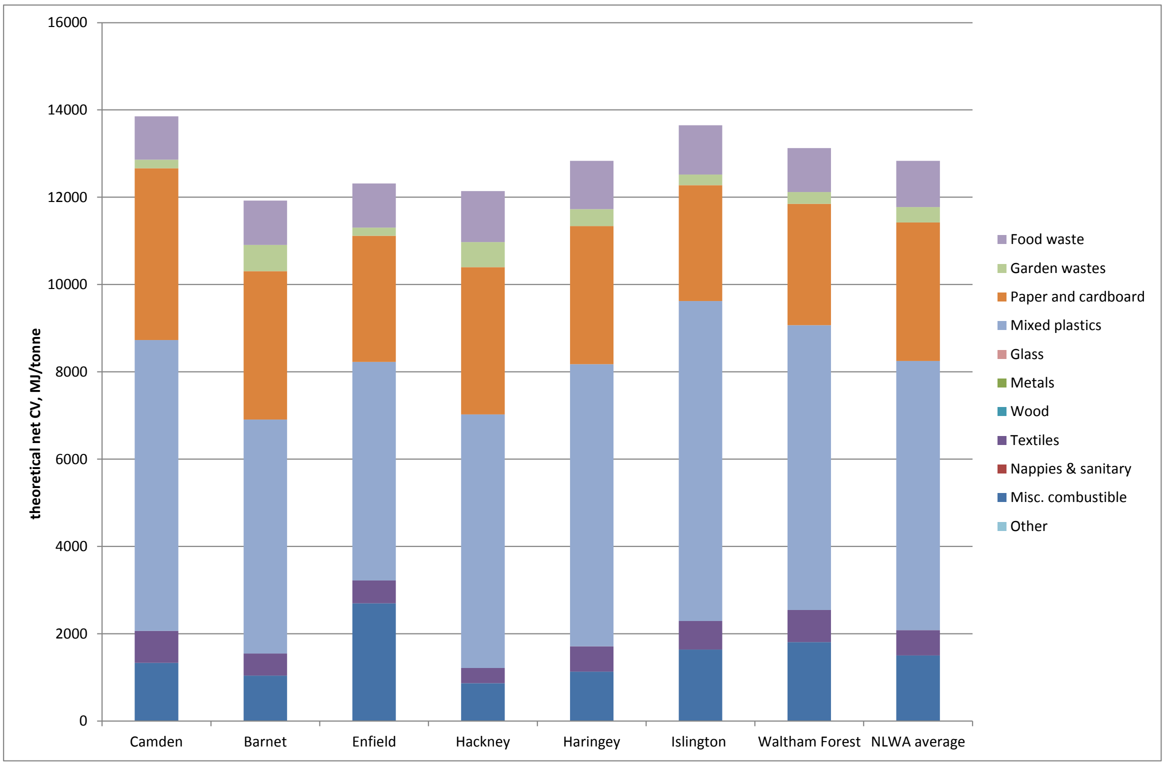


Figure 3.20 Comparison of theoretical net CV by composition for the boroughs of the NLWA (composition data from Entec, 2010).

Due to the differing collection regimes between houses and flats, it was difficult to classify the councils of this authority into FWC and non-FWC categories: although most had FWC for houses, most had limited or no FWC in flats, and in many of these areas, flats make up the bulk of the housing. As the waste composition analyses did not differentiate samples on the basis of whether the waste source was houses or flats, conclusions could not be drawn relating composition to collection regime. Also, socioeconomic factors may play a greater role in residual waste quantity and composition than the collection system. This was the only waste authority within the case studies examined where the average residual mass for councils with FWC for houses was actually higher than the average for councils without any form of FWC, but this is skewed by the two factors discussed – the difficulty in categorizing and the influence of differing income levels on waste production.

Further Actions:

Camden introduced borough-wide food waste collections in July /August 2010 with food waste for flats implemented beginning in August 2010. Waltham Forest now collects food and garden waste on a weekly basis during the summer months (April to September), continuing on a fortnightly basis from October to March.

3.8. London Borough of Hounslow

Hounslow is a borough in the west of London, covering approximately 55 km^2 with a population of approximately 255,000. It has had collection of dry recyclables for a number of years, and introduced separate collection of food waste from houses in 2009, along with a free garden waste service and expansion of its recycling program to include mixed household plastic packaging. Prior to that, garden waste collection was charged and the kerbside recyclables collection included paper, cans, glass, aerosols, foil, car and household batteries, clothing, shoes, cardboard and motor oil.

Waste composition analyses were carried out in March 2004, February 2005, October 2007, February 2008, December 2010, July 2011 and April and June 2012. These analyses cover the time before and after the introduction of food waste and other new collections.

Waste collected in Hounslow is disposed of under the responsibility of the West London Waste Authority (WLWA), which manages waste from six west London boroughs: Brent, Ealing, Harrow, Hillingdon, Hounslow and Richmond upon Thames, and comprises a population catchment of approximately 1.4 million people (WastesWork and AEA, 2010). The 2010 – 2012 waste composition studies were carried out for the whole of the WLWA but results specific to Hounslow are presented.

Audit Results:

Figure 3.21 shows the results by mass of residual waste per household. The weekly food waste collection service, along with more extensive dry recycling, was introduced in 2009; the results show that the overall amount of waste per household dropped after this, although the percentage of food waste in the residual stream does not change dramatically.

The quantity of waste per household was increasing from 2004 to 2008, but peaked in 2008, which was also the year of sharp decline in the UK economy following the banking crash of mid-2008.

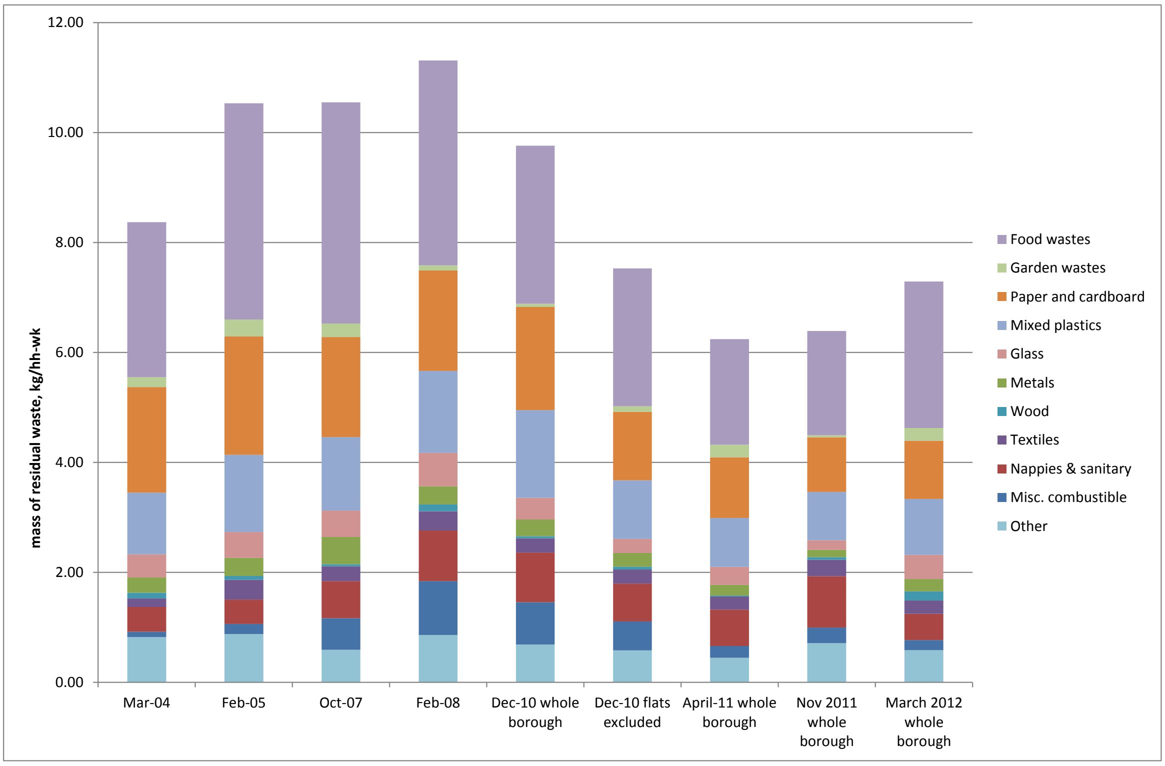


Figure 3.21 Comparison of household residual mass by composition for the London borough of Hounslow (data from MEL, 2004; 2005; 2007a; 2008; and WastesWork/AEA 2012b).

Figure 3.22 shows the theoretical net CV based on composition for each time period. The net CV is higher in the years after the introduction of FWC than the years prior.

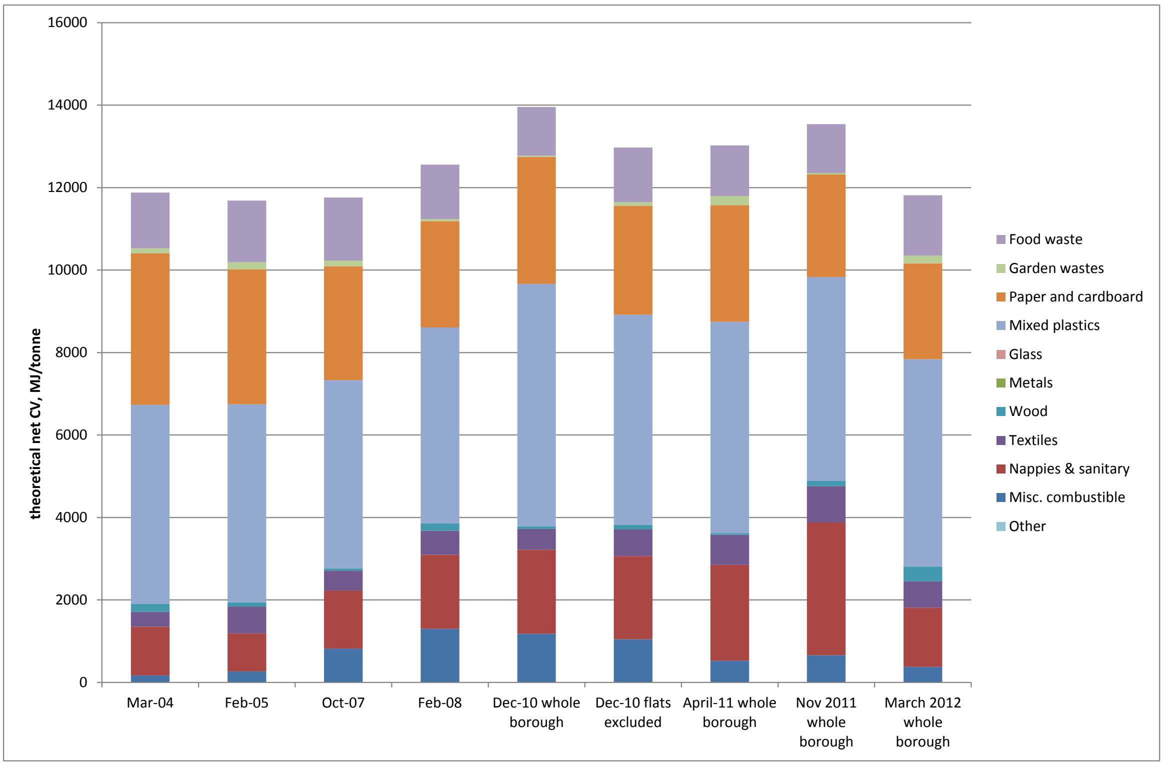


Figure 3.22 Comparison of theoretical net CV by composition for the London borough of Hounslow (data from MEL, 2004; 2005; 2007a; 2008; and WastesWork/AEA 2012b).

3.9. English Local Authorities Overall

Table 3.5 shows the overall differences between English authorities with weekly food waste collections, compared to those with no foodwaste collections (the comparisons are single authorities before & after introduction of FWC, or neighbouring authorities with and without weekly FWC). It is immediately followed by Table 3.6, which shows the same statistics with respect to fortnightly collection of foodwaste (as part of an organics collection) compared to no food waste collections.

Table 3.5 shows that weekly FWC is associated with an average decrease in household residual waste of 26%, an average increase in theoretical net CV of 17%, and an average decrease in the percentage of food waste in the residual of 9%. The differences can vary quite widely, however, as evidenced by the maximum and minimum percentages.

In comparison, Table 3.6 shows that fortnightly FWC as part of an organics collection service is associated with smaller differences in the same three factors, at 15%, 2% and 2%, respectively.

Table 3.5 Summary of differences before & after introduction of Weekly FWC in English local authorities surveyed

Parameter	Average Difference	Maximum Difference	Minimum Difference
Decrease in weekly household mass of residual	26%	47%	6%
Increase in theoretical net CV of residual stream	17%	37%	1%
Decrease in % of food waste in residual stream	9%	14%	6%

Table 3.6 Summary of differences before & after introduction of Fortnightly Organics Collection in English local authorities surveyed

Parameter	Average Difference	Maximum Difference	Minimum Difference
Decrease in weekly household mass of residual	15%	22%	8%
Increase in theoretical net CV of residual stream	2%	7%	-5%
Decrease in % of food waste in residual stream	2%	5%	-1%

It should be noted that the results from the North London Waste Authority (NLWA) have been excluded from this summary. For reasons discussed in Section 3.7 – the difficulty in categorizing by waste regime and the influence of differing income levels on waste production – the NLWA results were not included in the calculations. If the NLWA results were to be included, the average and minimum difference in residual waste mass would be 22% and -25%, respectively.

Figure 3.22 shows the mass of household residual waste for all of the cases studied, spanning a time period from 1998 to 2012. The average quantity of residual waste is lowest for local authorities providing weekly FWC, at an average of 8.4 kg household^{-1} week^{-1}, while areas with no FWC had the highest residual mass at 10.0 kg household^{-1} week^{-1}; this represents a difference, on the aggregate, of 16% between areas with and without FWC. Areas where food waste was collected with organics on a fortnightly (FN) basis fell in between, with an average of 8.8 kg household^{-1} week^{-1}.

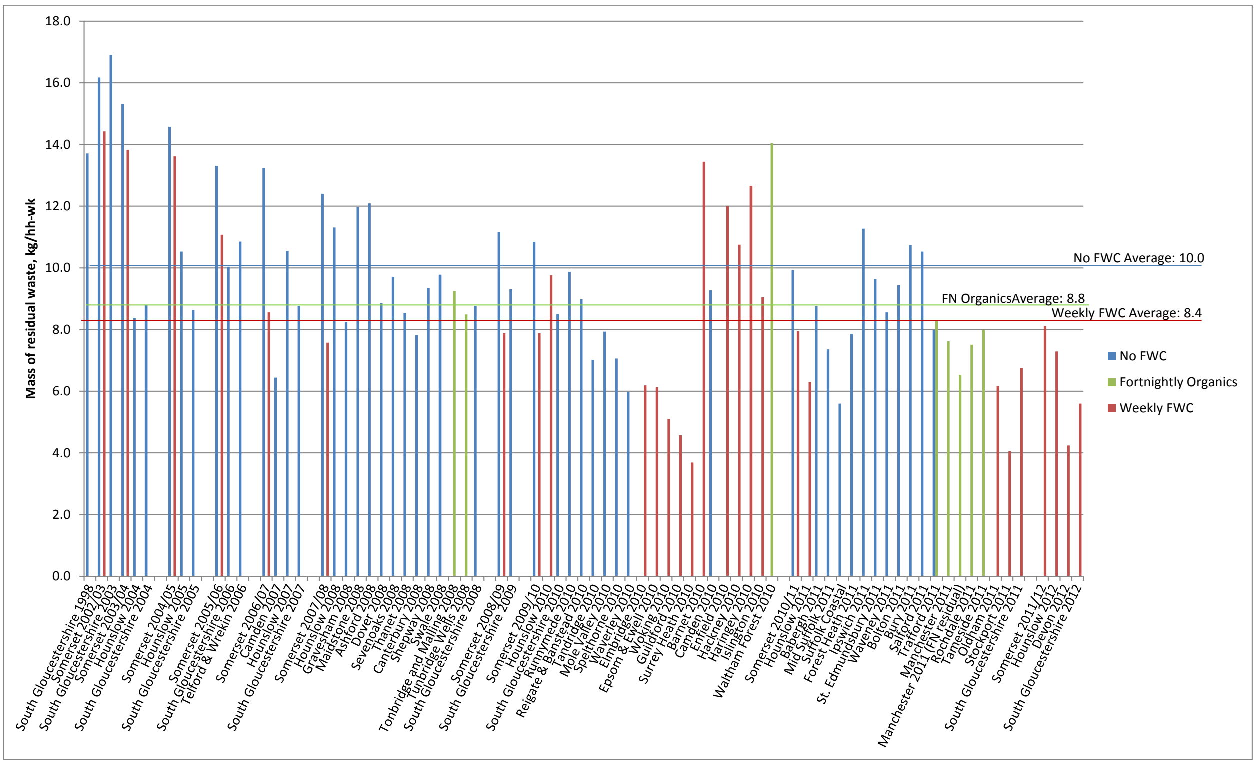


Figure 3.22 Comparison of weekly household residual waste quantity for English local authorities surveyed for this report. (Data compiled from references previously cited.)

This aggregate difference of 16% overall differs from the 26% average difference shown in Table 3.5 because of the way the two numbers are calculated. For Table 3.5, differences within individual cases were first determined, and then the average of those differences calculated, whereas for Figure 3.21 all of the authorities were grouped together and three gross averages determined, which were then compared to determine the overall 16% figure.

Figure 3.23 shows the theoretical net CV of the residual waste stream from the cases studied, spanning the same 1998-2012 time period. The average net CV is highest for local authorities providing weekly FWC, with an average of 12,900 MJ tonne^{-1}, while areas with no FWC had the lowest net CV at 11,400 MJ tonne^{-1}, 13% lower than the former. Again, areas with fortnightly food/organics collection fell in between, with an average of 12,600 MJ tonne^{-1}.

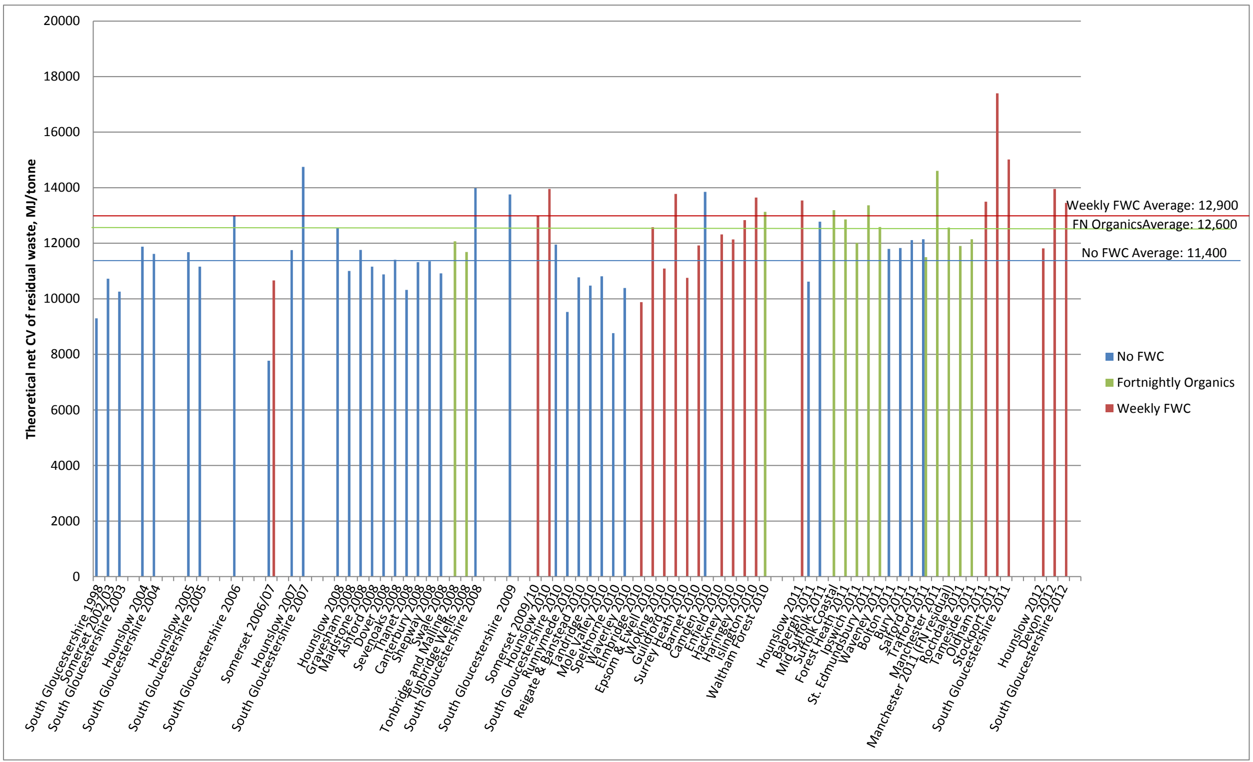


Figure 3.23 Comparison of theoretical net CV of residual waste for English local authorities surveyed for this report. (Data compiled from references previously cited.)

These both obey the general expected trend of lower residual quantity and higher net CV resulting from the introduction of food waste collections. The average differences, however, are not as much as could theoretically be possible.

A 16% to 26% lower mass is a significant decrease in quantity, but is not as high as the potential difference if the capture rate for food waste collections were 100%, which would reduce food waste in the residual stream to zero for those households with access to food waste collections. As food waste made up an average of 33% of the residual waste mass for authorities with no collection of food waste (as calculated from the compositions above), removing all food waste from the residual would give a corresponding mass decrease of 33%, a drop of 3.4 kg household^{-1} week^{-1} from the non-FWC average of 10.0 kg household^{-1} week^{-1}, resulting in a theoretical weekly household residual mass of 6.6 kg household^{-1} week^{-1} (as opposed to the current FWC average of 8.4 kg household^{-1} week^{-1}).

There were no areas found where all of the food waste had been eliminated from the residual stream; in all cases a significant portion of foodwaste remained in the residual stream, despite the separate food waste collection service.

Providing food waste as part of a fortnightly service has a less significant impact on residual waste than a weekly separate food waste collection, and a significant portion of food waste is likely to stay in the RW stream. Areas with fortnightly organics averaged 8.8 kg household^{-1} week^{-1}, a decrease of 13% from the non-FWC areas, as opposed to a 16% decrease for areas with weekly FWC. This higher residual mass could reflect the fact that householders may be more likely to dispose of their food waste in whichever bin will be picked up that week (WRAP, 2009).

4. Case Studies – Netherlands

A study of two municipalities in the Netherlands was carried out, as examples of two different waste collection systems.

4.1. Background

In 1995 the Dutch government imposed a general landfill tax. Following the implementation of this new tax, municipalities started to review and change their policies regarding waste treatment. The first phase was the erection of large incineration installations in a number of regions, spread over the country, where all waste was incinerated. This development changed the practice of waste collection significantly; from 50% landfill in 1985, to less than 10% in 2008.

