Material change for a better environment

Final report

Home Composting Diversion: District Level Analysis

Up-dating WRAP district level home composting diversion models

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WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

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resourcefutures

Front cover photography: Digging compost once made

Executive summary

Home composting makes a significant and environmentally sustainable contribution to the management of garden waste and other home compostable household wastes in the UK. The expansion of kerbside collections of garden waste has put extra emphasis on the need for the 'able and willing' to be encouraged to compost at home, so as to avoid garden waste being mobilised that would previously have been dealt with *in situ*.

The original home composting diversion models were constructed by WRAP (Waste & Resources Action Programme) in 2004/05 with the main objective of providing simple estimates of the quantities of biodegradable waste diverted from landfill by 'new' and 'enhanced' home composting participation. Diversion factors were intended for inclusion in LATS/LAS calculations, so as to put home composting on an equal footing with other diversion options for biodegradable municipal wastes. To this end, models were developed from household based research (termed 'household level diversion models') and from the analysis of district level municipal waste statistics (termed 'district level diversion models'). An overall diversion factor of 218 kg/household/year was suggested.

Since that time the total quantity of material collected from municipal sources for centralised composting has more than doubled and significantly less garden waste appears within the residual waste streams (at either kerbside or at household waste recycling centres). It is therefore necessary to revisit and up-date the original district level home composting diversion models, taking into account the additional work undertaken by WRc to up-date and extend the 2004/05 household level models (WRAP 2009).

The research reported on here first revisits the original residual waste diversion models and up-dates them using 2006/07 district waste arisings data. New versions of these models are then constructed to reflect the infrastructure changes that have taken place, specifically in relation to alternate week collections for refuse and garden waste policies. The up-dated kerbside residual waste model estimated that 47 kg/household/year were diverted away from residual waste collections by home composting households. This was less than was estimated in 2005, reflecting the fact that less garden waste is now found within the kerbside residual waste stream.

In order to reflect the growth in kerbside collections for garden waste since 2004/05, a new set of district level models were constructed to estimate diversion of garden waste away from garden waste collections and into home composting. The estimate obtained was 114 kg/household/year, (with a 95% confidence interval that the value was between 10 and 218 kg/household/year).

Models to estimate diversion from HWRC residual and HWRC segregated garden waste were less satisfactory than the kerbside models, reflecting weaknesses in the data and in the less direct link between sites and the characteristics of the districts in which they are located.

Taking the four main models together, the following diversion factors were obtained:

- 114 kg diverted from kerbside garden waste schemes
- 47 kg diverted from kerbside residual waste
- 31 kg diverted from HWRC residual waste
- 36 kg *extra* garden waste taken to HWRC garden waste skips.

Finally, these estimates were 'sense checked' against other datasets: the results of up-dated household level models (WRAP 2009), compositional data on residual waste streams, average scheme yields from garden waste collections and research based on refuse vehicle on-board weighing. The overall estimate obtained was 160 kg/household/year diversion from the municipal waste stream through home composting participation but it is recommended that a more conservative estimate of 150 kg/household/year should be used given the level of uncertainty involved with the figures.

The estimates of diversion from residual kerbside collection tally reasonably well. The household-level model (WRAP 2009) estimated 30 kg of non-garden waste (Model G) and 30 kg of garden waste diverted from the residual bin (Model H), giving a total of 60 kg. By comparison, the district-level model in this report puts the diversion from the residual bin at 47 kg (Model 5), which seems more realistic given the expansion of separate garden waste and food waste collections since the household-level data was collected in 2004/05. Estimating diversion from kerbside collections of garden waste appears to be more difficult but the district-level estimate of 114 kg (Model 7) in this report seems more realistic in the view of the authors of both this and WRAP (2009).

The estimate of 150 kg/household/year given here has been selected as it is based on a more comprehensive dataset and is more up to date but with these considerations in mind, it is broadly in line with the work by WRAP (2009).

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1.0 Background

The original home composting diversion models (WRAP 2005) were constructed by WRAP in 2004/05 with the main objective of providing simple estimates of diversion of residual waste from landfill brought about by new and enhanced home composting participation (see Table 1). The methodology used a dual approach based on a series of cross-referenced district and household level models to estimate factors that explained variation in total residual waste (kg per household). The district level models included both kerbside and household waste recycling centres (HWRCs) residual waste diversion estimates whereas the HWRC element could not be modelled at household level. Diversion factors were intended for inclusion in LATS/LAS calculations, so as to put home composting an equal footing with other diversion options for biodegradable municipal wastes.

Since that time the total quantity of material collected from municipal sources for centralised composting has more than doubled and significantly less garden waste now appears in the residual waste streams (at either kerbside or at household waste recycling centres). It is therefore necessary to revisit and up-date the original district level home composting diversion models, taking into account the additional work undertaken by WRc to up-date and extend the 2004/05 household level models.

WRAP commissioned WRc to revisit the 2004/05 household level data and to extend the diversion models to provide additional insight into the performance of different home composting groups. These new household level models were based on data from nine local authorities and produced material-specific estimates for diversion from both kerbside residual and kerbside garden waste collections, but not from HWRCs (WRAP 2009).

Table 1 Summary of home composting diversion reports

	2005 WRAP study	2009 WRc study	2009 Resource Futures study (this study)
Primary objectives	▪ Estimation of quantities of residual household waste diverted by 'new' and 'enhanced' home composting households ▪ Dual approach: household and district level models	▪ Re-analysis of 2005 household level models creation of new models to estimate diversion from garden waste collections; exploration of seasonality	▪ Up-date of original district level models for residual waste diversion ▪ Creation of new models to estimate diversion from kerbside and HWRC garden waste collections
Elements of waste stream included in models	▪ Kerbside residual (household model), kerbside residual (district model) kerbside residual + HWRC residual (district)	▪ Kerbside residual (household model), kerbside garden waste collections	▪ Kerbside residual (district model) ▪ HWRC residual (district) ▪ Kerbside garden waste (district model) ▪ HWRC garden waste (district)
Research elements	▪ 2004/05 Household level data from 9 collection rounds and district level data from English district authorities 2003/04, behavioural data from 2004 national survey	▪ 2004/05 Household level data from 9 collection rounds	▪ Data from English district authorities 2006/07, behavioural data from 2005 national survey

This report describes two types of district level diversion models: residual waste diversion and a new set of models to estimate diversion from centralised composting. These as based on more recent municipal waste datasets that take into account the changes that have occurred since the 2004/05 models were created. Clearly, much has happened in terms of local policies towards food and garden waste since 2005 and it is important that diversion factors for home composting diversion should reflect these changes: namely the expansion of garden waste collections, better segregation practices at HWRC sites and the linked reduction in quantities of garden waste discarded into residual waste streams.

The report provides a summary of the 2004/05 district level models, then reviews changes to local authority kerbside and HWRCs' practices since 2004/05. Finally, a new set of models are described and the resulting

diversion estimates are compared and assessed in order to reach an up-dated 'best-estimate' of current home composting diversion.

2.0 Objectives

In January 2009 WRAP commissioned Resource Futures to undertake a repeat analysis of the district level home composting diversion models and to update and improve the approach in light of changes to waste policy and the introduction of more widespread infrastructure for collecting green waste. More up-to-date data was to be used and the new estimates to include diversion from centralised composting as well as landfill. The main objectives were to:

- up-date the original residual waste home composting diversion estimates using more recent district level data sources
- provide more material-specific estimates for diversion by use of compositional datasets collected from districts in England between 2005 and 2007
- build up-dated models to take account of both kerbside diversion and HWRC diversion and, if possible, further sub-divide estimates into material diverted from landfill (i.e. residual waste: kerbside and HWRC) and material diverted from source-separated organic waste collections (i.e. garden/food waste at kerbside, garden waste at HWRCs).

The expectation was that the up-dated district level models would estimate significantly lower diversion from the residual waste stream compared with the comparable models from 2005. Diversion of material from kerbside garden waste collection schemes was now likely to be the main home composting diversion effect.

3.0 Chronology of data sources used in modelling

In up-dating the district level home composting models it is important to establish the chronology of the different data sources that were available to the original district level modelling study and all relevant data that have been collected since.

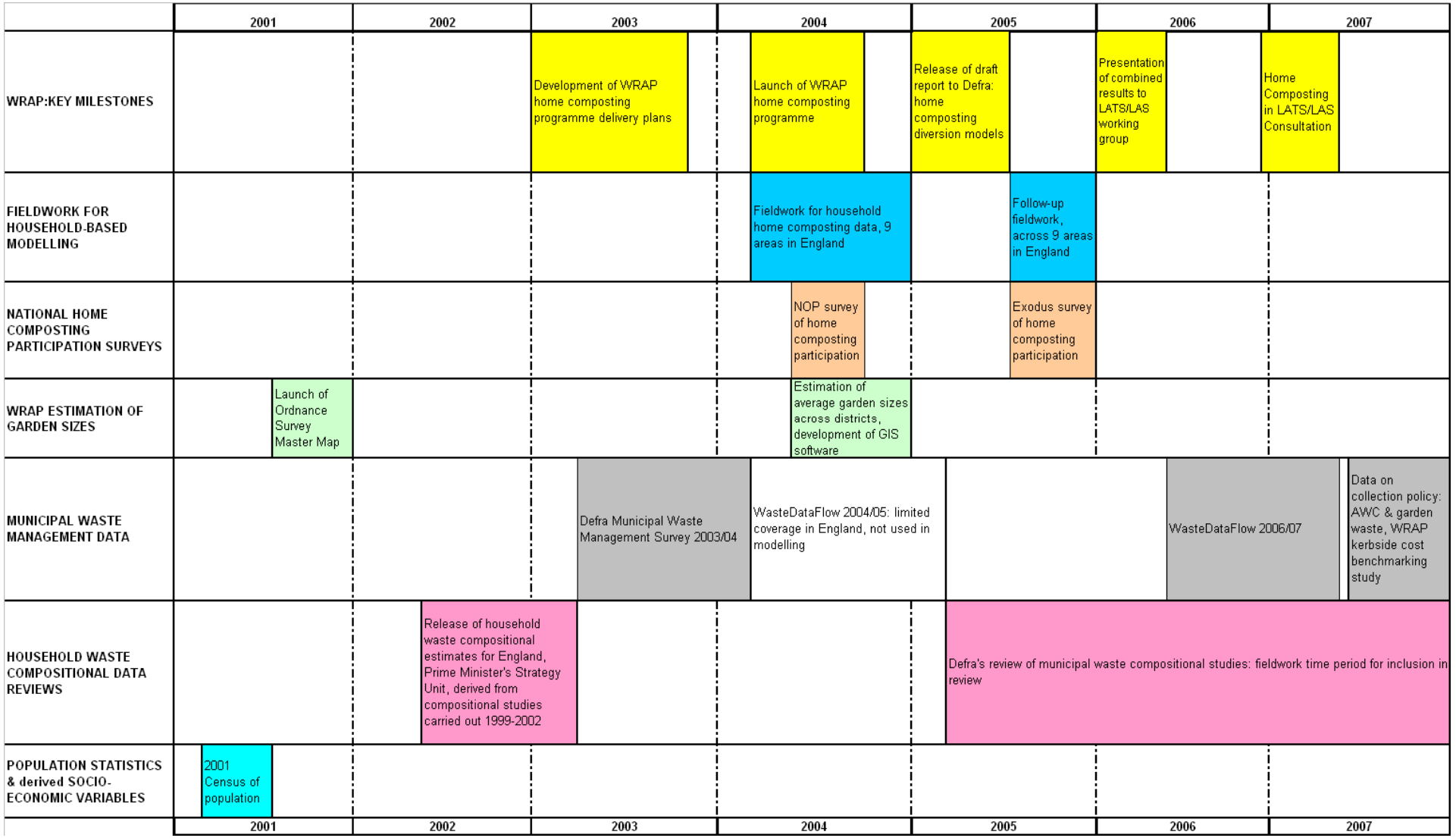
In an ideal world, all datasets used in building a home composting diversion model should be contemporary and therefore provide a sharp picture of the possible links and associations between household behaviour (home composting participation) and waste diversion (as implied by reductions in district level tonnages). However, the best available data in 2004/05 involved four different data sources relating to different points in time:

- district level tonnage data and waste service provision data from municipal waste survey returns (2003/04)
- data on home composting participation derived from a national survey (2004)
- GIS data used in the estimation of average garden sizes within district authorities based on Ordnance Survey Master Map data (2004/05)
- 2001 Census derived variables.

Figure 1 provides a chronology for the data sources used in the original modelling and in the up-dated work reported on here. One of the main design constraints over choice of data for district level modelling has been the extent to which participation data from national surveys coincided with annual waste arisings statistics.

