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**Final report**

# Home Composting Diversion: Household Level Analysis

Evaluating the effectiveness of home composting in diverting waste away from local authority kerbside collections

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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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**Front cover photography:** Ecomax compost bin in situ

# Executive summary

The goals of the present study were to (i) verify Parfitt's (2005) household-level models of home composting diversion, (ii) provide additional insight into how those diversion factors were derived, (iii) extend the modelling approach to consider garden waste in residual and garden waste collections, and (iv) track the performance of compost bins supplied by WRAP (Waste & Resources Action Programme) to households over a 16 month period.

Parfitt's (2005) household level models were verified as being a true representation of the data.

New regression models were constructed to better understand the performance of different home composting groups, to test the assumption that diversion factors are not seasonal, and to provide a better fit to the data, particular for garden waste. Diversion factors were produced for three groups of home composting households:

- Non-WRAP home composters – those that home composted without a WRAP bin;
- WRAP Enhanced – those households that composted prior to receiving their WRAP bin;
- WRAP New Recruits - those household that did not home compost prior to receiving their WRAP bin.

Analysis of waste composition and questionnaire data collected in 2004 from nine local authorities produced the following diversion factors (negative values indicate diversion and bold indicates significantly different from zero):

| Waste stream | Non-WRAP HC | WRAP Enhanced | WRAP New Recruits |
|---|---|---|---|
| Residual waste – other compostables | **-24.6** | **-34.2** | **-32.5** |
| Residual waste – garden waste | -22.4 | **-37.4** | -14.7 |
| Garden waste – all compostable | 43.8 | -43.4 | -49.4 |
| **All kerbside waste** | -3.2 | **-115.0** | **-96.6** |

Overall, non-WRAP home composters showed no significant diversion from kerbside collections, although this effect was mainly due to a large positive (but not statistically significant) diversion factor for compostable garden waste cancelling out a large negative (and statistically significant) diversion factor for residual waste. WRAP Enhanced households were estimated to divert a total of 115 kg/hhld/yr, of which around 112 kg/hhld/yr was attributable to the enhanced effect of participating in the WRAP home composting scheme. This diversion factor is much larger than the 40 – 80 kg/hhld/yr estimated by Parfitt (2005) for Enhanced households and to a large degree reflects the fact that the present study has explicitly assessed diversion from separate garden waste collections. Finally, WRAP New Recruits were estimated to divert a total of 97 kg/hhld/yr, which suggests that households new to home composting can achieve levels of diversion comparable to experienced home composters within just six months of participating in the WRAP scheme. This result was considerably lower than the 180-340 kg/hhld/yr estimated by Parfitt (2005) using district-level modelling.

There was no evidence that diversion factors differed between summer and autumn, although the high variability in the data made detecting for such interactions difficult.

Finally, there was only limited evidence that the performance of New Recruits and Enhanced households changed after they had had their WRAP bins for more than a year. There was also no evidence that New Recruits and Enhanced households that bought a WRAP bin later on were any more or less effective in diverting waste than those that bought a bin at the beginning of the scheme.

Since the modelling work was done for this report, further work has been done to update Parfitt's 2005 district-level modelling using more recent data and to include diversion from garden waste collections. The models in the two reports (which are published together) are broadly in line, taking into account underlying factors related to the timing of the research used to produce the data in each case. The models developed in the 2009 district-level analysis are being used to provide the most robust estimates of home composting diversion given that they use data from a larger number of local authorities and from more recent research by Resource Futures (2009). A central estimate of 150 kg/hhld/yr diversion from municipal collection is the main conclusion of these combined pieces of research.

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# 1.0 Introduction

## 1.1 Rationale for project

WRAP (Waste & Resources Action Programme) helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change. Established as a not-for-profit company in 2000, WRAP is backed by government funding from England, Scotland, Wales and Northern Ireland.

The Landfill Directive (1999/31/EC) has set challenging targets for reducing the amount of biodegradable municipal waste (BMW) going to landfill. In the UK the amount of BMW sent to landfill must be reduced to 75%, 50% and 35% of the 1995 baseline value by 2010, 2015 and 2020 respectively. Annual, and in most cases decreasing, allowances for landfilling BMW have been set for Waste Disposal Authorities (WDAs) within the UK under national Landfill Allowance (Trading) Schemes (LATS) (Defra 2006). A significant amount of the BMW collected consists of putrescible kitchen and garden wastes much of which might be composted at home instead and thereby provide a home produced soil improver and fertilizer for the garden. Significant home composting of BMW would make a valuable contribution to achieving local authority BMW landfill targets as less BMW would be collected in the first place. Reducing the amount of BMW collected also has other environmental benefits such as reducing emissions of greenhouse gases from waste collection vehicles.

WRAP has been promoting home composting in partnership with local authorities (LAs) in England and Scotland since 2003 providing a complete service to deliver compost bins to householders and support them while they get the composting habit. More than 1,700,000 compost bins have been supplied so far. The programme is supported by a team of Home Composting Advisers across England and Scotland.

A key question is how much BMW has been and is being diverted from landfill through the promotion of home composting. The current method used by the Environment Agency for estimating the amount BMW sent to landfill is based on the summation of all the municipal solid waste collected by the local authorities and then assuming that this contains 68% BMW in England and 61% BMW in Wales. As home composting removes waste that would otherwise be collected by local authorities and the home composted waste is 100% BMW the current approach does not fully take into account BMW diversion achieved by home composting. A reliable evaluation of the contribution home composting makes to achieving BMW diversion from landfill requires estimation of the amount of BMW home composted and this somehow to be included in the methodology for estimating the amount of BMW landfilled.

Previous research by WRAP on home composting has produced a diversion model for waste diverted from landfill, attributable to home composting (Parfitt 2005). The key explanatory variables that resulted from the regression analysis undertaken were found to be whether home composters were New Recruits or their activity was enhanced while they had already been composting. However, infrastructure (garden and food waste collections) may be seen to compete, at least to some extent, with home composting as a route for dealing with organic wastes, and has been extended since the initial research that went in to the model was conducted. WRAP now want to see, first and foremost, using the data that it already holds, whether it is possible to produce a model for home composting diversion that meets the criteria of simplicity, robustness and conservatism in the level of the diversion estimated and makes room for updating the model in the light of what is known about infrastructure changes.

WRAP has been engaged in a consultation process with national executives in each of the UK administrations, DEFRA and regulatory bodies, as well as local government representatives, relating to the inclusion of home composting in diversion claims under LATS. The outcome of this work in England has been agreement from DEFRA in principle that home composting should be able to contribute to LATS calculations for biodegradable municipal waste. The matter has been left to discussion between WRAP and the Environment Agency to arrive at a diversion figure per home compost bin. WRAP intend that the results of this project should inform those negotiations.

## 1.2 Aims and objectives

The overall purpose of this work was to provide a working model of home composting diversion from LA waste collections in a simple yet robust way, making it possible to estimate diversion per compost bin distributed through WRAP's home composting campaign.

The primary objective was to quantify the amount of waste diverted by home composting per household per year. Two options were sought:

(i) one formula with no more than two explanatory factors for home composting diversion (it was anticipated that this would include the number of bins sold); and
(ii) another formula with a maximum of three explanatory factors, as suggested by the data.

The focus of the project was on estimating diversion due to LA activities, specifically the WRAP home composting campaign carried out in partnership with LAs. Long-term home composters, whose activities pre-date the WRAP home composting scheme (and the 1995 LATS baseline), were of less interest because the waste they compost has effectively never been a part of the municipal waste stream.

This study takes as its starting point WRAP's earlier study on home composting (Parfitt 2005), which used data collected in 2004 to develop models estimating the quantity of BMW diverted from landfill by home composting. In this study we first verify and breakdown the results of Parfitt (2005) and then use additional datasets (observational data, 2005 waste composition and questionnaire data) to update and enhance the original diversion models.

In addition to estimating diversion factors, there were two secondary objectives:

(i) To assess the extent to which the increased availability and use of separate garden waste collections has displaced or complemented home composting activity.
(ii) To profile the current population of home composters, in order to understand what diversion is likely to be achieved in the future if home composting were rolled out to more households.

Following preliminary analysis of the data, it was agreed with the WRAP Project Manager to focus the remaining effort on attempting to improve the precision of the home composting diversion estimates rather than addressing these secondary objectives.

## 1.3 Scope of work

This study considers only kerbside waste collections (residual waste plus separate garden waste collections). No quantitative data was made available by WRAP on waste disposal via Civic Amenity (CA) sites. Waste collected at CA sites represents a significant fraction of total household waste arisings (about 20%, Defra 2006/07 estimates based on WasteDataFlow returns). Specifically, CA sites are likely to be disposal routes for periodic extra loads of garden waste above that collected from kerbside collections, hence at certain times of the year may have particularly high garden waste inputs of relevance to home composting. They may also however attract waste not under the control of the LA, e.g. waste taken to the site by nearby residents from a neighbouring authority which should then not be attributed to the WCA total waste arising. Whilst kerbside collections from households represents about 60% of WCA waste arising, the exclusion of CA sites means that the total waste collected by the WCAs is not available and that the study will not be able to quantity the total waste diversion attributable to home-composting.

Ultimately household diversion factors must be scaled up to estimate the total diversion per WCA/WDA. This calculation takes into account the local participation rate, which may be measured directly by surveying household behaviour, or inferred indirectly from number of home composting bins in use. WRAP already hold this information for all bins supplied via their home composting campaign, combined with knowledge of lapse rates for users of these bins. The present study focuses only on estimating diversion factors per household, not diversion factors per WCA/WDA.

## 1.4 Structure of the report

The remainder of the report is divided into five sections. Section 2 provides background information on home composting in the context of municipal waste management and review previous diversion modelling studies. Section 3 describes the origin, collation and processing of the datasets used in the present study. Section 4 details the statistical approach taken to estimating home composting diversion factors. Section 5 presents the results of the analysis for both residual and garden waste, and considers how the results might be scaled up form weekly to annual figures. Finally, Section 6 draws some general conclusions, makes comparisons with previous studies and considers the adequacy of the models produced.

# 2.0 Background

## 2.1 Home composting in the context of waste management

Municipal Solid Waste (MSW) is the waste collected by local WCAs and comprises mainly waste generated from households combined with some commercial wastes. It includes biodegradable waste materials such as food, garden, wood, paper and textiles, which in this context is Biodegradable Municipal Waste (BMW), and non-biodegradable wastes such as glass, stones, pottery, metal and plastics.

There are two main methods applied by WCAs to collect waste from households (Figure 1). These are kerbside collection using refuse collection vehicles (RCVs) and centralised Civic Amenity (CA) sites where households take their waste. Both kerbside and CA routes may include the collection of specific segregated wastes in different bins or skips. For example garden waste, kitchen waste, paper and card, metals, plastics and glass are often collected separately. Such source segregated wastes may be more easily recycled, treated and recovered. WCAs differ in the range of MSW components that are separately collected from both kerbside and CA sites and not all the components may be collected in particular districts. Households may then still generate a mixed residual waste stream that will contain those materials that are either not separately collected or the householder has not source segregated. The residual waste is then collected as the traditional black bag or black wheelie bin waste from kerbside collection as well as being collected at CA sites.