Household waste collection in the Netherlands is recorded in the National Waste Policy Plan II (LAP). This Plan is based on the Ladder of Lansink, which forms the leading standard for the Dutch waste treatment policy, introduced in the Dutch parliament in 1979. The policy sets priorities and ranks the most environmentally friendly waste treatment systems. Governmental policies and regulations should be focussed on achieving waste to move up the ladder into better ways of treatment. The Ladder of Lansink consists of 4 steps:

- prevention
- recycling
- combustion
- disposal (landfill)

The National Waste Policy Plan II (LAP), based on the above, took effect in 2009 and will stay valid until 2021. Its main goals are:

1. To increase waste separation by citizens.
2. To increase household waste recycling from 51 per cent in 2006 to 60 per cent in 2015.
3. To reduce the disposal of burnable waste.
4. To reduce the environmental impact of waste by 20% by 2015 for the following waste streams:

- Paper and card;
- Textile/clothing;
- Construction and demolition waste materials

- Organic waste (garden) / food (GFT)
- Aluminium;
- Plastic;
- Larger household waste.

The waste collector in Gouda, Cyclus, has been reported as stating that currently in the Netherlands in ‘urban density 2’ areas (1500-2500 households km^{-2}; see Utrecht Municipality, 2007) the waste separation rate lies between 50 to 55%. In rural municipalities (urban density 4 and 5 – less than 1000 households km^{-2}) this is said to be higher, approximately 65%. This is, however, anecdotal evidence.

Waste collection in the Netherlands is the responsibility of local authorities. These can be large(r) city councils, a single municipality or a group or cluster of smaller municipalities in cooperation. The government does supply guidelines but in general these are not compulsory, which gives local authorities a high degree of autonomy in waste collection system implementation.

In 1994 the Dutch government made separate garden, fruit and vegetable waste collection compulsory for the whole country. However, the form of implementation was a municipality’s decision, resulting in many differences between municipalities, even in neighbouring areas where waste is collected by the same waste collection company.

On average, Dutch citizens produce 537 kg of household waste per person on a yearly basis, equivalent to 10.3 kg $person^{-1}$ $week^{-1}$. Half of this waste is separated by households, for kerbside collection and delivery to civic amenity sites in the case of bulky wastes. 1.3 kg $person^{-1}$ $week^{-1}$ is composed of garden, fruit and vegetable waste, referred to in the Netherlands as GFT (in Dutch ‘groente, fruit, tuin’).

In many municipalities citizens pay for waste collection via local taxes. Separated waste and residual waste are collected every fortnight; this is the law in the Netherlands for general waste collection. Another method now growing in interest is differentiated tariffs for waste collection (Diftar). In this system each separated type of waste is charged at different rates.

In 2010 approx. 150 municipalities (about 30-35%) used a form of Diftar. However, amongst these municipalities no larger cities or towns were to be found with urban density rate 1. Only three cities with density rate 2 use a Diftar system: Nijmegen, Apeldoorn and Maastricht. All others were more rural municipalities with density rates 4 and 5 (Utrecht Municipality, 2007).

There are several Diftar arrangements currently being used in the Netherlands. For example some municipalities collect waste in underground containers which can only be opened with a personal card, provided by the local authority. Each time the container is opened, the name of the household or person is registered and a certain amount for waste disposed will be charged to that household.

Another option for Diftar charging is to use a charge per weight of type of waste. In some municipalities food and garden waste is not charged, to incentivise separation of waste. Only the residual waste is being charged for by weighing the bags. Frequency and weight are other ways of charging Diftar.

The Flanders region of Belgium is implementing a similar system, with an even more strict policy, which has resulted in more types of waste being collected separately. Rules in Flanders are set by the central government and not left to the discretion of the local municipalities. Hence, in the Netherlands, Diftar implementation is greatly influenced by the political situation and will of local authorities whereas in Flanders the law applies to the whole region.

4.2. Methodology

For the study, two municipalities were chosen - one that collects waste separately for a fixed price per year (Gouda) and one that uses the Diftar system, different tariffs for waste collection (Apeldoorn). Apeldoorn was chosen because it now has some years of experience with using Diftar.

Evidence was gathered through discussions with representatives of the municipalities or their waste collection contractors. Following the two case studies, a comparison of the calorific values and the amount of residual waste for both municipalities was made. It is important to note, however, that the data collected applies only to the two municipalities investigated and does not represent practice in the Netherlands as a whole, as municipalities are free to develop and implement their own waste treatment policies.

The two municipalities represent a total population of 228,000 people, approximately 1.4% of the population of the Netherlands.

4.3. Non-Diftar system - Gouda

Gouda is a town with just over 71,000 inhabitants in an area of just under 17 square kilometres (CBS, 2012). Waste collector Cyclus collects the waste for 14 municipalities, including Gouda, which together own the company.

Gouda is a non-Diftar municipality. The waste is collected in separated waste streams, every other week. The streams are ‘GFT’ (Fruit, vegetable and garden waste), paper, residual waste and (since 2009) hard plastics.

The first three types of waste are collected in mini containers held by households or via large collective (underground) containers in specific areas. Plastic is collected bi-weekly in large special plastic bags, which are freely available at supermarkets and other shops. This schedule applies for areas with one- or two- storey houses.

Garden waste and Christmas trees are collected via special delivery and collection appointments. The municipalities in the Netherlands do not differentiate between garden, fruit and vegetable waste but collect it as one stream, usually for composting, and little compositional data is available on the further breakdown of the GFT stream into its component parts.

Gouda does not collect nappies & sanitary paper separately. Textiles are collected by charity organisations. Metal is collected at amenity sites, while batteries can be disposed of at supermarkets.

Gouda's historic city centre and some quarters with mainly flats and apartment buildings are not included in this system. This is similar in most town centres in medium size and larger cities. These areas often do not have separate waste collection for practical reasons – lack of space – but there is a growing trend to build large size collective underground storage containers in areas with apartment buildings, where the regular collection of separate waste is replaced by this compulsory form of waste disposal. In case of historical town centres, however, such as the city centre of Gouda, the sub-ground is 'crowded' with historic remains of walls, pipes and other material which make it logistically difficult to put in underground containers.

Gouda decided not to implement the Diftar system. New mini containers are chipped and the underground containers can only be opened with a personal card, two requirements for Diftar.

Analysis Results
Analysis of the residual waste stream in Gouda has been carried out since 1998 by Cyclus on a regular basis, i.e. 1998, 2000, 2002, 2005, 2007 and 2010.

The amount of residual waste in Gouda is on average 4.7 kg person^{-1} week^{-1} (244 kg person^{-1} year^{-1}). This amount has not changed significantly in the past ten years (Figure 4.1 below). The residual waste stream is analysed by hand at the Cyclus compound by a third party agency 'Bureau Milieu & Werk'. To avoid incidents and season effects all analyses are carried out twice at different times/seasons for each area. Samples taken each time were of a size of 750 kilogram, of which about half was actually being sorted.

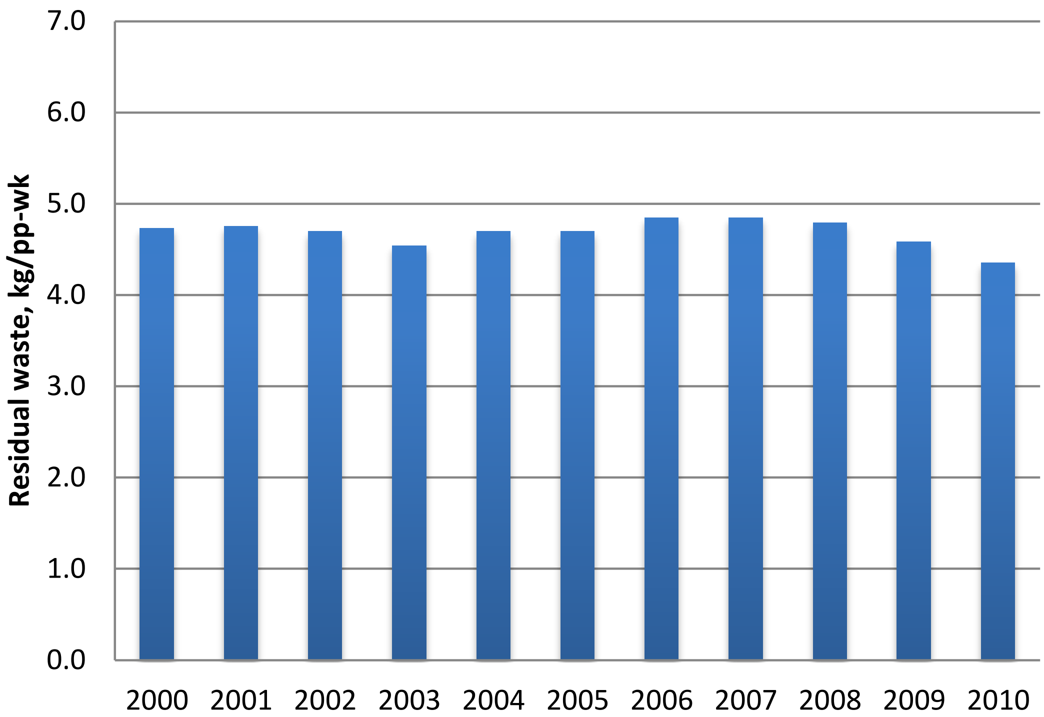


Figure 4.1 Weekly residual waste quantities per person in Gouda, 2000-2010 (Cyclus Gouda, De Informatieman, Gouda, The Netherlands)

The waste analysis of 2010 (Cyclus, 2010) showed that the residual waste in the whole region contained approximately 39.4% Fruit/Garden/Vegetable waste (GFT), 14% paper and carton boards and 16% plastics. In Gouda specifically the average of the amount of GFT in residual waste is 34.9%. Glass and textiles, separately collected via containers, were hardly found in the residual waste stream.

The rise in the amount of GFT in the residual waste is shown in Figure 4.2. Vegetables and fruit, rather than garden waste, appear to be responsible for this increase, according to the personnel interviewed. 45% of this is unavoidable preparation waste, e.g. potato peelings, but 55% is avoidable: unused food thrown away. One of the main reasons behind this may be the growing trend of supermarkets to sell easy preparable quick meals and pre-prepared vegetables and fruit, which have a shorter shelf- and refrigerator life than untreated vegetables and fruit. Another factor is food presented in larger packages or for discount prices (e.g., two for the price of one).

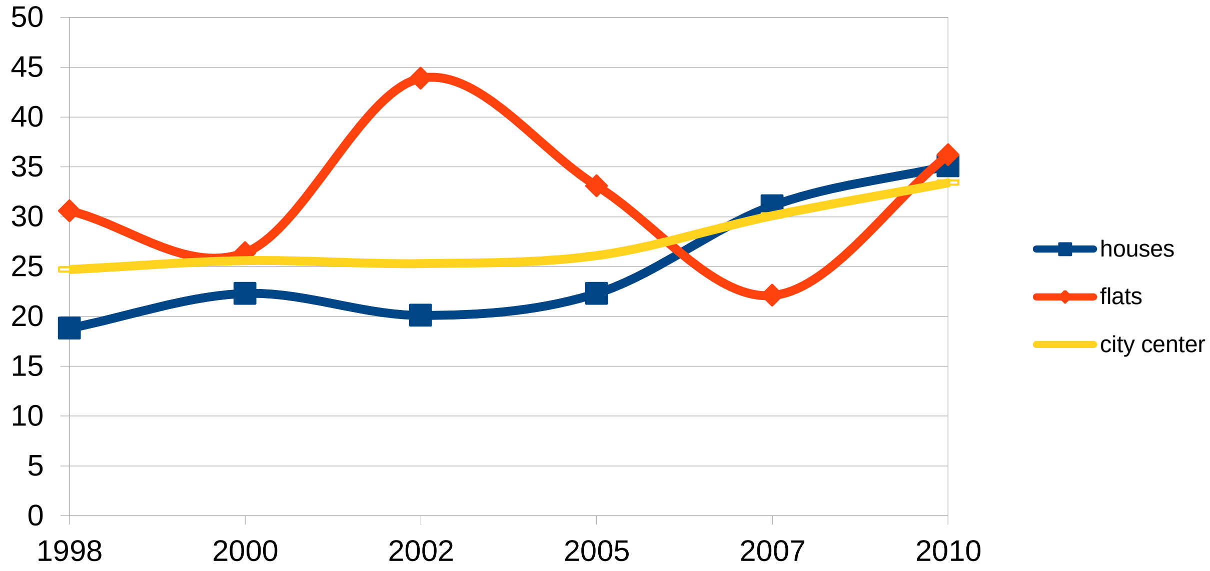


Figure 4.2 GFT% in residual waste in Gouda, 1998-2010 (Cyclus Gouda, De Informatieman, Gouda, The Netherlands)

The Cyclus spokesman expects that Diftar might be a method to positively influence people’s behaviour and to stimulate separation again. Another change is expected from the suppliers, as producers have recently been made responsible for the packaging they present their products in.

Figure 4.3 shows the estimated net calorific value for the residual waste stream of the municipality of Gouda. Even though the amounts of GFT, paper and plastic in the refuse waste stream are slowly increasing, the calorific value of the total residual waste stream stays fairly stable.

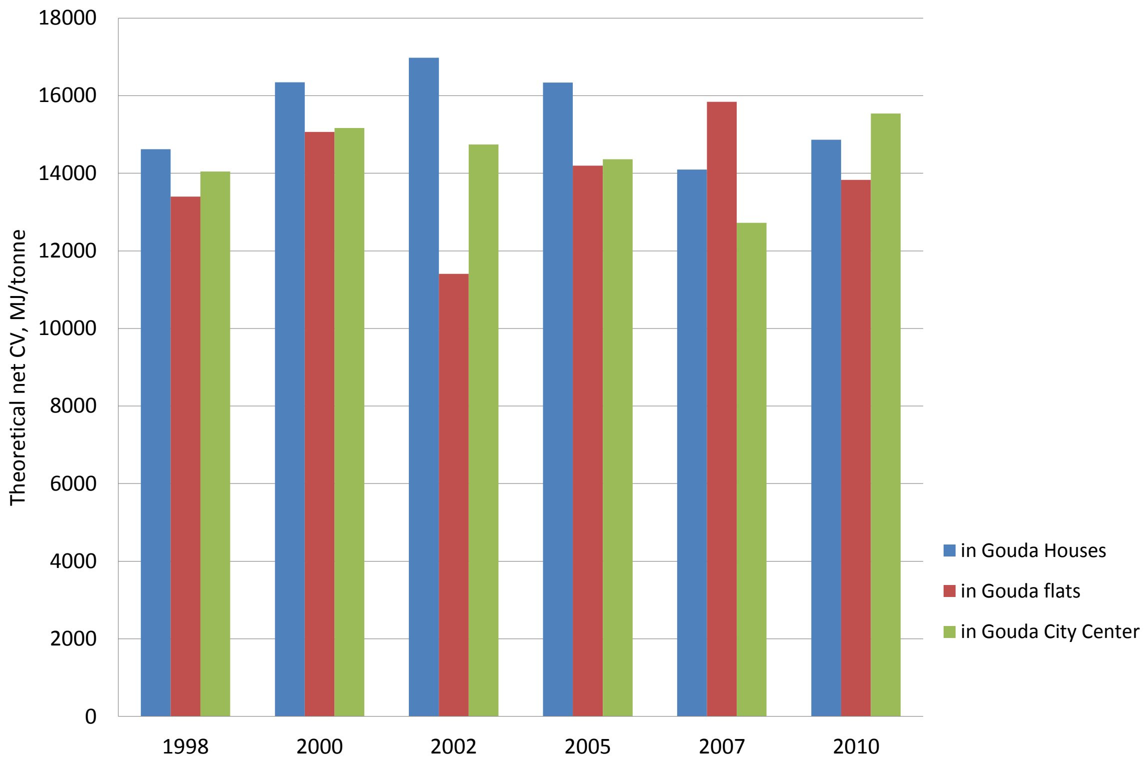


Figure 4.3: Theoretical net CV of the total residual waste stream in Gouda, 1998-2010 (Cyclus Gouda, De Informatieman, Gouda, The Netherlands)

4.4. Diftar system - Apeldoorn

The municipality of Apeldoorn has just over 157,000 inhabitants (CBS, 2012), and recycles 61% of its waste. This is above the country's average according to waste collector Circulus en Berkel Milieu. Apeldoorn was an early adopting town of the Diftar system. However, some of the data collected was for the whole serviced region in which the waste collector is active. Where this occurs it is noted, otherwise the data refers to Apeldoorn.

Apeldoorn, and some of the other municipalities in this region, have historic city centres and some quarters with mostly apartment blocks. These are not included within the system which is used in areas with one or two storey houses. This is similar in most town centres in medium size and larger cities in the Netherlands - such areas are not subject to separate waste collection for practical reasons.

Nevertheless in some municipalities the implementation of underground containers was started recently - Apeldoorn being one of them.

Garden waste and Christmas trees are collected by a collection appointment system and are used to create biomass for energy by company Bruins & Kwast. Textiles are collected by charity organisations. There is no municipality or governmental policy on this, however.

Metals are collected at amenity sites, and batteries can be disposed of at supermarkets as well. Plastic is being collected in orange containers. Since the implementation of plastic collection the separated amount has doubled.

Analysis Results

Apeldoorn started fortnightly GFT collection in 1994, and Diftar in 2004 (Apeldoorn municipality, 2005). The inhabitants of Apeldoorn currently produce approx. 460 kg of total domestic waste per person per year, equivalent to 8.8 kg person^{-1} week^{-1}. This is far less than the country's average of 10.3 kg person^{-1} week^{-1}, and also a significant decrease compared to the average of 10.4 kg person^{-1} week^{-1} (540 kg person^{-1} year^{-1}) in Apeldoorn before the introduction of Diftar.

In 2002 the residual waste amount per inhabitant was 4.7 kg person^{-1} week^{-1} (242 kg person^{-1} year^{-1}). After the introduction of Diftar the separation of waste in the municipality improved significantly and in 2009 the amount of residual waste was only 3.4 kg person^{-1} week^{-1} (179 kg person^{-1} year^{-1}), as shown in Figure 4.4 below.

The city of Apeldoorn aims to increase the separation percentage further, from 61 % to 65 % by 2015.

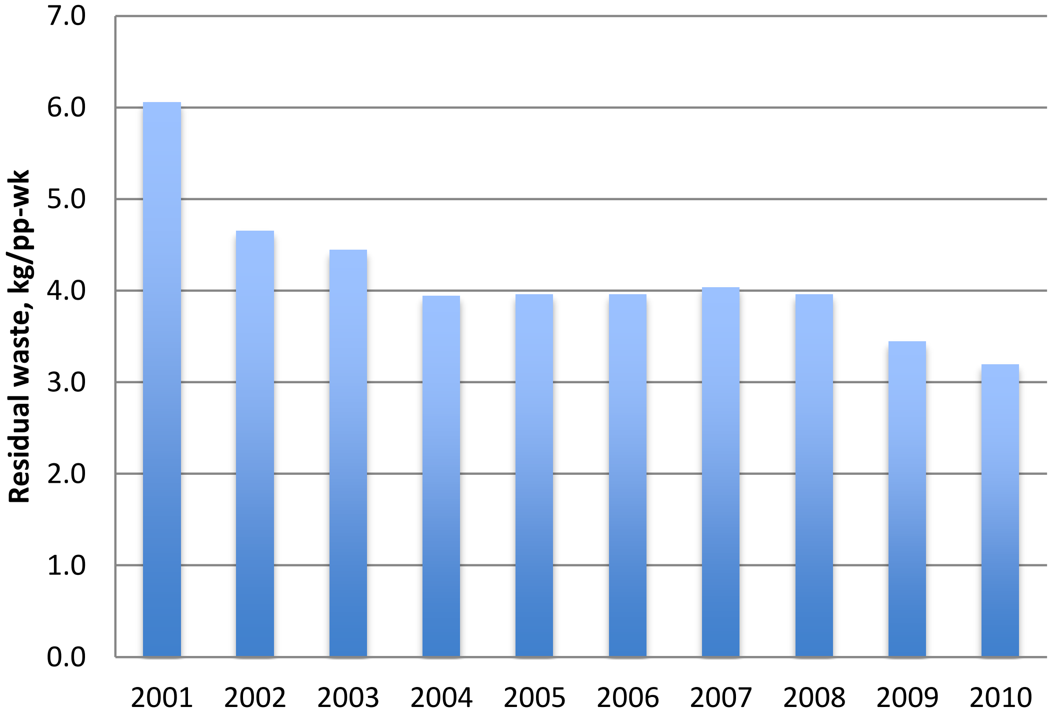


Figure 4.4 Weekly residual waste quantity per person in Apeldoorn, 2001-2010 **(**Circulus & Berkel Milieu; Ministerie van Volkshuisvesting; De Informatieman)

Analysis of the residual waste stream in Apeldoorn is carried out by a third party agency 'Twence', under contract to Circulus and Berkel Milieu. The analyses are done on a regular basis, in autumn of each year starting from 1997. For this study data was available for the years 2002, 2003, 2004, 2006 and 2009.

Before 2004, Apeldoorn collected GFT waste separately in most of the municipality other than the town centre, but areas with flats and apartment buildings were not recorded separately. Following the governmental decision to simplify the rules for GFT collection, the city council of Apeldoorn in 2004 decided to stop the regular separate GFT collection for areas with flats and apartment buildings (Apeldoorn municipality, 2005). Following this decision the percentage of GFT in the refuse stream rose by 11.9% to 35%. Diftar brought this percentage down for some time, but like Gouda, Apeldoorn recently has also seen a rise in the amount of GFT in the residual waste stream.

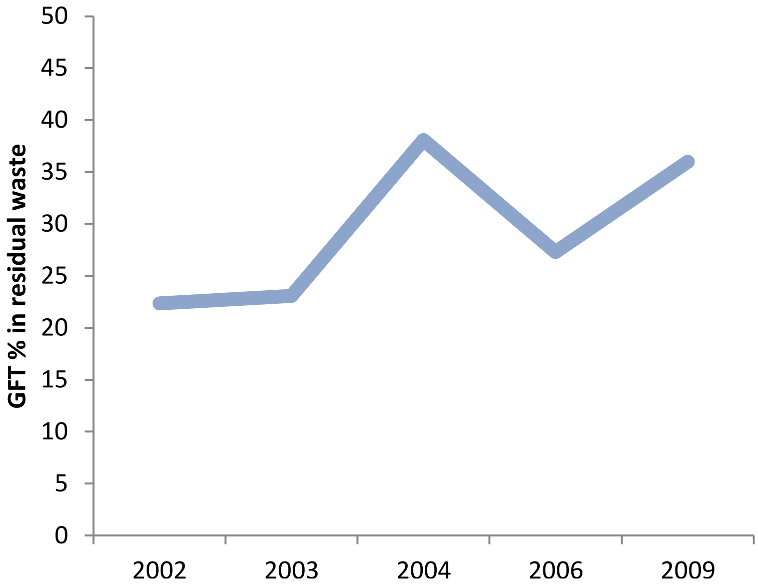


Figure 4.5 GFT % in residual waste in Apeldoorn, 2002-2009 (Circulus & Berkel Milieu; Ministerie van Volkshuisvesting; De Informatieman)

Collecting the GFT waste in underground containers is not perceived to be a feasible option. Fermentation processes and odour are issues of concern associated with this solution. Research is being carried out into finding other ways to encourage inhabitants of the region to separate GFT from residual waste.