The original district level models were derived from 2003/04 local authority returns in the last year of the paper-based Defra municipal waste management survey. Although 2004/05 was the first year of the web-based tool (WasteDataFlow) designed to replace the paper-based survey, it was a piloting exercise and responses were available from only 45% of English districts. WasteDataFlow became fully-functional in 2005/06, the first reporting year of LATS in England. The reference year for municipal waste tonnages used in the original district level home composting models was therefore 2003/04, not 2004/05.

Figure 1 Chronology of data sources used for home composting diversion models



In the present study 2006/07 WasteDataFlow returns have been used, rather than 2007/08, for two main reasons:

- the choice represents a good compromise between the needs of reflecting changes to the collection of garden waste made since 2003/04 and the requirement to be reasonably contemporary with the most recently available data on national home composting participation (WRAP commissioned Exodus survey, November 2005);
- this was also the reference year for compiling new municipal waste compositional estimates as part of Defra's review of municipal waste compositional datasets (Defra 2009, forthcoming).

Geographical coverage of the modelling has been restricted to datasets relating to England, although the WRAP home composting programme includes Scotland. This coverage relates to the historical fact that at the time of the original modelling the WRAP scheme only included English partner authorities and the household-level modelling sampled areas within 9 English districts. No similar work has been conducted in Scotland, although there are no reasons for supposing that the results are not directly transferable.

Since 2007, WRAP has decided that a review of the previous modelling work is needed to account for changes to infrastructure. The home composting campaign, meanwhile, is being shifted towards promoting waste reduction and prevention generally so that the sale of bins and take-up of home composting will continue to be promoted and remain as priorities for support and advice, but increasingly other opportunities to engage households in waste prevention measures such as junk mail prevention are being pursued. The new focus on prevention including home composting has meant adjustments for the home composting team which began to take effect in April 2009.

4.0 Changes to garden waste and kitchen waste collections since 2004/05

There have been significant changes in the collection of organic wastes from households (garden waste, food waste and other materials, such as cardboard) since 2003/04. There are three aspects that need to be considered here in relation to home composting diversion:

- materials diverted into centralised composting schemes;
- the total amount arising in the mixed residual waste stream; and
- the potential impact of collections on garden waste that was not previously collected by municipal schemes: either because it was home composted, or dealt with by householders through other *in situ* methods.

4.1 Garden waste policies

Since 2003/04 there have been a number of infrastructure developments in relation to garden waste collection and municipal household wastes in general:

1. The expansion of kerbside collections of garden waste from 0.195 m tonnes in 2002/03 to 1.75 m tonnes in 2006/07 (compare fourth pair of columns in Figure 2), with many authorities collecting garden waste free of charge (currently two-thirds of districts in England), whilst others have introduced a variety of different charging policies (fixed annual fees for wheeled bins, charged sack schemes, fees set beyond a certain allocation of collections and so on). Many of the 'free garden waste' authorities have also introduced alternate week collections for refuse, in most (but not all) cases alternating refuse with garden waste collections. Some garden waste collections are seasonal, others collect throughout the year. In recent years a significant growth in material sent for composting from all household sources has been recorded in England (Figure 3). Quantities have roughly doubled between 2003/04 and 2006/07.

2. There has been a marked improvement in the capture of garden waste at Household Waste Recycling Centres (HWRCs). According to the results of compositional analysis carried out at HWRCs, garden waste capture has increased from 40% to 90%, thus the quantities of garden waste found in residual HWRC have declined accordingly (Figure 4). Furthermore, significantly less garden waste is now taken to HWRCs as a consequence of the expansion of kerbside collections. The latter is now the main municipal route for garden waste from household sources.

3. Many Waste Disposal Authorities have implemented policies to exclude or control non-household wastes from HWRCs (for example, trade waste permitting schemes, van bans, and height restrictions). These policies have had an impact on arisings of residual and segregated waste streams at HWRCs, including the amount of garden waste derived from non-household sources, such as from commercial grounds maintenance or gardening contractors. A few authorities have introduced policies that restrict HWRC use to residents within their local authority area, or that limit the number of loads that a resident is permitted to take to a local site within a stated period of time.

4. There has been continued growth in home composting participation, mainly through the WRAP home composting programme. This programme has distributed 1.75 million subsidized bins through a supported joint-working with local authority partners and advice to the public.

4.2 Food waste policies

A further change in collection systems relates to food waste, with the introduction of district-wide separate food waste collections in a limited number of authorities and the trialing of collections across a dozen or so authorities that participated in the WRAP food waste collection trials (Evaluation of the WRAP Separate Food Waste Collection Trials, WRAP 2008). A larger number of schemes collect food waste (either all types or restricted) mixed with garden waste. It has been established that the food waste yields from mixed collections are significantly below those of separate food waste collections. The WRAP 'Love Food Hate Waste' campaign has also directed efforts to persuade householders to reduce food wastage in the home. There is also some evidence that householders on separate food waste collections set out less food waste overall, but the relationship between food waste collections and home composting has not been fully investigated.

4.3 Implications of changes in policies for home composting diversion models

Data from Defra's review of compositional analysis studies in the UK (a substantial number of compositional studies collected between 2005 and 2007) suggest that the overall garden waste capture rate by 2006/07 had reached about 75%, compared with a capture rate below 25% in 2002/03 (using compositional data derived from 'Waste Not Want Not', Prime Minister's Strategy Unit, 2002). These capture rates are compared in Figure 4.

The high capture rate that has now been achieved for garden waste, probably now in excess of 80% given the further expansion of centralised composting, has significant implications for home composting diversion modelling. The main interaction to model is now that between home composting and material collected for centralised composting. The residual waste stream (kerbside, HWRC) has become a less significant route for the garden waste fraction (Figure 2: compare first pair of columns), but will still be the main alternative route for home compostable food waste and other materials, such as paper tissues.

This is a major change from the situation reflected in the 2002/03 compositional data and the 2004/05 models, where the main objective had been to account for 'new diversion' of biodegradable waste away from landfill and into home composting.

Figure 2 Total quantities of household garden waste collected in 2002/03 compared with 2006/07, by waste stream (England, 1000s tonnes per annum)

Sources: Defra municipal waste management surveys 2000/01-2003/04, WasteDataFlow 2004/05-2006/07; Defra 2009 review of municipal waste component analyses

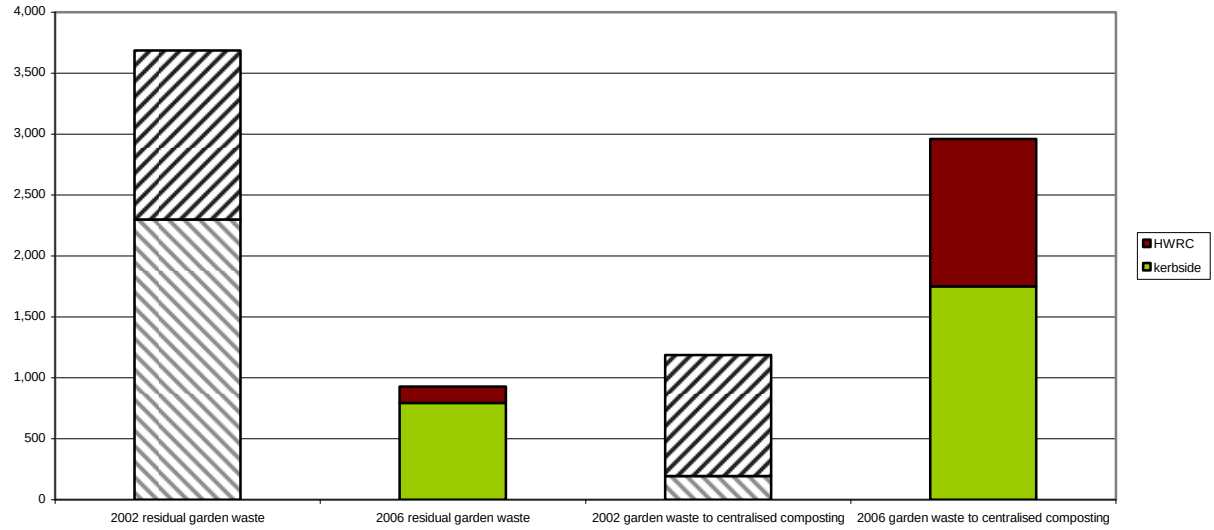


Figure 3 Expansion of total quantity of material collected for composting in England, 2000-2006 (1000s tonnes per annum)

Sources: Defra municipal waste management surveys 2000/01-2003/04, WasteDataFlow 2004/05-2006/07

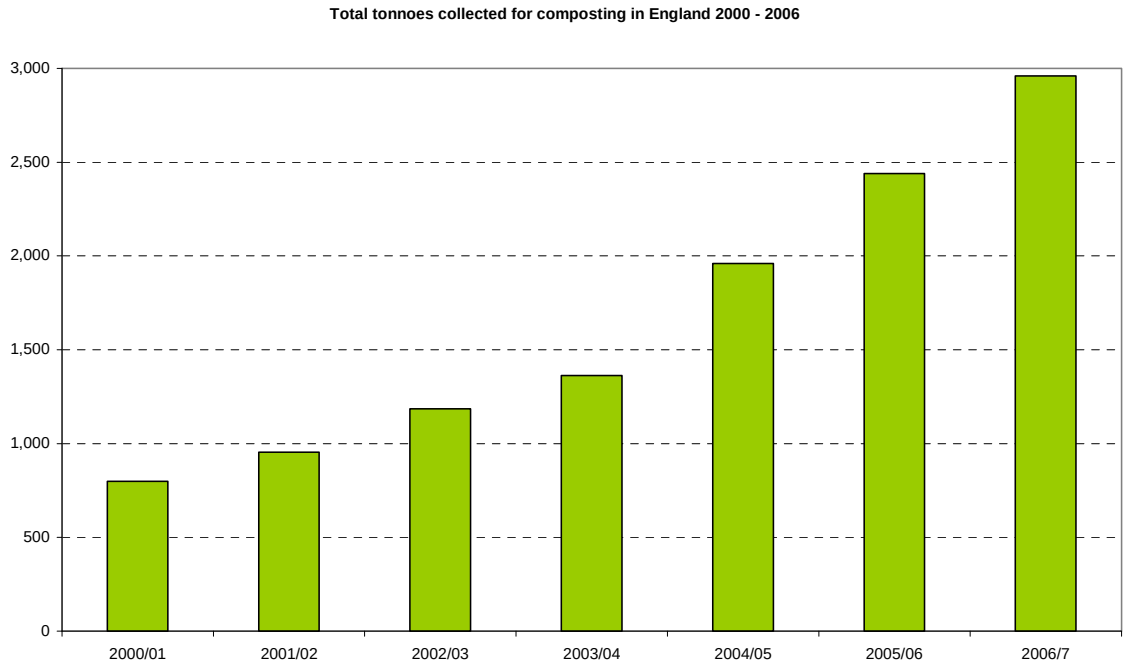
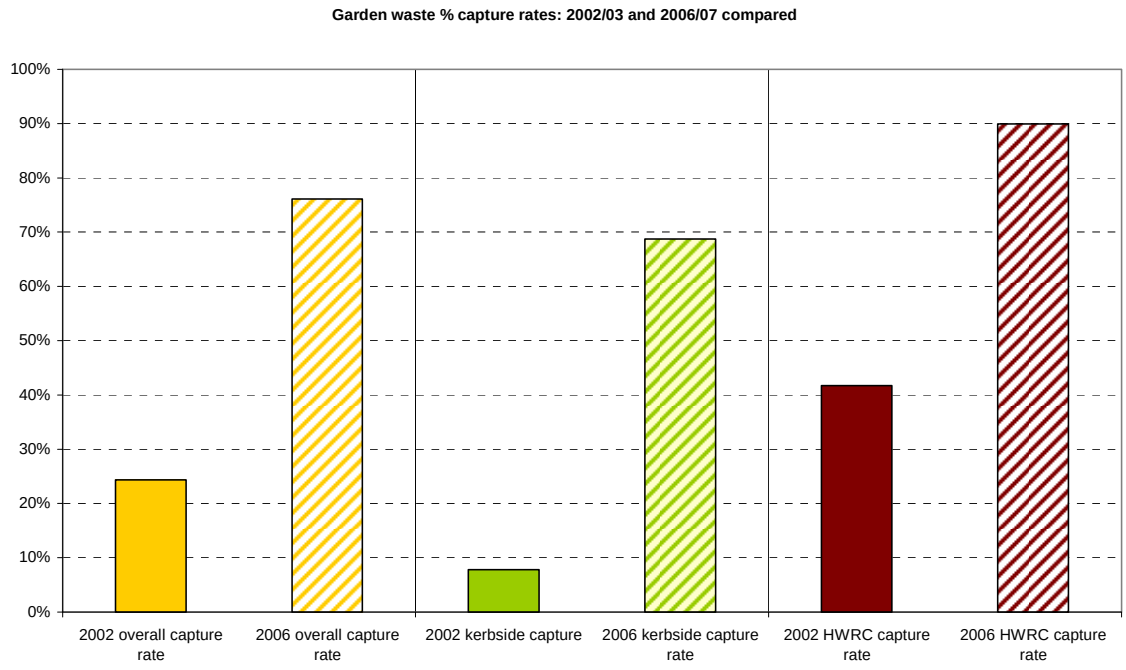


Figure 4 Capture rates for garden waste, 2002 and 2006 compared in total, for kerbside arisings and for materials taken to HWRCs

Sources: Defra municipal waste management surveys 2000/01-2003/04, WasteDataFlow 2004/05-2006/07; Defra 2009 review of municipal waste component analyses



4.4 Classification of kerbside garden waste collection policies 2006/07

Against this back-drop of the expansion in garden waste collections, information on local garden waste policies was compiled from visiting local authority websites and recording details of garden waste collections, as well as from variables obtained from WRAP's ORIS database (2007/08).