The "disposal" of the collected MSW is the main responsibility of the WDA although there is usually some cross-over with the WCAs. Waste disposal in this context means the management of the collected waste by a whole variety of means such as landfill, recycling, energy from waste, and treatment by such means as composting, mechanical biological treatment and anaerobic digestion. Unitary local authorities may have both the WCA and WDA roles whilst in two-tier local government the WCA role is usually the lower tier district or borough council and the WDA the higher tier county council.

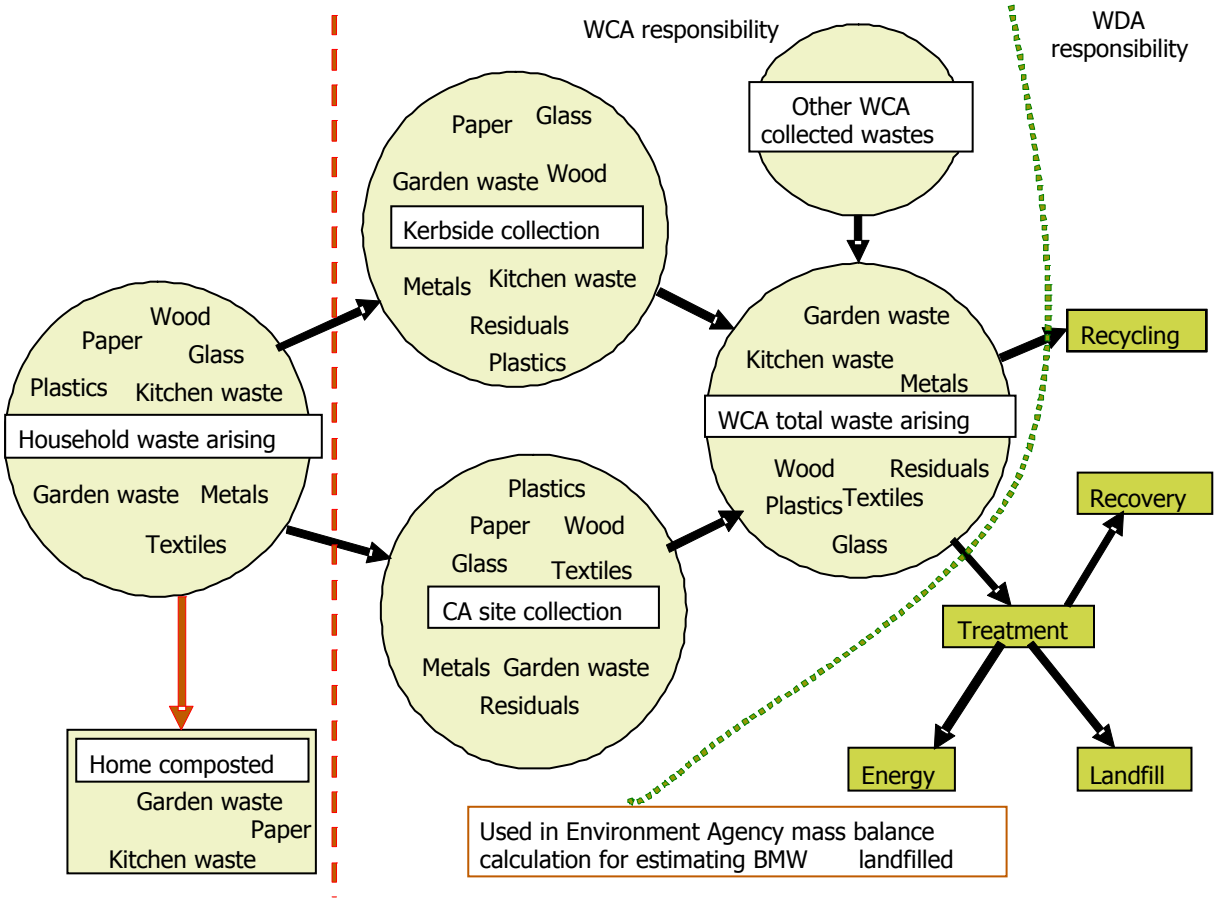
The Landfill Directive (1999/31/EC) has set challenging targets for reducing the amount of BMW going to landfill. In the UK the amount of BMW sent to landfill must be reduced to 75%, 50% and 35% of the 1995 baseline value by 2010, 2015 and 2020 respectively. Annual, and in most cases, decreasing allowances for landfilling BMW have been set for WDAs within the UK under LATS (Defra 2006). The landfilling of BMW by WDAs is regulated and monitored by the Environment Agency and the calculation of the amount of BMW is a mass balance approach based on estimating the total amount of BMW arising and then subtracting the amounts of BMW that are diverted from landfill, e.g. by recycling of paper and the composting of garden waste. The calculation of the total amount of BMW arising is from the summation of all the kerbside and CA collected wastes and assuming that this contains 68% BMW in England and 61% in Wales. A simplified mass balance equation for estimating BMW landfilled in England is therefore.

BMW landfilled = (Total MSW collected by WCA x 68/100) - BMW removed by recycling and treatment

A key feature of this calculation is that it only considers the waste collected by the WCAs as the starting point for estimating the initial BMW arisings. Home composting is a means of treating some of the BMW (particularly garden and kitchen waste) and the promotion and expansion of home composting would be expected to reduce the total amount of MSW (and BMW) collected by a WCA and therefore contribute to reducing the amount of BMW ultimately landfilled. Home composting falls outside the current Environment Agency mass balance because the BMW home compost is not collected by the WCA (Figure 1). Consequently the current mass balance calculation (based on the total mass of waste collected and the assumption that the total waste collected is 68% BMW) under-estimates the BMW reduction achieved by the expansion of home composting. That is for every tonne of additional BMW home composted there would be one tonne less of total waste collected, but according to the current method this would be only a reduction of 0.68 tonnes BMW for the calculation of BMW landfilled.

It is important therefore to understand the effectiveness of home composting, especially that from additional home composting resulting from post 1995 (including WRAP's) promotion of home composting, as any increase in BMW treated by this means would contribute to achieving the UK BMW landfill targets. Additionally it would be important to evaluate what this contribution is in order that the contribution would be fully included in the calculation of BMW landfilled. Consequently the cost benefit of continuing to maintain the promotion of home composting and this contribution compared with other waste management options.

**Figure 1** Sources, pathways and disposal routes of Municipal Solid Waste




## 2.2 Review of Parfitt (2005) home composting diversion models

The effectiveness of home composting in diverting BMW from landfill is measured using a diversion factor, typically expressed in kg per participating household per year (kg/hhld/year). The diversion factor currently used by WRAP is based upon a study by Julian Parfitt (2005), the details of which are reviewed briefly below.

### *2.2.1 Overview of Parfitt (2005)*

Parfitt (2005) describes an evaluation of 2004 home composting data with the development of modelled factors to describe the amount of BMW diverted from landfill by home composting under several different modelling scenarios. The model output units are kg BMW diverted from landfill per participating household per year.

The paper also speculates on how the model outputs may be incorporated in the estimation of BMW landfilled for LATS purposes which is a primary issue for deriving a cost benefit for the continued promotion of home composting by local authorities. This aspect is not considered further here.

Parfitt (2005) used multiple regression analysis to model residual waste arisings as a function of a large number of independent variables. The independent variables used were very comprehensive and derived from household, district and national consensus sources and included data on home composting, household residents, house type, house ownership, garden size, kerbside and CA site collection details. Crucially, the study adopted a two-level approach to diversion modelling:

1. A **district-level approach** - this focused on waste collected at the scale of Waste Collection Authorities (WCAs) and modelled variations in waste arisings as a function of home composting

participation and relevant characteristics such as average household size, garden size, census variables and a range of waste management variables.

2. A **household-level approach** – this involved the collection and analysis of data linked to individual households, their behaviour (questionnaire data), their waste (waste composition analysis) and other relevant factors such as garden size and garden use (through a combination of observational study and GIS). Diversion estimates were derived by comparing waste arisings from similar composting and non-composting households.

Before reviewing the results of the study, it is important to acknowledge the pros and cons of these contrasting but complementary approaches. District-level models, by averaging together the activities of thousands of individual households, provide a space and time-integrated measure of waste arisings in an area, and take into account both municipal waste collected via kerbside collections and that collected via civic amenity sites. The downsides of modelling with this type of data are: it can be difficult to link variation in waste arisings to specific patterns of home-composting behaviour; the tonnage data is susceptible to different reporting regimes among local authorities (particularly in relation to the split between household and non-household municipal waste; and there will be reporting errors that add noise to the data.

By contrast, household-level data is extremely noisy (i.e., the quantity of waste produced is highly variable from household to household and from week to week) and typically only a small proportion of this variation can be explained by the known characteristics of the household. For this reason it is likely that any estimated diversion factors will have wide confidence intervals (i.e., it will be difficult to say with confidence what the true diversion factor is). In the case of garden waste, it may not even be possible to produce a valid diversion factor, unless it is possible to predict accurately the garden waste arisings of each household. A second disadvantage is that it is difficult to measure diversion of waste from civic amenity sites, in that it is difficult to establish patterns of civic amenity site use by households and therefore attribute activities at civic amenity sites to particular households unless direct observational data has been collected; for this reason, household level models tend to focus on kerbside collections of residual and garden waste. On the plus side, household-level models have a much finer spatial and temporal resolution so it is easier to draw direct cause-and-effect relationships between waste arisings and home composting activity, and even to distinguish between different categories of home-composter.

In adopting a dual approach, Parfitt (2005) constrained the district-level and household-level models to have similar independent variables. The household-level models were therefore designed to provide a cross-comparison with the district-level models and did not necessarily include all possible independent variables (Julian Parfitt, *pers. comm.*).

### *2.2.2 Household-level models*

The household-level models used questionnaire and waste composition data to define the following overlapping categories of household:

- Experienced home composters - those who have more than one years experience home composting (includes WRAP Enhanced and non-WRAP composters).
- Inexperienced home composters - those who have less than one years experience home composting (includes non-composters).
- WRAP Enhanced home composters – those who have home composted for more than a year but who have taken a WRAP promoted bin in the last six months.
- Non-WRAP home composters - those who have home composted for more than a year but who have not taken a WRAP promoted bin in the last six months.
- Non-composters – includes lapsed households that have stopped home composting and households that have never home composted.

New Recruits – households that had recently taken up home composting with a WRAP bin – were not explicitly addressed in the household-level modelling and were excluded from Models 2 and 3 because it was assumed that they bought their WRAP bins too recently for them to be home composting effectively at the time the waste composition survey was conducted.

The conceptual model behind these sub-categories is that households may comprise either existing home composters or non-home composters. The WRAP promotion of home composting may convert some non-home composters into New Recruit home composters which after 1 year become experienced home composters. The WRAP promotion may also by uptake of bins upgrade an existing home composter to an 'Enhanced' home composter. Lapsed home composters are a reduction in the number of home composters.

The independent variables included in the final household-level models included:

- Total garden area;
- Household size (number of occupants);
- Number of dry recyclable materials collected by separate kerbside collection;
- Use of separate kerbside garden waste collection; and
- Residual waste container (wheeled bin or sack).

Confidence intervals were not reported for estimated diversion factors, although it was noted that there were significant uncertainties in some of the statistical models. The 95% confidence intervals have been re-constructed using the information provide in Appendix 3 of Parfitt (2005).