In 2008 an experiment with small sized indoors GFT waste bins - the so-called BioBox - was set up as a friendly, i.e., non-odorous method (Wieg tot wieg, 2008). In 2011, Wageningen University initiated research into the issue of the growing amount of GFT in the refuse stream, commissioned by the Dutch government, as part of the National Waste Management Plan 2009 – 2021 (LAP 2009).

The research included an inventory of reasons for the habits of GFT treatment in waste. Some of the results are similar to what was said for Gouda. The way of packaging some prepared food, vegetables and fruit could be a cause. Prepared food, fruit and vegetables are often not properly stored and last for less time than untreated. Families with children appear to produce more GFT waste. Sales promotions influence consumers as well, such as 3 for the price of 2. They buy or cook too much and throw it away when not used or past the expiration date, and the latter often ends up in the refuse waste stream. This research is ongoing and is intended to inform national policy (Wageningen, 2012).

Figure 4.6 below shows the estimated net CV for the residual waste stream of the municipality of Apeldoorn. Though in absolute amounts the contribution of GFT to residual waste decreased after the introduction of Diftar, it quite rapidly rose again. It was expected that due to this relatively rising amount of GFT in the refuse waste stream, the net calorific value of the total residual waste stream would decrease. However, the amounts of paper and plastic in the residual waste stream increased as well and in line with that rise, the calorific value shows higher values as well.

Data for 2010-2012 is not available yet but in 2009 the policy for plastic collection changed and with plastics being separated the statistics are expected to change again.

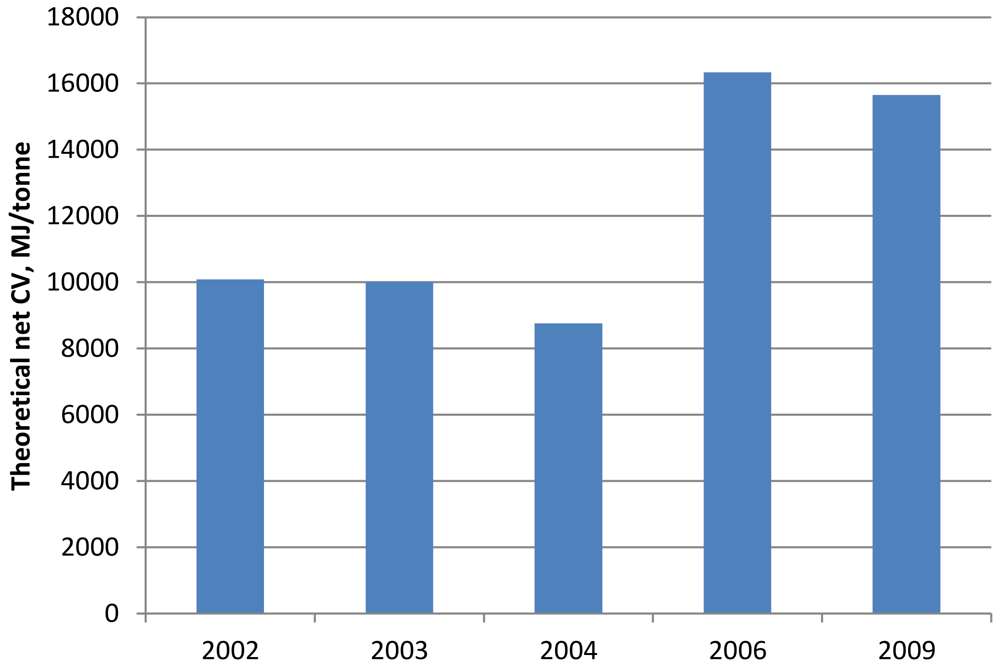


Figure 4.6 Theoretical net CV of residual waste in Apeldoorn, 2002-2009 (Circulus & Berkel Milieu; Ministerie van Volkshuisvesting; De Informatieman)

4.5. Comparison between the municipalities

Figure 4.7 shows the estimated calorific values of both municipalities, followed by figure 4.8 which shows a comparison of residual waste quantities for both municipalities, giving an indication of the performance of the Diftar system in Apeldoorn compared with Gouda, which does not use this system.

The theoretical net CV of Apeldoorn has risen in the years since the introduction of the Diftar system, and as of 2009 was above that of any of the Gouda categories.

Residual waste mass in Apeldoorn has decreased from 4 to 3.2 kg person^{-1} week^{-1} during the years since Diftar introduction (2004), while Gouda's average residual waste mass has stayed relatively constant at around 4.7 kg person^{-1} week^{-1}. Both municipalities have food waste collection in the form of the GFT collection, but have different methods for encouraging the use of the GFT collection service. The Diftar system appears to be associated with lower residual waste mass and higher theoretical net CV in this analysis.

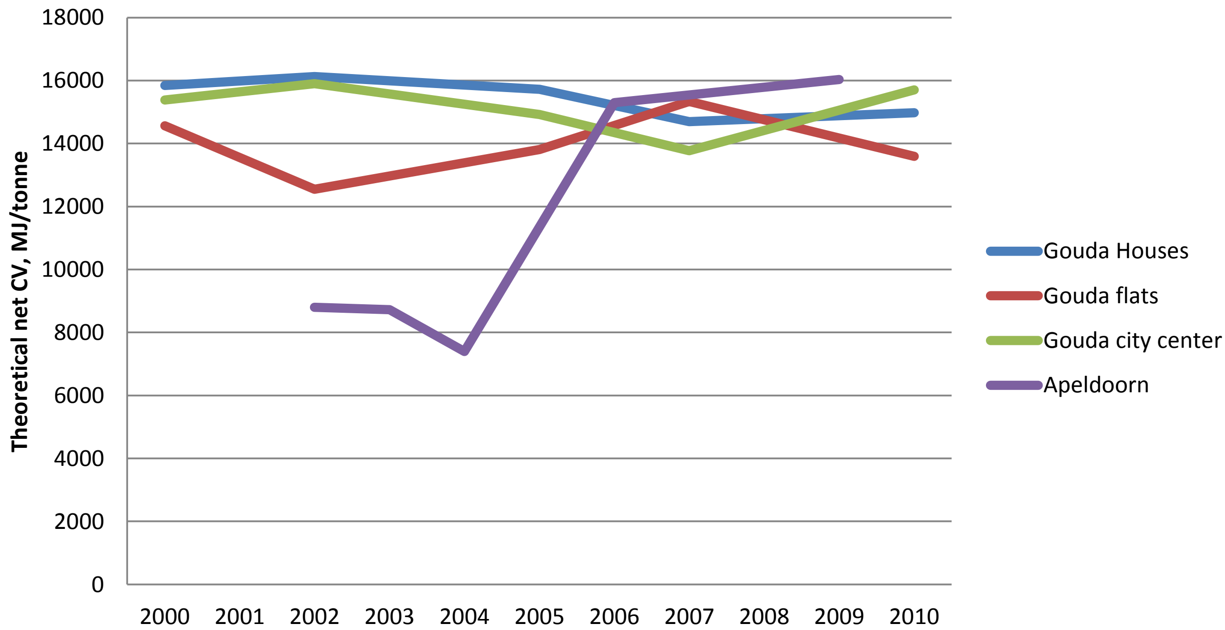


Figure 4.7 Theoretical net CV of the residual waste stream in Gouda and Apeldoorn, 2000-2010 (Cyclus Gouda, Circulus & Berkel Milieu; De Informatieman)

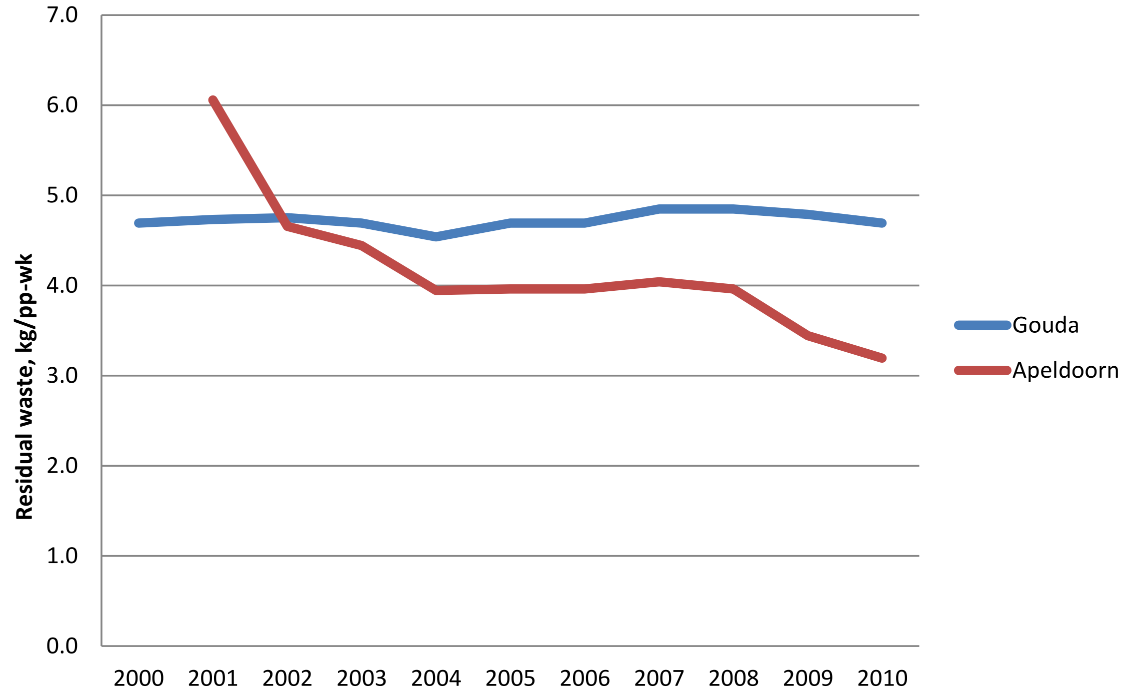


Figure 4.8 Residual waste quantities in Gouda and Apeldoorn, 2000-2010 (Cyclus Gouda, Circulus & Berkel Milieu; De Informatieman)

5. Case Studies - Catalonia, Spain

5.1. Background

Spain's national waste management plan, 'Plan Nacional Integrado de Residuos (PNIR), 2008-20015' has established national targets for waste management. The development and execution of methodologies to achieve them are the responsibility of the local authorities, following guidance of the autonomous regions, of which there are 19 in Spain.

The PNIR requires that each municipality with a population of 5000 or more collects source separated waste, and specifies that at least four separate streams should be collected. Most local authorities have chosen to collect the four streams as: i) paper and card; ii) glass; iii) containers and iv) organic fraction.

The organic fraction is usually referred to as the Fraccion Orgànica de los Residuos Municipales (FORM) in Spanish (or Fracció Orgànica dels Residus Municipals in Catalan), which translates in English to the Organic Fraction of Municipal Solid Waste (OFMSW). It includes both food and garden waste; this is the most common type of organics collection in Spain. Some areas of the Basque Country collect food waste on its own, but the collection of FORM as a single stream is most common, with programs developed in Catalonia, Castilla y Leon, Islas Baleares, Castilla La Mancha and La Rioja (VALORGAS Deliverable D2.2, 2012).

The most common form of waste collection in most urban areas of Spain is via streetside bins, to which residents bring and deposit their waste. Since collection is not door-to-door, there is less opportunity to influence householder behaviour through mechanisms such as fortnightly rather than weekly collection of refuse; however the provision of additional bins for separate streams may have an effect on the overall quantity and composition of residual waste collected, and this effect is examined in this report.

5.2. Methodology

A total of 56 waste composition analyses are examined in this report, from the 50 municipalities given in the table below. All are from the region of Catalonia, which first started separate collection of organic waste in 1999. The process of rolling out separate collection of FORM to all areas, however, has been ongoing over a number of years, which allows comparison of municipalities with separate organics collection to those in which it has yet to be introduced.

The municipalities studied represent a total population of approximately 3,250,000 people - about 43% of the population of Catalonia, or 7% of the total population of Spain.

The waste compositions were also used to develop an estimate of the heating value of the residual waste. To assess heating value based on composition, the same standard calorific values were used for each waste category as shown in Table 2.1 of Section 2.

In Table 5.1, the 50 municipalities included in the present study are presented with key data in each case. Some of the municipalities had composition analyses done in multiple years.

Table 5.1 Catalonia municipalities for which waste composition analyses were examined

Municipality	Area	Year of Analysis	Population	Separate FORM Collection?
L'Aldea	Tarragona	2006	3 795	No
L'Arboç	Tarragona	2006	4 802	No
Bellpuig	Lleida	2006	4 454	No
La Bisbal	Baix Empordà	2006	9 261	No
Borges Blanques	Lleida	2006	5 606	No
Cadaqués	Girona	2006	2 922	No
Capellades	Anoia	2006	5 383	No

Cardona	Barcelona	2006	5 226	No
Gironella	Berguedà	2006	4 786	No
Manlleu	Barcelona	2006	19 979	No
Mollerussa	Lleida	2006	12 569	No
Montgat	Maresme	2006	9 427	No
Mora la Nova	Ribera d'Ebre	2006	3 216	No
Palamós	Girona	2006	17 197	No
Piera	Anoia	2006	12 951	No
Pobla de Lillet	Berguedà	2006	1 327	No
Roda de Barà	Tarragona	2006	5 196	No
Sant Quirze del Vallès	Vallès Occidental	2006	17 138	No
Solsona	Lleida	2006	8 823	No
Tivissa	Ribera d'Ebre	2006	1 788	No
Torroella de Montgri	Girona	2006	11 494	No
Vila-seca	Tarragona	2006	17 305	No
Vidreres	Girona	2006	6 676	No
Banyoles	Girona	2006	17 309	Yes
Castellbisbal	Vallès Occidental	2006	11 272	Yes
Cornellà de Llobregat	Baix Llobregat	2006	84 289	Yes
Figueres	Girona	2006	39 641	Yes
L'Hospitalet de Llobregat	Baix Llobregat	2006, 2011, 2012	248 150	Yes
Lleida	Lleida	2006	125 677	Yes
Mollet del Vallès	Vallès Oriental	2006	51 713	Yes
Olot	Girona	2006	31 932	Yes
Puigcerdà	Girona	2006	8 859	Yes
Rubí	Valles Occidental	2006	70 006	Yes
La Seu d'Urgell	Alt Urgell	2006	12 533	Yes
Sitges	Barcelona	2006	25 642	Yes
Tona	Barcelona	2006	7 328	Yes
Tossa de Mar	Costa Brava	2006	5 414	Yes
Tremp	Pallars Jussà	2006	5 401	Yes
Castellar del Valles	Valles Occidental	2010	23 129	Yes
Matadepera	Valles Occidental	2010	8 606	Yes
Palau de Plegamans	Valles Occidental	2010	14 190	Yes
Sabadell	Valles Occidental	2010	207 338	Yes
Sant Cugat del Valles	Valles Occidental	2010	81 745	Yes
Terrassa	Valles Occidental	2010	212 724	Yes
Vacarisses	Valles Occidental	2010	6 017	Yes
Viladecavalls	Valles Occidental	2010	7 323	Yes
Barcelona	Barcelona	2011, 2012	1 620 943	Yes
Sant Feliu de Llobregat	Baix Llobregat	2011, 2012	43 671	Yes
Sant Just	Baix Llobregat	2011, 2012	15 874	Yes

5.3. 2006 Analyses – various Catalan regions

Figure 5.1 shows composition analyses of 42 municipalities in various regions of Catalonia, collected by the agency Agència de Residus de Catalunya (ARC) in 2006. At the time of data collection, 18 municipalities had separate collection of FORM, while the remaining 24 did not. The average of the two groups of municipalities are represented in pie charts. For municipalities without separate collection of FORM, organic waste (food and garden waste) constituted an average of 43 ± 18% of the residual waste, while municipalities providing separate collection of FORM had an average of 37 ± 13% organics in the residual. Food waste alone accounted for an average of 32 ± 8% in areas with organics collection, and 35 ± 9% in those without. Separate collection of organics therefore resulted in a lower percentage of organics being disposed of in the general refuse, although the standard deviations overlap.

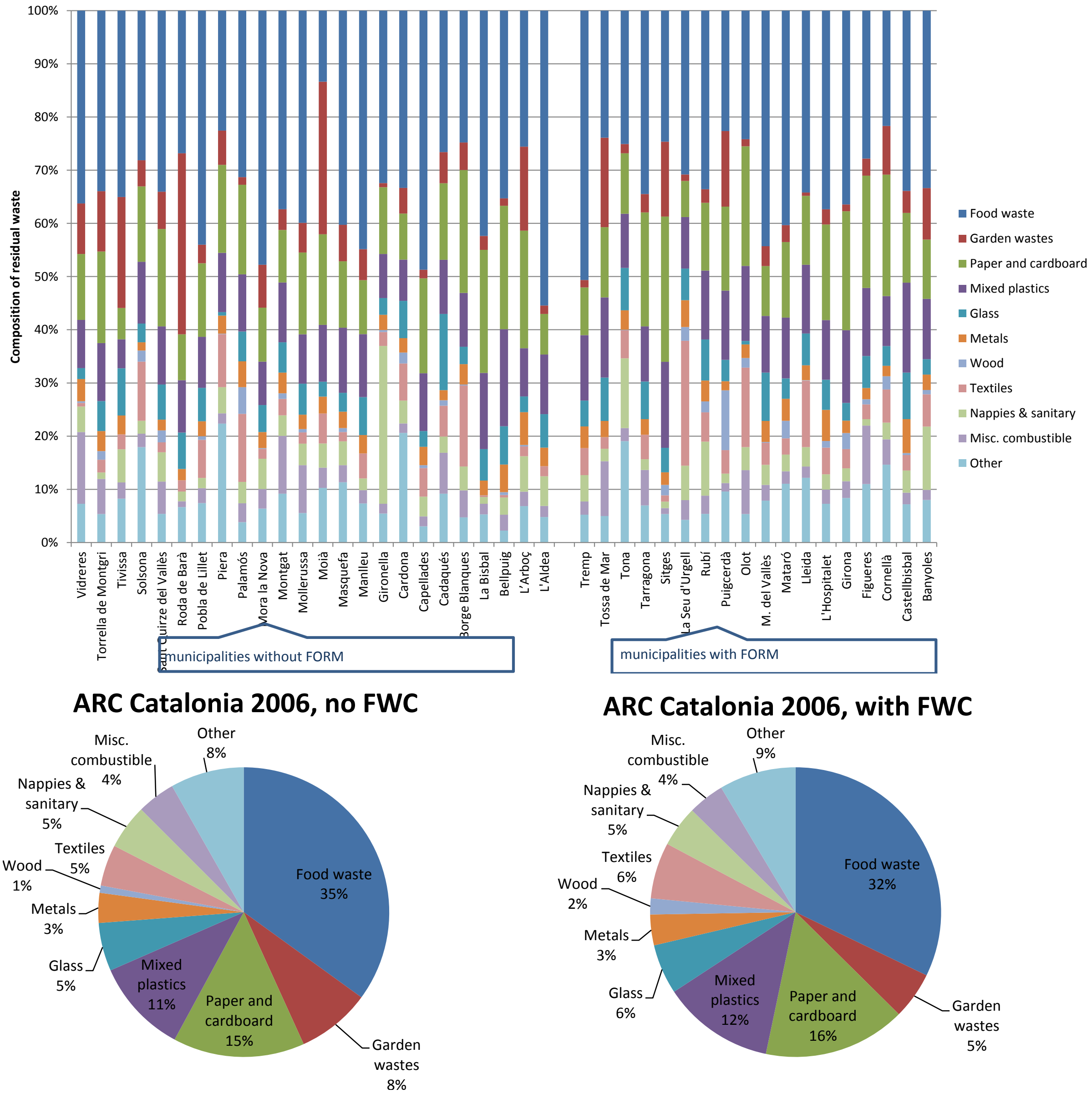
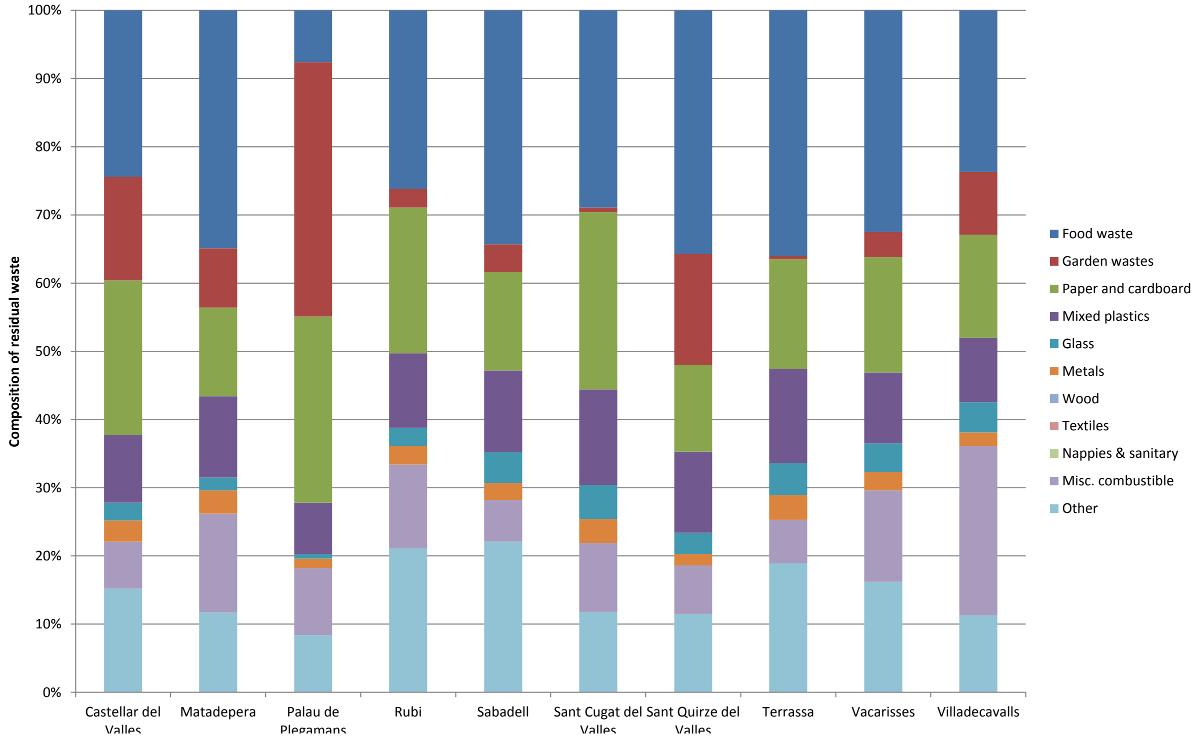


Figure 5.1 Residual waste composition in 24 municipalities of Catalonia with and without separate collection of organic waste (FORM), 2006.