A variety of different collection policies are evident (Table 2), ranging from not collecting garden waste at all (7% of districts in England in 2007/08), through to collections of different combinations of garden waste mixed with other compostable materials (such as card or food waste). Two out of three schemes collected garden waste free of change and those that charged were equally split between wheeled bin and sack-based containment systems. Three quarters of the free collection systems were based on wheeled bin systems and the majority of these were a component of alternate week collections for refuse. Those schemes that collected more than just garden waste were mainly free collections; 92% of the charged schemes only collected garden waste.

Frequency of garden waste collection varies, with the majority (85%) being fortnightly collections. A far higher proportion of collections that included food waste were collected weekly (30%) compared with collections that just accepted garden waste (12% weekly).

Table 2 Summary of kerbside garden waste collection systems: England 2007/08

		Frequency	Percent
Valid	no garden waste collected	21	6.9
	garden waste not mixed with food waste	242	79.1
	garden and food waste mixed	43	14.1
	Total	306	100.0
	Policy not known in detail	88	
Total		394	

The geographical and area type coverage of garden waste collection policy was found to be markedly regional, with the South East and South West regions contrasting with the rest of the country (Figure 5). These two regions had a far higher proportion of charged garden waste collections, mainly associated with sack-based collections (Figure 6). By contrast, the North East, North West and East Midlands regions predominantly operated wheeled-bin-based systems that collect garden waste free of charge. Overall, the pattern of garden waste policy and home composting participation (based on 2005 Exodus survey for WRAP) follows a socio-economic and urban-rural gradient, with more affluent and more rural districts with higher levels of home composting participation and more likely to charge for garden waste collections (Figure 7). Those areas operating free garden waste collections had significantly lower home composting participation rates compared with areas that charged (35% versus 42%, t=5.9, significant at 99.9%).

Figure 5 Proportion of districts within region with free kerbside garden waste collections (2007/08, England)
Source: WRAP ORIS 2007/08

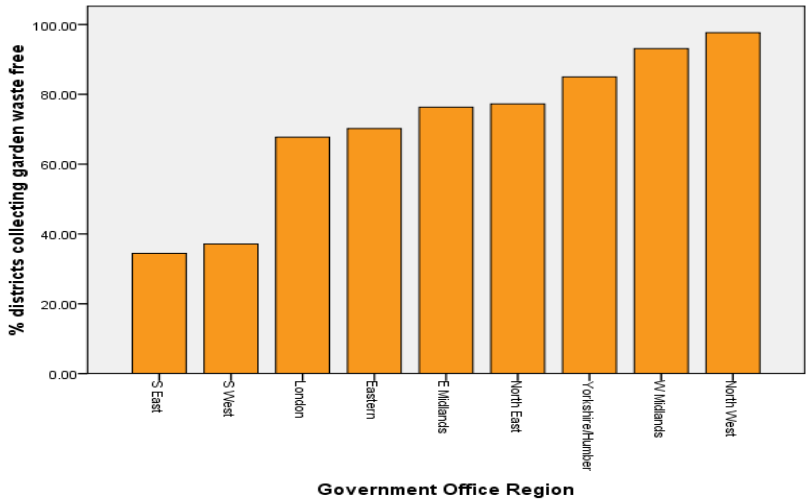


Figure 6 Mean proportion of households within district participating in home composting (2005) and proportion of districts with sack-based garden waste collections, charged versus free within region
Sources: Exodus survey 2005, WRAP ORIS 2007/08

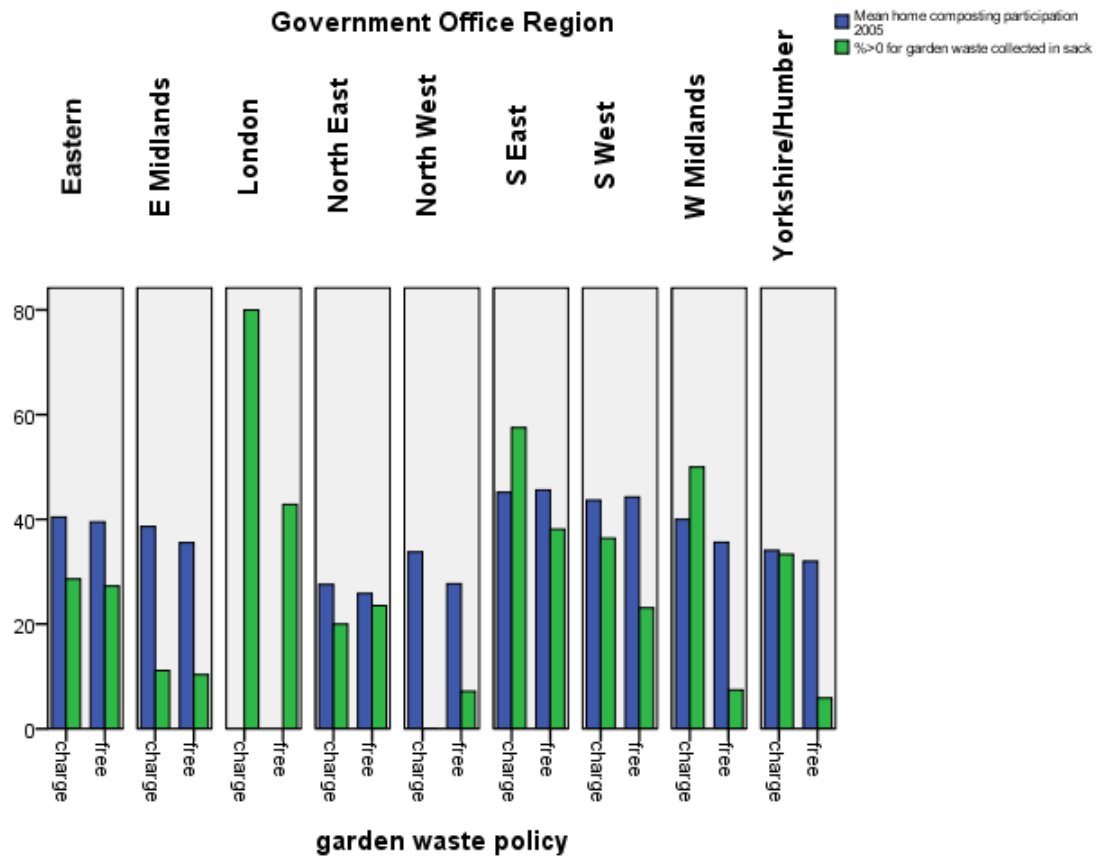
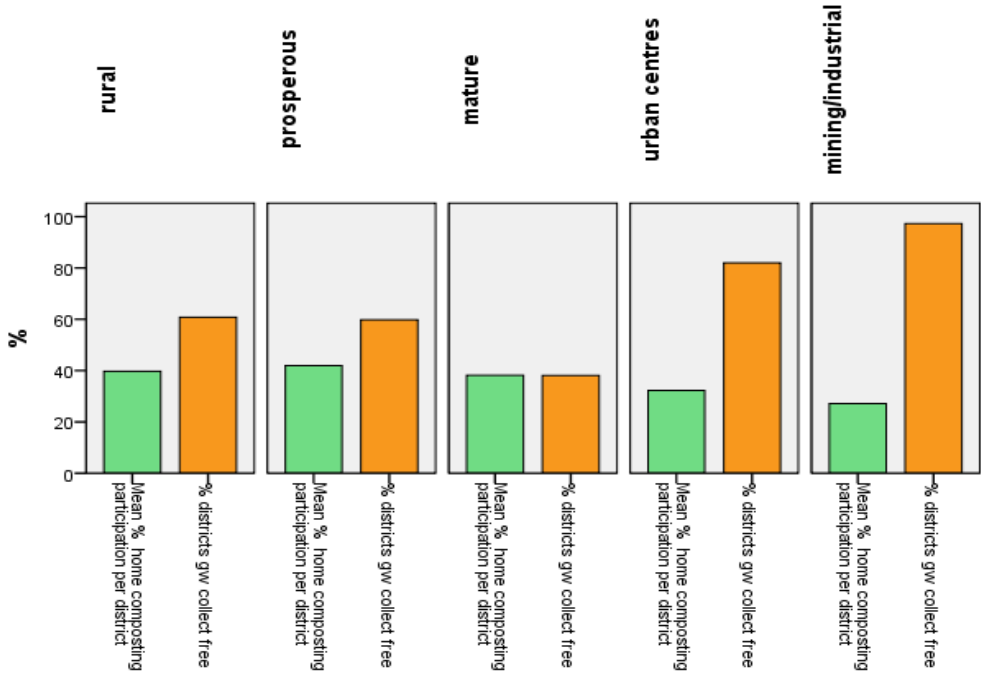


Figure 7 Mean proportion of households within district participating in home composting (green bars) and proportion of districts with free kerbside garden waste collections (orange) within ONS area type classification

Sources: Exodus survey 2005, WRAP ORIS 2007/08



4.5 Interaction between collection policies and waste composition

A combined analysis of WasteDataFlow statistics and results from 120 kerbside residual waste compositional datasets collected between 2005 and 2007 was used to examine how collection policies influence the quantities of garden waste arising across different household waste streams. Figure 8 compares the amount of kerbside residual garden waste (kg/household/week, from compositional data pegged to WDF statistics), source-separated garden waste (kerbside and HWRC, from WDF 2006/07) and residual food waste estimates for 120 districts in England. It was not possible to integrate estimates of HWRC residual garden waste within this analysis as too few HWRC compositional datasets were available.

The analysis found that systems that do not collect garden waste separately at kerbside record more within the residual waste bin and marginally more at HWRC's (first set of bars, Figure 8). Those that collect garden mixed with food waste recorded the least garden waste in the residual bin. A slight reduction in mean quantities of food waste in the residual bin was also apparent.

The most significant influence on the apportionment of garden waste between kerbside and HWRC waste streams was associated with charging policy (Figure 9). Areas with charged garden waste were more reliant on HWRC's as an outlet for garden waste and also put slightly more garden waste into the residual bin. Areas with free garden waste collections also had greater overall arisings of garden waste compared with charged areas: although the comparison excludes any garden waste contained within HWRC residual waste.

The analysis of the links between garden waste collection policies and quantities of compostable material arising across the different household waste streams has important implications for home composting diversion calculations. More specifically, the effect of home composting participation will be confounded by the influence of garden waste policies and this influence needs to be included in diversion modelling. The evidence from compositional studies suggests that charged systems tend to push garden waste towards HWRCs and (marginally) into residual waste collections, with areas charging for kerbside garden waste collections also recording significantly higher home composting participation rates.