Models 1 to 3 were based on household models and the statistics of kerbside RCV residual waste collection. Model 1 considered total RCV residual waste and compared experienced with inexperienced home composters to derive a value of 87 (95% confidence interval = 42 to 132) kg diverted per household per year. Models 2 and 3 were based on only the kitchen waste component of the RCV residual waste households. Model 2 found a difference of 42 (95% CI = 20 to 64) kg per household per year between WRAP Enhanced home composters and non-composters, whilst Model 3 found a difference of 24 (95% CI = 2 to 48) kg per household per year between non-WRAP home composters and non-composters. The difference between Models 2 and 3 of 18kg therefore provides an estimate of the additional diversion achieved by Enhanced households after they bought their WRAP bin.

It was not possible to develop meaningful models for garden waste due to the much larger degree of random variation in the garden waste recorded in the waste analysis samples (Parfitt 2005, p. 41).

### *2.2.3 District-level models*

Models 4 to 6 were based on district level models again on RCV residual waste. Model 4 included all the data and derived a value of 115 kg BMW diverted per household per year which is comparable with the value from Model 1. Models 5 and 6 investigated the impact of garden size where, as expected, the results suggested that households with gardens of <200 $m^2$ diverted less than those with gardens >200 $m^2$.

Models 7 to 9 were the same as Models 4 to 6 except that both kerbside RCV and CA site residual waste was considered. The modelling when CA site residuals was included resulted in about a doubling of the kg BMW diverted per household per year. This is perhaps one of the most interesting findings as CA sites represent about 25% of the household waste collected. As Parfitt (2005, p. 41) notes, studies that focus just on RCV diversion caused by home composting activity are therefore likely to produce significantly lower diversion estimates.

### *2.2.4 Final diversion factors*

The paper presents an estimation of the total amount of BMW diverted from landfill resulting from the WRAP Phase 1 promotion of home composting. The derivation of the estimate is not absolutely clear as it included some extrapolation from the models presented.

The average diversion achieved by Enhanced existing home composting households was estimated from the household-level models. Because it was not possible to develop meaningful models for garden waste, it was assumed that households in districts with small average garden sizes would divert an additional 20 kg of garden waste per household per year, and that households in districts with larger average garden sizes would divert an additional 60 kg of garden waste per household per year (Parfitt 2005, p. 50). Adding these figures to the ca. 20 kg of kitchen waste diverted by Enhanced households (Models 2 and 3) gave a total diversion of between 40 and 80 kg per household per year.

By contrast, the average diversion achieved by New Recruits was estimated from the district-level models (specifically Models 8 and 9, which gave diversion factors of 340 kg and 180 kg per household per year for households with large and small gardens, respectively).

Finally, Parfitt (2005) took into account the proportion of new and Enhanced home composters to arrive at an overall diversion factor of 170 kg per year for every household that bought a WRAP bin. Clearly this result was

influenced heavily by the higher values of diversion for New Recruits. Whilst this may represent the short term benefit of home composting bin promotion it is equally important to understand the long term benefit. In the long term it might be argued that the number of home composters would become saturated and that the number of New Recruits would simply balance the number of lapsed home composters. Therefore the weighting of home composters would be more towards composters with more than 1 years experience and the cost benefit of continued promotion of home composting might be significantly different to that estimated for the initial Phase 1 promotion. Subsequent research by WRAP has attempted to address this issue by establishing the types of participation in different area types across England and Scotland, and modelling work undertaken by WRAP for Defra's LAWRRD model incorporated assumptions about the likely saturation levels and diversion effectiveness of future home composting (J. Parfitt, *pers. comm.*).

Follow-up work based on analysis of WRAP bin New Recruits in their second year of home composting established diversion factors similar to the experienced home composting households (WRAP 2008). This implies that separation of the initial first year New Recruit effect is important for estimating long-term cost benefit of home composting promotion.

# 3.0 Data sources for diversion models

## 3.1 Introduction

Three sources of data were used to model home composting diversion factors:

- Questionnaire and waste composition data from a 2004 study (HOM5-007) conducted for WRAP by Network Recycling (hereafter referred to as the '2004 dataset').
- Questionnaire and waste composition data from a 2005 study (DV53041/ADR) conducted for WRAP by Hyder and MEL (hereafter referred to as the '2005 dataset').
- Observational data on garden size and garden use collected in 2004.

Details of the survey design and data collection are given in Parfitt (2005) and Hyder (2006). Importantly, the 2004 and 2005 studies focused on 'intensive pilot areas' – discrete areas of between 800 and 1500 households within nine local authorities that equated with RCV round-days. The intention was to estimate diversion using a case-control approach by collecting operational data from the RCV rounds in the intensive pilot areas and comparing the results with nearby control areas. (Unfortunately, the case-control approach did not produce a viable means for assessing home composting diversion and had to be abandoned.) The intensive pilot areas were selected by WRAP so as to ensure that across the study there was a sufficient range of neighbourhood types to permit effective modelling, taking into account some of the known influences on both kitchen and garden waste arisings, such as the type of residual waste containment (black sack or wheeled bin), whether or not a garden/kitchen waste kerbside scheme was in operation and the extent to which dry recyclables were collected by kerbside schemes. Thus, the households within the intensive pilot areas were not selected to provide a representative sample from the wider, national population. This could lead to a biased assessment of the diversion due to home composting at a national scale, except that the modelling approach adopted by Parfitt (2005) and by the present study specifically accounts for the variation in household characteristics and produces a generic diversion factor that is applicable to all nine intensive pilot areas.

The 2004 questionnaire, waste composition and observational datasets were previously analysed in the Parfitt (2005) study of home composting diversion models; the key findings are summarised in Section 2.2.

The following sections describe how the three datasets were collated, processed and cleaned prior to analysis.

## 3.2 2004 dataset

### *3.2.1 Overview*

Network Recycling was appointed by WRAP in 2004 to undertake compositional analysis and questionnaire surveys in nine of the LA areas which participated in Phase 1 of the Home Composting Scheme. The local authorities involved and the types and frequencies of waste collection they offered are shown in Table 1. The compositional analysis focused on residual and garden waste kerbside collections, but did not include dry recyclables set out by householders for kerbside collection nor wastes taken by households to civic amenity sites or other bring facilities.

**Table 1** Summary of Local Authority waste collection schemes in 2004

| Local Authority | Waste container | Waste collection frequency | Garden waste container | Garden waste collection frequency | Garden waste materials | Dry recycling collection frequency | Dry recycling materials |
|---|---|---|---|---|---|---|---|
| Christchurch | sack | weekly | charged sack | weekly | garden | fortnightly | paper, glass, cans |
| Enfield | sack | weekly | box | weekly | garden, kitchen | weekly | paper, card, plastic bottles/bags, cans, textiles, foil |
| Fareham | wheeled bin | weekly | N/A | N/A | N/A | fortnightly | plastic, cans, paper, card |
| Great Yarmouth | sack | weekly | N/A | N/A | N/A | N/A | N/A |
| Halton | wheeled bin | weekly | wheeled bin | fortnightly | garden | fortnightly | paper, glass |
| Lancashire | wheeled bin | fortnightly | wheeled bin | fortnightly | garden | fortnightly | Plastic bottles, glass, cans, foil, paper |
| North Lincolnshire | wheeled bin | weekly | N/A | N/A | N/A | ? | paper |
| Wigan | wheeled bin | weekly | N/A | N/A | N/A | fortnightly | paper |
| Wiltshire | sack | weekly | N/A | N/A | N/A | fortnightly | paper |

N/A = not applicable

Data from the waste composition survey was linked to the questionnaire responses using a unique ID number for each household.

A total of 1207 households presented waste for the composition analysis (Table 2). The households were not a random or representative selection of the population as in each LA waste was "collected from between 60-90 households that had received a WRAP compost bin" (Parfitt, 2005) with additional samples from other households used to bring the total number of samples in each area to around 200. However, many samples were discarded as problems on the day of collection meant they could not be reliably linked to addresses (*ibid.*). This did not compromise the analysis since the goal was to estimate diversion factors by comparing home composting and non-home composting households that are alike in all other respects (rather than by simply comparing all composting households with all non-composting households).

Some of the households that presented waste did not complete a questionnaire, leaving 875 households that had both waste composition and questionnaire data (Table 2).

**Table 2** Number of households participating in 2004 study

| Local Authority | No. of households presenting waste for composition analysis | No. of households in questionnaire survey | No. of households presenting waste and completing questionnaire |
|---|---|---|---|
| Christchurch | 86 | 336 | 60 |
| Enfield | 144 | 348 | 105 |
| Fareham | 139 | 308 | 102 |
| Great Yarmouth | 143 | 302 | 92 |
| Halton | 183 | 332 | 141 |
| Lancashire | 155 | 293 | 114 |
| North Lincolnshire | 123 | 338 | 86 |
| Wigan | 118 | 328 | 88 |
| Wiltshire | 116 | 345 | 87 |
| **Total** | **1207** | **2930** | **875** |

### *3.2.2 Waste composition data*

The following summary of the waste composition analysis methodology is taken from Parfitt (2005): "Waste analysis was conducted on kerbside residual and garden/kitchen waste collected from a sample of home composting and non-home composting households within the nine intensive pilot areas. Waste analysis samples were collected over two time periods to cover an element of seasonal variation in source material. Phase One was conducted between 14 June and 9 July 2004. During Phase Two (13 September and 10 October 2004) the same households were repeat sampled."

The raw waste composition data was supplied to WRc by the WRAP project manager as an Excel spreadsheet. In total, samples of residual waste were collected from 1207 households in both June and September and samples of garden waste were collected from 197 households in June and 150 households in September (Table 3). Figures for local authorities with fortnightly collections were halved so that all the data was expressed as kg per household per week.

Waste samples from each household were hand sorted into the categories shown in Table 4. Figures 2 and 3 show the average composition of the residual waste and garden waste samples for June and September 2004 across the nine local authorities included in the study.