5.4. 2010 Analyses – Valles Occidental

In 2010, waste composition studies were done on ten municipalities of the Catalan region of Valles Occidental (Sans Fonfria, 2010). All of the municipalities had separate FORM collection, and thus no comparison could be made among them; however the results can be compared to the 2006 ARC compositions.

The average percentage of food waste in the residual for these municipalities was 28 ± 9%, with organics comprising 35 ± 14%. Unfortunately, the categories of wood, textiles, and nappies & sanitary were not included in the audit categories; these are embedded within the two broad categories of 'Misc. combustible' and 'Other' in the figures below.



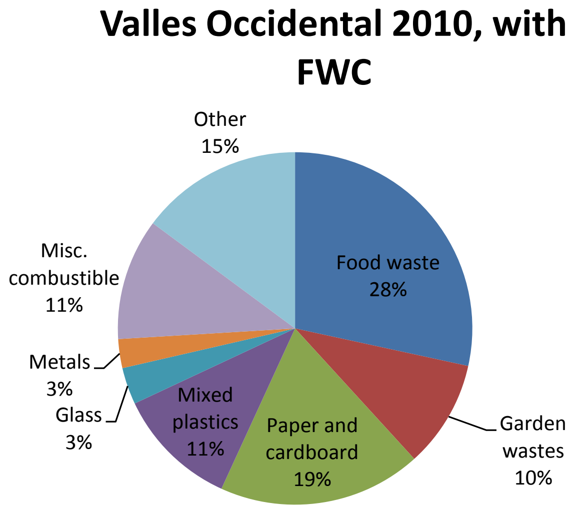


Figure 5.2 Average residual waste composition in municipalities of Valles Occidental, all with separate collection of organics (FORM), 2010.

5.5. 2011/2012 Analyses – El Baix Llobregat and El Barcelonès

A further set of waste composition studies were carried out in four municipalities, in the neighbouring counties of El Baix Llobregat and El Barcelonès, Catalonia, in 2011 and 2012. All of these municipalities had introduced food waste collection previously (Barcelona-1998; Sant Just-2000; Sant Feliu-2001; and L'Hospitalet-2002) and therefore again comparisons between them cannot give insight into the effect of separate organics collection, but they can be compared to the earlier compositions. The average percentage of food waste in the residual for these municipalities was 26 ± 5%, and overall organics comprising 27 ± 7% in 2011, and 27 ± 5% food waste with organics comprising 28 ± 6% in 2012. This shows a drop of 15 percentage points from the 43% organics that were present in the residual of non-FORM municipalities in 2006.

For the municipality of Hospitalet, which had also been analysed in the 2006 study, the fraction of food waste decreased from 37% in 2006 to 29% in 2012, while garden waste decreased from 3% in 2006 to 0% in 2012. It should be noted, however, that the studies were carried out by different organisations, with different analysis protocols, so a direct comparison between the figures must be treated with caution.

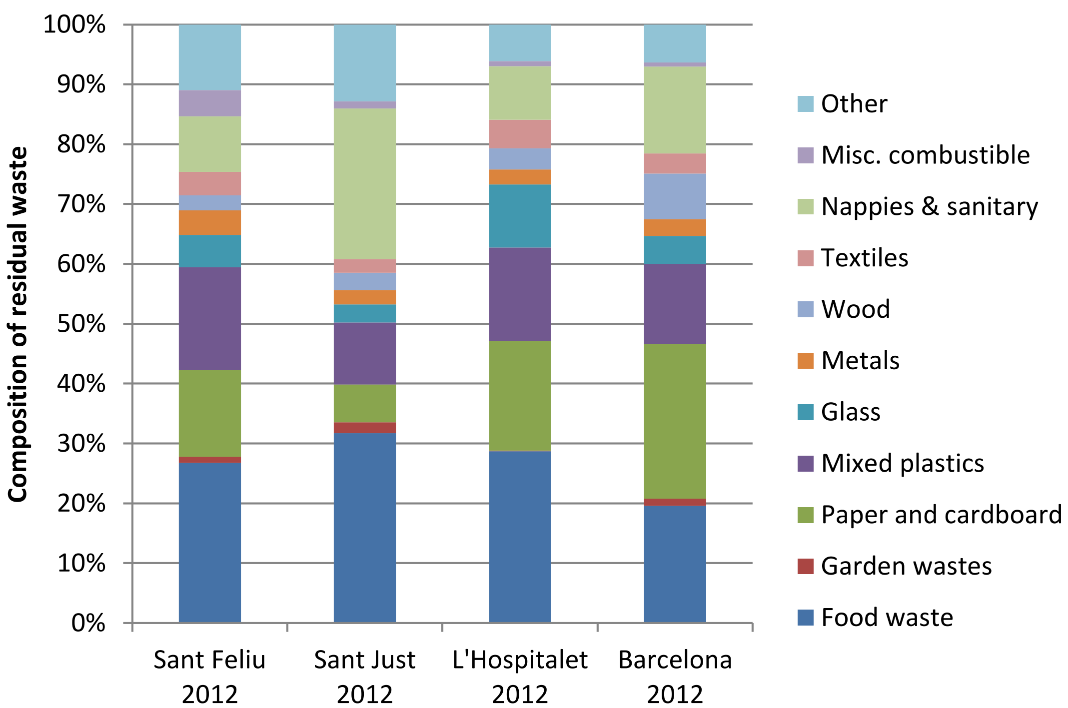


Figure 5.3 Residual waste composition in municipalities of El Baix Llobregat and El Barcelones, all with separate collection of oganics (FORM), 2012.

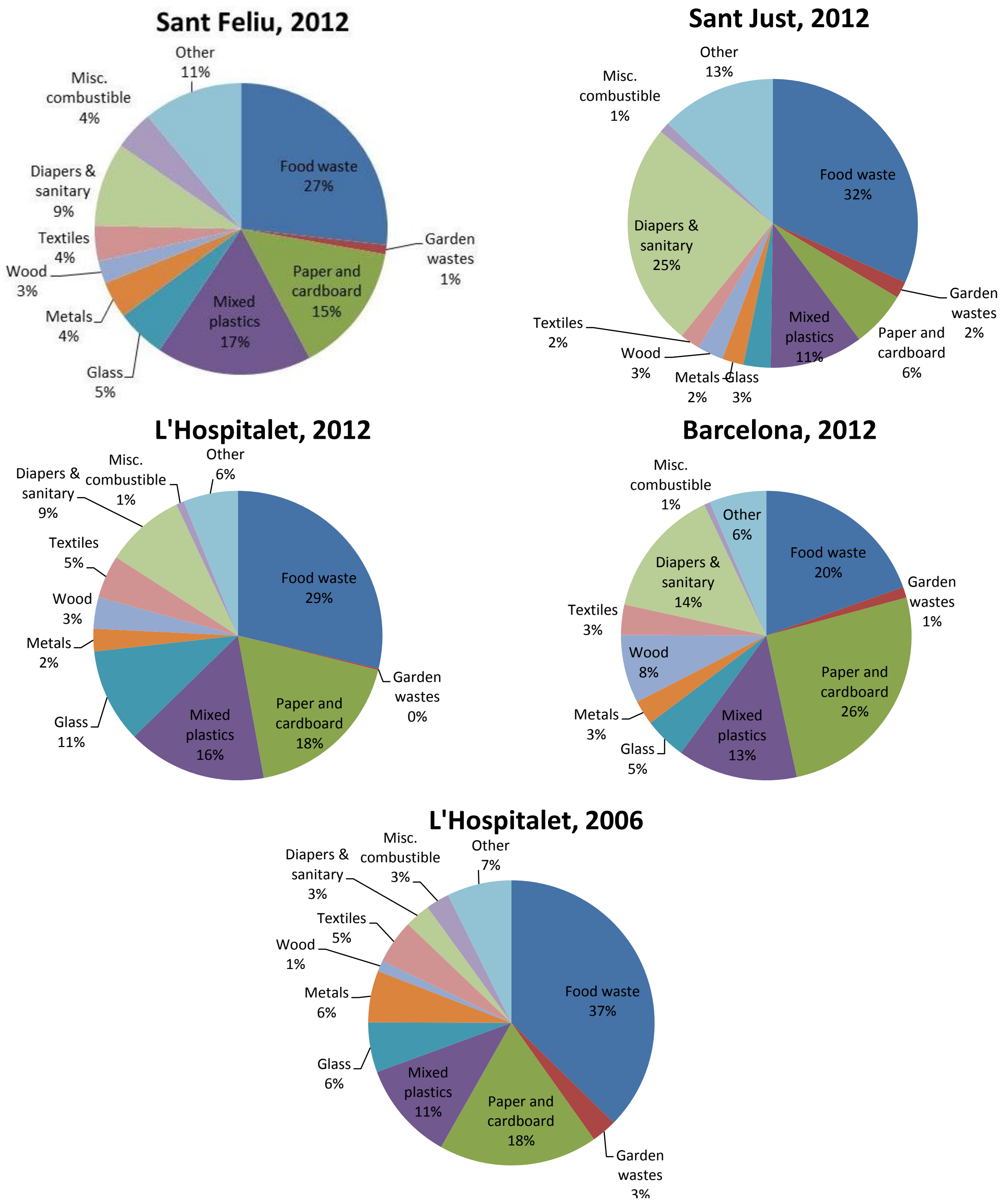


Figure 5.4 Average residual waste composition in municipalities of El Baix Llobregat and El Barcelones, all with separate collection of oganics (FORM), 2012, and composition of L'Hospitalet in 2006.

5.6. Calorific value of residual waste

The effect on the net calorific value of residual waste between municipalities with and without separate organics (FORM) collection is shown in Figure 5.5. Theoretical net CV was again calculated from the composition using the lower heating values in Table 2.1. The food waste fraction gives a low contribution to the net CV in the residual waste.

The average net CV of municipalities without FORM was 10 800 ± 1400 MJ $tonne^{-1}$, whereas for municipalities with FORM collection this increased to 11 700 ± 1200 MJ $tonne^{-1}$. The average net CV value is shown as a thin line across each group in Figure 5.5.

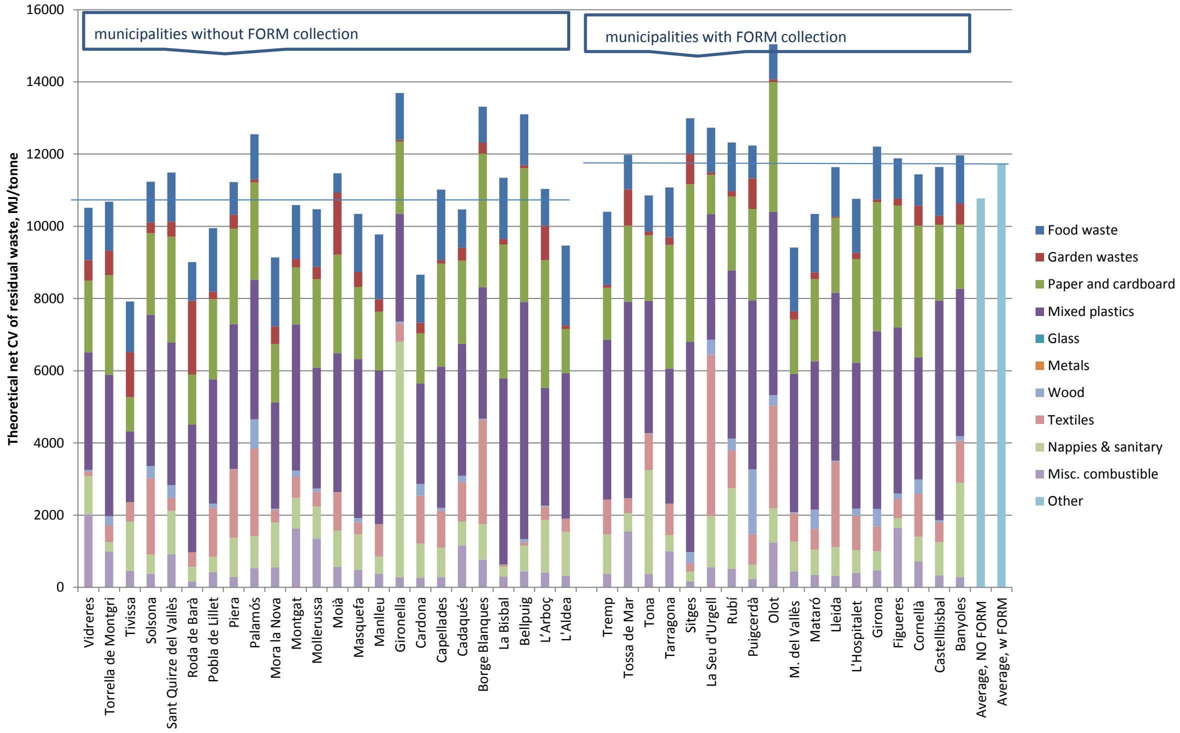


Figure 5.5 Theoretical net CV of residual waste, based on composition, in municipalities of Catalonia, with and without separate collection of organic waste (FORM), 2006.

In the Valles Occidental 2010 data, the average net CV for municipalities with FORM collection was calculated at 10 400 ± 800 MJ $tonne^{-1}$; however these compositional analyses did not include the categories of wood, textiles or nappies & sanitary, and it is unknown whether the auditors included those items as 'misc. combustibles' or 'other', so the net CV may have been underestimated as a result. No figure is shown for these data.

Figure 5.6 shows the calculated net CV of the four neighbouring municipalities in El Baix Llobregat and El Barcelones for 2012. The average CV was calculated to be 13 600 ± 1000 MJ $tonne^{-1}$, an increase of 26% on the 2006 average for municipalities without FORM collection.

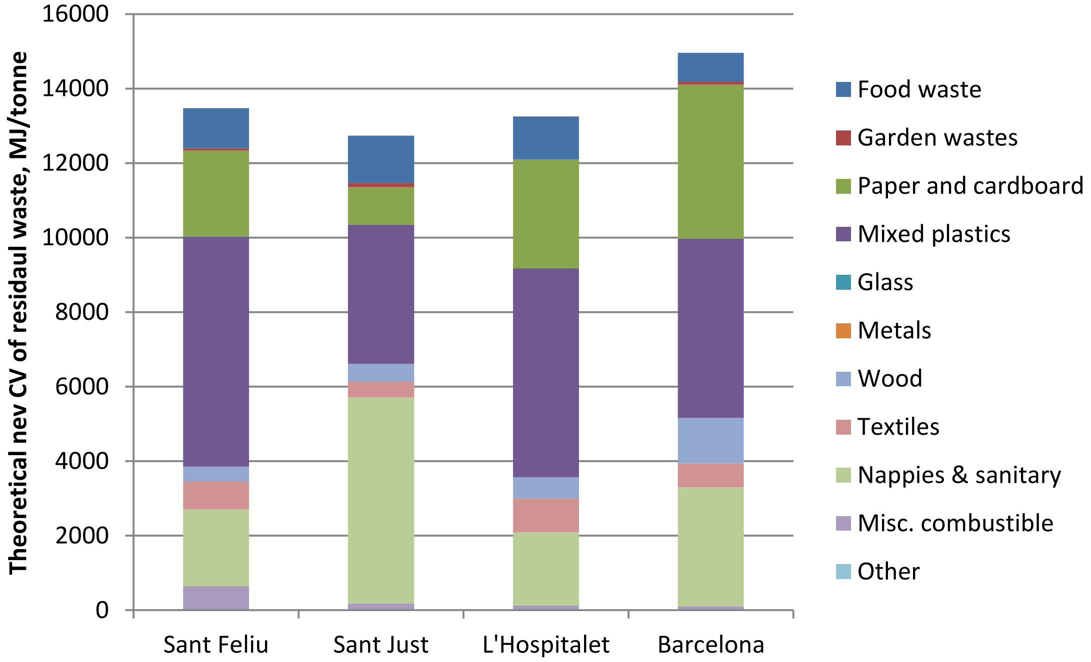


Figure 5.6 Calculated heating value of residual waste, based on composition, in municipalities of El Baix Llobregat and El Barcelones, which all have separate collection of organic waste (FORM), 2012.

5.7. Quantity of residual household waste

Figure 5.7 shows the total quantity of residual waste collected per person in 2006, for the 42 municipalities for which waste composition was determined. Figure 5.7 shows the quantity per person in 2010 and 2011, in those regions for which waste compositions have been examined. The average quantity of residual waste per person in 2006 was 10.2 kg person^{-1} week^{-1} without FORM collection, and 8 kg person^{-1} week^{-1} with FORM collection, a difference of 22%. In the municipalities analysed in 2010 and 2011, the average quantities were 281 and 265 kg person^{-1} respectively, or 5.4 and 5.1 kg person^{-1} week^{-1}; 47% and 50% less than the 2006 non-FORM municipalities.

Although Spain's average household size is 2.7 people (Eurostat, 2013) using England's average household size of 2.3 people (ibid.) allows a more direct comparison of residual waste generation between the two countries. The above quantities, therefore, would translate to 23.4 kg household^{-1} week^{-1} and 18.3 kg household^{-1} week^{-1} for the 2006 non-FORM and FORM municipalities, respectively, decreasing to 12.4 kg household^{-1} week^{-1} in 2010 and 11.7 kg household^{-1} week^{-1} in 2011, in which all had FORM collection.

It should be emphasized again that the data has been taken from different municipalities in different years, making direct comparison difficult, but there appears to be an overall downward trend in residual waste in the years since separate collection (including FORM, among other recyclable streams) has been commenced.

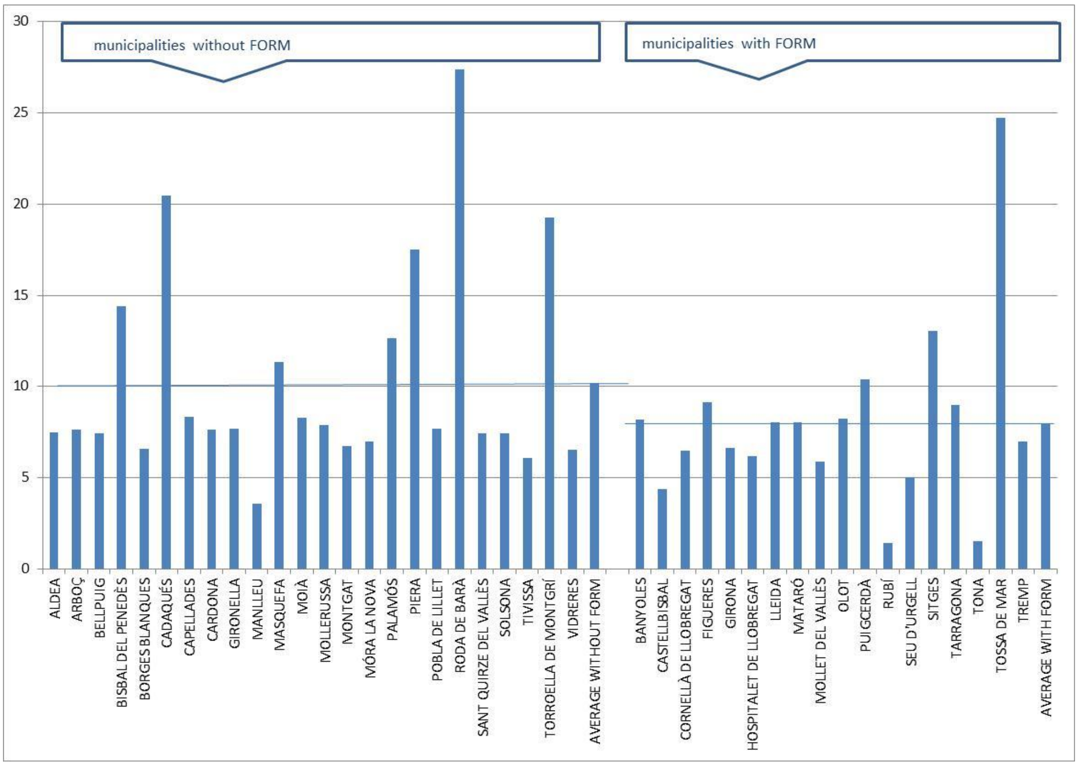


Figure 5.7 Weekly quantity per person of residual waste in municipalities of Catalonia with and without separate collection of organic waste (FORM), 2006.

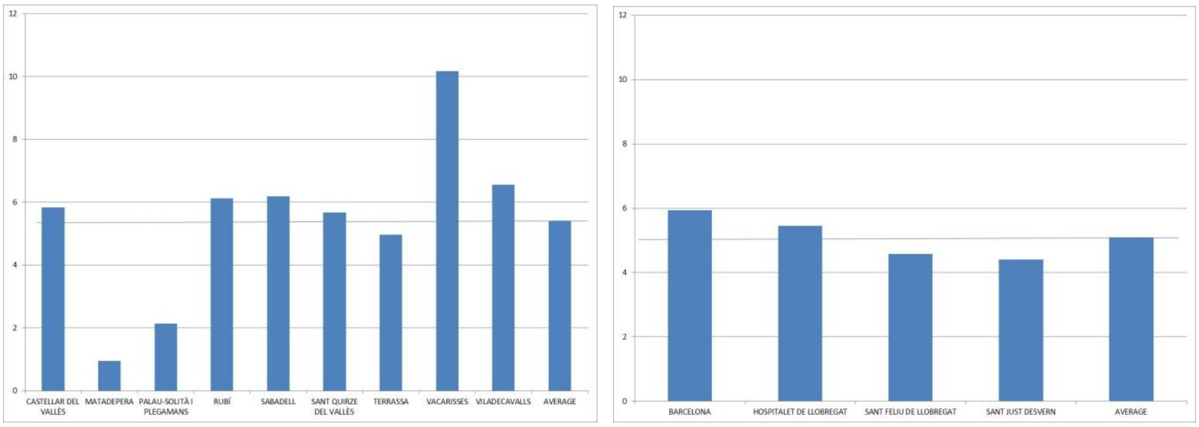


Figure 5.8 Weekly quantity per person of residual waste in municipalities of Valles Occidental, 2010 (left), and El Baix Llobregat and El Barcelones, 2011 (right).

5.8. Summary of Catalonia results

On average, residual waste streams for municipalities with separate collection of organic wastes had a lower concentration of food and garden waste, increased calorific value and decreased overall quantity than residual waste streams from municipalities without separate organic waste collection. The average difference in waste mass in 2006 was 22% between municipalities with and without FORM collection. By 2011 residual waste mass was 50% less than in non-FORM municipalities in 2006.