Figure 8 Garden waste in kerbside residual, kerbside collection of garden waste for composting, HWRC garden waste segregated for composting and food waste in kerbside residual by garden waste collection policy

Sources: Defra (2009) municipal waste composition: review of municipal waste component analyses, WasteDataFlow 2006/07; WRAP ORIS 2007/08

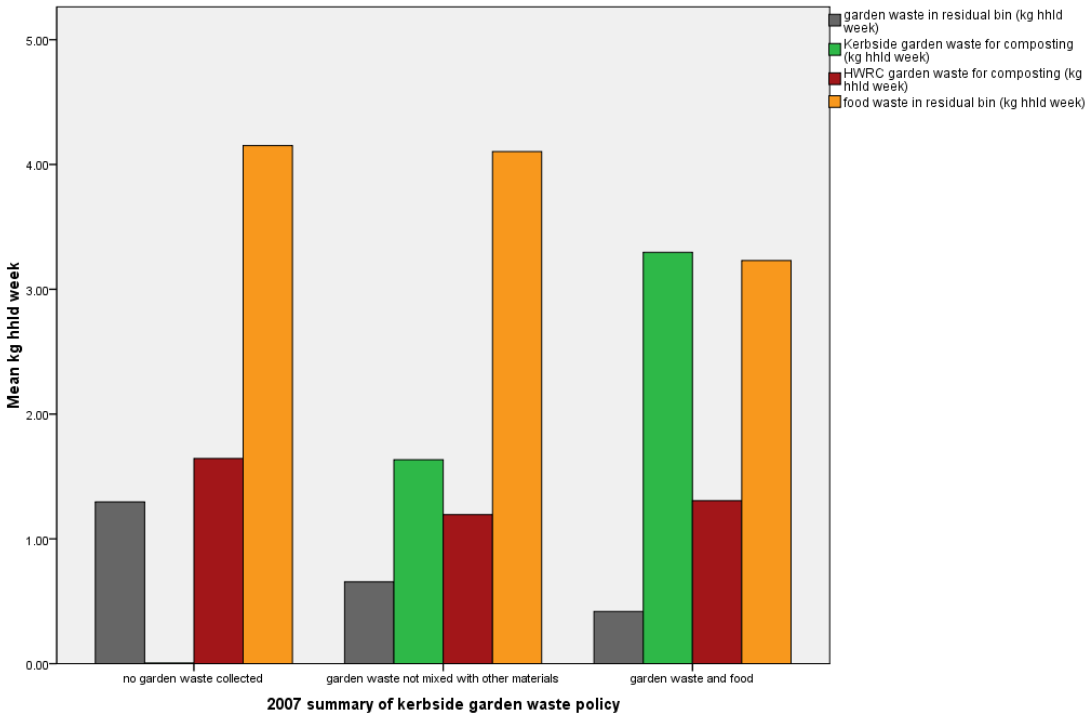
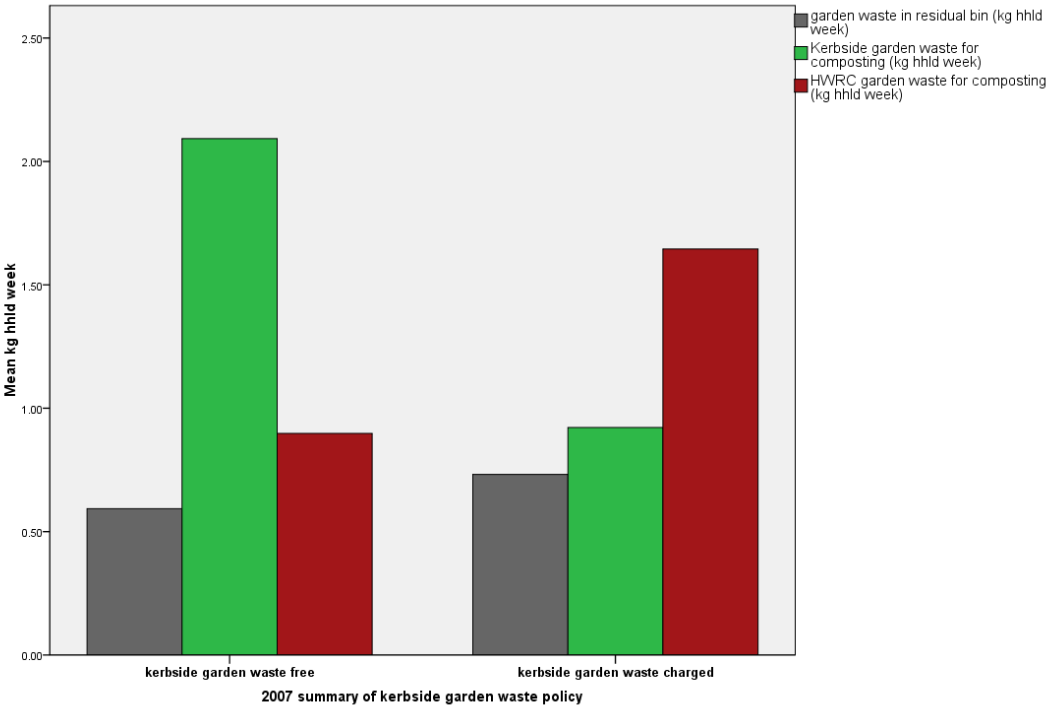


Figure 9 Garden waste in kerbside residual, kerbside collection of garden waste for composting, HWRC garden waste segregated for composting by garden waste charging policy

Sources: Defra (2009) municipal waste composition: review of municipal waste component analyses, WasteDataFlow 2006/07; WRAP ORIS 2007/08



5.0 2004/05 residual waste diversion models

This section describes the main features of the original district level models (WRAP 2005) that estimated the diversion from residual waste associated with home composting participation. It describes the explanatory variables used, how districts were selected for inclusion in the modelling and gives a summary of the two main diversion models.

5.1 Datasets assembled for 2004/05 district level modelling

As already discussed, data from the 2003/04 Defra municipal waste management survey were used as the main source of waste management and waste arisings data (Figure 1). The dependent variables were derived from annual residual waste tonnages (kerbside and HWRC). A number of predictor variables were also obtained from 2003/04 data that described residual waste containment capacity and materials collected for recycling/composting.

In two-tier districts, Waste Disposal Authorities are responsible for HWRC sites (although there are exceptions). As the focus of the modelling was on districts (Waste Collection Authorities), rather than on counties, care was taken in deriving the district-specific HWRC tonnages from WDA-level datasets. In 2003/04 most WDAs reported WCA level figures to Defra for HWRC residual waste and recycling within their area. However, a number of larger counties were only able to provide county-level statistics for HWRCs; in these cases estimates for HWRC residual waste were derived from the population split between WCAs.

The 2004 national home composting participation survey (commissioned by WRAP and conducted by NOP, n=2,600), was used as the source of data on home composting participation. This survey was an up-date of an earlier NOP survey commissioned by DETR in 1997.

Estimates of mean garden sizes for English districts were derived from GIS analysis conducted by WRAP. As there is no national dataset for garden sizes (and it is not a census variable), WRAP developed a method of extracting garden size estimates from Ordnance Survey Master Map data. This work was carried out in late 2004 and early 2005, using up-dated OS Master Map data and provided area estimates of both front and back-gardens.

The general approach to modelling at district level was described in the 2004/05 report to Defra (WRAP August 2005) and was designed, as far as possible, to cross-reference with variables used in the household-level modelling. In order to make valid comparisons between up-dated and original diversion models it was decided to follow the same procedures for excluding outliers that were followed in 2004/05 and to run the new models on the same set of explanatory variables.

5.2 Selection of districts for 2004/05 district level modelling

Exclusion of outliers from the 2004/05 residual waste arisings data was an important aspect of preparing data for the modelling exercise. Of the 354 English districts a significant number were known to produce household waste statistics (kg per household) that were far higher than expected. Knowledge of these occurrences was built from the experience of analysing DETR/Defra local authority returns from 1995/96- 2002/03. Of 354 collection authorities in England, 36 were excluded from the 2004/05 diversion modelling. Most of the exclusions were authorities with unusually high household waste arisings that included elements of trade waste or co-collected non-household wastes. A further group of authorities were not able to separate out RCV-collected household waste from street sweepings, litter and other household collections.

The histogram for kerbside residual waste arisings for the remaining 318 authorities (Figure 10) still contained a wide range of kg/household/week, from less than 10 to over 22 kg/household/week. This was found to partly relate to the method of waste containment for residual waste, represented by the variable '% households with district on 240 litre wheeled bins for residual kerbside waste' (Figure 11). The picture was made more complex by a dozen or so authorities that only collected residual waste fortnightly and provided wheeled bins for garden waste collection in the alternate week. These authorities formed a cluster of cases with approximately 100% of households on wheeled bins, but with less than 14 kg/household/week for residual waste (Figure 11, bottom right of scatter-plot).

The histogram relating to the HWRC residual waste associated with the 318 selected authorities (Figure 12) indicated that a number of authorities reported no HWRC data. These were checked to establish that they were genuine cases of districts that did not contain any HWRC sites.

Figure 10 Refuse collection vehicle residual (bin/sack) waste, kg/household/week 2003/04

Source: Defra municipal waste management survey 2003/04

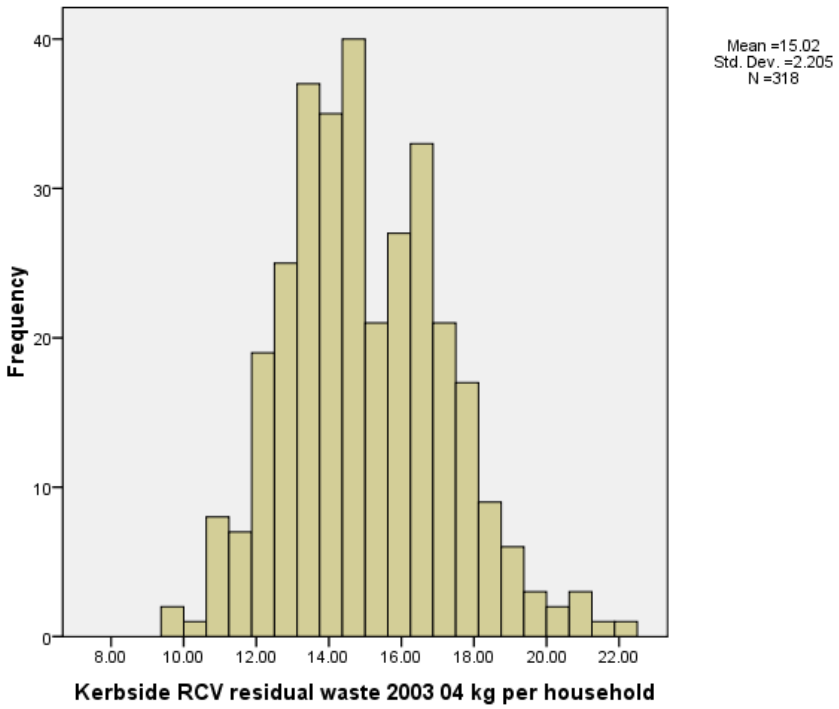


Figure 11 Proportion of households within district on 240 litre wheeled bin collections for residual waste and district refuse collection vehicle residual (bin/sack) waste, kg/household/week 2003/04

Source: Defra municipal waste management survey 2003/04

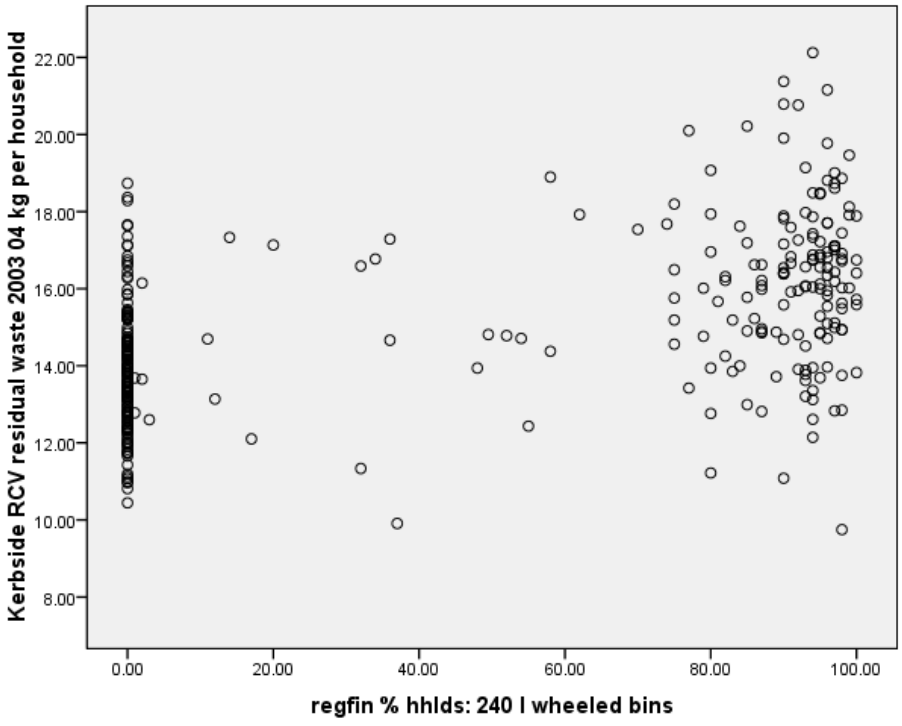
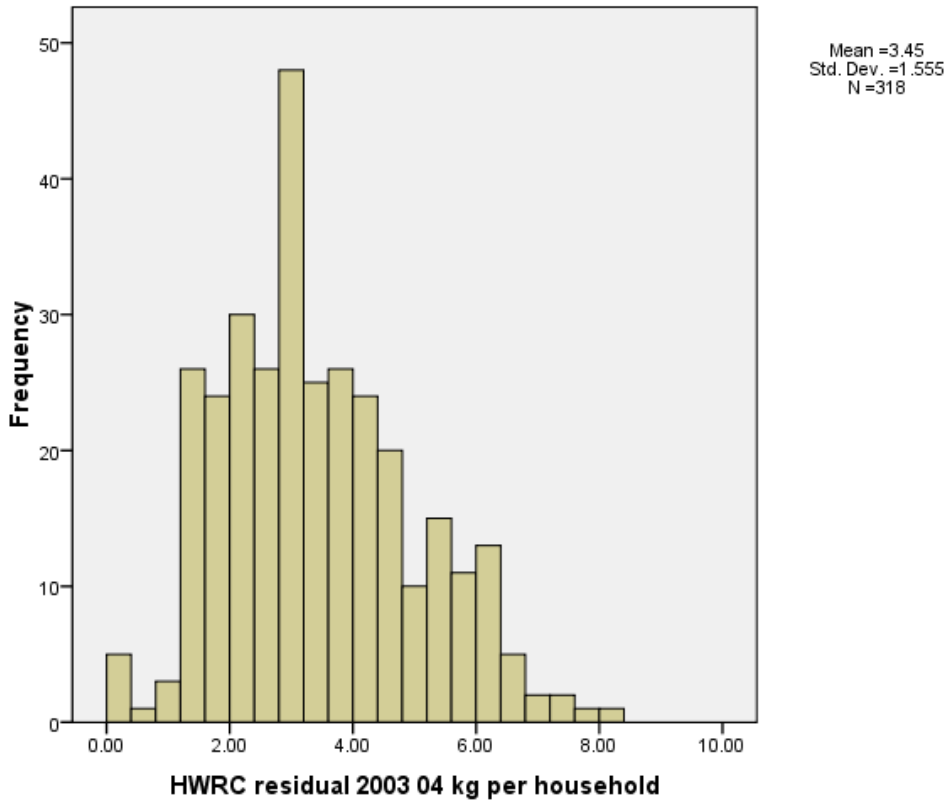