**Table 3** Number of households presenting each type of waste in 2004

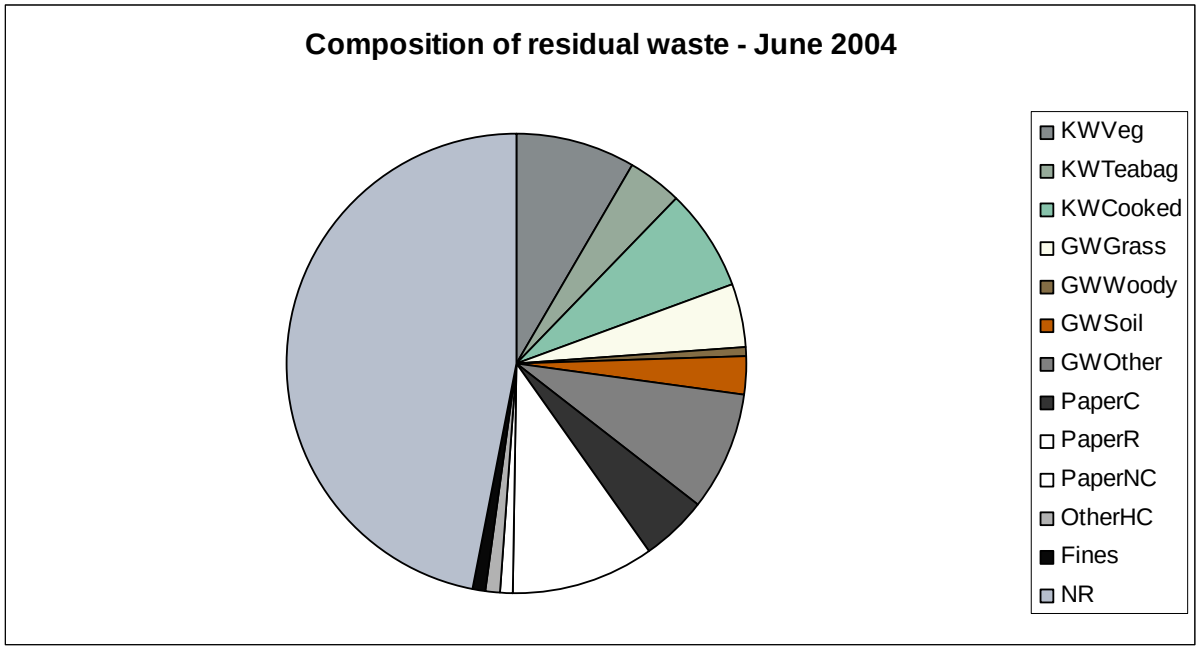
| Local Authority | Total no. of households presenting residual waste - June | Total no. of households presenting residual waste – September | Total no. of households presenting garden waste – June | Total no. of households presenting garden waste – September |
|---|---|---|---|---|
| Christchurch | 86 | 86 | 11 | 7 |
| Enfield | 144 | 144 | 61 | 45 |
| Fareham | 139 | 139 | N/A | N/A |
| Great Yarmouth | 143 | 143 | N/A | N/A |
| Halton | 183 | 183 | 43 | 55 |
| Lancashire | 155 | 155 | 82 | 43 |
| North Lincolnshire | 123 | 123 | N/A | N/A |
| Wigan | 118 | 118 | N/A | N/A |
| Wiltshire | 116 | 116 | N/A | N/A |
| **Total** | **1207** | **1207** | **197** | **150** |

N/A = not applicable

**Table 4** Classification of residual and garden waste types

| Category | Type | Abbreviation |
|---|---|---|
| Kitchen waste | Vegetable peel, fruit scraps | KWVeg |
| | Teabags, tea leaves, coffee, egg shell, bread - | KWTeabag |
| | Cooked food, meat, dairy products, fish, bones and pastries | KWCooked |
| Garden waste | Grass cuttings | GWGrass |
| | Woody garden waste stem diameter greater than 5mm and woody | GWWoody |
| | Soil | GWSoil |
| | Other organic garden waste e.g. plants, flowers, leaves- | GWOther |
| Paper and card | Compostable, non-recyclable: kitchen roll, tissues, KLS, egg boxes, toilet roll tubes, greased paper | PaperC |
| | Recyclable: newspapers and magazines, office paper, paper bags, glossy paper, envelopes, glossy card e.g. cereal packets | PaperR |
| | Non-Compostable, non-recyclable: plastic costed or laminated paper and card, foil type gift wrap, waxed paper or card | PaperNC |
| Other home compostables | Straw, hay, wood-chips, sawdust, feathers | OtherHC |
| Fines | Fine materials (excluding grass cuttings) | Fines |
| Non-requested materials | All other waste not included in one of the above categories | NR |

**Figure 2** Composition of kerbside residual waste collections in June and September 2004. See Table 4 for key to abbreviations.



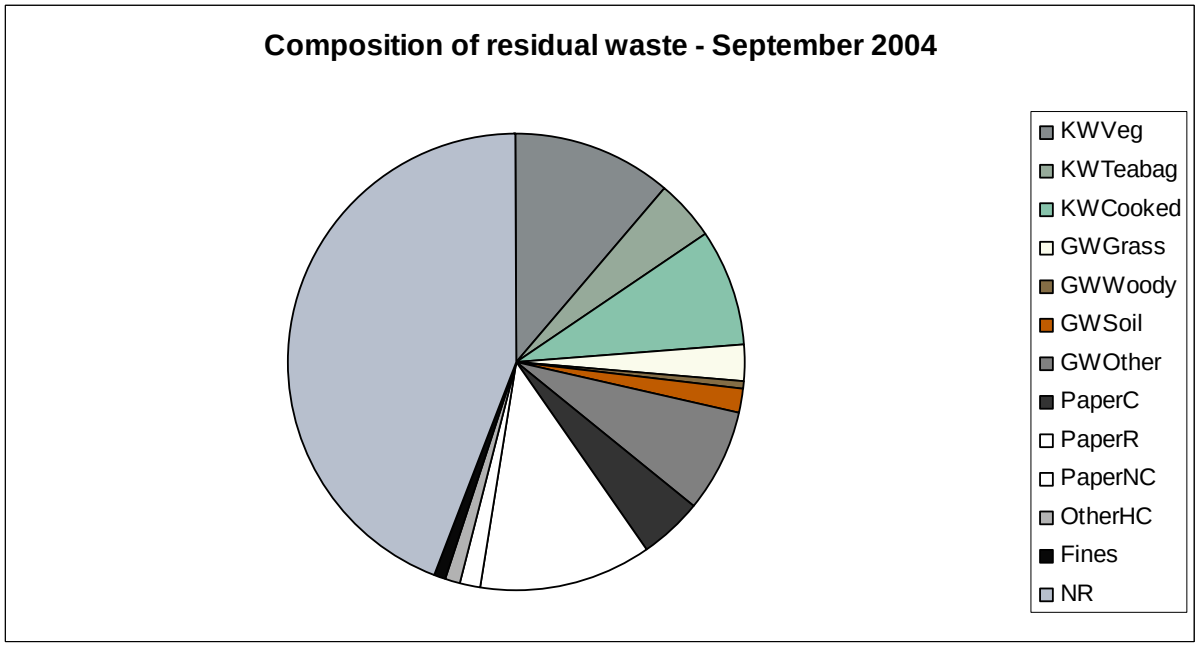
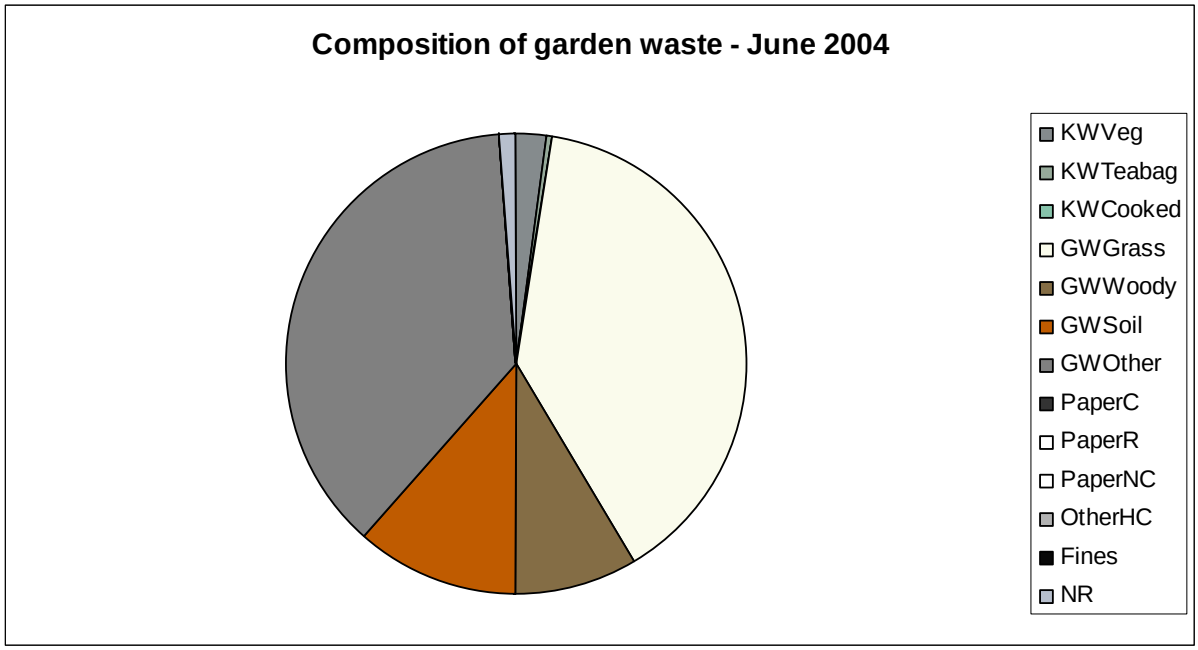
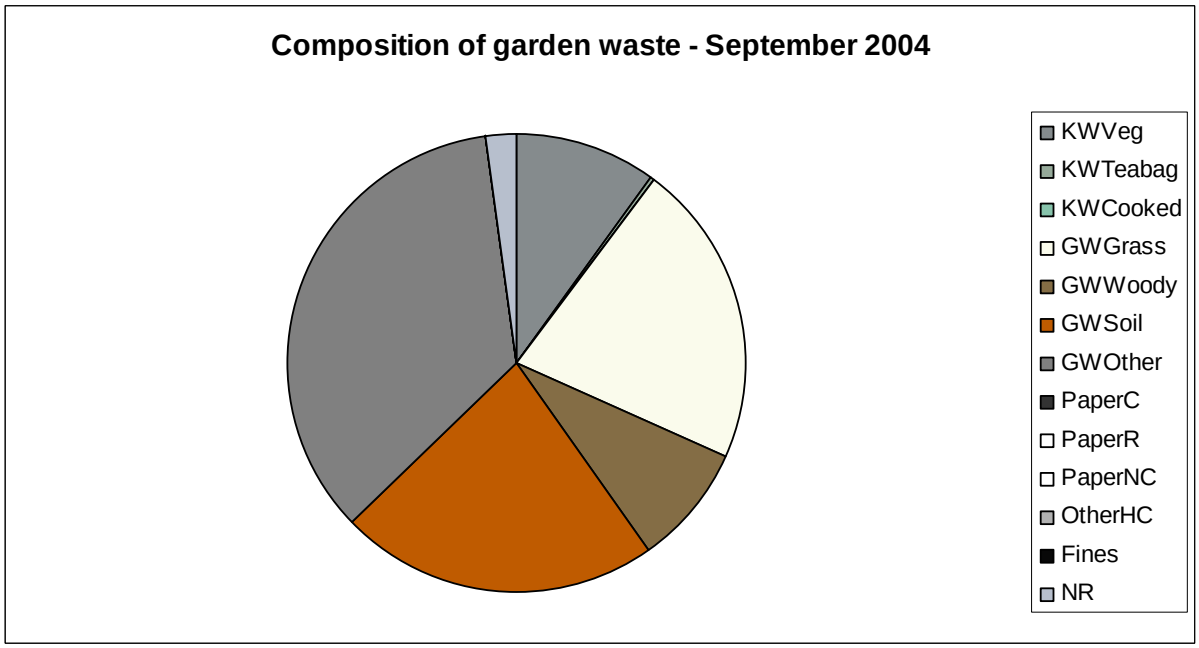



**Figure 3** Composition of kerbside garden waste collections in June and September 2004. See Table 4 for key to abbreviations.