This pattern was not statistically significant, however: the ranges and standard deviations between the two 2006 groups overlap and an independent t-test resulted in a p-value greater than 0.05. There is a statistically significant difference between the 2006 non-FORM average and the average mass of all FORM municipalities analysed in 2006, 2010, 2011 and 2012, but the difference cannot be attributed entirely to food waste collections, as economic and other factors were also present to drive down residual waste mass in later years.

Nonetheless, there has been a general downward trend in residual waste quantity and prevalence of organic waste in the residual waste, indicating that the separate collection of organic waste in Catalonia has had a positive impact.

One important difference between this area of Spain and England, is the difference in the collection system and receptacles for household waste. While the majority of household waste collection in the UK is by door-to-door collections in which each household is provided with its own containers for waste, the primary form of waste collection in this area of Spain is via streetside bins – large on-street containers sized for a number of households' waste. Residents are responsible for bringing and depositing their waste in the correct bin, and there is no way to know which waste is from which household. In addition, since there is no way of restricting bin access to householders only, streetside containers may be used by businesses to dispose of some commercial wastes that should have been managed through private commercial waste collection, and could be part of the reason why per-household and per-person quantities are so high relative to England.

In the case of door-to-door collections, residents have direct responsibility for the contents of their own bin; this is not the case for streetside bins. In this case there is less opportunity to influence householder behaviour through mechanisms such as AWC rather than weekly collection of refuse, or enforcement of quantity or contamination limits.

However, the average decrease in residual waste mass of 22% between FORM and non-FORM municipalities in the year 2006 is similar to the England results for mass decrease.

6. Case Studies – Sweden

6.1. Background

Since 2005, a National Environmental Quality Objective in Sweden states that 50% of the food waste from households, restaurants and industrial kitchens should be separately collected and biologically treated by 2018. The responsibility to implement this objective falls on the shoulders of the municipalities.

In many cases, waste composition analyses are performed prior to introduction of food waste collection schemes in order to assess potential amounts of collected material. Analyses are commonly also performed after the collection scheme has been introduced as a part of a continuous evaluation of the waste recycling performance in the municipality. Thus, there is an extensive number of waste composition analysis protocols available which describe the situation in Sweden with respect to the composition of residual waste before and after source-separation of food waste from households.

6.2. Methodology

The municipal company NSR is currently the predominant provider of waste composition analyses in Sweden. This company was contacted to get access to performed waste composition analyses. All municipalities included in this study were contacted and have given their permission for use of their protocols. This method was completed with an extensive mail correspondence to a further 20 municipalities where separate collection schemes for food waste were introduced recently.

In many cases, waste composition analyses have been performed with a focus on the quality of separately collected food waste. Thus, in a majority of the analyses, only the food waste fraction had been analysed. In other cases, the data was not presented in relation to the number of households from which the waste had been collected. In these cases, it was only possible to assess the composition of residual waste on a relative basis, i.e. as percent of total residual waste. In three analyses (from Luleå municipality), the amount of packaging materials and newspapers was presented as one fraction and only indicative data on the internal partitioning between different types of packaging materials was given. Thus, it was assumed that 50% of this fraction consisted of paper (newspaper and paper packaging), 30% of plastic packaging, 10% of glass packaging and 10% of metal packaging.

A total of 23 waste composition analyses have been examined. In six of the cases, studies represent situations before and after introduction of separation of food waste at source in the same municipality and residential area. The study includes both single-family and multi-family dwellings. The different areas included in the study are described briefly below.
In most of the before and after studies, waste composition analyses were performed 2-4 weeks prior to the introduction of source-separation of food waste. Analyses after the introduction of the scheme were performed 3-4 months after the scheme had been introduced. However, in some cases, the time lapse between the analyses was longer.

The methodology for waste composition analysis is relatively standardized through a guideline provided by the Swedish Waste Management Association (2005). This guideline was developed by PhD Lisa Dahlén and Sanita Vulcievic in collaboration with the municipal waste management company NSR, i.e. the predominant provider of waste composition analyses in Sweden over the last decade.

Thus, there is a strong coherence between the methodology used for waste composition analyses performed in different parts of the country. However, depending on the interest from the client, the reporting format can differ between different studies. In some cases, results are reported for individual packaging types separately and in others as a general fraction of “dry recyclables”. In some cases, non-recyclables and non-food waste is classified as “others”, while this fraction in other cases can be differentiated as “nappies”, “textiles”, ”inert material”, “wood” and “other combustibles”.

According to the guidelines, neither shredding nor screening is done prior to the analysis. No correction factors are used to compensate for moisture and dirt on dry materials and residues of food waste and other adherents are simply scraped off the material prior to weighting. No correction factors are made to compensate for evaporation of moisture from wet food waste. Biodegradables are commonly divided into the fractions "food waste" and "garden waste", the latter referring to soil, leaves, pot plants, flowers etc.

The waste composition analyses were collected from a total of 10 Swedish municipalities with a summed population of 880,745 persons (SCB, 2013). This represents 9.2% of the total Swedish population.

The waste compositions were also used to develop an estimate of the heating value of the residual waste. To assess heating value based on composition, the same standard calorific values were used for each waste category as shown in Table 2.1 of Section 2.

In Table 6.1, the 23 waste composition analyses included in the present study are presented with key data in each case.

Table 6.1 Key data for the 23 Swedish waste composition analyses. In all cases where food waste is collected in bins, paper bags are used.

ID	Municipality	Area	Type of households	Type of ownership	Sample size*	Collection frequency	Type of food waste collection
1	Malmö	Augustenborg	Multi-family	Rental	210	Weekly	Separate bin in recycling buildings
2	Lund	LKF	Multi-family	Rental	244	Weekly	Separate bin in recycling buildings
3	Lund	Havstruten	Multi-family	Resident owned	140	Weekly	Separate bin in recycling buildings
4	Lund	Mandolinen	Multi-family	Resident owned	38	Weekly	Separate bin in recycling buildings
5	Helsingborg	Maria Park	Single family		465	Weekly	Multi-compartment bin
6	Åstorp	Urban area	Single family		686	Weekly	Multi-compartment bin
7	Höganäs	N.S.	Single family		400	Weekly	Separate bin
8	Båstad	City center	Single family		275	Weekly	Separate bin
9	Lund	Torna Hällestad	Single family		NS	NS	2-compartment bins (residual waste/food waste)
10	Lund	Torna Hällestad	Single family		NS	NS	4-compartment bins
11	Helsingborg	Ödåkra	Single family		110	Weekly	Separate bin
12	Helsingborg	NS	Single family		170	Every other week	4-compartment bins
13	Västerås	Västerås city	Single family		NS	None	Home composting
14	Västerås	Västerås city	Multi-family	NS	NS	Weekly	Separate bin in recycling buildings
15	Västerås	Västerås city	Single family		NS	Weekly	Separate bin
16	Västerås	Västerås city	Single family		NS	None	None
17	Surahammar	NS	Single family		NS	NS	Separate bin
18	Surahammar	NS	Single family		NS	None	Home composting
19	Surahammar	NS	Single family		NS	None	Food waste grinder

20	Växjö	NS	Single family		192	Every other week	Separate bin
21	Luleå	Urban area	Single family		288	Weekly	Separate bin
22	Luleå	Rural areas	Single family		193	Weekly	Separate bin
23	Luleå	Urban area	Multi-family	NS	2239	Weekly	Separate bin in recycling buildings

*Number of households in sample.

In the following cases, analyses represent the situation before and after introduction of separate food waste collection in a specific residential area. Thus, the data is not influenced by differences in household size or demography.

6.3. Lund municipality

The municipality of Lund has performed tests of source-separation of food waste in two steps. In the first step, a total of 1000 single house residents were contacted and asked if they wanted to participate in a trial with source-separation of food waste. 260 persons participated in the trial and also received a 600 SEK (roughly 65 euros) reduction of annual waste collection fee. The introduction of separate collection of food waste, in this case in paper bags in separate bins (140 liters) collected every other week had a large impact on the composition of the residual waste. The source separation ratio of food waste was very high, at 89%. Also, the percentage of contamination from miss-sorting was very low; around 2%. Unfortunately, no analyses were made on the residual waste in this trial.

In the second step, source-separation of food waste was introduced in a total of 500 apartments in multi-family dwellings in 2009. Around 50% of these were rentals and 50% were owned by residents. In these cases, food waste separation was not presented as voluntary. All households were provided with plastic bins for separate collection of food waste in paper bags and informed that all generated food waste should be separated in these bags. However, the impact on the composition of residual waste was inferior compared to the trial amongst single houses. Source separation rates varied from 26% in rental apartments to 44-49% in resident owned apartments based on averages from three waste composition analyses performed over the first 18 months after the scheme was introduced.

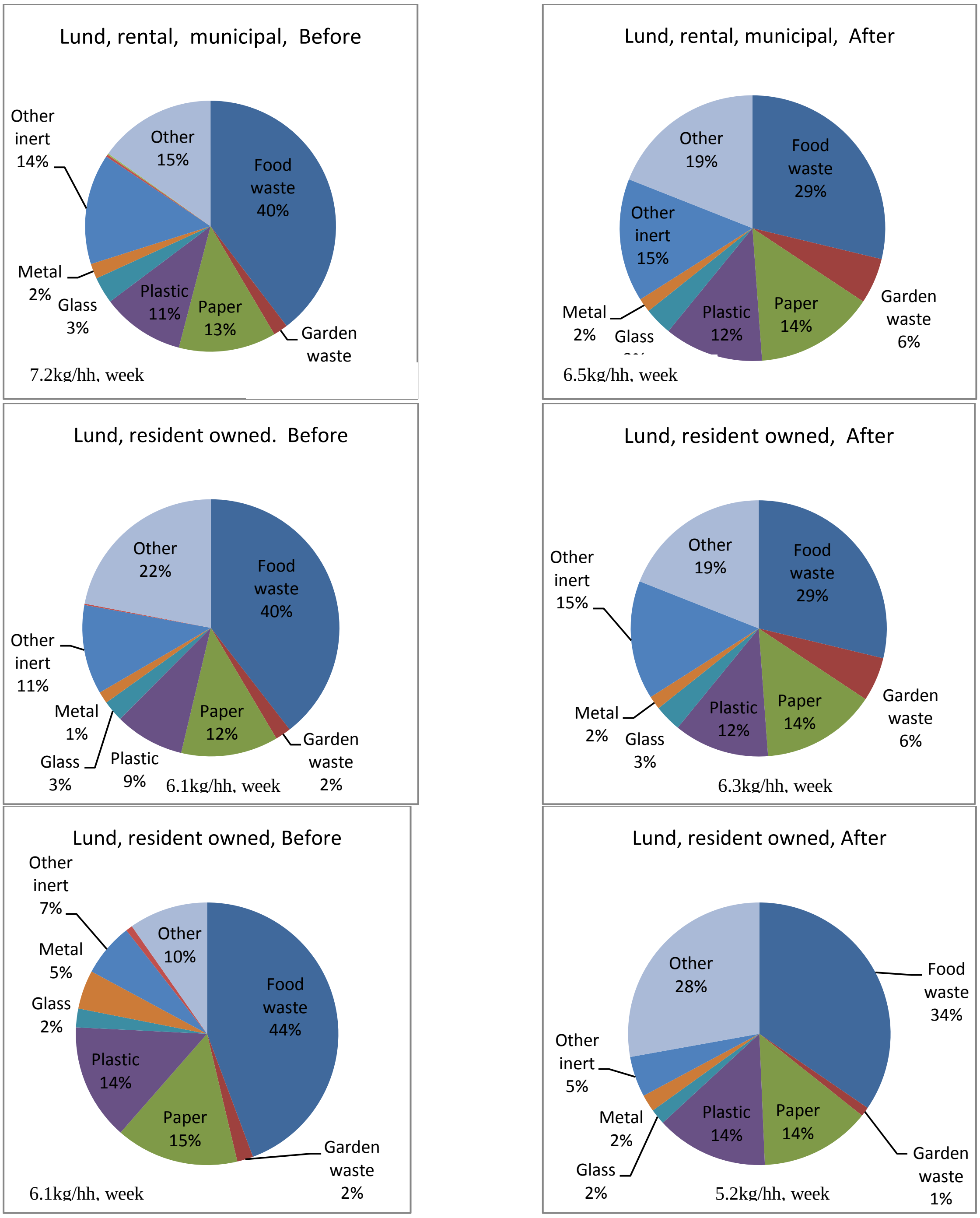


Figure 6.1 Residual waste composition in different multi-family residential areas in Lund municipality before and after introduction of separate collection of food waste.

6.4. Malmö municipality

The data analysed represented the situation in the multi-family dwelling area of Augustenborg, with a total of 1631 rental apartments. Separate collection of food waste for biogas production was introduced in spring 2008 and waste composition analyses were performed prior to introduction of the scheme and on four subsequent occasions over the initial years after the introduction. A sample was taken, representing 107 apartments and the waste generation over 1 week. Results showed that the food waste separation rate was low at

26%. The percentage of food waste in residual waste is still over 40%. Data represents an average from performed waste composition studies.

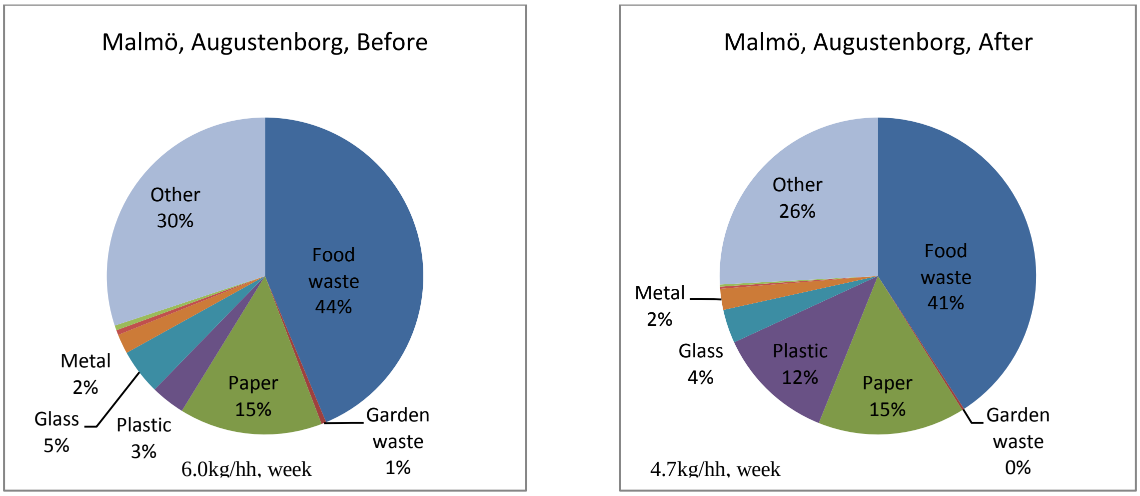


Figure 6.2 Residual waste composition in a multi-family residential areas in Malmö municipality before and after introduction of separate collection of food waste.

6.5. Helsingborg municipality

Single family houses in Helsingborg municipality are provided with multi-compartment bins, where different waste fractions are separated into different compartments in the same bin.

Each single family household is provided with two bins (370 or 240 litres) for a total of eight waste fractions, including residual waste. Bins are emptied weekly or fortnightly. Paper bags for separate collection of food waste are provided by the waste collection company. Waste composition analyses are performed on a regular basis in different areas of the municipality in order to follow developments in household source-separation behavior.

Separate collection of household food waste has been mandatory in Helsingborg municipality for several years. Thus, only one waste composition analysis was available showing the composition of residual waste before and after separation. In this case, food waste separation was introduced in summer 2004, and the waste composition analyses were performed in March 2004 (before) and February 2005 (after).

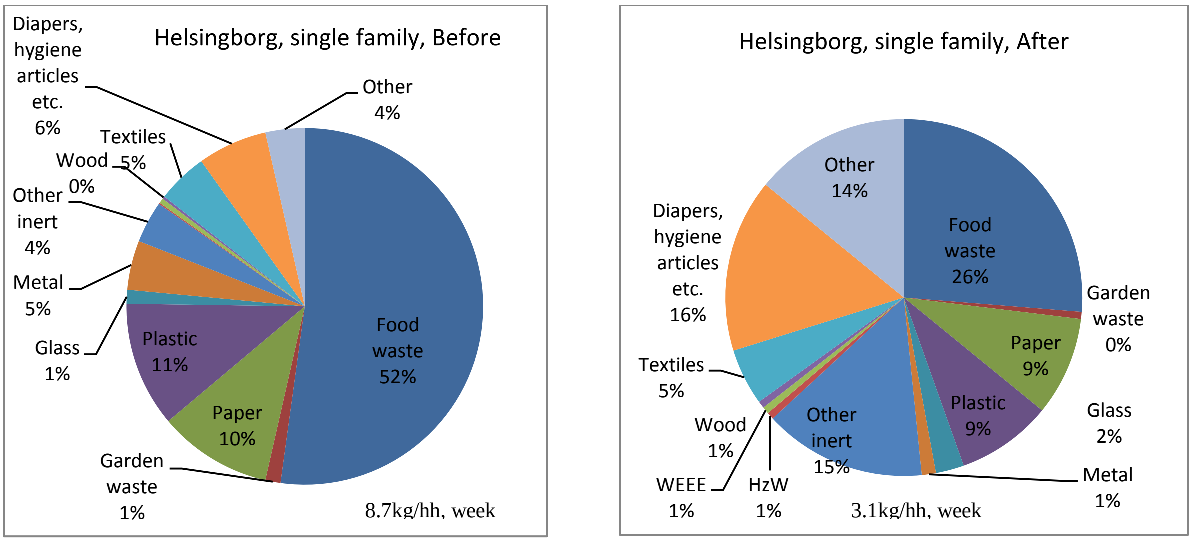


Figure 6.3 Residual waste composition in single family houses in Ödåkra village, Helsingborg municipality before and after introduction of separate collection of food waste.

6.6. Växjö municipality

Separate collection of food waste amongst single houses in Växjö municipality was introduced in 2011. The separation scheme consists of separation of food waste in paper bags and disposal in separate bins. Bins for food waste as well as bins for residual waste are collected once every other week, always on the same day for both fractions. A waste composition analysis was performed in 2010, prior to the introduced separation scheme, and a follow up analysis was performed in 2012. The source separation rate of food waste is very high, at 94%, while the ratio of miss-sorting is low, at 1.5%.

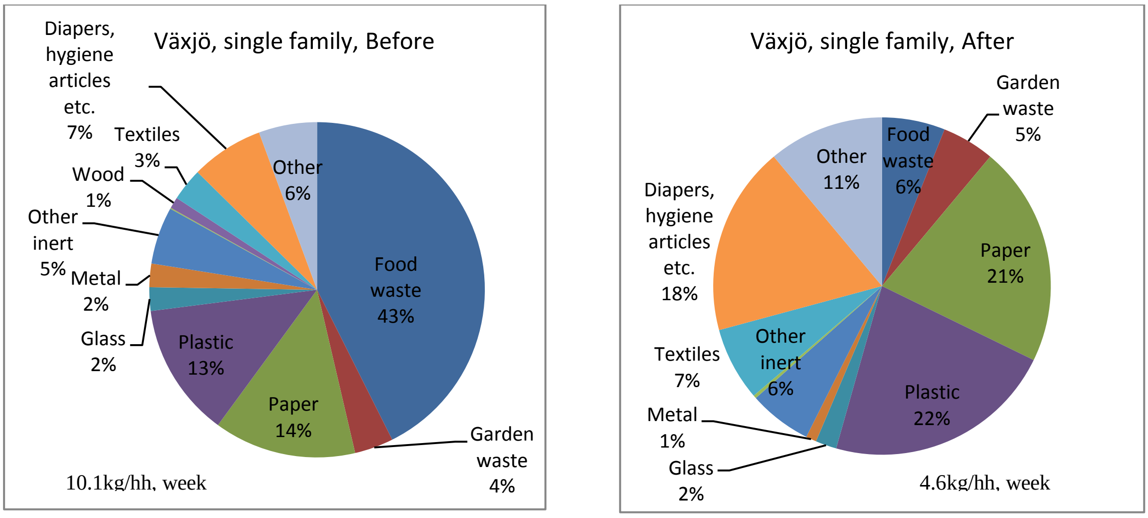


Figure 6.4 Residual waste composition amongst single family households in Växjö municipality before and after introduction of separate collection of food waste.

6.7. Surahammar and Västerås municipalities

In the following municipalities, separate food waste collection has been introduced in parts of the municipality or different types of schemes have been employed in different parts of the municipality. This provides for comparisons between households with and without separate food waste collection or with different food waste collection schemes.

Surahammar municipality
Several schemes for food waste separation are utilized in parallel in Surahammar municipality: home composting, food waste grinders and separation in paper bags and disposal in separate bins. Based on the analyses performed in 2011, the fraction of food waste in residual waste is relatively high amongst households belonging to all these three separation schemes: between 33-37% of total residential waste in all cases.

Västerås municipality
Separate collection of food waste has been introduced in several areas in Västerås municipality over the last 10 years. However, some areas still do not have the possibility to sort their food waste. Thus, a comparison between areas with and without food waste collection is possible. In the area without food waste collection, the amount of food waste in residual waste averaged 4.45 kg household^{-1} week^{-1} or 47% of the total mass of residual waste. In multi-family areas and single family house areas with separate food waste collection, the average amount of food waste was 1.00 and 1.25 kg household^{-1} week^{-1} respectively. In single family house areas with home composting, the amount of food waste was 2.1 kg household^{-1} week^{-1}.

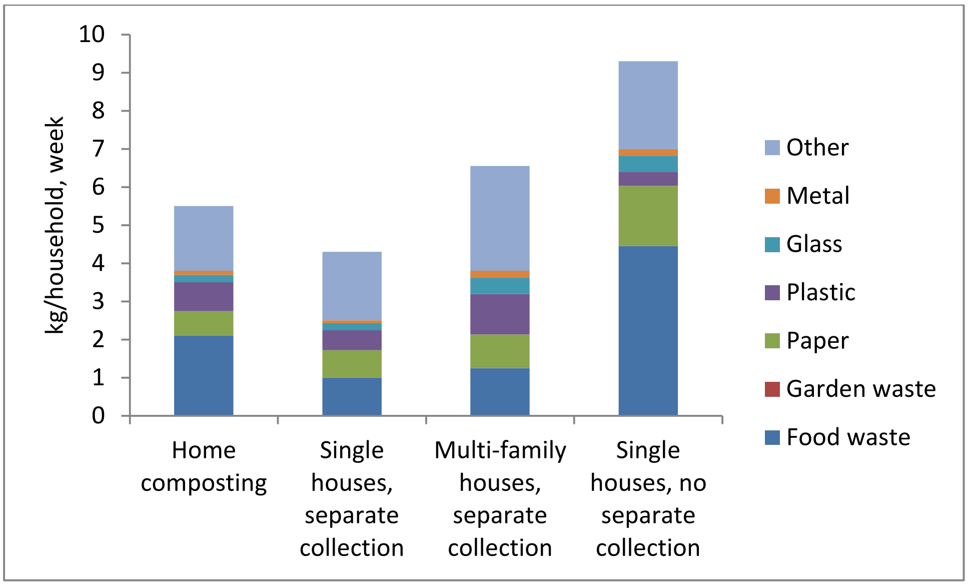


Figure 6.5 Residual waste composition in different types of households in Västerås municipality, with and without separate food waste collection.