Figure 12 HWRC residual waste, kg/household/week 2003/04

Source: Defra municipal waste management survey 2003/04



5.3 Summary of 2004/05 residual waste diversion models (Models 1 and 2 [1])

In the simplest 'best-fit' regression model with kerbside residual waste (kg/household/week) as the dependent variable, the four variables with the greatest explanatory power were '% of households within district with 240 litre wheeled bins as the method of waste containment for residual waste', 'average garden size per district' and the two BVPI variables: '% dry recycling' and '% composted'. When the home composting participation variable was added to the model, it produced a marginally statistically significant negative coefficient (Table 3).

The same variables were entered into the model that included kerbside and HWRC residual waste as a combined dependent variable. The 'goodness of fit' of the model was less than the case for kerbside residual alone (R-squared, adjusted value 31.5% compared with 52%), however the coefficient for home composting participation was more statistically significant than was the case in Model 1. These two models formed that basis of the home composting diversion factors for residual waste shown in Table 4 (114 and 218 kg/household/year).

Table 3 Explanatory variables in Models 1 and 2[Error! Bookmark not defined.]

Explanatory variables in final 2004/05 residual waste models
■ (-/ve) % of households within district participated in home composting over last 12 months ■ (+/ve) % of households within district on 240 litre wheeled bin for refuse ■ (+/ve) mean garden size (front and back) within district in square metres ■ (-/ve) % recycling attributed to dry recyclables 2003 04 bvpi ■ (-/ve) % recycling attributed to garden waste sent for composting 2003 04 bvpi

Table 4 Models 1 and 2 summary statistics

2004/05 Models 1 and 2: summary statistics

Model	diversion factor: central estimate	95% CI lower bound	95% CI upper bound	% of variance accounted for in model	Unstandardized coefficient: home composting participation	't' value	Statistical significance
	(kg/ hhld / year)	(kg/ hhld / year)	(kg/ hhld / year)	(R^2 adjusted)	'B'		
Model 1: Kerbside residual waste diversion model	-114	-244	10	52%	-0.022	-1.795	0.074
Model 2: Kerbside and HWRC residual waste diversion model	-218	-380	-57	31.5%	-0.042	-2.686	0.008

6.0 2006/07 residual and garden waste diversion models

6.1 Datasets assembled for 2006/07 district level modelling

The approach to developing up-dated models involved two stages: the first was to obtain the equivalent up-dated variables to those used in residual waste Models 1 and 2, to see what changes resulted from re-running these models on 2006/07 data (resulting in Models 3 and 4). The second stage involved using new variables to reflect the changes to collection systems discussed in Section 4 and to create new diversion models for kerbside and HWRC residual waste (Models 5 and 6, respectively) and for separately collected kerbside and HWRC garden waste (Models 7 and 8, respectively).

6.2 Selection of districts for 2006/07 district level modelling

The process of identifying outliers in the 2006/07 residual waste dataset followed a similar method to that described in Section 5.2. In total, 312 districts were included in the modelling on the basis of the consistency of their reported RCV residual waste arisings. The left-hand 'tail' of authorities with very low arisings (Figure 13) reflected those authorities with the highest recycling and composting rates and with the lowest overall arisings. The overall range of values was more restricted compared with 2003/04 (6.5 to 16 compared with 9.7 to 22 kg/hhld/week). As was the case with 2003/04 data, some of the values on the lower end of the range were associated with alternate week collections for residual waste, found in 48% of districts and associated with wheeled bin containment (Figure 14).

With HWRC residual waste reporting, WasteDataFlow does not provide district level HWRC tonnages, as these are reported by WDAs at county level only. Rather than use out of date factors derived from the 2003/04 data, another route was used to estimate HWRC residual arisings in two-tier areas. Most WDAs do provide WasteDataFlow with district level data for HWRC recycling and composting tonnages. These were used as the basis for apportionment of the WDA level HWRC residual waste arisings amongst constituent WCAs. This approach suffers from the assumption that all districts within a county achieve equal segregation efficiency for their HWRCs: a situation that is not likely to be the case, given the mix of urban and rural districts and different site operators that occur within different two-tier areas. Although the overall distribution in Figure 15 (with obvious outliers removed) does not look too different to the 2003/04 data, a more pronounced shift in the distribution to the left would have been expected given the dramatic improvements in HWRC segregation efficiencies made between 2003/04 and 2006/07. With outliers removed, data from a total of 305 authorities were selected for use in the 2006/07 HWRC modelling, a similar number to the 2003/04 dataset.

Figure 13 Refuse collection vehicle residual (bin/sack) waste, kg/household/week 2006/07

Source: WasteDataFlow 2006/07

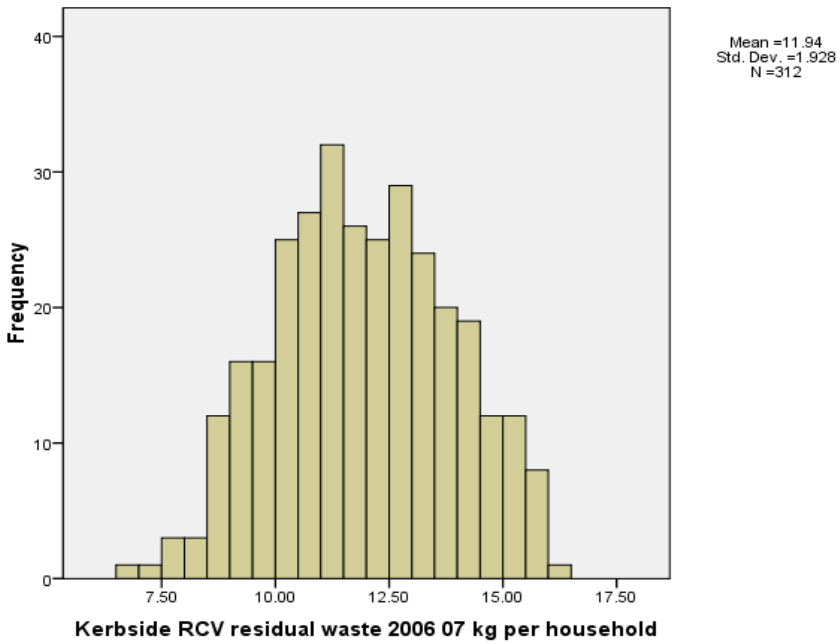


Figure 14 Proportion of households within district on 240 litre wheeled bin collections for residual waste and district refuse collection vehicle residual (bin/sack) waste, kg/household 2006/07, colour coding illustrates frequency of refuse collection

Source: WasteDataFlow 2006/07

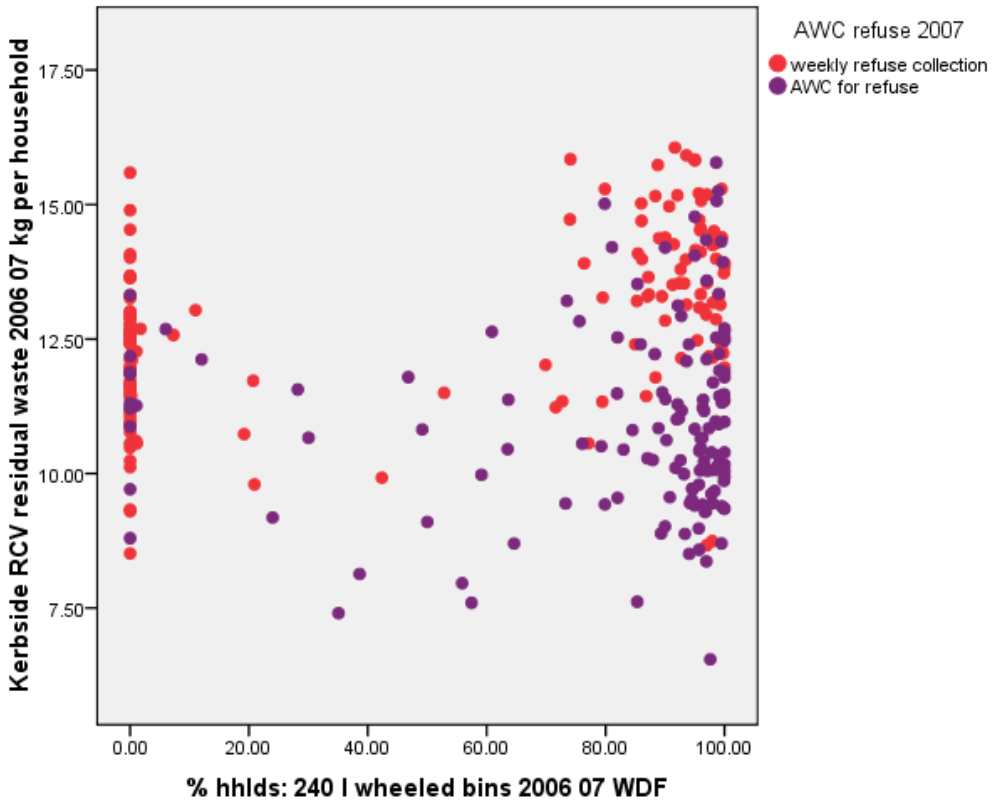
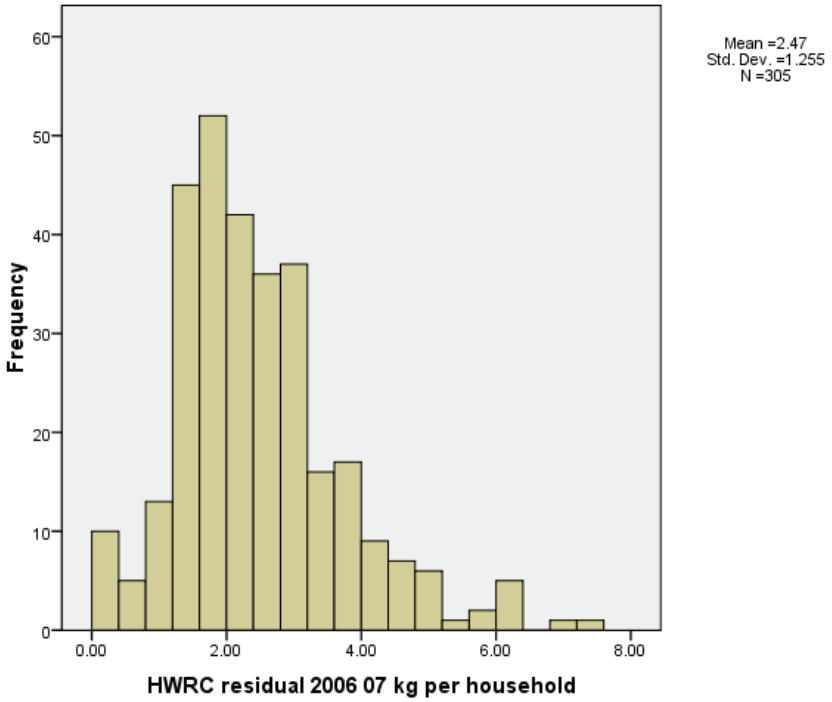


Figure 15 Household waste recycling centre residual (waste, kg/household/week 2006/07)

Source: WasteDataFlow 2006/07



Apart from the variables used to define collection policies described in Section 4, the most important addition to the 2006/07 analysis was the use of a more extensive survey of home composting participation, commissioned by WRAP in 2005 (Exodus 2005) and up-dating the 1997 DETR and 2004 NOP surveys.
In total over 20,000 interviews were conducted across England, Scotland and Wales. The 15,687 interviews conducted in England were spread across local authority area type and region (Table 4) and the majority of these were accurately coded to district authority (170 were rejected as county councils were named as the local authority). Variation in home composting participation by region and local authority area type, derived from the Exodus 2005 data, has already been described in Figures 6 and 7.