### *3.2.3 Questionnaire survey*

The following summary of the waste composition analysis methodology is taken from Parfitt (2005): "Household surveys covering attitudinal and behavioural aspects of home composting were conducted … in order to assess participation and identify underlying factors in behaviour observed. The questionnaire survey was conducted immediately after the second wave of the waste sampling, so as to eliminate any modified waste behaviour post-interview biasing what households set out for collection during the sampling week". Surveys were carried out with households that had presented waste for analysis but also in additional areas using the same sampling strategy as used to select households for waste analysis. The surveys were completed between 7 September and 21 October 2004 by means of face-to-face interviewing.

In total, 2,930 interviews were completed across the nine LAs (Table 2). The survey questions used in the analysis are listed in Table 4. In some cases, responses were re-coded to simplify their interpretation.

**Table 4** Coding of 2004 questionnaire responses

| Variable Name | Question(s) | Levels |
|---|---|---|
| CompYN | Q1. Has your household composted at home in the last 12 months? | 1 = Y<br>2 = N |
| BinType | Q2. What sort of container do you use for home composting? | 1 = WRAPBin<br>2-8 = NonWRAPBin |
| Previous | Q7. Before you got your new bin what did you usually do with waste that you now compost at home? | 1 = Residual<br>2 = HomeCompost<br>5 = GW<br>3-4,6-13 = Other |
| CompostGardenWYN | Do you compost garden waste? (amended version of Q10). | 1-8 = Y<br>9 = N |
| CompostKitchenWYN | Do you compost kitchen waste? (amended version of Q11). | 1-3 = Y<br>4 = N |
| CompostPaperYN | Do you compost paper? (amended from Q16) | 1-2 = Y<br>3-5 = N |
| CompostBeddingYN | Do you compost pet bedding? (amended from Q16) | 3 = Y<br>1-2,4-5 = N |
| CompostOtherYN | Do you compost any other materials? (amended from Q16) | 4 = Y<br>1-3,5 = N |
| WhyNot | Q24. Is there any particular reason why your household does not compost waste at home? | 10 = Residual<br>11 = GWColln<br>12 = CASite<br>1-9,13-24 = Other |
| OtherGardenW | Q26. What do you usually do with garden waste that you currently do not compost at home? | 1 = Residual<br>2-3 = CASite<br>4 = GWColln<br>11 = None<br>12 = CompostAll<br>5-10,13-15 = Other |
| GWColln | Q31. Do you use your council's garden waste collection? | 1 = Y<br>2 = N |
| OtherKW | Q34. What do you usually do with home compostable kitchen waste that you currently do not compost at home? | 1 = Residual<br>2 = GWColln<br>7 = CompostAll<br>3-6,8 = Other |
| NinH | Q35. How many people are there in your household? | Count |
| Age | Q36. How many people are there in each of the age groups? | Oldest category (01 = 0-4 up to 08 = over 65) |
| Tenant | Q37. Do you own your house or are you renting? | 1 = Owner<br>2 = Tenant |
| House | Record housing type | 1 = Detached<br>2 = Semi<br>3 = Terraced<br>4 = Bungalow<br>5 = Flat<br>6 = Other |

## 3.3 2005 dataset

### *3.3.1 Overview*

A study similar to that in 2004 was undertaken in 2005 by Hyder Consulting and MEL Research, in the same nine LA areas. Table 5 summarises the collection characteristics of each LA in 2005.

**Table 5** Summary of Local Authority waste collection schemes in 2005

| Local Authority | Waste container | Waste collection frequency | Garden waste container | Garden waste collection frequency | Garden waste materials | Dry recycling collection frequency | Dry recycling materials |
|---|---|---|---|---|---|---|---|
| Christchurch | Sack | Weekly | Charged sack | Weekly | Garden | Fortnightly | Paper, glass, cans |
| Enfield | Sack | Weekly | Box | Weekly | Garden and kitchen | Weekly | Paper, card, plastic bottles/bags, cans |
| Fareham | Wheeled bin | Fortnightly | Wheeled bin | Fortnightly | Garden | Fortnightly | Paper, cans, glass, plastic bottles, foil |
| Great Yarmouth | Wheeled bin | Fortnightly | N/A | N/A | N/A | Fortnightly | Paper, card, plastic bottles, cans |
| Halton | Wheeled bin | Weekly | Wheeled bin | Fortnightly | Garden, cardboard | Fortnightly | Paper |
| Lancashire | Wheeled bin | Fortnightly | Wheeled bin | Fortnightly | Garden | Fortnightly | Paper, cans, glass, plastic bottles, foil |
| North Lincolnshire | Wheeled bin | Weekly | N/A | N/A | N/A | Fortnightly | Paper |
| Wigan | Wheeled bin | Weekly | Wheeled bin | Fortnightly | Garden, cardboard | Fortnightly | Paper |
| Wiltshire | Sack | Weekly | Charged bin | Fortnightly | Garden | Fortnightly | Paper |

N/A = not applicable

A total of 1248 households presented waste for the waste composition analysis survey (Table 2). These households did not appear to be a random or representative selection of the population of households in each LA; the Hyder report (2006) states that: "Households selected for sampling came from a list of properties held by WRAP of households that had purchased a home compost bin, whilst additional non-participating households were taken from the same streets to ensure consistency in data and socio-economic detail". As with the 2004 data, this did not compromise the analysis because the aim was to estimate diversion factors by comparing home composting and non-home composting households that are alike in all other respects.

Waste composition data was linked to the corresponding questionnaire data using the same household unique ID number as used in 2004. Of the 1248 households that presented waste, 376 did not complete the questionnaire, presumably because the householder was not available to complete the interview or because the householder declined to be interviewed. These households were omitted from the analysis, giving a total of 872 households that presented waste and completed the questionnaire (Table 6). The omission of these households will not affect validity of the results if it can be assumed that participation in the questionnaire survey was not related to the household's waste behaviour.

**Table 6** Number of households participating in 2005 study

| Local Authority | No. of households presenting waste for composition analysis | No. of households completing questionnaire survey | No. of households presenting waste AND completing questionnaire |
|---|---|---|---|
| Christchurch | 125 | 196 | 94 |
| Enfield | 125 | 173 | 85 |
| Fareham | 172 | 196 | 128 |
| Great Yarmouth | 132 | 172 | 92 |
| Halton | 187 | 201 | 135 |
| Lancashire | 130 | 192 | 90 |
| North Lincolnshire | 117 | 188 | 79 |
| Wigan | 119 | 154 | 73 |
| Wiltshire | 141 | 194 | 96 |
| **Total** | **1248** | **1666** | **872** |

### *3.3.2 Waste composition survey*

The following summary of the waste composition analysis methodology is taken from Hyder (2006): "The composition analysis was carried out by twelve teams over a four-week period during September and October 2005. Residual and garden waste was collected from individual households by the waste analysis team operating in advance of the LA's normal collection round, so as to avoid missing waste presented at the kerbside and limiting the survey sample. Once collected the sampled waste was taken to an analysis area (typically located at the LA's waste transfer station) for analysis."

In total, samples of residual waste were collected from 1,188 households and samples of garden waste from 371 households (Table 7). Figures for local authorities with fortnightly collections were halved so that all the data was expressed as kg per household per week (kg/hhld/wk).

Lancashire was recorded as offering a fortnightly garden waste collection in 2005, but none of the 130 households presenting residual waste that week put out garden waste for collection.

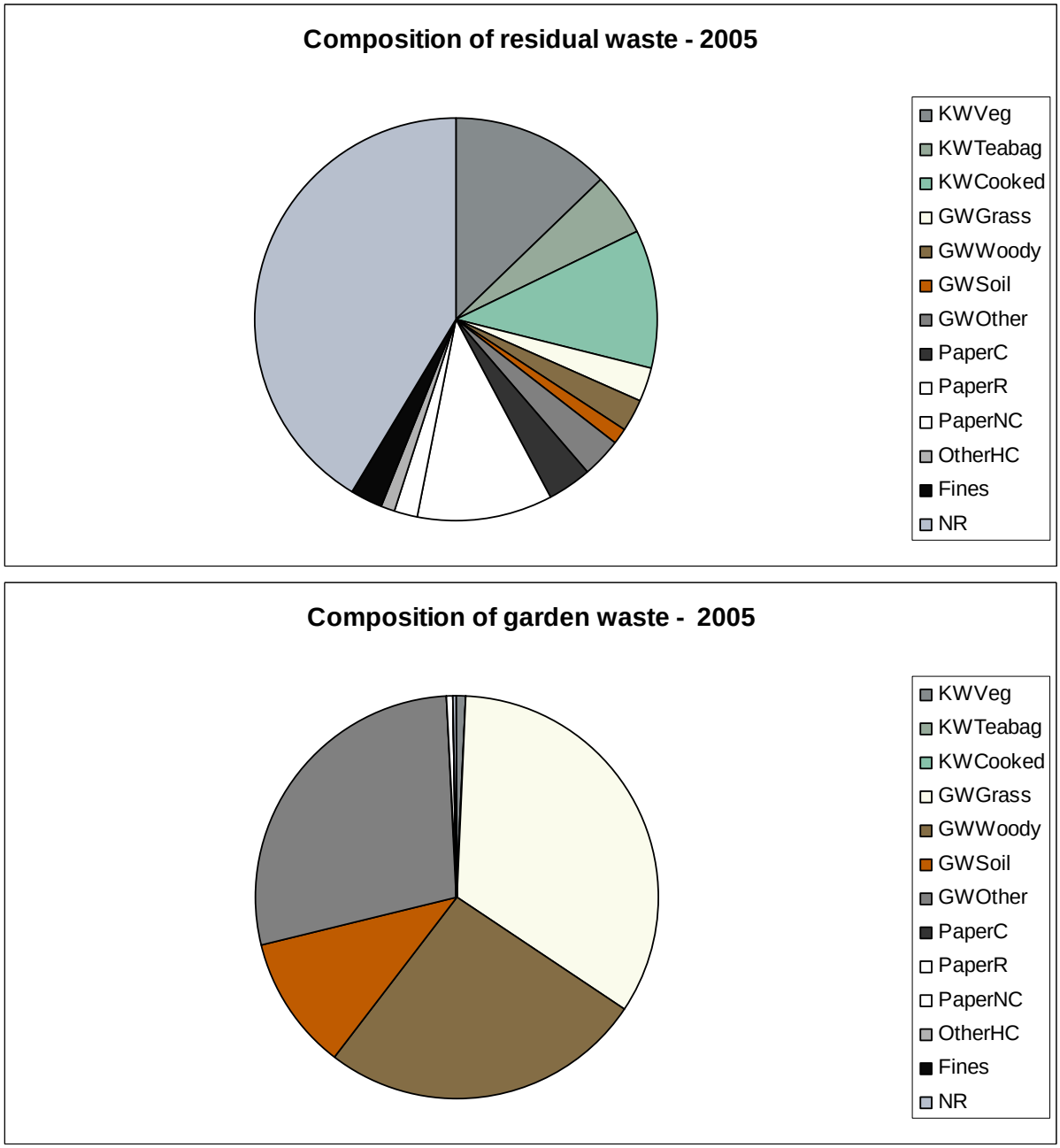
Waste was again divided into the 13 categories shown in Table 4. Figure 4 shows the average composition of the residual waste and garden waste samples respectively across all nine local authorities.