6.8. Torna Hällestad, Lund municipality

In the village of Torna Hällestad, Lund municipality, single households can choose between food waste separation in two or four compartment bins. Results from waste composition analyses where waste from both types of collection schemes was analyzed shows that the ratio of food waste in residual waste was similar (34-36%), while the ratio of paper, plastics, metal and glass (i.e. materials which to a large extent can be separately collected in four compartment bins, but not in the two compartment bins) are higher in residual waste from households with two compartment bins – 38% compared to 29% respectively (Figure 6.6).

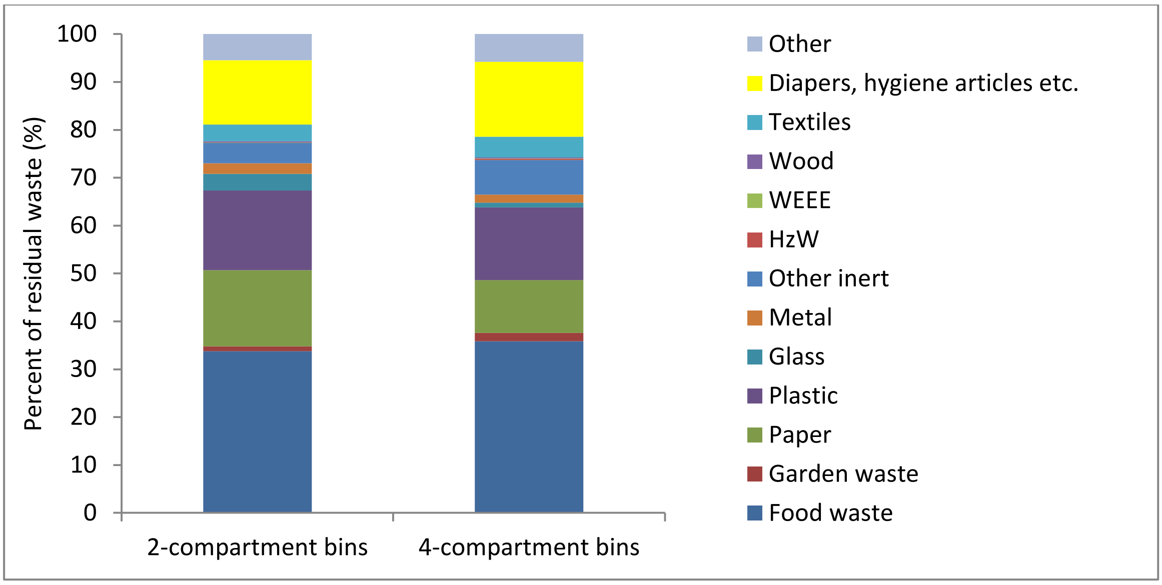


Figure 6.6 Residual waste composition in Torna Hällestad, where households can choose between 2- and 4-compartment bins.

6.9. Calorific value of residual waste

In Figures 6.7-6.12, the effect on the lower heating value in residual waste after introduction of food waste source-separation is displayed. As seen in the figures, food waste, constituting a considerable fraction of the residual waste on mass basis, gives a low contribution to the net calorific value (CV) in the residual waste. Based on data from all 23 case studies, the contribution to the calorific value in residual waste from food waste varies between 15-21%, with an average of 17% prior to separate collection of food waste. After introduction of separate food waste collection, the contribution to the net calorific value in residual waste from food waste varies between 1-12% with an average of 8%. Thus, although the amount of residual waste has decreased, the net CV per tonne generated residual waste has increased.

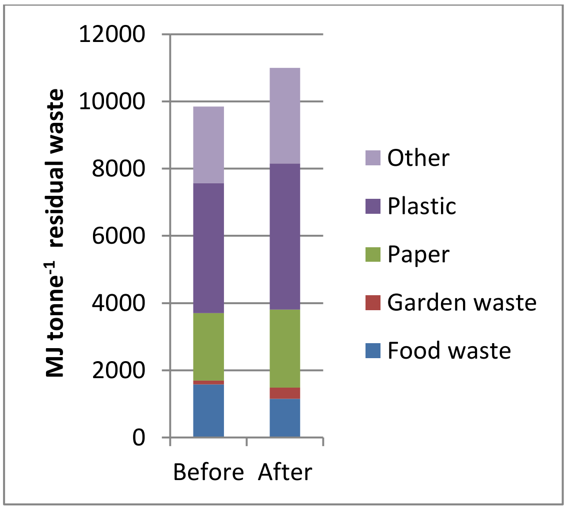


Figure 6.7 Lund municipality, rental apartments in municipally owned buildings.

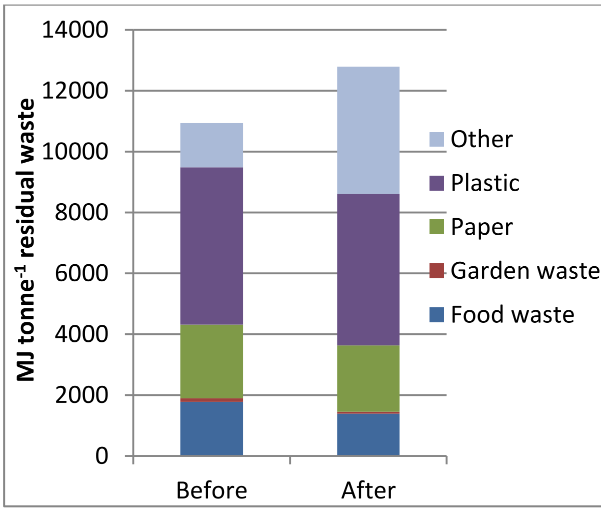


Figure 6.8 Lund municipality, resident owned apartments.

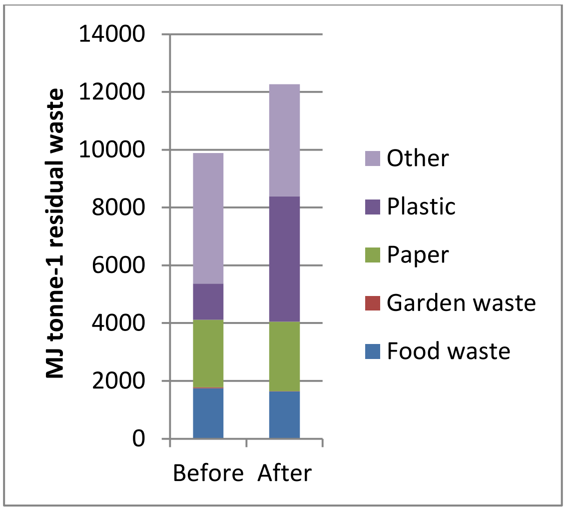


Figure 6.9 Malmö municipality, rental apartments in municipally owned buildings.

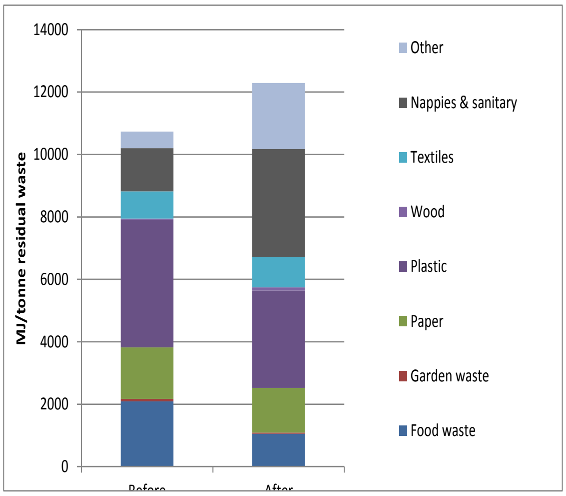


Figure 6.10 Helsingborg municipality, Ödåkra village, single family houses.

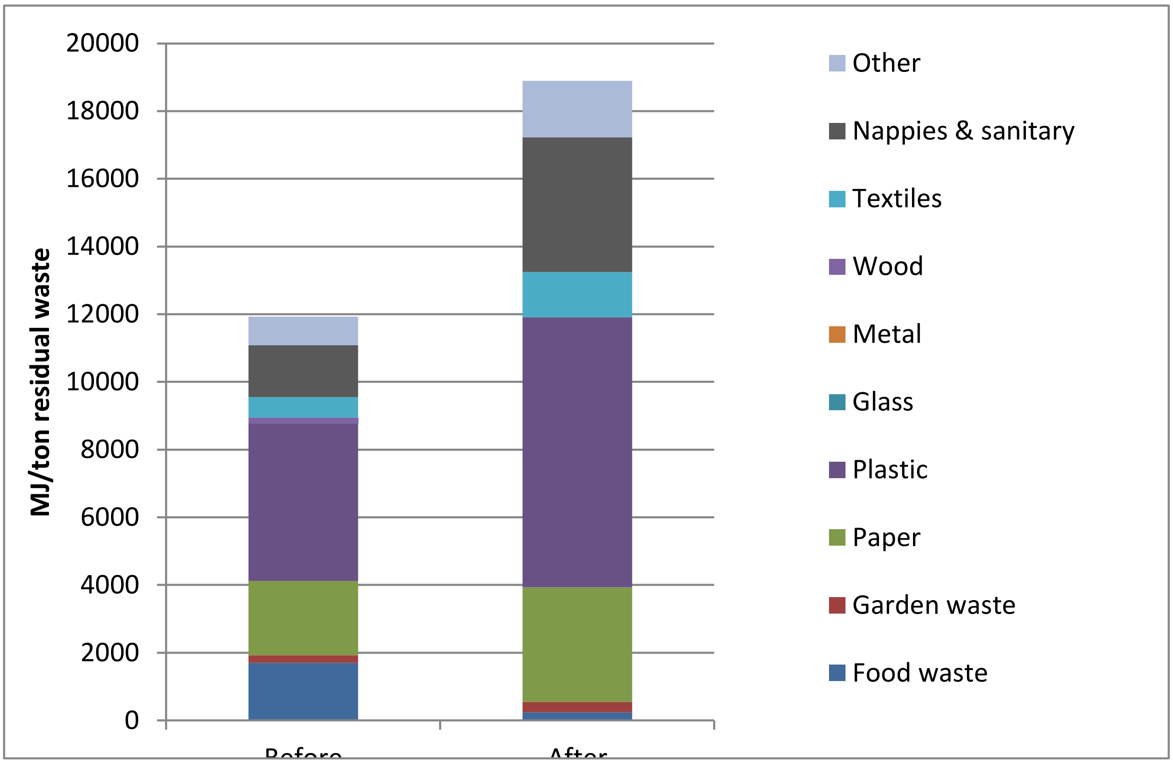


Figure 6.11 Växjö municipality, single family houses.

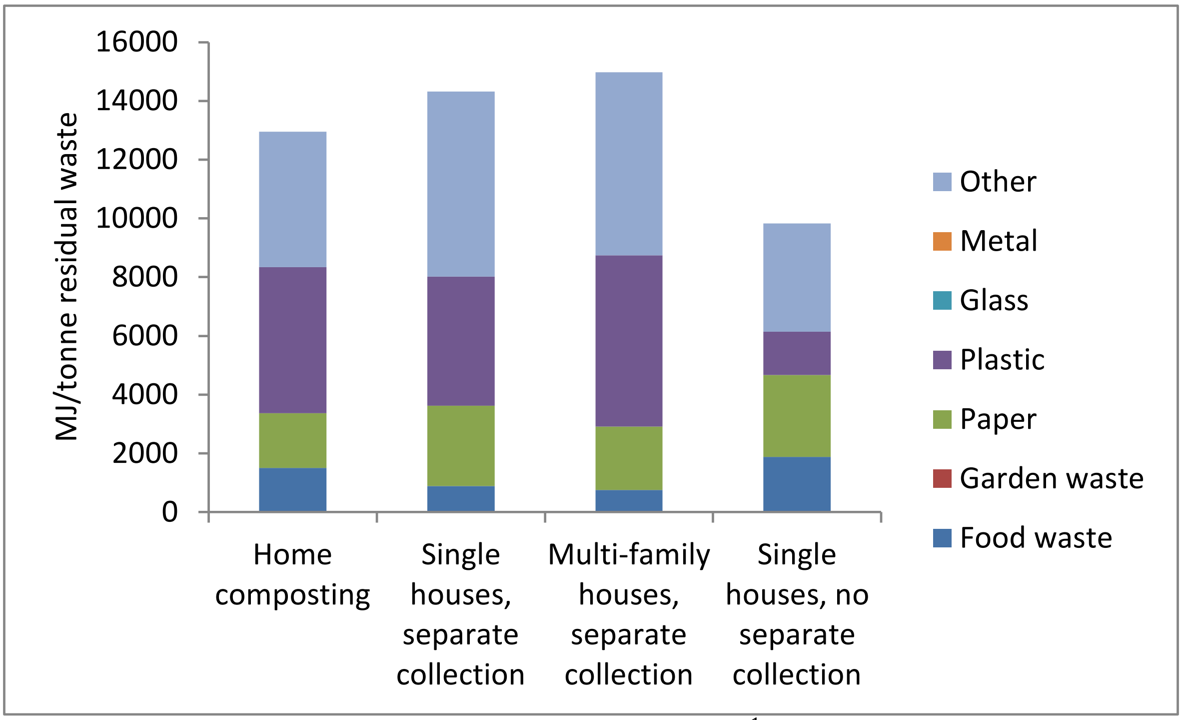


Figure 6.12 Calorific value in residual waste as MJ tonne^{-1} residual waste in different types of households in Västerås municipality, with and without separate food waste collection.

As seen in Figure 6.11, the net CV in Växjö municipality increased substantially when separate collection of food waste was introduced. This was a result of the high separation rate of 94% amongst single houses in the municipality, resulting in an increase in residual stream calorific value of 62%.

Comparing Figures 6.5 and 6.12, it is seen that there is an association between a lower heating value and higher amount of food waste in residual waste from households without separate collection of food waste.

In Figure 6.13, the heating values in residual waste in the 23 case studies are summarized. The figure clearly shows that the calorific value in the residual waste increased after an introduced separation of food waste. The average calorific value in residual waste from areas without separate food waste collection was on average 10 500 MJ tonne^{-1} while the average was 13 900 MJ tonne^{-1} in areas with separate collection. This represents an increase of 33%.

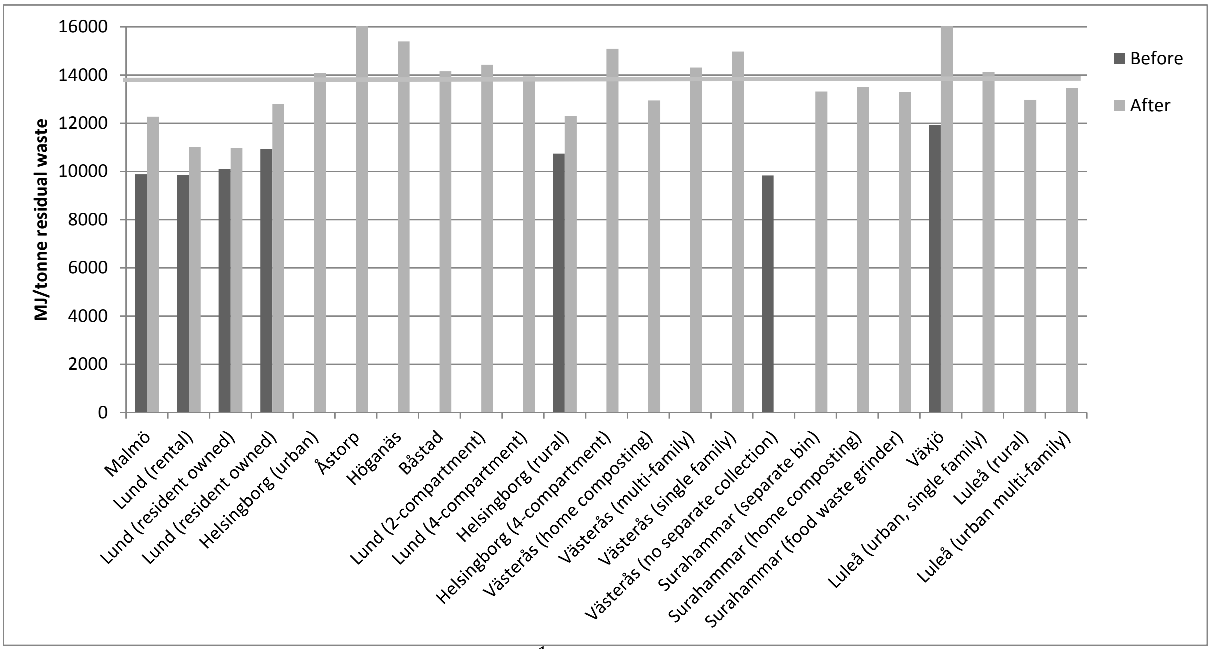


Figure 6.13 Heating values (as MJ tonne^{-1}) in residual waste before and after the introduction of source-separation schemes for food waste in assessed residential areas.

The differences in calorific values could however be influenced by demographic differences between the assessed studies, as these were collected from several different municipalities. However, when assessing data only for areas where analyses were made both before and after an introduction of food waste collection, the difference was comparable. The average calorific value in residual waste prior to the separate collection was on average 10 600 MJ tonne^{-1} but increased by 23% to an average of 13 000 MJ tonne^{-1} after the separation scheme had been introduced.

In Figure 6.14, the heating value is presented in dis-aggregated form, demonstrating the influence from each different waste fraction on the overall per tonne residual waste heating value. Results are presented separately for waste composition analyses made in areas with and without separate collection of household food waste.

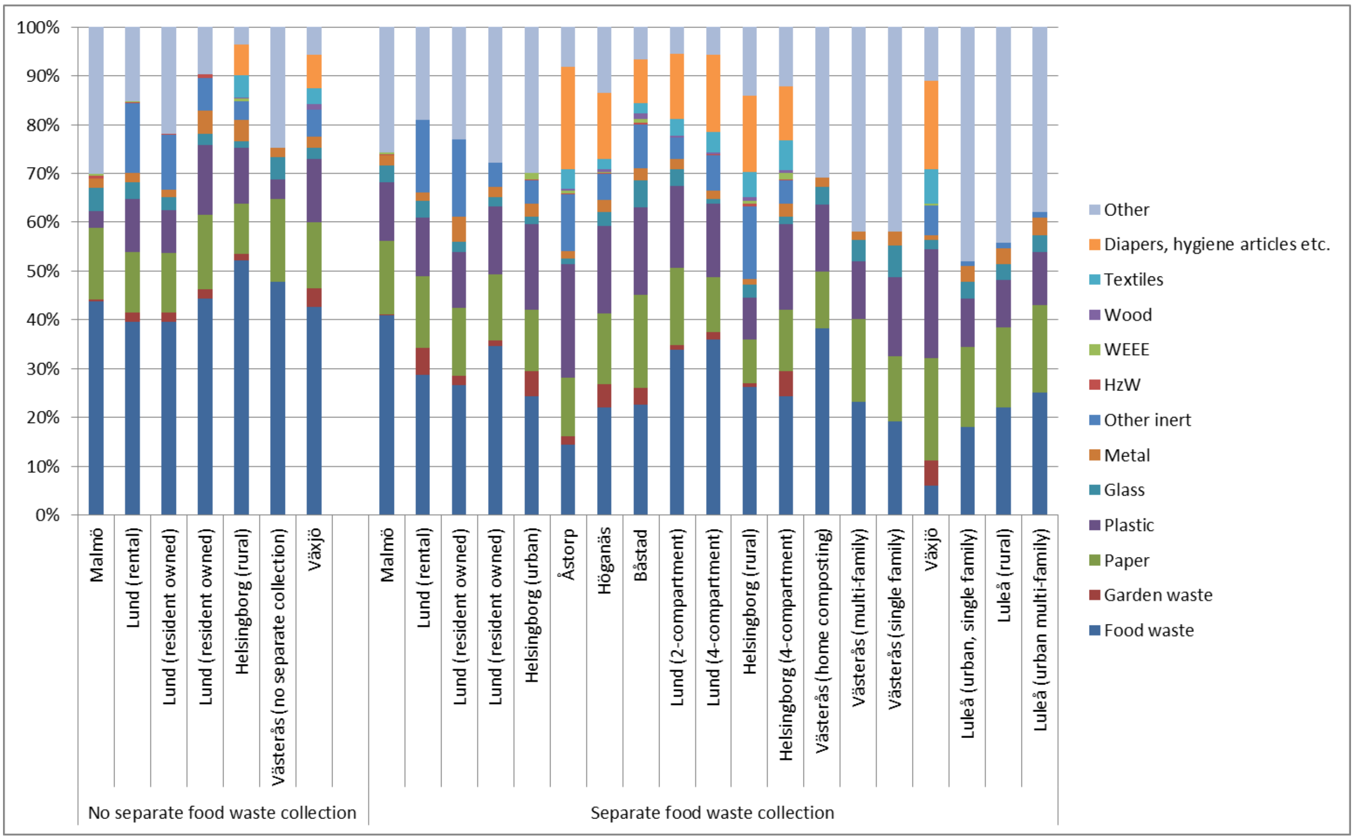


Figure 6.14 Dis-aggregated presentation of per-tonne residual waste heating value based on waste composition analyses made in areas without (left) and with (right) separate collection of household food waste.

While the food waste in most cases represents between 40-50% of the residual waste fraction (mass-basis) in areas without separate food waste collection, it rarely exceeds 30% in areas with separate collection.

6.10. Quantity of residual household waste

In 20 of the case studies presented here, it was possible to assess the impact of food waste separation on the amount of residual waste generated per household per week. As seen in Figure 6.15, the average generation differs by 2.6 kg per household per week (from 7.6 kg per household per week before to 5.0 after), a decrease of 34%. However, the generation varies largely between the different cases. The impact was also seen to vary largely in areas where waste compositions were made both before and after food waste separation; from an increase of 4% (in absolute terms; its proportion in residual waste decreased but the overall residual waste amount increased slightly) to a decrease of 55%. Figure 6.16 presents the relative composition of residual waste in areas without and with separate collection of household food waste.