Table 5 2005 Exodus survey: interviews completed by area type and English region

	London suburbs and periphery	Prosperous non-London	Other urban centres	Rural and coastal	Mining and industrial	Total
NE	0	80	118	34	784	1,016
NW	0	760	418	118	565	1,861
Yorkshire and Humber	0	368	570	95	627	1,660
EM	0	937	143	36	386	1,502
WM	0	875	428	32	347	1,682
East	88	1,422	137	203	0	1,850
London	1,112	119	24	0	0	1,255
SE	204	2,271	251	251	140	3,117
SW	0	895	233	617	0	1,745
Total	1,404	7,727	2,322	1,386	2,849	15,688

6.3 2006/07 residual waste diversion models (Models 3-6)

Models 3 and 4 (Table 5) used the same dependent and explanatory variables as Models 1 and 2, but with all variables updated to 2006/07. In particular, home composting participation was defined by the Exodus survey rather than the 2004 NOP survey. The main differences in model performance were that the home composting coefficients were not significant in either model and the overall ability to explain variation in kerbside residual

waste arisings was much reduced (37% in Model 3 compared with 52% in Model 1), and was similar for both models.

In terms of the derived diversion estimates, the 2004/05 Model 1 (-144 kg/household/year) and 2006/07 Model 3 (-83 kg/household/year) were similar but the 2006/07 combined model (Model 4) produced an estimate similar to the kerbside residual model (-88 kg/household/year) rather than the doubling in diversion that was estimated for the original 2004/05 combined model (Model 2; -218 kg/household/year). This difference reflects the substantial changes that have occurred at HWRCs discussed in Section 4.3, with very little garden waste remaining in residual skips at HWRCs. The more comparable results for Model 1 and Model 3 perhaps conflict with the evidence of compositional analysis relating to garden waste: an issue that is discussed further in Section 6.5.

Table 6 Explanatory variables in Models 3 and 4: 2006/07 residual waste models based on Models 1 and 2

Explanatory variables in 2006/07 residual waste models	
■ (-/ve) % of households within district participated in home composting over last 12 months Exodus survey 2005 ■ (-/ve) dry recyclables 2006 07 kg per household per week ■ (-/ve) garden waste sent for composting 2006 07 kg per household per week	■ (+/ve) % of households within district on 240 litre wheeled bin for refuse 2006/07 ■ (+/ve) mean garden size (front and back) within district in square metres

Table 7 Residual Models 3 and 4: 2006/07 residual waste models based on Models 1 and 2, summary statistics

Model	diversion factor: central estimate	95% CI lower bound	95% CI upper bound	% of variance accounted for in model	Unstandardized coefficient: home composting participation	't' value	Statistical significance
	(kg/ hhld / year)	(kg/ hhld / year)	(kg/ hhld / year)	(R^2 adjusted)	'B'		
Model 3: Kerbside residual waste diversion model	-83	-194	26	37.5%	-0.016	-1.534	0.126
Model 4: Kerbside and HWRC residual diversion model	-88	-218	42	32.9%	-0.017	-1.312	0.191

New models for residual waste diversion were constructed from 2006/07 variables in order to reflect the recent developments in infra-structure discussed in Section 4. The approach involved testing models that included explanatory variables that were up-dated versions of those used in the original models as well as those that represented new developments in infra-structure: particularly relating to the introduction of alternate week collections for refuse, different types of garden waste collections, dry recycling scheme characteristics and socio-economic variables (such IMD scores). The overall objective was to develop models containing the fewest possible variables that explained as much variation in dependent variables as possible. The usual tests on model residuals were carried out on the extent to which they were normally distributed and had homogeneous variances. Tests were carried out on the extent to which explanatory variables were inter-correlated and a number of variables were excluded on this basis. Unlike Models 2 and 4, which combined residual waste for kerbside and HWRC, the new models relating to HWRC residual waste were kept separate from the kerbside residual waste models as they were found to be unstable with very limited ability to explain variations in HWRC residual waste, as discussed below.

Model 5 (independent variable: kerbside residual waste) included a significant effect of food/garden mixed waste collections and AWC for refuse and Model 6 (HWRC residual) included a significant effect of kerbside garden waste collection policy (garden waste charged/ not collected or collected free; Table 7). Although Model 5 was an improvement on model 3, in terms of ability to explain variance in residual waste arisings (R^2 adjusted 47.5% compared with 37.5%), the home composting participation variable did not contribute a statistically significant coefficient to the model (-47 kg/household/year). Model 6 attempted to explain variation in HWRC residual waste (not combined with kerbside residual, as in Model 2), but resulted in a very poor 'goodness of fit' and again, the home composting coefficient (-31 kg/household/year) was not statistically significant. The failure to produce a robust HWRC residual model might well be linked to the way in which the district level HWRC residual waste statistics were derived from the WDA data (as described in Section 6.2).

Table 8 Explanatory variables in Models 5 and 6

Model 5: Explanatory variables in 2006/07 revised kerbside residual waste model	
■ (-/ve) AWC refuse 2007 ■ (-/ve) % of households within district participated in home composting over last 12 months Exodus survey 2005 ■ (-/ve) Food waste collected with garden waste 2007 ■ (-/ve) kg per hhld week dry recyclables collected kerbside 2006/07 ■ (-/ve) kg per hhld week compostables collected kerbside 2006/07 ■ (-/ve) kg per hhld week garden waste collected at HWRC 2006/07	■ (+/ve) % of households within district on 240 litre wheeled bin for refuse 2006/07
Model 6: Explanatory variables in 2006/07 revised HWRC residual waste model	
■ (-/ve) % of households within district participated in home composting over last 12 months Exodus survey 2005	■ (+/ve) kg per hhld week dry recyclables collected at HWRC 2006/07
	■ (+/ve) kg per hhld week garden waste collected at HWRC 2006/07 ■ (+/ve) Garden waste charged or not collected 2007

Table 9 Residual Models 5 and 6: 2006/07, using new variables to reflect changes in RCV and HWRC residual, splitting kerbside and HWRC into separate models

Model	diversion factor: central estimate	95% CI lower bound	95% CI upper bound	% of variance accounted for in model	Unstandardized coefficient: home composting participation	't' value	Statistical significance
	(kg/ hhld / year)	(kg/ hhld / year)	(kg/ hhld / year)	(R^2 adjusted)	'B'		
Model 5: Kerbside residual waste diversion model	-47	-140	47	47.5%	-0.009	-0.69	0.491
Model 6: HWRC residual waste diversion model	-31	-151	94	12.7%	-0.006	-0.49	0.625

6.4 2006/07 garden waste diversion models (Models 7 and 8)

The final modelling task was to explore variation in the quantities of waste segregated for composting (primarily garden waste) through kerbside collections and material separated into garden waste skips at HWRCs. This analysis drew on a set of variables describing local garden waste collection policies compiled in 2007/08, supplemented by clarifications obtained from visiting local authority websites (Section 4.4). The original garden size variable from the 2005 GIS analysis was also used, as well as home composting participation estimates derived from the 2005 Exodus survey data.

Model 7, which has garden waste collected at kerbside as the dependent variable, represents the most robust model to date in terms of explaining variance through a combination of behavioural, service type and area type variables. It explains 67% of the variance in garden waste collected by kerbside schemes (kg/household/week) and contains a negative coefficient for home composting participation (-114 kg/household/year) that is significant at the 95% statistical significance level. In comparison, the most robust residual waste model from 2004/05 explained just over half of the variance in kerbside residual waste. Model 7 also contains an indication of the wider influences on the quantities of garden waste collected. 'Whether or not the district operated a free garden waste collection' contributed a strong positive coefficient to the model (i.e. more garden waste collected kerbside in areas with free collections), and was a more powerful explanatory variable (as indicated by the standardised coefficients) than the two other positive factors: 'garden size' and 'whether or not additional materials were accepted' (e.g. schemes accepting materials such as card or food waste mixed in with garden waste).

The influence of charging was explored further by means of separate models constructed for areas with charged (7A) and free (7B) garden waste collections (Table 10). In areas with free garden waste collections the home composting, the diversion factor derived was greater than for the areas with charging schemes (-156 kg/household/year versus -94). This result does not necessarily imply that home composting households living in areas with free garden waste collections are more effective at home composting overall. Kerbside systems that collect garden waste for free attract more garden waste down this route: hence the greater diversion estimated for home composting compared with areas that charge. It is also worth recalling from Section 4.5 that areas with charged collections collected more garden waste at HWRCs, but collect less overall (see Figure 9). This is an important interaction, but difficult to model given the problematic nature of the HWRC data applied to district level modelling. Also, far fewer districts contributed data to the charged collections model (82 districts) contributing greater uncertainty to the diversion factors compared with the free garden waste collection systems (with 120 authorities)

Table 10 Explanatory variables in Model 7

Model 7: Explanatory variables in 2006/07 kerbside garden waste diversion model	
■ (-/ve) % of households within district participated in home composting over last 12 months Exodus survey 2005 ■ (-/ve) kg per hhld week kerbside residual waste 2006/07 ■ (-/ve) kg per hhld week HWRC garden waste 2006/07 ■ (-/ve) No garden waste collected at kerbside ■ (-/ve) Garden waste collected in sack	■ (+/ve) garden size : square metres ■ (+/ve) Garden waste collection free of charge ■ (+/ve) Kerbside garden waste collection includes additional materials

Table 11 Kerbside garden waste diversion Models 7, 7A and 7B: 2006/07 comparison between charged (7A) and free (7B) garden waste collections

Model	diversion factor: central estimate	95% CI lower bound	95% CI upper bound	% of variance accounted for in model	Unstandardized coefficient: home composting participation	't' value	Statistical significance
	(kg/ hhld / year)	(kg/ hhld / year)	(kg/ hhld / year)	(R^2 adjusted)	'B'		
Model 7: Kerbside garden waste diversion model	-114	-218	-10	66.9%	-0.022	-2.173	0.031
Model 7A: Charged kerbside garden waste diversion model	-94	-250	57	29.3%	-0.018	-1.226	0.224
Model 7B: Free kerbside garden waste diversion model	-156	-328	-10	53.9%	-0.030	-1.864	0.065

A less successful model was constructed for garden waste diversion at HWRCs, with five explanatory variables and an R^2 adjusted value of 40.2% (Model 8; Tables 11 and 12). In this case, the coefficient contributed by the home composting variable was positive (+36 kg/household/year), implying that in areas with higher home composting rates (presumably reflecting more gardening activity), more garden waste is segregated for composting at HWRCs. This model was particularly unstable, with minor changes in the selection of other explanatory variables leading to the home composting diversion estimates switching between positive and negative values. Furthermore, the confidence interval around the diversion estimate straddles zero, so that it is particularly uncertain whether or not there was net diversion into home composting or net diversion to HWRC by home composting households. The main difficulty in the HWRC data modelling was that the wide range of site segregation efficiencies (range 14-100%, mean 51.5%) masked any real differences in the quantities of garden waste taken by householders to these sites. Despite this problem, it was possible to detect the 'push' of garden waste into HWRC discussed in Section 4.5 (see Figure 8), as reflected by the positive coefficient in the model for the dichotomous variable 'garden waste collection charged

Table 12 Explanatory variables in Model 8

Model 8: Explanatory variables in 2006/07 HWRC garden waste diversion model	
■ (-/ve) kg per hhld week kerbside residual waste 2006/07	■ (+/ve) % of households within district participated in home composting over last 12 months Exodus survey 2005
■ (-/ve) kg per hhld week garden waste collected kerbside 2006/07	■ (+/ve) HWRC overall segregation efficiency ■ (+/ve) Garden waste collection charged at kerbside

Table 13 Model 8: HWRC garden waste diversion, 2006/07

Model	**diversion factor: central estimate**	**95% CI lower bound**	**95% CI upper bound**	**% of variance accounted for in model**	**Unstandardized coefficient: home composting participation**	**'t' value**	**Statistical significance**
	(kg/ hhld / year)	(kg/ hhld / year)	(kg/ hhld / year)	(R^2 adjusted)	'B'		
Model 8: HWRC garden waste diversion model	+36	-26	+99	40.2%	+0.007	1.177	0.241

6.5 Cross comparison of 2006/07 district level models with other data sources

This section brings together all of the district level models to compare the diversion factors obtained and to 'sense check' them against data from compositional analysis, data from operational sources (WasteDataFlow) and estimates from the WRc household-based models which were based on 2004/05 fieldwork (WRAP 2009).