**Table 7** Number of households presenting each type of waste

| Local Authority | Total no. of households presenting residual waste | Total no. of households presenting garden waste |
|---|---|---|
| Christchurch | 125 | 12 |
| Enfield | 118 | 56 |
| Fareham | 172 | 100 |
| Great Yarmouth | 132 | N/A |
| Halton | 152 | 123 |
| Lancashire | 130 | 0 |
| North Lincolnshire | 117 | N/A |
| Wigan | 101 | 74 |
| Wiltshire | 141 | 6 |
| **Total** | **1188** | **371** |

N/A = not applicable

**Figure 4** Composition of kerbside residual and garden waste collections in September 2005. See Table 4 for key to abbreviations.




### *3.3.3 Questionnaire survey*

A follow-up questionnaire survey was undertaken in October and November 2005, a month after the waste composition survey. Face-to-face interviews on the household doorstep were undertaken using two teams of three surveyors. Questionnaire surveying was undertaken at a range of times during the day and evening in order to interview a broad spectrum of respondents and to ensure that a sufficient number of households were interviewed in each authority. For instance, the elderly were likely to be at home for most of the day whereas young couples or families were most accessible during the evening.

Although the questionnaire survey was intended to target those households for which a waste composition analysis had been undertaken, questionnaires were completed by over 1600 households. Only those 872 households that could be linked to a household that participated in the waste composition survey were included in the analysis (see Section 3.3.1).

The survey questions used in the analysis are listed in Table 8. In some cases, responses were re-coded to simplify their interpretation. Responses for some households were found to be either incomplete or to contain inconsistencies. For example, 14 households stated in question four that they had not composted any waste at home in the last 12 months, yet went on to answer question five and identify the type of container used for home composting. Inconsistent responses were generally resolved by taking the first response to be the correct answer whereas incomplete records were left blank.

## 3.4 Observational data

The size of a household's garden and the type of land use within it are potentially important in determining composting behaviour and the level of garden waste production. Garden sizes of households that participated in the 2004 study were measured by WRAP using a Geographical Information System (GIS) based on Ordnance Survey Master Map.

In addition, observational data was collected in September/October 2004 on how households used their gardens (front and back), the location, number and use of compost bins, as well as data on total home composting capacity. Specifically, land use was characterised by estimating to the nearest 5% the percentage given over to flowerbeds, lawn, vegetable patch, hard standing, built structures, and hedges/shrubs. For the modelling work, the total garden area was multiplied by the coverage of each land use to give the area of each land use in $m^2$. No observational data was available for 2005; it was therefore assumed that land use was unchanged from 2004.

Observations were also made of the type and number of compost bins, and the variety of waste types in the bins. This information was used in Parfitt (2005) to validate and refine the classification of households (see Section 4.2) and was not considered further in the present study.

**Table 8** Coding of 2005 questionnaire responses

| Variable Name | Question(s) | Levels |
|---|---|---|
| CompYN | Q4. Has your household composted at home in the last 12 months? | 1 = Y<br>2 = N |
| BinType | Q5. What sort of container do you use for home composting? | 1 = WRAPBin<br>2-8 = NonWRAPBin |
| Previous | Q9. Before you got your new bin what did you usually do with waste that you now compost at home? | 1 = Residual<br>2 = HomeCompost<br>5 = GW<br>3-4,6-14 = Other |
| CompostGardenWYN | Do you compost garden waste? (amended version of Q17). | 1-8 = Y<br>9 = N |
| CompostKitchenWYN | Do you compost kitchen waste? (amended version of Q18). | 1-2 = Y<br>3 = N |
| CompostPaperYN | Do you compost paper? (amended from Q25) | 1-2 = Y<br>3-5 = N |
| CompostBeddingYN | Do you compost pet bedding? (amended from Q25) | 3 = Y<br>1-2,4-5 = N |
| CompostOtherYN | Do you compost any other materials? (amended from Q25) | 4 = Y<br>1-3,5 = N |
| WhyNot | Q33. Is there any particular reason why your household does not compost waste at home? | 10 = Residual<br>11 = GWColln<br>12 = CASite<br>1-9,13-19 = Other |
| OtherGardenW | Q37. What do you usually do with garden waste that you currently do not compost at home? | 1 = Residual<br>2-3 = CASite<br>4 = GWColln<br>12 = None<br>13 = CompostAll<br>5-11,14 = Other |
| GWColln | Q40. Do you use your council's garden waste collection? | 1 = Y<br>2 = N |
| OtherKW | Q42. What do you usually do with home compostable kitchen waste that you currently do not compost at home? | 1 = Residual<br>2 = GWColln<br>7 = CompostAll<br>3-6,8 = Other |
| NinH | Q44. How many people are there in your household? | Count |
| Age | Q45. How many people are there in each of the age groups? | Oldest category (01 = 0-4 up to 08 = over 65) |
| Tenant | Q46. Do you own your house or are you renting? | 1 = Owner<br>2 = Tenant<br>3 = Other |
| House | Q47. Record housing type | 1 = Detached<br>2 = Semi<br>3 = Terraced<br>4 = Bungalow<br>5-6 = Flat<br>7 = Bedsit<br>8 = Other |

# 4.0 Methodology

## 4.1 Overview of approach

The goal of the present study was to first verify and then extend the household-level models developed by Parfitt (2005). The main similarities and differences between the present approach and that adopted by Parfitt (2005) are listed below.

Like Parfitt (2005), the present study:
- used questionnaire, waste composition and observational data from 2004;
- used multiple regression models to estimate diversion factors per household per year;
- developed household-level models of kerbside collections of residual waste;

Unlike Parfitt (2005), the present study:
- used questionnaire and waste composition data collected in 2005 to test whether the performance of home composting households was steady over time;
- did not constrain the household-level multiple regression models to align with district-level models;
- did not average waste composition data collected in June and September 2004, so testing for possible seasonal variation in diversion;
- developed household-level models to estimate diversion from kerbside garden waste collections;
- did not use district-level modelling to consider the possible diversion of waste from CA sites;
- used a refined classification of households that explicitly recognised New Recruits (see Section 4.2 below);
- divided the municipal waste stream into compostable and non-compostable materials (see Section 4.3 below).

As a result, the present study was able to (i) verify Parfitt's (2005) household-level models, (ii) provide additional insight into how those diversion factors were derived, (iii) successfully extend the modelling approach to consider garden waste in residual and garden waste collections, and (iv) track the performance of WRAP-bin households over a 16 month period.

The following sections detail how households' composting behaviour was classified (section 4.2), how the residual and garden waste streams were broken down into compostable and non-compostable items (section 4.3), and the statistical methodology used to test whether a household's home composting behaviour affects the quantity of waste set out for kerbside collection (section 4.4).

## 4.2 Classification of households

Of 3369 households in the database, Julian Parfitt successfully classified 3031 (90%) as follows: WRAP home composters (845), Non-WRAP home composters (667), lapsed home composters (330) or never (1189). The home composting groups were further divided according to their level of experience (>1 year or <1 year). This classification was based upon the responses given to the September 2004 questionnaire survey. This classification was verified using separate observation data from 2004 on the number and type of compost bins in households' gardens. The observational data revealed significant discrepancies between the householder's responses and what was happening in reality, and the classification was refined accordingly.

Rather than attempt to repeat this verification process (which required detailed knowledge about what type of bins were supplied through the WRAP promotion), the present study took Julian's classification as its starting point and developed it in three ways:
1. The WRAP home composting category was divided into WRAP 2004 New Recruits (those household that did not home compost prior to receiving their WRAP bin) and WRAP 2004 Enhanced households (those households that composted prior to receiving their WRAP bin).
2. Households were classified separately for the time of the first waste composition survey in June 2004 and the second waste composition survey in September 2004, to account for the fact that some households bought their WRAP bin between the two surveys.
3. The classification was extended to households surveyed in September 2005.

WRc decided to focus the analysis on the 875 households that had (i) had been successfully classified by Julian Parfitt in September 2004, and (ii) completed the questionnaire and the waste composition survey in both June and September 2004. Of these, 479 households (i) also completed the questionnaire and waste composition survey in September 2005, and (ii) not had a change of occupancy in the intervening period. This approach was taken for two main reasons. First, the task of accurately tracking changes in diversion by particular home composting groups over time is made much easier by comparing the same households in two time periods, rather

than by comparing two different groups of households in two different time periods. Second, the unreliability of householders' answers to questions regarding the ownership and use of WRAP bins, combined with the fact that no observational data was available for 2005, would have made it difficult to verify the classification of 2005 households that either did not participate in the 2004 survey, or had had a recent change of occupancy.

**Classification of households in September 2004**

Before distinguishing between New Recruits and Enhanced households, we attempted to check whether all the WRAP bins had been owned for less than a year by September 2004. 94% of WRAP bin households stated that they bought their bin since March 2004 (Q3). The rest did not answer Q7 and/or Q9 so it was not possible to deduce how long they had been using their WRAP bin. On the basis of these results, we assumed that all WRAP bins had been owned for less than 1 year by September 2004.

Having done this, there were two possible ways to distinguish New Recruits from Enhanced households. Q7 asks "Before you got your new bin(s) what did you usually do with waste that you now compost at home?". 38% of WRAP households stated that they used another compost bin (=2004 Enhanced), 53% stated that they did not home compost (=2004 New Recruit), and 9% did not give an answer (mainly because they stated that they did not have a WRAP bin, which was later contradicted by the observational study). Alternatively, Q9 asks "How long have you been making compost at home?" To this question, 47% WRAP households said 1 year or more (=2004 Enhanced), 52% said less than 1 year (=2004 New Recruit), and 1% did not give an answer.

Q7 gives a more direct assessment of the prior status of each household, whereas Q9 risks over-estimating the number of New Recruits because some households may be composting for less than a year but have home composted for a short period before buying their WRAP bin. However, the proportion of New Recruits was slightly lower using Q9, suggesting that the New Recruits were not over-estimated. To be consistent with Parfitt's (2005) 2004 methodology we decided to use Q9. The 1% of WRAP households that did not respond to Q9 were classified instead using Q7.

The final step was to check that all the WRAP households were actually using their WRAP bins at the time of the first waste composition survey in September 2004. All home composting households stated (Q1) that they had composted some waste in the past 12 months, so all WRAP 2004 New Recruits must have used their WRAP bin. However, around 19% of WRAP 2004 Enhanced households stated (Q5) that they had not yet put any waste in their WRAP bin and were therefore still using just their original bin. These households were therefore relegated back to being non-WRAP composters.

**Classification of households in June 2004**

Most (ca. 80%) households bought their WRAP bin before June 2004 and therefore had the same status at the time of both the June and September 2004 waste composition surveys. A small minority (9%) of households bought their bin between June and September (Q4) and therefore were either non-composters or non-WRAP composters in June 2004 before becoming WRAP New Recruits or Enhanced households in September 2004. The June status of these households was therefore adjusted accordingly. Finally, the 11% of households did not know exactly when they received their new bin were assumed to have received their bin before June 2004.

It was assumed that if a household was using its WRAP bin in September 2004 that it was also using the bin in June 2004.