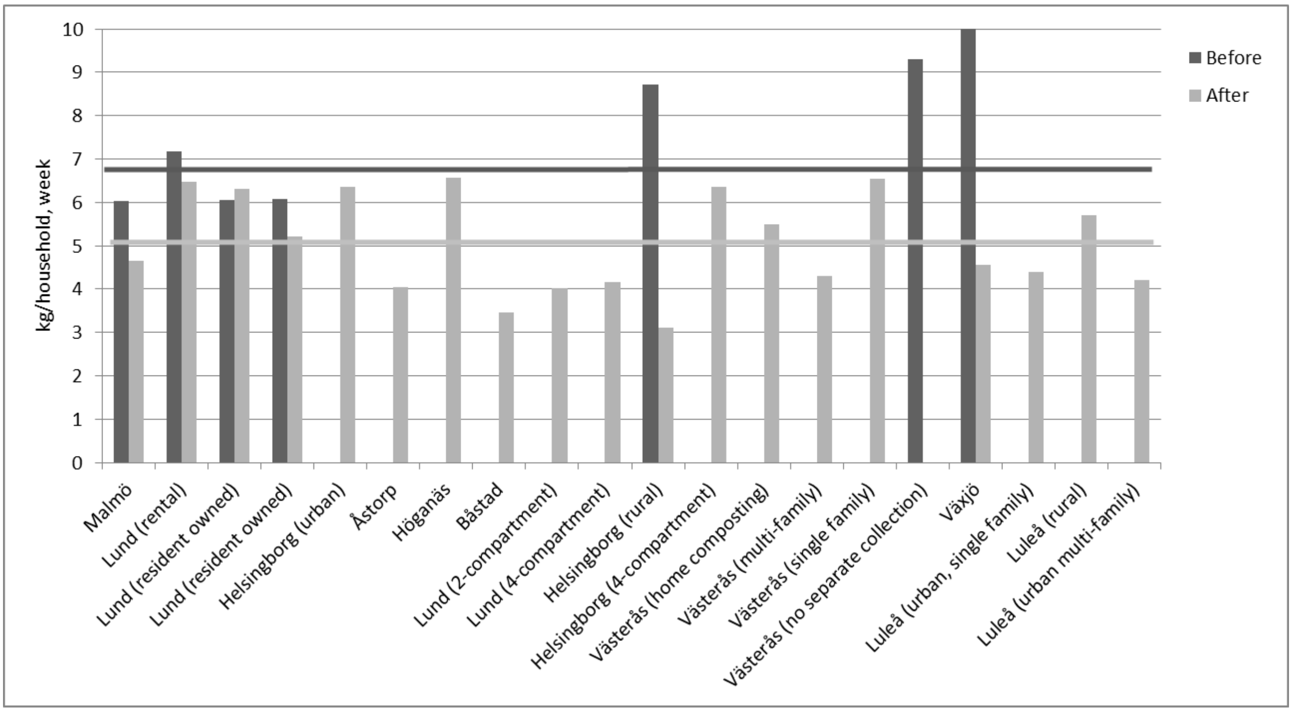


Figure 6.15 Generation of residual waste as kg per household per week, before and after the introduction of source-separation schemes for food waste in assessed residential areas.

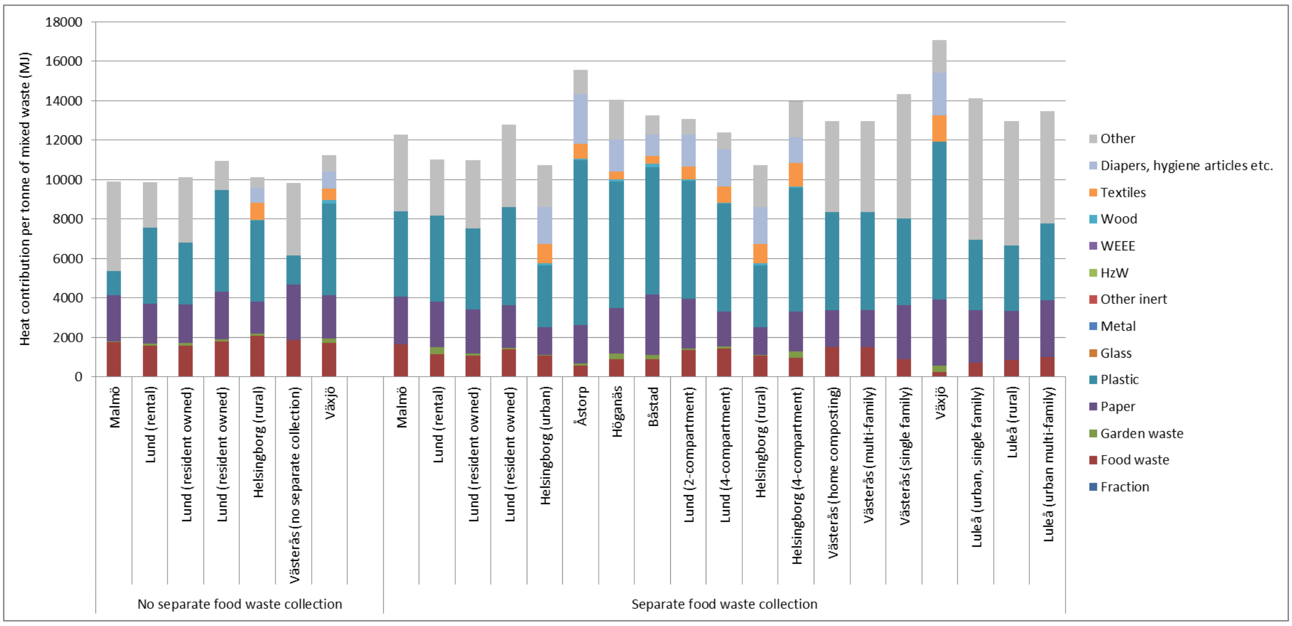


Figure 6.16 Relative composition of residual waste based on waste composition analyses made in areas without (left) and with (right) separate collection of household food waste.

7. Case Study – Portela district, Loures, Portugal

7.1. Background

Organic waste collection and treatment in Portugal is at a fairly early stage, with 7.4% of municipal solid waste sent for organic recovery, primarily via mechanical-biological treatment (MBT) of mixed waste (VALORGAS D2.2, 2012).

The strategic national waste plan for the years 2007-2016 (PERSU II) established that the organic valorisation technologies (anaerobic digestion and/or composting) should be implemented considering the implementation of selectively collected food waste schemes. Due to the financial constraints of these selective schemes, and to ensure the collection of a sufficient quantity of biodegradable waste to fulfil the targets for reducing the landfilling of biodegradable waste, the PERSU II considered that in the first phase of operation these plants will receive organic waste from the mixed MSW collection (through the implementation of Mechanical Biological Treatment – MBT), alongside the progressive increase in the quantity of food waste selectively collected (VALORGAS D2.2, 2012).

As of 2012, selective food waste collection schemes had been implemented in four areas of Portugal: Lisbon, Cascais, Oporto and Funchal (Madeira Island). Most of these focus on collections from large producers, rather than households, with the exception of a pilot door-to-door collection in Funchal, and a collection circuit in Portela, Loures (a suburb of Lisbon) that includes a number of households (VALORGAS D2.2, 2012).

7.2. Portela – Composition of Residual Waste

The neighbourhood of Portela, one of the two areas with separate collection of food waste from households, was chosen as the case study for this report. It consists primarily of high-rise apartment blocks and has had separate collection of food waste since 2005.

It occupies an area of 0.95 km^2 and had a population of 11 809 inhabitants in 2011. This is a 23.5% decrease from its 2001 population of 15,441 inhabitants (Vaz, 2013, pers.comm; Vitor, 2008). There have also been some changes in demographic structure during that time, with an increase in number of inhabitants over 65 years of age, and decrease in other age structures, and a decrease in average family size (Vaz, 2013 pers. comm.). The neighbourhood consists of approximately 238 multi-family buildings, primarily high-density high-rises. Collection bins for source-separated and residual waste streams are located either in a storage area on the bottom floor of the buildings, or outdoors on the building grounds. Residents have been provided with food waste bins for their flats, but need to bring their waste to the communal bins for collection (VALORGAS D2.4, 2011).

Composition studies on residual waste from households in Portela have been carried out in 2001, 2003, 2004, 2012 and 2013. The first three years represent the composition before the introduction of the food waste collection scheme, while the last two represent the composition after the scheme had been running for seven years.

The composition results are shown in Figure 7.1. These figures show that there is very little difference in residual waste composition before and after the food waste collections were introduced. In all years, food waste represents the greatest proportion of the residual waste, from 37-41% in the years before FWC, and has actually increased slightly in 2012 and 2013, at 42% and 46% of the residual stream, respectively.

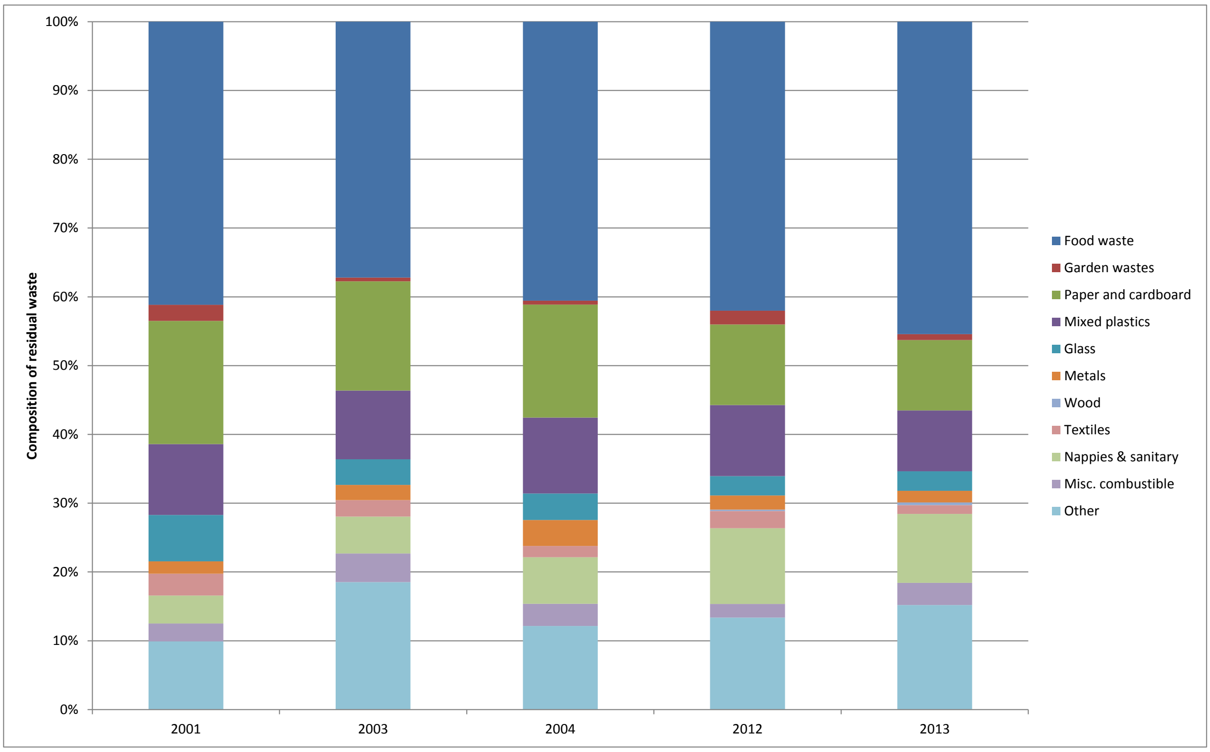


Figure 7.1 Composition of residual waste in Portela area before (2001-2004) and after (2012-2013) separate collection of household food waste.

7.3. Quantity of residual household waste

Data on the quantities of residual waste were collected for the study years and compared to the population of the Portela neighbourhood. Figure 7.2 shows the weekly quantity per person of residual household waste.

It should be noted that the overall waste quantities were obtained from data on quantities collected by the municipality of Loures on a collection route of the parish of Portela. The route was comprised primarily of domestic properties, but also included schools, one seminary and one military headquarters (all covered with separate collection of organic waste), and some on-street collection in public areas of social housing. Therefore the amount of waste exceeds that produced solely by the domestic properties, which would lead to a slight overestimation of waste per person. However the trends between years can be compared.

The overall per-person quantity of residual waste is lower in 2012 and 2013 than in the years preceding the introduction of FWC.

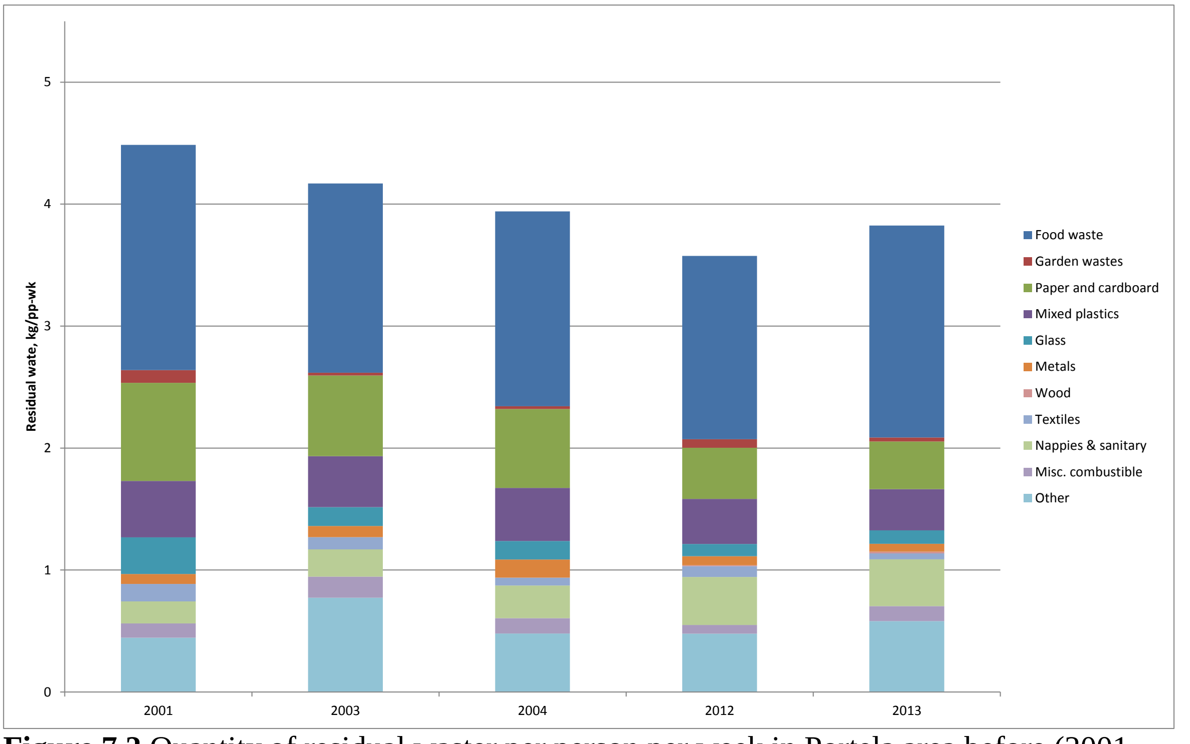


Figure 7.2 Quantity of residual waster per person per week in Portela area before (2001-2004) and after (2012-2013) separate collection of household food waste.

7.4. CV of Residual Waste

Figure 7.3 shows the theoretical net CV of residual waste from the Portela neighbourhood, based on the waste compositions in the years studied. The overall net CV did not show a significant change from 2004 to 2012, and has decreased slightly in 2013.

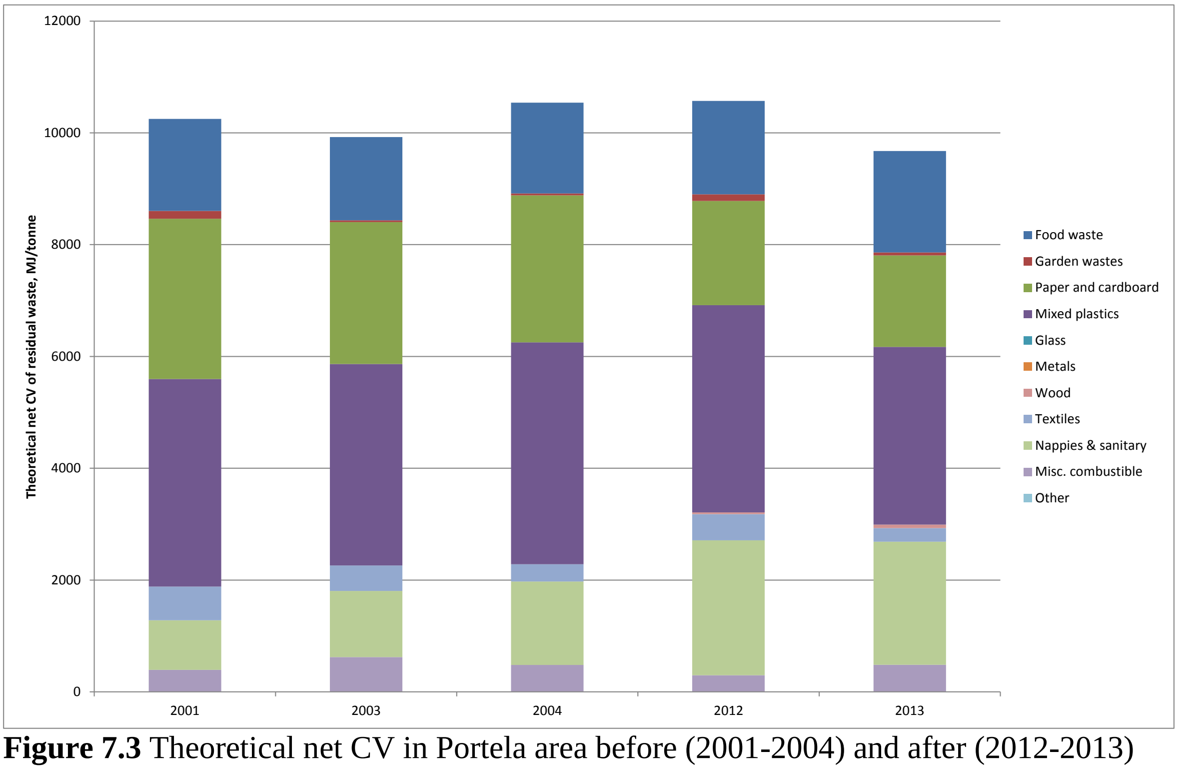


Figure 7.3 Theoretical net CV in Portela area before (2001-2004) and after (2012-2013) separate collection of household food waste.

7.5. Summary and Discussion of Portela Results

The figures in this section show that in terms of composition and net CV, there is little difference in residual waste before and after the introduction of the separate food waste collection program. There is, however, a slight reduction in quantity in 2012, although it appears to have increased in the first quarter of 2013 – however this could be a seasonal effect as waste quantities could be higher in the first few months of the year than in summer months; a full year's data would be required for an accurate comparison.

The results appear to reflect little impact from separate food waste collection on the composition and quantity of residual waste. However, there are a number of contributing factors that should be taken into account.

Firstly, there is significant use of the separate food waste collection service, with 31% of all food waste being diverted via the separate organics collection. 2% is disposed in the recycling bins, and the remaining 67% is disposed in the residual (Vaz, 2013, pers. comm.). This shows that at least some of the residents use the separate food waste system, and quantities of food waste in the residual stream would be significantly higher if the separate FWC were not in place. The organics collection service collects a stream with an average putrescibles content of 90% (contaminants such as plastic bags and packaging comprising the balance) (VALORGAS D2.4, 2011). This shows that the food waste service is being utilised, although a significant amount of food is still being deposited in the residual bins.

Secondly, the high proportion of food waste in the residual reflects a high success rate of dry recycling, rather than just low capture of food waste. The district of Portela has greater capture rates for glass, plastics, metals and paper/card than the Lisbon Metropolitan Area (LMA) (Vaz, 2013, pers.comm.). During the years since 2005 in Portela, quantities of plastics and metals recycled have increased by 42%, while recycled glass has increased by 15%; as a consequence the proportion of those materials in the residual stream have dropped from 13% to 10.7%, and from 4.9% to 3.3%, respectively. The percentage of paper/card in the residual has decreased by an even greater amount, from 17.0% to 10.1%, although the quantities collected via the recycling stream have not shown a corresponding increase, and have also decreased. This, however, is thought to be partly attributable to factors such as theft of these materials from recycling bins before collection, and the current economic recession. The lower quantities and proportions of all of these dry recyclables in the residual stream is therefore reflected in an increased proportion of food waste in the residual stream, even though the actual mass of food waste in the residual has actually decreased.

Also it should be noted that as there is no composition data from the years immediately following the introduction of the food waste collection program, it cannot be determined whether there had been a greater initial impact in the first few years following the introduction of the service. There may have been a greater initial reduction of food waste in the residual waste for the first few years, but as residents moved out of the area and were replaced by new residents unaware of the food waste service, participation may have dropped.

There was an extensive communications program '+ Valor' in 2005 when the program was first introduced; since then, there have been further public education and communication programs in 2006, 2007 and 2008. In the intervening four years, resident turnover could potentially be a factor, as some of the residents who were present for the campaigns may have moved out and been replaced by new residents unfamiliar with the food waste collection. Although building managers provide information on the separate food waste bins, some new residents may still be unaware of or unaccustomed to the system, and continue to dispose of food waste in the residual bins as they did at their previous residences. The 31% food waste capture rate could possibly reflect a split between longer term residents using the program and newer residents not using it.

There may even be an effect of residents choosing the wrong communal bin in which to place their food waste, even if it has been initially separated in their residence. Visual observation during the 2013 waste audit confirmed that there were many bags containing only food waste, but these had been deposited into the residual bin, rather than the organic bin. This may also be a consequence of the presence of refuse chutes in some of the buildings, which allow residents to dispose of all wastes directly from their own corridor into a chute that goes directly to a single refuse bin, rather than carrying it down to the dedicated waste management area and placing the different wastes in separate bins.

8. Summary of Case Studies

Table 8.1 is a summary of the results in the various cases studied. It should be noted that these are snapshots from individual regions or municipalities, and do not represent the whole country. However it does give a good indication of a range of different food waste collection programs implemented, and how their results have varied in the different situations.

The greatest decrease in average household residual waste quantities collected was in Sweden, where there was a decrease of 34% between the average weekly residual waste mass before and after the introduction of FWC. This also showed the greatest decrease in food waste percentage and highest increase in theoretical net CV. This is in contrast to Portela in Portugal, where overall average residual waste mass decreased but the percentage of food waste in the residual actually increased by 4%, with an accompanying decrease in net CV of 6%. It should be noted, however, that the Portela studies were done eight years apart, during which other recycling programs for dry materials were implemented and expanded. The high proportion of food waste in the residual may reflect high diversion of dry recyclables rather than low diversion of food waste. The data in this report does, however, demonstrate the inverse relationship between the proportion of food waste in the residual stream and the stream's net CV, due to the high moisture content of food waste compared to other waste fractions (e.g., paper and plastics).

No data was available for the years preceding the introduction of separate collection of food waste in the Netherlands in 1994, and therefore only its current average residual mass is shown for comparison against the other case studies. Composition and CV were not used, as Dutch composition studies do not distinguish between garden and food waste, but instead group both together under the term 'GFT'. It is not possible, therefore, to directly compare composition data, other than between the two Dutch municipalities.