Table 14 contains estimates from 2006/07 referenced compositional arisings studies for the key waste fractions of interest to home composting (kg/ household/ year), split into the four relevant household waste streams: kerbside residual, kerbside garden waste collections, HWRC residual and HWRC garden waste. Each is an average obtained from compositional analysis and WasteDataFlow statistics, and therefore contains both home composting and non-home composting households (it would therefore be expected for these averages to be higher in the case of non-home composting households, as they divert none of the materials into home composting). Below each estimate is the diversion factor obtained from each relevant home composting diversion model.

Although the disposition of garden waste discussed in Section 4.3 concluded that very little remained in the residual stream compared with the situation in 2003/04, compositional data suggests that other home compostable materials may represent about 100 kg/household/year in the residual bin (more if separate estimates were available for non-home composting households). The diversion estimate obtained from Model 5 suggested 47 kg/household/year diverted from the residual bin through home composting participation (i.e. the estimated difference between composting and non-home composting households). This estimate would appear to be realistic if householders are diverting home compostable food waste and other materials. Householder survey data and observation studies carried out as part of the 2004/05 fieldwork suggested that this was the case, particularly with respect to WRAP bins. The comparable diversion factor from the WRc reworking of the 2004/05 household level data (WRAP 2009) was 47 kg / household / year for non-WRAP home composters (Table 15), the same as for WRAP new recruits and 72 kg for WRAP bin households that were already composting (WRAP 'enhanced' households).

Cross-comparison between the district level kerbside garden waste diversion model (Model 7) and the average quantity of waste collected by districts through kerbside 'green waste' schemes, including those that collected no garden waste, suggest that the Model 7 diversion estimates are within the same range. However, it should be acknowledged that the 114 kg is the difference between home composting and non-home composting households, whereas the 111 kg is the average yield of garden waste across all districts and it cannot be assumed that home composting households would not contribute any materials at all for centralised composting through kerbside collections.

Estimates from the household level models (WRAP 2009) to predict home composting diversion from garden waste collections were more contradictory (Table 15), with the WRAP bin home composting household diversion factors 100 kg/year less than the Model 7 factor. For non-WRAP home composting households the household level model coefficient was positive and produced an estimate of these households contributing 43.8 kg/household/year more than equivalent non-home composting households. However, the high variability in garden waste among households and over time means that the diversion estimates derived from the household-level models were highly uncertain. Furthermore, three of the nine study areas had received new garden waste collection systems midway through the 2004/05 fieldwork period, so the household-level models cover a period of considerable change in garden waste policies (WRAP 2009). The district level models developed in the present study use more up-to-date data and provide better spatial and temporal integration and for these reasons it is believed that the diversion factor of -114 kg/household/year is closer to the present-day true value. One of the main advantages of using district level data, as discussed in the 2005 WRAP report, is that they are not subject to seasonality and week-to-week variation, as are the household level data.

Similar comparisons for the estimates obtained from HWRC models suggested an over-estimation in the case of residual HWRC waste diversion (Model 6: -31 kg the difference between home composting and not, versus the 7 kg/household/year district average). For Model 8 (HWRC garden waste) the model estimates that home composting households take more garden waste to HWRC sites compared with non-home composting

households. The estimated increase (36 kg/household/year) is a plausible estimate when compared against the average quantity of segregated garden waste at HWRCs in 2006/07 (70 kg/household/year).

One final source of evidence to cross-reference the home composting diversion estimates is research carried out by Imperial College on quantifying diversion from landfill through home composting participation (Mitaftsi and Smith, 2006). This research used an automated weighing system fitted to a refuse collection vehicle to provide weight data on 324 households in the Borough of Runnymede, Surrey. The households were divided up into different groups, by whether or not they participated in home composting and the local kerbside recycling scheme. The on-board weighing data was complemented by detailed compositional analysis of residual waste from each household. It was estimated that home composting participation reduced the total amount of biodegradable waste sent to landfill by 42 kg/household/year (Table 14), much of it associated with food waste diversion. It was found that compared with the control group, home composting households put more garden waste in their residual bin and that in this suburban area (with no kerbside garden waste collection), the main benefit of home composting in relation to kerbside collected materials, was the decrease in food waste set out in the dust bin for disposal. This estimate is similar to the 47 kg diversion estimate from Model 5.

Table 14 Summary of relevant waste arisings from compositional studies and WasteDataFlow (kg/household/year) and model diversion factors 2006/07

Kerbside: residual waste		**Kerbside: separately collected materials**		**HWRC: residual waste**		**HWRC: segregated materials**	
	kg/h'hold/year		kg/h'hold/year		kg/h'hold/year		kg/h'hold/year
garden waste	36	garden waste (with or without other compostables/ food waste)	111	garden waste	7	garden waste	70
home compostable food waste	90						
other home compostables	10						
total home compostable	136						
Model 5 diversion factor	**-47**	**Model 7 diversion factor**	**-114**	**Model 6 diversion factor**	**-31**	**Model 8 diversion factor**	**+36**
Estimated diversion BMW: Imperial College RCV automated weighing	-42						

Table 15 Comparison of Model 5 with 2004/05 household level residual waste diversion factors (kg/household/year; WRAP, 2009)

	non-WRAP	WRAP enhanced	WRAP New Recruits
Residual garden waste	-24.6	-34.2	-32.5
Residual home compostable food waste Residual other home compostables	-22.4	-37.4	-14.7
total residual diversion	-47	-71.6	-47.2
Model 5 diversion factor	**-47**		

Table 16 Comparison of Model 7 with 2004/05 household level kerbside garden waste diversion factors (kg/household/year; WRAP 2009)

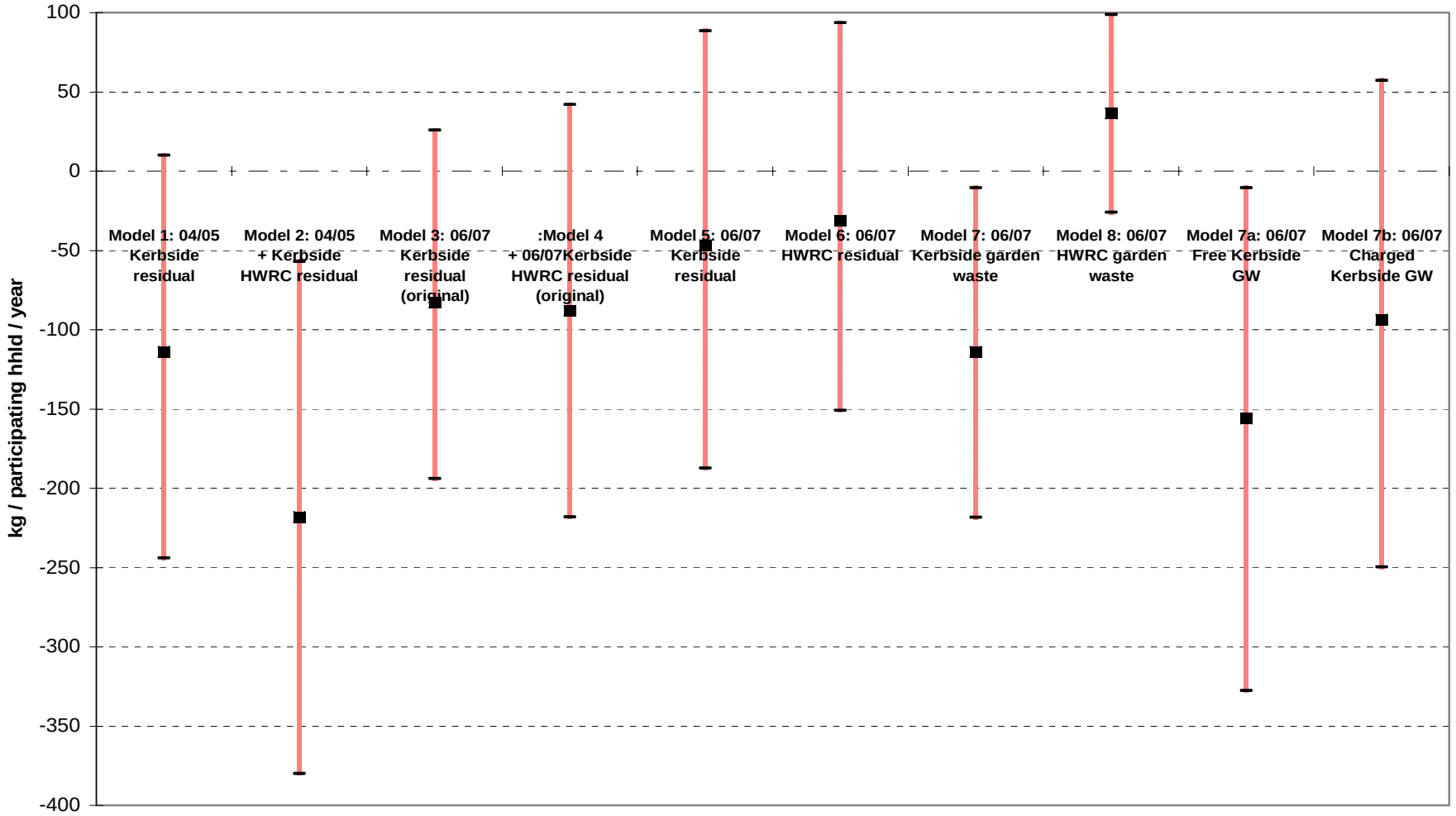
	non-WRAP	WRAP enhanced	WRAP New Recruits
kerbside garden waste	43.8	-43.4	-49.4
Model 7 diversion factor	**-114**		

6.6 Summary of modelled diversion factors 2004/05 and 2006/07

The development of statistical models to estimate home composting diversion involves consideration of the statistical uncertainties associated with the variability of waste data. Figure 15 displays the 95% confidence intervals associated with estimates obtained from the eight district level models developed in the present study. This is an inherent difficulty in addressing an issue that cannot easily be directly measured and has to be inferred using statistical techniques. It is also a consequence of the amount of 'noise' in reported household waste statistics.

The confidence intervals in Figure 16 give an indication of the range in which the true value is likely to be found. For example, in Model 7 the 95% confidence interval associated with the -114 kg diversion factor suggests that there is a 95% chance that the true value lies between -10 and -218 kg/household/year. Models 7a and 7b, which contain a subset of the data that contributed to Model 7 have wider confidence intervals because the models contain less data and therefore give less reliable estimates. Many of the 95% confidence intervals span zero, implying that we cannot state with high confidence that home composting participation results in net diversion. However, when the outputs from the diversion models are considered alongside the evidence from the household level models and sense-checked against changes in waste collection policies, the combined picture gives one greater confidence that the diversion factors are reasonable estimates.

Figure 16 Comparison of 95% confidence intervals around home composting diversion estimates: 2004/05 models 1 and 2; 2006/07 models 3-8



7.0 Conclusions

The 2006/07 district level models were developed to reflect changes in waste collection infra-structure that have occurred since 2003/04. The kerbside garden waste model (Model 7), suggested that 114 kg/household/year is diverted away from garden waste collections by home composting households. The updated kerbside residual model estimated 47 kg/household/year diversion, less than the comparable model based on 2003/04 data. Taking these diversion factors together, home composting is estimated to divert a total of 161 kg/household/year from kerbside collections.

The models developed to estimate diversion from HWRC waste streams were less able to explain overall variability in waste arisings than the kerbside models; the factors obtained were -31 kg for residual HWRC and +36 kg hhld year for garden waste segregated.

Taking into account both garden waste and residual streams, and weighing-up the other evidence discussed in Section 6.6, the overall diversion estimated for households that are home composting is about 160 kg/household/year (combination of Models 5 – 8). A recommended estimate to use in diversion estimates, erring on the side of caution, would be 150 kg/household/year.

8.0 References

Mitaftsi, O and Smith, S.R. (2006) Quantifying household waste diversion from landfill disposal by home composting and kerbside collection. Centre for Environmental Control and Waste Management, Department of Civil and Environmental Engineering, Imperial College report, December 2006.

Prime Minister's Strategy Unit (2002) Waste Not Want Not.

WRAP (2005) Home composting diversion models. WRAP report, 2 August 2005.

WRAP (2008) Evaluation of the WRAP Separate Food Waste Collection Trials. WRAP report, September 2008.

WRAP (2009) Home composting diversion: household level modelling. WRc for WRAP, 2009.