The final classification of households in June and September 2004 was as follows:

**Table 9** Classification of households in 2004

| Category | June 2004 | September 2004 |
|---|---|---|
| WRAP 2004 New Recruits | 153 | 165 |
| WRAP 2004 Enhanced | 114 | 124 |
| Non-WRAP composters | 199 | 189 |
| Non-composters | 409 | 397 |
| **Total** | **875** | **875** |

**Classification of households in September 2005**

Amongst the focal group of 479 households, responses to the same question in 2004 and 2005 were not always consistent, possibly because a different member of the household was interviewed on each occasion. We therefore assumed that the status of each household in September 2005 was the same as that in September 2004 unless there was evidence for one of the following changes in behaviour:

- A lapse in home composting. A number of households that were composters in September 2004 stated in September 2005 that they had not composted any of their waste at home over the past 12 months. These were pooled with the original 2004 non-composters.
- The household started composting with a WRAP bin. This includes households that were non-composters in September 2004 and that had subsequently bought and started using a WRAP bin (termed 2005 WRAP New Recruits) and households that were non-WRAP composters in September 2004 and that had subsequently bought and started using a WRAP bin (termed 2005 WRAP Enhanced).
- Non-composting households started composting with a non-WRAP bin. These more recent non-WRAP composters were pooled with the original 2004 non-WRAP composters.

The final classification of households in 2004-2005 was as follows:

**Table 10** Classification of households in 2004-05

| Category | June 2004 | September 2004 | September 2005 |
|---|---|---|---|
| WRAP 2004 New Recruits | 87 | 97 | 93 |
| WRAP 2005 New Recruits | - | - | 18 |
| WRAP 2004 Enhanced | 65 | 71 | 68 |
| WRAP 2005 Enhanced | - | - | 65 |
| Non-WRAP composters | 115 | 109 | 54 |
| Non-composters | 212 | 202 | 181 |
| **Total** | **479** | **479** | **479** |

Between September 2004 and September 2005, 7 out of 168 (4.2%) WRAP households became lapsed composters. Eighteen households that were non-composters in September 2004 and 65 households that were non-WRAP composters were composting with a WRAP bin by September 2005. This confirms that the majority (168 / 168+18+65 = 67%) of WRAP bins were bought within the first six months of the study (March-September 2004).

Using this classification, the diversion achieved by WRAP New Recruits was determined by comparing them with equivalent Non-composters, whilst the Enhanced effect of WRAP bins on existing home composters was determined by comparing Enhanced households with equivalent Non-WRAP composters.

## 4.3 Definition of compostable waste

The analysis focused only on the compostable component of municipal waste. This is roughly equivalent to the biodegradable component of municipal waste because only biodegradable materials can be home composted. Although some non-biodegradable materials are occasionally added to home compost bins (e.g. soil), they constitute only a small proportion of the total residual waste stream and are therefore not considered to be compostable.

Table 11 shows how waste was classified as being either compostable or non-compostable.

For residual waste, the compostable fraction was defined as: uncooked food, all organic garden waste (excluding soil), most paper and card, other organic materials (straw, hay, wood-chips, sawdust, feathers). Fines were assumed to be 50:50 compostable and non-compostable. Cooked food is biodegradable but is not considered to be compostable because its addition to home compost bins is discouraged and very few home composters admit to composting it. Soil, plastic-coated/waxed paper and card, and non-requested materials are not or are very poorly biodegradable and are therefore not considered to be compostable.

The compostable component of residual waste was split into two categories: garden waste (hereafter referred to as 'ResidualGW') and other compostable waste hereafter referred to as 'ResidualOCW'). There are two reasons for this division. Firstly, garden waste and other compostable waste have different characteristics. Garden waste arises from sources outside the home, is likely to be influenced primarily by garden size and is expected to be highly seasonal in quantity and composition. By contrast, other compostable waste types arise mainly from within the home, are influenced by the number and behaviour of the occupants in the household, and are expected to be relatively unseasonal in quantity and composition. Secondly, garden waste and other compostable waste have different disposal routes. Specifically, separate garden waste collections, which are available in seven out of the nine LAs surveyed, comprise almost exclusively garden waste and very little other compostable waste. The availability and use of garden waste collections is therefore likely to have differing effects on the quantity of garden waste and other compostable waste in the residual bin.

For garden waste, the compostable fraction was defined as for residual waste. Specifically, soil, which accounts for around 10% of garden waste collected, was excluded from the analysis because soil is not strictly biodegradable and is only occasionally added to home compost bins.

**Table 11** Compostable and non-compostable waste types

| Category | Type | Category |
|---|---|---|
| Kitchen waste | Vegetable peel, fruit scraps | Compostable |
| | Teabags, tea leaves, coffee, egg shell, bread | Compostable |
| | Cooked food, meat, dairy products, fish, bones and pastries | Not compostable |
| Garden waste | Grass cuttings | Compostable |
| | Woody garden waste stem diameter greater than 5mm and woody | Compostable |
| | Soil | Not compostable |
| | Other organic garden waste e.g. plants, flowers, leaves | Compostable |
| Paper and card | Compostable, non-recyclable: kitchen roll, tissues, KLS, egg boxes, toilet roll tubes, greased paper | Compostable |
| | Recyclable: newspapers and magazines, office paper, paper bags, glossy paper, envelopes, glossy card e.g. cereal packets | Compostable |
| | Non-Compostable, non-recyclable: plastic costed or laminated paper and card, foil type gift wrap, waxed paper or card | Not compostable |
| Other home compostables | Straw, hay, wood-chips, sawdust, feathers | Compostable |
| Fines | But not grass cuttings | 50:50 compostable/ non-compostable |
| Non-requested materials | All other waste not included in one of the above categories. | Not compostable |

## 4.4 Statistical methodology

The statistical analysis had three components:

1. Verification of Parfitt (2005) models;
2. Development of new household-level models for 2004;
3. Extension of models to 2005.

### *4.4.1 Verification of Parfitt (2005) models*

Parfitt's Model 1 was re-run using the raw data supplied to WRc to check that the data used in the present study match those used in Parfitt (2005), and then re-run with a variety of different response variables to provide additional insight into how those diversion factors were derived.

### 4.4.2 Development of new household-level models for 2004

The goal of the analysis was to test whether a household's home composting behaviour affects the quantity of residual and garden waste set out for kerbside collection. The analysis was therefore restricted to the 875 households that participated in both the waste composition survey and the questionnaire survey in 2004. It is likely that some households did not present waste for collection but subsequently completed the questionnaire survey, but they were not included in the analysis because it was not possible to distinguish them from households that did not participate in the waste composition survey but completed the questionnaire survey.

The 2004 study surveyed the same households in summer (June/July) and autumn (September/October). Each household completed the questionnaire just once (so the responses are the same for these two time periods), but the waste composition analysis was conducted twice. The quantities of waste presented in autumn 2004 were only weakly correlated with those presented in summer 2004, so these two sets of measurements were treated as being statistically independent.

Three response variables were analysed: ResidualOCW, ResidualGW, and compostable garden waste (GardenC). The quantity of waste per household per week was modelled as a function of the following variables:

- Quantity of non-compostable residual waste (kg/hhld/week) – this is a surrogate measure of the general level of waste production in each household (ResidualOCW and ResidualGW only).
- Number of occupants in household.
- Tenancy status of household (owner, tenant, other).
- House type (detached, semi, flat etc).
- Age of oldest occupants in household.
- Time of survey (summer 2004, autumn 2004).
- Home composting behaviour (WRAP-Enhanced, WRAP-New Recruit, non-WRAP HC, Non-composters). The 'Non-composters' group was used as the baseline against which the other groups were compared. For example, the average diversion achieved by WRAPNewRecruits was defined as the difference in mean weight of waste per household between the WRAPNewRecruit group and the Non-composters group.
- The identity of the Local Authority.
- Area of garden used for each of the following: flowerbeds, lawn, vegetable patch, hard standing, built structures and hedges/shrubs (ResidualGW and GardenC only).
- Whether or not the household uses the council's separate garden waste collection, where available (not whether a separate garden waste collection was put out that week, since some households may accumulate garden waste over a number of weeks before putting it out for collection, or may put out garden waste only occasionally) (ResidualGW and GardenC only).

The analysis adopted a generalised linear modelling approach, which isolates, tests and quantifies the independent effect of each variable. So, for example, the analysis tested whether the type of home composting behaviour affects the quantity of ResidualOCW presented *when all other factors are held constant*. A maximal model containing all the explanatory factors was used to check that the residuals were normally distributed and had homogeneous variances. A stepwise model selection procedure was used to identify the most parsimonious model – the one that explains as much of the variation in the data as possible with the fewest possible factors. Factors were retained in the model if the variance ratio was ≥2 and removed if the variance ratio was <2. To ensure that a diversion estimate was always produced, the composting behaviour factor was forcibly included in the model even if it wasn't statistically significant.

In addition, the analysis tested for interactions between composting behaviour and the other explanatory factors in the final model. Of particular interest was the interaction between home composting behaviour and use of a garden waste collection service; all else being equal, is the diversion achieved by home composting lower in households that use a garden waste collection?

95% confidence intervals were computed for all diversion factors in the final model.

### 4.4.3 Extension of models to 2005

Finally, the models in Section 4.4.2 were extended to track the performance of WRAP-bin households over a 16 month period from June 2004 to September 2005. Specifically, these models tested the hypothesis that the diversion achieved by WRAP New Recruits and by WRAP Enhanced households would decrease in the second year as the bins filled up and had less spare capacity.

### 4.4.4 Scaling up from kg/hhld/week to kg/hhld/year

The regression models of household waste arisings produce diversion factors in units of kg/hhld/week, but for LATS calculations diversion is measured in kg/hhld/year.

The simplest way to scale up from kg/hhld/week to kg/hhld/year is to multiply the diversion factors (and their confidence intervals) by 365/7 = 52.14, but this assumes that the data collected during the study are representative of waste arisings throughout the whole year. The present study therefore compared waste composition data collected in summer and autumn 2004 in an attempt to test whether the resulting home composting diversion factors were independent of season. The expectation was that diversion of garden and green waste would be higher in the autumn than in the summer, but that diversion of other compostable residual waste would not be significantly different among seasons. It is recognised that this approach is not perfect – ideally waste composition data would be collected in all four seasons to permit a full comparison to be made – but it does permit the assumption of no seasonality to be tested, at least partially.

There was no statistical evidence that home composting diversion factors differed between summer and autumn 2004 - see Results for details. This was unexpected, but may reflect the high level of variability in the data, which makes detection of such interactions difficult. Consequently, the combined diversion factor for summer and autumn was multiplied by 52.14 to give an annual diversion factor in kg/hhld/yr.

## 5.0 Results

The results are divided into three sections. Section 5.1 verifies Parfitt's Model 1 to check that the data used in the present study match those used in Parfitt (2005) and then re-runs Parfitt's Model 1 with different response variables to provide additional insight into how those diversion factors were derived. Section 5.2 presents new household-level models that estimate diversion from kerbside residual waste and garden waste collections. Finally, Section 5.3 extends the models in Section 5.2 to track the performance of WRAP-bin households over a 16 month period from June 2004 to September 2005.

### 5.1 Verification of Parfitt (2005) models

Parfitt's Model 1 analysed the total residual waste averaged across June and September 2004 from 861 households and produced a diversion factor of 87 kg/hhld/yr (Model A in Table 4). This Model was reproduced almost exactly using the raw data supplied to WRc by Julian Parfitt.

Using the new dataset of 875 households (see Section 4.2) but the same independent variables gave a diversion factor of 75 kg/hhld/yr (Model B in Table 12). The slight discrepancy between Models A and B can be explained by the fact that the present study uses a slightly different subset of households, and keeps the waste composition data from June and September 2004 separate rather than averaging it.