To compare results for Spain, the figures in Table 8.1 are calculated using 2006 numbers only, comparing municipalities with FORM collection vs. those without. Data sets from the years 2010, 2011 and 2012 reflect a large decrease in residual mass in the years following the introduction of FWC, but during those years other factors could also be having an effect, such as increased dry recycling and the current economic recession. As FORM collection had been rolled out earlier, there were no non-FWC municipal waste streams during those years (for which data was available), and therefore no comparisons on the sole basis of presence or absence of FWC could be made. The overall residual mass showed a decrease of 33% from 2006 (non-FWC) to 2012 (with FWC), while the amount of food waste in the residual decreased by 39% in the same time period.

Table 8.1 Summary of results in case studies surveyed (averages and standard deviations).

Parameter	**England** various authorities	**Netherlands** Gouda & Apeldoorn	**Spain** Catalonian authorities	**Sweden** various authorities	**Portugal** Portela district
Quantity of residual household waste, kg person^{-1} week^{-1} *before FWC*	4.3 ± 1.1		10.2 ± 5.7	3.6 ± 0.8	4.2 ± 0.3
Quantity of residual household waste, kg person^{-1} week^{-1} *after FWC*	3.6 ± 1.4	4.1 ± 0.9	8.0 ± 5.2	2.4 ± 0.5	3.7 ± 0.2
Theoretical net CV of residual, MJ kg^{-1} *before FWC*	11.4 ± 1.4		10.8 ± 1.4	10.5 ± 0.8	10.2 ± 0.3
Theoretical net CV of residual, MJ kg^{-1} *after FWC*	12.9 ± 1.7		11.7 ± 1.2	13.9 ± 1.8	10.1 ± 0.6
Average proportion of FW in residual, *before FWC*	34 ± 4 %		35 ± 9.5 %	44 ± 4 %	40 ± 2 %
Average proportion of FW in residual, *after FWC*	25 ± 5 %		32 ± 8 %	28 ± 9 %	44 ± 3 %
Average mass FW in residual, kg person^{-1} week^{-1} *before FWC*	1.4 ± 0.3		3.4 ± 1.6	1.6 ± 0.5	1.7 ± 0.01
Average mass of FW in residual, kg person^{-1} week^{-1} *after FWC*	1.0 ± 0.4		2.5 ± 1.4	0.7 ± 0.4	1.6 ± 0.01
Decrease in average weekly mass of residual	16%		22%	34%	12%
Increase in average theoretical net CV of residual	13%		9%	33%	- 1%
Decrease in average proportion of FW in residual	9%		3%	16%	- 4%
Percentage decrease of FW mass in residual	26%		26%	55%	3%
Year of FWC introduction	various	1994	2006 +	2005 +	2005

The most pronounced difference occurred in Vaxjo, Sweden, where the percentage of food waste in the residual stream dropped from 43% to 6%, and overall residual waste mass decreased from 10.1 to 4.6 kg household^{-1} week^{-1}, a drop of 54%, after the introduction of food waste collections. The actual mass of food waste in the residual dropped from 4.32 to 0.28 kg household^{-1} week^{-1} between 2010 and 2012, after introduction of the food waste collection program in 2011.

This is contrasted with the Portela neighbourhood in Loures, Portugal, where there was little difference in waste quantity or composition in years before and after food waste collection, despite the fact that the food waste collection system is also being used. It should be again noted, however, that there is a time gap of eight years between the waste analyses, during which other recycling programs were introduced and expanded, and results in the intervening years may have reflected a greater effect of the FWC.

In the case of England, the average differences have been around 20%. This is a significant decrease in quantity, but is not as high as the potential difference if the capture rate for food waste collections were 100%, which would theoretically reduce the residual stream by an average of 33% (the average percentage of food waste in residual) for areas with access to food waste collections. In the full survey there were no areas found where this had occurred; in all cases a significant portion of food waste remained in the residual stream.

Weekly vs. Fortnightly Collection of Residuals
In several of the English case studies examined, fortnightly collection of residuals was found to result in lower average weekly household quantities of residual waste, and higher net CV of the residual, than weekly collection of residuals. This was true in the cases of South Gloucestershire, Somerset, Surrey, and Greater Manchester. As this study was focused primarily on areas with food waste collections, its scope did not include a comprehensive survey of residual waste collection frequency throughout the UK, but it has been noted previously that many of the top performing recycling authorities in England and Wales collect residuals on a fortnightly basis, and that as of 2012 a total of 250 authorities were using this system (Williams and Cole, 2013). The results found in this study do appear to support the assertion that less-frequent collection of residual waste has a positive effect on decreasing residual quantities. Food waste trial collections in areas with and without fortnightly collections of residuals have also shown better food waste separation when residuals are collected fortnightly, consistent with these findings (WRAP, 2009).

Weekly vs. Fortnightly Collection of Food Waste / Organics
The frequency of collection of food waste, either on its own or as part of an organics stream with garden waste, also has an effect. It was found that in areas where food waste was collected on a weekly basis, this had a greater effect on decreased percentage of food waste in the residual, higher net CV of the residual, and lower residual quantities overall, as compared to fortnightly food waste or organics collection, or no separate collection.

While weekly food waste collections in England resulted in an average residual quantity decrease of 26%, net CV increase of 16% and food waste percentage decrease of 9% compared to no food waste collections, the fortnightly collection of food waste resulted in differences in these three parameters of 15%, 1% and 2% respectively relative to no food waste collections (see Tables 3.5 and 3.6).

These results have shown that providing food waste collection as part of a fortnightly service has had a less significant impact on the residual waste than a weekly separate food waste collection. Where organics are collected on an alternating week basis to residual waste, householders may be inclined to dispose more of their food waste in whichever bin is to be picked up that week, to avoid keeping putrescibles for longer than a week (WRAP, 2009).

It should be noted that these findings on frequency of collection of residuals and organics apply to England, in which waste collection is on a door-to-door basis, rather than areas with communal streetside bins (such as Spain), where individual households are less affected by frequency of collection.

In the case of Vaxjo, Sweden, the top performing program, the subject area was comprised of all single-family houses. The separation scheme was one in which food was collected in paper bags on a fortnightly basis, always on the same day as the residual waste, which was also collected fortnightly. In this way, there would be no incentive for householders to put their food waste into the residual bin to dispose of it earlier, as both bins are picked up at the same time. The fortnightly collection of food waste was not a disincentive to use of the food waste collection system, in this case.

9. Energy Benefits and Costs of FWC

These case studies have shown that separate FWC has benefits in terms of reducing residual waste quantities, reducing the proportion of food waste in the residual stream and (thereby) increasing heating value of the residual stream. This is in addition to the energy benefit of collecting a clean separate food waste stream, from which energy and nutrients can be recovered by anaerobic digestion.

The energy benefit of separate FWC can therefore be quantified as the sum of:

i) net energy generated from AD of separately-collected food waste;

ii) displacement of chemical fertiliser by digestate from AD, and thus avoided energy cost for fertiliser production;

minus:

iii) net energy cost of food waste collection.

In addition, the energy benefits relating to the compositional change and decreased volume of residual waste resulting from FWC are:

iv) energy benefit of the increased heating value of the residual stream; and

v) avoided collection energy cost for management of decreased residual stream.

This assumes that collected food waste is treated by AD rather than composting, and that collected residual waste is treated by thermal incineration with energy recovery (Energy-from-Waste).

In addition to significant annual savings in landfill tax or thermal treatment processing costs, there may be energy benefits to the reduction of food waste in the residual stream. The implementation of a separate food waste collection system, however, has substantial transport and logistics costs, and municipalities must weigh that cost against the potential savings when making decisions on the implementation of food waste collections.

The cost aspects are varied and greatly dependent on site-specific factors, and are thus beyond the scope of this report, but an approximate estimation of typical per-tonne energy costs and benefits is given in this section.

9.1. Energy Calculations

A quantification of energy costs and benefits was made based on values from literature and the average percentages compiled from these case studies. The calculation is based on per-tonne energy costs or savings for food waste or residual waste.

i) Energy benefit – AD of food waste

The first energy benefit is the energy gained from anaerobic digestion of the food waste stream resulting from the introduction of FWC. This was estimated by calculating theoretical energy yield from food waste, less plant parasitic energy, using the literature values shown in Table 9.2.

ii) Energy benefit – displacement of chemical fertiliser and avoided energy of fertiliser production

The anaerobic digestion of food waste produces a nutrient-rich digestate which can be applied to land and displace the use of chemical fertiliser, which requires large energy inputs for its production (Jenssen and Kongshaug, 2003). Therefore the use of digestate theoretically allows energy savings equivalent to the production of chemical fertiliser for an equivalent amount of nutrient. This energy saving is not at the level of the local council, but nonetheless shouldn't be neglected as part of the overall system. There is also an energy cost associated with transport and spreading of the digestate, but as chemical fertiliser would also require transport and spreading, these are assumed to net out close to zero and are thus left out of these calculations. Nitrogen is the nutrient upon which these energy balance calculations are based, with an energy input value of 40.3 GJ $tonne^{-1}$ nitrogen, typical of Western Europe; this figure is higher in other areas of the world (Jenssen and Kongshaug, 2003).

iii) Energy cost – collection energy for separate FWC

The largest energy cost associated with implementation of separate food waste collection is the energy required to operate the waste collection and transport vehicles. As collection of waste is by refuse collection vehicles (RCVs) which generally run on diesel fuel, this energy cost can be estimated in terms of diesel fuel consumed in collection and transport of food waste.

There have been a limited number of studies relating waste tonnage to diesel fuel consumption based on empirical data collected from municipal collection systems. The fuel consumption rates determined in these studies are shown in Table 9.1. Fuel consumption rates are dependent on factors including distances between properties, ease of vehicle access and waste quantity per stop.

A range of fuel consumption values are shown in Table 9.1, varying according to the type of collection system. Values at the lower end of the range are for bring and co-collection systems, while those in the higher range are generally for door-to-door single-stream collections.

iv) Energy benefit – increased heating value of residual waste stream

The increase in net CV of the residual stream resulting from lower food waste quantities gives an increased energy yield per tonne of residual waste combusted.

A different but important benefit, which is not accounted for in these energy calculations, is the freeing-up of extra capacity at the EFW plant, resulting from less waste in the residual waste stream. At a local level, less residual waste being delivered to an EFW plant by one council would mean that there was capacity at the plant to accept waste from other areas, so that greater geographical areas can be covered by fewer plants, with a potential result of fewer EFW plants needing to be built, as less capacity is needed. This might be counteracted by greater transport distances for waste as catchment areas are increased, but an overall decrease in necessary EFW capacity would be a benefit.

v) Avoided energy cost – collection of reduced residual waste stream

There is also a potential energy benefit of the decrease in residual waste quantities following the introduction of FWC. Lower quantities of residual waste means less energy consumed in collection. Similarly to the estimation of collection energy cost for food waste, this can be estimated in terms of diesel fuel consumed per tonne residual waste, however in this case this would be avoided energy input for each tonne that no longer needs to be collected. Table 9.1 shows the range of values found for per-tonne diesel consumption in the collection of residual waste.

A reduction in per-household residual quantity as a result of FWC is not likely to give a linear reduction in residual collection energy, as the same number of properties would still need to be visited, which could increase the per-tonne fuel consumption rate. However, the lower quantities could have step-wise benefits - such as fewer trips between the collection area and the waste unloading point (transfer station or EfW facility), if the RCV fills up fewer times on the route. This type of step-wise benefit is difficult to quantify theoretically, and would require data from actual collection routes to be estimated with accuracy. Thus, the per-tonne fuel consumption is instead used as an approximation.

Table 9.1 Fuel consumption values (averages and standard deviations, where available) from various studies

Waste type & Collection situation	Diesel consumption (L tonne^{-1})	Location and Year	Source
Food Waste, Single Compartment			
Municipal organic waste, urban areas	3.4	Swedish municipalities, 2006	(Borjesson & Berglund, 2006)
Food Waste, urban bring system	4.1	Kaufbeuren, Germany 2010-2011	(Gredmaier et al., 2013)
Food Waste, urban bring system	4.4	Landshut, Germany 2010-2011	(Gredmaier et al., 2013)
Food Waste for composting, urban areas	6.0	Taipei City, Taiwan, 2005	(Chen & Lin, 2008)
Municipal organic waste, assumed average	7.0	Sweden, 2006	(Borjesson & Berglund, 2006)
Municipal organic waste, suburbs and rural areas	9.2	Swedish municipalities, 2006	(Borjesson & Berglund, 2006)
Food Waste, suburban door-to-door	10.9	Flintshire County, UK 2010-2011	(Gredmaier et al., 2013)
Food Waste, suburban door-to-door	12.9	Broadland District, UK 2010-2011	(Gredmaier et al., 2013)
Co-Collected Food Waste			
Food waste and recyclables, urban door-to-door	3.06	Undisclosed municipality, UK 2013	(VALORGAS unpublished data)
Food waste and paper, urban door-to-door	6.21	Undisclosed municipality, UK 2013	(VALORGAS unpublished data)
Residual Waste			
Residual, single-family & apartments in urban areas	1.4 ± 0.4	Herning, Denmark 2006	(Larsen et al., 2009)
Residual, apartments outside city centre	1.6 ± 0.5	Aarhus, Denmark 2006-2007	(Larsen et al., 2009)
Residual, apartments outside city centre	1.7 ± 0.5	Aarhus, Denmark 2002-2003	(Larsen et al., 2009)
Residual, small towns	2.4 ± 0.3	Herning, Denmark 2006	(Larsen et al., 2009)
Residual, city centre	3.0 ± 1.6	Aarhus, Denmark 2002-2003	(Larsen et al., 2009)
Residual, city centre	3.1 ± 1.1	Aarhus, Denmark 2006-2007	(Larsen et al., 2009)
Residual, single family urban areas	3.3 ± 1.5	Aarhus, Denmark 2006-2007	(Larsen et al., 2009)
Residual, single family & apartments in urban areas	3.6 ± 1.3	Aarhus, Denmark 2003-2003	(Larsen et al., 2009)
Residual, small towns	5.7 ± 0.8	Aarhus, Denmark 2002-2003	(Larsen et al., 2009)
Refuse, urban areas	5.9	Taipei City, Taiwan, 2005	(Chen & Lin, 2008)
Residual, rural areas	6.3 ± 1.3	Aarhus, Denmark 2006-2007	(Larsen et al., 2009)
Residual, rural areas	6.3 ± 1.2	Aarhus, Denmark 2002-2003	(Larsen et al., 2009)
Residual, rural areas	10.1 ± 2.6	Herning, Denmark 2006	(Larsen et al., 2009)

Table 9.2 shows the values chosen for each of the parameters used to quantify the energy costs and benefits explained above. It should be noted that the diesel consumption in residual collection was chosen from the low end of the range, while diesel consumption for food waste collection was picked from an upper end of the range. This was to be conservative in estimating the energy benefit for the former, and to avoid underestimation of the energy cost for the latter.

Table 9.2 Values used in energy balance calculations

Parameter	Value	Source
Total Solids (TS) content of FW	28%	(Banks et al., 2011)
Volatile Solids (VS) content of FW	24%	(Banks et al., 2011)
Methane yield	402 m^3 CH_4 $tonne^{-1}$ VS	(Banks et al., 2011)
Energy value of methane	35.85 MJ m^{-3}	(Engineering Toolbox.com, 2012)
AD plant electrical conversion efficiency	32%	(Banks et al., 2011)
AD plant parasitic energy requirement	144 MJ $tonne^{-1}$ food waste	(Borjesson and Berglund, 2006 – average of OFMSW and food industry waste)
Nitrogen content of FW	28 kg N $tonne^{-1}$ TS	(VALORGAS Deliverable D2.1)
Energy input required for fertiliser production, per kg nitrogen	40.3 MJ kg^{-1} N	(Jenssen and Kongshaug, 2003)
EFW plant electrical conversion efficiency	28.4%	(Yassin et al., 2009)
EFW plant parasitic energy requirement	12.5%	(Yassin et al., 2009)
Diesel fuel consumption – residual collection	3.1 L $tonne^{-1}$	(Larsen et al., 2009)
Diesel fuel consumption – food waste collection	10.9 L $tonne^{-1}$	(Gredmaier et al., 2011)
Energy value of diesel fuel	35.33 MJ m^{-3}	(Altin et al., 2001)

Quantification of Energy Costs and Benefits

The calculations of energy costs and benefits per tonne of waste collected or avoided are shown below.

i) Energy benefit – AD of food waste:

VS content of FW	CH_4 per tonne VS	CH_4 per tonne FW	Energy value of CH_4	Electrical conversion efficiency	Energy generated from FW	Parasitic Requiremen t	Net Energy from AD Plant	**Net Energy Benefit from AD of FW**
VS%	m^3 $tonne^{-1}$ VS	m^3 $tonne^{-1}$	MJ m^{-3}	%	MJ $tonne^{-1}$	MJ $tonne^{-1}$	MJ $tonne^{-1}$	**GJ $tonne^{-1}$ FW**
24%	402	98	35.85	32%	1,125	144	981	**0.98**

ii) Energy benefit – displacement of chemical fertiliser:

Nitrogen Content of FW	TS Content of FW	Nitrogen available for land application	Nitrogen Fertiliser Energy Consumption	**Net Energy Benefit of Digestate Application**
kg $tonne^{-1}$ TS	TS%	kg $tonne^{-1}$	MJ kg^{-1} N	**GJ $tonne^{-1}$ FW**
28	28%	7.7	40.3	**0.31**

iii) Energy cost – collection energy for separate FWC:

FW Collection Diesel Consumption	Energy Value of Diesel	**Net Energy Consumed in FW Collection**
L $tonne^{-1}$ FW	MJ L^{-1}	**GJ $tonne^{-1}$ FW**
10.9	35.33	**0.39**

Thus, the energy balance per tonne of food waste collected and processed by AD equates to: 0.98 GJ $tonne^{-1}$ + 0.31 GJ $tonne^{-1}$ – 0.39 GJ $tonne^{-1}$ = 0.91 GJ $tonne^{-1}$ food waste. Therefore, although separate collection of food waste requires an input of energy, this would be compensated by the energy yield from AD and displaced fertiliser use, with an overall energy benefit.

iv) Energy benefit – increased heating value of residual waste stream

	LHV before FWC	LHV increase after FWC	LHV after FWC	electrical generation efficiency	Parasitic power req't	Net post-FWC power available	Pre-FWC power available	**Net Energy Benefit of Increased CV**
	MJ $tonne^{-1}$	%	MJ $tonne^{-1}$	%	%	GJ $tonne^{-1}$	GJ $tonne^{-1}$	**GJ $tonne^{-1}$ RW**
England	11400	13%	12882	28.4%	12.6%	3.2	2.8	**0.37**
Spain	10800	9%	11772	28.4%	12.6%	2.9	2.7	**0.24**
Sweden	10500	33%	13965	28.4%	12.6%	3.5	2.6	**0.86**
Portugal	10200	-1%	10098	28.4%	12.6%	2.5	2.5	**-0.03**

The energy benefit per tonne of residual waste collected and processed by EFW varies from a high of 0.86 GJ $tonne^{-1}$ residual waste in Sweden, where FWC gave the highest diversion of food waste and resulted in the greatest increase in LHV of the residual stream, to a low of -0.03 GJ $tonne^{-1}$ residual waste (representing an energy cost) in Portugal, where the proportion of food waste in the residual after FWC was slightly higher than the pre-FWC values.

v) Avoided energy cost – collection of reduced residual waste stream

Residual Collection Diesel Consumption	Energy Value of Diesel	**Net Energy Savings of Avoided Residual Waste Collection**
L $tonne^{-1}$ FW	MJ L^{-1}	**GJ $tonne^{-1}$ RW**
3.1	35.33	**0.11**

The energy savings from the reduced residual quantities can be estimated as 0.11 GJ $tonne^{-1}$ residual waste *avoided*; this therefore differs from the previous energy benefit which is based on GJ $tonne^{-1}$ of residual waste *processed*. It should be noted again that there is not necessarily a linear relationship between the residual waste amount collected and the energy consumption, but if a net overall decrease in residual quantities allows for fewer round trips between the collection area and transfer stations/disposal facilities, or allows smaller RCVs to be used, this could have an energy benefit.

It should be noted that these energy calculations were done on a per-tonne basis, rather than using theoretical overall quantities of waste, to avoid a misleading result. Comparing the overall energy from combustion of the pre-FWC amount of residual vs. the post-FWC amount of residual would appear to give an overall energy *cost*, because despite the higher

LHV of the post-FWC stream, the overall amount of waste combusted is lower, giving less fuel to the EFW plant, and therefore the energy produced by EFW would decrease. This would be a misleading result, however, as it would imply that we can produce more energy by producing and combusting more waste. However the amount of energy recovered by combustion of waste is always less than the initial amount of energy that was required to produce the original goods from virgin materials. Therefore, although an energy balance solely around an EFW plant implies a greater energy benefit of more waste, an energy balance of the whole system, including initial production of goods would show an energy benefit of less waste. Therefore, calculations that show the energy benefits or costs on a per-tonne basis are more representative of the true situation.

10. Conclusions

The survey of residual waste quantities and composition has shown that in most cases where food waste collection has been introduced, the proportion of food waste in the residual stream has decreased, in comparison with earlier studies before the introduction of food waste in the same area, or simultaneous studies in neighbouring areas with and without food waste collection. This is also generally accompanied by a decrease in overall quantity and increase in net CV. Food waste quantities decreased by 3%-55%, residual net CV changed by -1%-33%, and overall residual mass decreased by 12%-34%, in the different areas examined.

The introduction of a separate food waste collection system requires significant inputs of energy for collection and transport of the food waste. Based on the case study averages examined here, however, if energy is then recovered from the collected food waste by anaerobic digestion, the energy cost of food waste collection is outweighed by the energy benefits of energy from anaerobic digestion of the food waste, giving a net energy benefit of 0.91 GJ $tonne^{-1}$ food waste collected. Energy generation from EfW treatment of the remaining residual waste would have an energy cost or benefit ranging from -0.03 to 0.86 GJ $tonne^{-1}$ residual waste collected, based on the average results from the four countries. The reduced quantities of residual waste requiring collection and treatment could have an avoided collection energy benefit of 0.11 GJ $tonne^{-1}$ residual waste avoided.

There is also a benefit in terms of less residual waste treatment capacity required, which could result in fewer EFW plants needing to be built over the long term. This might be offset by an increase in AD plants built.

It should be noted that if the collected organics are composted rather than digested, the energy balance becomes negative. This is because composting requires energy inputs and has no energy outputs, in contrast to anaerobic digestion. Composting, however, is still common among many municipalities for other reasons including cost, infrastructure inertia, and the ease of adapting an already-existing green waste collection system by simply instructing householders to deposit their food waste into the same bin. Although this report has shown that fortnightly organics collections divert less food waste than separate weekly food waste collections, councils may still choose this option.

Overall, the results compiled in this report show that the introduction of FWC decreases the amount of food waste in the residual stream, with an associated increase in theoretical net CV of the residual stream and decreased residual waste quantities overall. Although the reductions in food waste and residual are less than could theoretically be possible, the introduction of FWC has had an effect in the case studies examined.

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