Appendix Regression Model Output Files

Model 1: 2004/05 Kerbside residual diversion model

Descriptive Statistics

	Mean	Std. Deviation	N
Kerbside RCV residual waste 2003 04 kg per household	15.0139	2.18924	293
regfin % hhlds: 240 l wheeled bins	44.9608	44.68711	293
garden size square m.	253.9704	80.97487	293
home composting participation estimate	37.4924	8.83173	293
dry recyclables 2003 04 bvpi	13.2805	4.39910	293
garden waste sent for composting 2003 04 bvpi	3.7787	4.51729	293

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.727[a]	.529	.520	1.51599

a. Predictors: (Constant), garden waste sent for composting 2003 04 bvpi, home composting participation estimate, regfin % hhlds: 240 l wheeled bins, garden size square m., dry recyclables 2003 04 bvpi

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	17.106	.480		35.602	.000	16.161	18.052
	regfin % hhlds: 240 l wheeled bins	.018	.002	.357	8.280	.000	.013	.022
	garden size square m.	.006	.001	.236	5.268	.000	.004	.009
	home composting participation estimate	-.022	.013	-.091	-1.795	.074	-.047	.002
	dry recyclables 2003 04 bvpi	-.247	.024	-.495	-10.127	.000	-.294	-.199
	garden waste sent for composting 2003 04 bvpi	-.102	.020	-.211	-5.115	.000	-.141	-.063

a. Dependent Variable: Kerbside RCV residual waste 2003 04 kg per household

Model 2: 2004/05 Kerbside and HWRC residual diversion model

Descriptive Statistics

	Mean	Std. Deviation	N
total kerbside RCV and HWRC residual 2003 04 kg per household per week	18.3929	2.28446	293
regfin % hhlds: 240 l wheeled bins	44.9608	44.68711	293
garden size square m.	253.9704	80.97487	293
home composting participation estimate	37.4924	8.83173	293
dry recyclables 2003 04 bvpi	13.2805	4.39910	293
garden waste sent for composting 2003 04 bvpi	3.7787	4.51729	293

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.572[a]	.327	.315	1.89081

a. Predictors: (Constant), garden waste sent for composting 2003 04 bvpi, home composting participation estimate, regfin % hhlds: 240 l wheeled bins, garden size square m., dry recyclables 2003 04 bvpi

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	20.996	.599		35.035	.000	19.816	22.175
	regfin % hhlds: 240 l wheeled bins	.011	.003	.216	4.192	.000	.006	.016
	garden size square m.	.006	.002	.199	3.721	.000	.003	.009
	home composting participation estimate	-.042	.016	-.162	-2.686	.008	-.073	-.011
	dry recyclables 2003 04 bvpi	-.197	.030	-.378	-6.473	.000	-.256	-.137
	garden waste sent for composting 2003 04 bvpi	-.092	.025	-.182	-3.685	.000	-.141	-.043

a. Dependent Variable: total kerbside RCV and HWRC residual 2003 04 kg per household per week

Model 3: 2006/07 Kerbside residual diversion model based on 2004/05 up-dated variables

Descriptive Statistics

	Mean	Std. Deviation	N
RCVres0607kg	11.9150	1.88810	280
% hhlds: 240 l wheeled bins 2005 06 WDF	64.5418	41.76007	280
home composting participation 2005	37.6477	9.47851	280
garden size square m.	254.6564	80.46832	280
dry06kg	2.8457	.93396	280
GWKWreckg	1.8832	1.60446	280

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.621[a]	.386	.375	1.49262

a. Predictors: (Constant), GWKWreckg, home composting participation 2005, dry06kg, % hhlds: 240 l wheeled bins 2005 06 WDF, garden size square m.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	15.292	.485		31.524	.000	14.337	16.246
	% hhlds: 240 l wheeled bins 2005 06 WDF	.008	.002	.176	3.450	.001	.003	.013
	home composting participation 2005	-.016	.011	-.081	-1.534	.126	-.037	.005
	garden size square m.	.001	.001	.045	.867	.387	-.001	.003
	dry06kg	-.998	.102	-.494	-9.818	.000	-1.199	-.798
	GWKWreckg	-.378	.060	-.321	-6.294	.000	-.496	-.260

a. Dependent Variable: RCVres0607kg

Model 4: 2006/07 Kerbside and HWRC residual diversion model based on 2004/05 up-dated variables

Descriptive Statistics

	Mean	Std. Deviation	N
Res_RCV_CAkg06rev	14.2840	2.23481	280
% hhlds: 240 l wheeled bins 2005 06 WDF	64.5418	41.76007	280
home composting participation 2005	37.6477	9.47851	280
garden size square m.	254.6564	80.46832	280
dry06kg	2.8457	.93396	280
GWKWreckg	1.8832	1.60446	280

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.584[a]	.341	.329	1.83024

a. Predictors: (Constant), GWKWreckg, home composting participation 2005, dry06kg, % hhlds: 240 l wheeled bins 2005 06 WDF, garden size square m.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	18.149	.595		30.514	.000	16.979	19.320
	% hhlds: 240 l wheeled bins 2005 06 WDF	.003	.003	.050	.938	.349	-.003	.008
	home composting participation 2005	-.017	.013	-.072	-1.312	.191	-.042	.008
	garden size square m.	.002	.002	.073	1.349	.178	.000	.005
	dry06kg	-1.054	.125	-.441	-8.454	.000	-1.300	-.809
	GWKWreckg	-.486	.074	-.349	-6.611	.000	-.631	-.342

a. Dependent Variable: Res_RCV_CAkg06rev

Model 5: 2006/07 Kerbside residual diversion model, based on new variables set

Descriptive Statistics

	Mean	Std. Deviation	N
RCVres0607kg	11.9350	1.89317	286
home composting participation 2005	37.6746	9.62288	286
dry06kg	2.8568	.93943	286
GWKWreckg	1.8993	1.60648	286
AWC refuse 2007	.4825	.50057	286
% hhlds: 240 l wheeled bins 2005 06 WDF	64.8995	41.61288	286

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.689[a]	.475	.466	1.38366

a. Predictors: (Constant), % hhlds: 240 l wheeled bins 2005 06 WDF, dry06kg, GWKWreckg, home composting participation 2005, AWC refuse 2007

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	14.800	.426		34.744	.000	13.961	15.638
	home composting participation 2005	-.009	.009	-.044	-.950	.343	-.027	.009
	dry06kg	-.772	.096	-.383	-7.997	.000	-.962	-.582
	GWKWreckg	-.252	.055	-.214	-4.618	.000	-.360	-.145
	AWC refuse 2007	-1.429	.196	-.378	-7.307	.000	-1.813	-1.044
	% hhlds: 240 l wheeled bins 2005 06 WDF	.013	.002	.283	5.787	.000	.008	.017

a. Dependent Variable: RCVres0607kg

Model 6: 2006/07 HWRC residual diversion model, based on new variables set

Descriptive Statistics

	Mean	Std. Deviation	N
ResCAkg06rev	2.5465	1.27455	211
home composting participation 2005	41.9462	7.30039	211
dryCAkg06rev_kg	1.5801	.64216	211
Garden waste policy	.3644	.51019	211
gwCAkg06rev_kg	1.3557	.81795	211

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.378[a]	.143	.127	1.19121

a. Predictors: (Constant), gwCAkg06rev_kg, home composting participation 2005, dryCAkg06rev_kg, Garden waste policy

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.712	.526		3.257	.001	.676	2.749
	home composting participation 2005	-.006	.012	-.033	-.490	.625	-.029	.018
	dryCAkg06rev_kg	.321	.139	.162	2.304	.022	.046	.595
	Garden waste policy	.364	.186	.146	1.960	.051	-.002	.730
	gwCAkg06rev_kg	.324	.125	.208	2.588	.010	.077	.570

a. Dependent Variable: ResCAkg06rev

Model 7: 2006/07 Kerbside garden waste diversion model

Descriptive Statistics

	Mean	Std. Deviation	N
GWKWreckg	2.1296	1.71401	220
home composting participation 2005	41.9462	7.14881	220
garden size square m.	281.7794	71.67070	220
RCVres0607kg	11.6460	1.91278	220
gwCAkg06rev_kg	1.3557	.80097	220
GWsack	.2682	.44402	220
gwmorematerials	.2511	.43367	220
NOcollectorganics	.0548	.22758	220
gwcollectfree	.5941	.47163	220

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.825[a]	.681	.669	.98678

a. Predictors: (Constant), gwcollectfree, NOcollectorganics, garden size square m., RCVres0607kg, home composting participation 2005, GWsack, gwmorematerials, gwCAkg06rev_kg

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	5.731	.707		8.109	.000	4.338	7.124
	home composting participation 2005	-.022	.010	-.093	-2.173	.031	-.042	-.002
	garden size square m.	.003	.001	.125	3.116	.002	.001	.005
	RCVres0607kg	-.279	.036	-.311	-7.653	.000	-.350	-.207
	gwCAkg06rev_kg	-.578	.097	-.270	-5.988	.000	-.768	-.388
	GWsack	-.797	.165	-.206	-4.839	.000	-1.121	-.472
	gwmorematerials	.728	.175	.184	4.164	.000	.383	1.072
	NOcollectorganics	-1.738	.312	-.231	-5.573	.000	-2.353	-1.123
	gwcollectfree	1.083	.169	.298	6.424	.000	.751	1.415

a. Dependent Variable: GWKWreckg

Model 8: 2006/07 HWRC garden waste diversion model

Descriptive Statistics

	Mean	Std. Deviation	N
gwCAkg06rev_kg	1.3557	.79375	224
home composting participation 2005	41.9462	7.08440	224
GWKWreckg	2.1296	1.69857	224
RCVres0607kg	11.6395	1.88245	224
ca efficiency revised	52.8992	12.56479	224
Garden waste policy	.3644	.49509	224

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.644[a]	.415	.402	.61388

a. Predictors: (Constant), Garden waste policy, RCVres0607kg, ca efficiency revised, home composting participation 2005, GWKWreckg

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	1.846	.491		3.757	.000	.877	2.814
	home composting participation 2005	.007	.006	.065	1.177	.241	-.005	.019
	GWKWreckg	-.193	.033	-.413	-5.858	.000	-.258	-.128
	RCVres0607kg	-.108	.024	-.257	-4.462	.000	-.156	-.060
	ca efficiency revised	.014	.003	.228	4.319	.000	.008	.021
	Garden waste policy	.309	.104	.193	2.972	.003	.104	.515

a. Dependent Variable: gwCAkg06rev_kg

Model 7A: 2006/07 Charged collection: kerbside garden waste diversion model

Descriptive Statistics

	Mean	Std. Deviation	N
GWKWreckg	1.1171	.96903	82
home composting participation 2005	43.9456	6.51390	82
garden size square m.	284.7918	67.14760	82
RCVres0607kg	11.5974	1.80376	82
gwCAkg06rev_kg	1.7546	.76375	82
GWsack	.4146	.49569	82
gwmorematerials	.0854	.28114	82
NOcollectorganics	.0000	.00000	82
gwcollectfree	.0000	.00000	82

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.587[a]	.345	.293	.81507

a. Predictors: (Constant), gwmorematerials, garden size square m., gwCAkg06rev_kg, RCVres0607kg, home composting participation 2005, GWsack

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	4.318	1.064		4.057	.000	2.198	6.438
	home composting participation 2005	-.018	.015	-.122	-1.226	.224	-.048	.011
	garden size square m.	.001	.001	.058	.568	.572	-.002	.004
	RCVres0607kg	-.137	.053	-.255	-2.588	.012	-.242	-.031
	gwCAkg06rev_kg	-.498	.126	-.393	-3.957	.000	-.749	-.247
	GWsack	-.541	.195	-.277	-2.769	.007	-.930	-.152
	gwmorematerials	.478	.324	.139	1.473	.145	-.168	1.123

a. Dependent Variable: GWKWreckg

Model 7B: 2006/07 Free collection: kerbside garden waste diversion model

Descriptive Statistics

	Mean	Std. Deviation	N
GWKWreckg	3.0796	1.57082	120
home composting participation 2005	39.7946	6.41047	120
garden size square m.	282.1450	74.15952	120
RCVres0607kg	11.6285	1.91425	120
gwCAkg06rev_kg	1.0063	.65008	120
GWsack	.1917	.39526	120
gwmorematerials	.3833	.48824	120
NOcollectorganics	.0000	.00000	120
gwcollectfree	1.0000	.00000	120

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.750[a]	.562	.539	1.06629

a. Predictors: (Constant), gwmorematerials, gwCAkg06rev_kg, garden size square m., home composting participation 2005, RCVres0607kg, GWsack

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	8.116	1.008		8.049	.000	6.118	10.114
	home composting participation 2005	-.030	.016	-.124	-1.864	.065	-.063	.002
	garden size square m.	.004	.001	.179	2.799	.006	.001	.006
	RCVres0607kg	-.373	.054	-.454	-6.945	.000	-.479	-.266
	gwCAkg06rev_kg	-.588	.155	-.243	-3.807	.000	-.894	-.282
	GWsack	-1.090	.267	-.274	-4.085	.000	-1.619	-.561
	gwmorematerials	.620	.224	.193	2.765	.007	.176	1.064

a. Dependent Variable: GWKWreckg

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