**Table 12** Re-analysis of Parfitt (2005) Model 1

| Model | Details | Diversion factor* (kg/hhld/year) | Upper 95% CI | Lower 95% CI |
|---|---|---|---|---|
| **A** | Parfitt Model 1 – total residual waste | -86.8 | -41.6 | -131.9 |
| **B** | Parfitt Model 1 – with new dataset of 875 households | -75.1 | -42.7 | -107.1 |
| **C** | Model B with response = Total non-compostable waste in residual bin | -46.4 | -16.5 | -76.2 |
| **D** | Model B with response = Total compostable waste in residual bin | -28.5 | -3.3 | -53.7 |
| **E** | Model B with response = ResidualOCW | -20.9 | -3.6 | -38.2 |
| **F** | Model B with response = ResdiualGW | -7.6 | +11.2 | -26.5 |

*difference in waste presentation compared with an identical non-composting household. Negative values indicate diversion.

Using Model B as a baseline, the response variable was changed to break down the 75 kg/hhld/yr diversion factor into its component parts (Models C to F, Table 4). Models C and D show that 62% of the 75 kg represents diversion of non-compostable materials and only 38% represents diversion of compostable materials. A possible explanation for the apparent diversion of 46 kg/hhld/yr of materials that would not normally be composted is that experienced home composting households consume less and/or recycle more than equivalent inexperienced households. This may or may not be a side-effect of WRAP activities. This result provides a clear illustration of the risk that diversion factors may be over-estimated if an inappropriate response variable is used.

Parfitt (2005) got round this problem by analysing the kitchen waste component of the residual waste stream (Models 2 and 3). Model E estimates a diversion factor of 20.9 kg/hhld/yr for 'other' compostable waste in the residual bin, which is comparable with the 24 kg/hhld/yr reported by Parfitt's Model 3 but less than that reported by Parfitt's Model 2. Model F estimates a further diversion of 7.6 kg/hhld/yr for compostable garden waste (not statistically significant), which gives a total diversion of 28.5 kg/hhld/yr from the residual bin when experienced home composters are compared with inexperienced home composters.

### 5.2 Development of new household-level models for 2004

Having verified and attained some additional insight into Parfitt's household-level models, the next step was try to build some new household-level models (Models G, H and J) that provide a better understanding of the performance of different home composting groups, test the assumption that diversion factors are not seasonal, and provide a better fit to the data, particularly for garden waste.

### 5.2.1 Residual waste – 'other compostables' (Model G)

The explanatory factors that significantly influenced the quantity of ResidualOCW presented for kerbside collection were:

- The quantity of non-compostable residual waste (kg/hhld/week) – households typically put out 0.18 kg of ResidualOCW for every 1kg of non-compostable waste.
- Number of people in the household – households produced 0.43 kg/hhld/week more for every additional person in the household.
- House type – households in detached houses produced the most waste; households in flats produced the least.
- Time period – households produced on average 0.83 kg/hhld/week less waste in June 2004 than in September 2004.
- Local Authority: After controlling for other factors, Wiltshire and North Lincolnshire presented the most waste per household and Halton and Lancashire presented the least.

Composting behaviour had a statistically significant effect on the quantity of ResidualOCW and the diversion factors were as follows:

**Table 13** Model G: Diversion factors for different types of composting households – ResidualOCW

| Group | Diversion factor* (kg/hhld/year) | Upper 95% CI | Lower 95% CI |
|---|---|---|---|
| Non-WRAP HC | **-24.6** | -4.7 | -44.5 |
| WRAP 2004 Enhanced | **-34.2** | -10.7 | -57.6 |
| WRAP 2004 New Recruits | **-32.5** | -11.7 | -53.3 |

*difference in waste presentation compared with an identical non-composting household. Negative values indicate diversion. Bold indicates significantly different from zero.

Non-WRAP home composters, WRAP Enhanced and WRAP New Recruits all had a similar level of diversion, and all three diversion factors were statistically significant. The Enhanced effect of WRAP bins on existing home composters was 34.2 – 24.6 = 9.6 kg/hhld/yr, which was not significantly different from zero and significantly less than the diversion achieved by New Recruits.

There was no statistically significant interaction between composting behaviour and time in the final model, suggesting that the diversion factors were not affected by seasonality.

### 5.2.2 Residual waste – 'garden waste' (Model H)

The explanatory factors that significantly influenced the quantity of ResidualGW presented for kerbside collection were:

- Number of people in the household – households produced 0.21 kg/hhld/week *less* for every additional person in the household. Possibly this is because large families spend less time gardening.
- Age – households with older occupants produced more garden waste than those with younger occupants, possibly because older occupants have a greater interest in, or more time for, gardening.
- House type – households in detached houses and flats produced the most waste; households in terraced houses produced the least.
- Time period – households produced on average 0.36 kg/hhld/week more waste in June 2004 than in September 2004.
- Local Authority - After controlling for other factors, Wigan and North Lincolnshire presented the most waste per household and Halton and Lancashire presented the least.
- Garden use – garden waste in the residual bin was positively correlated with the area of lawn and negatively correlated with the area of hard standing.
- Composting behaviour had a statistically significant effect on the quantity of ResidualGW and the diversion factors were as follows:

**Table 14** Model H: Diversion factors for different types of composting households – ResidualGW

| Group | Diversion factor* (kg/hhld/year) | Upper 95% CI | Lower 95% CI |
|---|---|---|---|
| Non-WRAP HC | -22.4 | 0.4 | -45.2 |
| WRAP 2004 Enhanced | **-37.4** | -10.7 | -64.1 |
| WRAP 2004 New Recruits | -14.7 | 8.8 | -38.3 |

*difference in waste presentation compared with an identical non-composting household. Negative values indicate diversion. Bold indicates significantly different from zero.

Of the three home composting groups, only WRAP Enhanced households had a diversion factor that was significantly less than zero. The enhanced effect of WRAP bins on existing home composters was 37.4 – 22.4 = 15.0 kg/hhld/yr, which was not significantly different from zero and almost exactly the same as the diversion achieved by New Recruits.

There was no statistically significant interaction between composting behaviour and time in the final model, suggesting that the diversion factors were not affected by seasonality.

To investigate the effect of separate garden waste collections on home composting activities, Model H was re-run with the inclusion of a factor to indicate which households made use of a separate garden waste collection. Households that used a separate garden waste collection put on average 22 kg/hhld/year less garden waste in their residual bin. However, the diversion factors were virtually unchanged and there was no significant interaction between composting behaviour and the use of garden waste collections, indicating that garden waste collections tend to complement rather than compete with home composting as a way of reducing the quantity of residual waste collected at the kerbside.

### *5.2.3 Garden waste (Model J)*

The analysis of garden waste collections was performed using data from 420 households in the four local authorities (Christchurch, Enfield, Halton and Lancashire) that offered a separate kerbside garden waste collection in 2004.

The explanatory factors that significantly influenced the quantity of compostable garden waste presented for kerbside collection were:

- House type – households in detached houses and bungalows produced the most waste; households in terraced houses produced the least. This likely reflects the size and type of garden.
- Age – households with older occupants produced more garden waste than those with younger occupants, presumably because older occupants have greater interest in, or more time for, gardening.
- Time period – households produced on average 0.89 kg/hhld/week more waste in June 2004 than in September 2004. This was mainly due to a greater production in June of grass, which was the single largest waste component.
- Local Authority - After controlling for other factors, Enfield and Lancashire presented the most waste per household and Christchurch presented the least.
- Garden use – the quantity of compostable garden waste presented for collection was positively correlated with the area of lawn and flowerbeds and negatively correlated with the area of hard standing.

After taking into account the above factors, there was not a statistically significant effect of home composting behaviour on the quantity of compostable garden waste presented for kerbside collection. When this term was forcibly included in the model, the following diversion factors were obtained:

**Table 15** Model J: Diversion factors for different types of composting households – compostable garden waste

| Group | Diversion factor* (kg/hhld/year) | Upper 95% CI | Lower 95% CI |
|---|---|---|---|
| Non-WRAP HC | 43.8 | 110.9 | -23.2 |
| WRAP 2004 Enhanced | -43.4 | 37.8 | -124.5 |
| WRAP 2004 New Recruits | -49.4 | 19.4 | -118.2 |

*difference in waste presentation compared with an identical non-composting household. Negative values indicate diversion. Bold indicates significantly different from zero.

None of the three home composting groups had a diversion factor significantly different from zero, which reflects the high level of variability in the data, even after including information on garden land use. However, the two WRAP composting groups presented significantly less garden waste than equivalent non-WRAP composting households, which themselves presented *more* waste than equivalent non-composting households. The enhanced effect of WRAP bins on existing home composters was 43.4 + 43.8 = 87.2 kg/hhld/yr, whilst the diversion achieved by New Recruits was 49.4 kg/hhld/yr.

There was no statistically significant interaction between composting behaviour and time in the final model, suggesting that the diversion factors were not affected by seasonality.

### *5.2.4 Summary of 2004 household-level models*

Table 16 shows the total diversion of municipal waste from residual and garden waste kerbside collections.

**Table 16** Combined diversion factors (kg/hhld/year)

| Model | Waste stream | Non-WRAP HC | WRAP 2004 Enhanced | WRAP 2004 New Recruits |
|---|---|---|---|---|
| **G** | Residual waste – other compostables | **-24.6** | **-34.2** | **-32.5** |
| **H** | Residual waste – garden waste | -22.4 | **-37.4** | -14.7 |
| **J** | Garden waste – all compostable | 43.8 | -43.4 | -49.4 |
| | **All kerbside waste** | -3.2 | **-115.0** | **-96.6** |

Negative values indicate diversion. Bold indicates significantly different from zero.

Overall, non-WRAP home composters showed no significant diversion, although this effect is mainly due to a large positive (but not statistically significant) diversion factor for compostable garden waste cancelling out a large negative (and statistically significant) diversion factor for residual waste. WRAP Enhanced households were estimated to divert a total of 115 kg/hhld/yr, of which around 112 kg/hhld/yr was attributable to the enhanced effect of participating in the WRAP home composting scheme. This diversion factor is much larger than the 40 – 80 kg/hhld/yr estimated by Parfitt (2005) for Enhanced households and to a large degree reflects the fact that the present study has explicitly assessed diversion from separate garden waste collections.

Overall, WRAP New Recruits were estimated to divert a total of 97 kg/hhld/yr, of which roughly half was from residual waste collections and half was from garden waste collections (the latter component being not statistically significant). This is an important result because it suggests that households new to home composting can achieve levels of diversion comparable to experienced home composters within just six months of participating in the WRAP scheme. The obvious question of whether that level of performance can be maintained, or even improved with greater experience, is addressed in Section 5.3. This result was, however, considerably lower than the 180-340 kg/hhld/yr estimated by Parfitt (2005) using district-level modelling, which underlines the fact that household-level modelling cannot easily account for waste diverted from civic amenity sites by home composting.

### *5.2.5 Sensitivity analysis*

Comments from Julian Parfitt on an earlier version of this report suggested that the results could be influenced by the classification of households (Section 4.2) and the definition of compostable waste (Section 4.3). To test the sensitivity of the estimated diversion factors to the assumptions made in Section 4.0, Models G, H and J were re-run with adjustments made to these variables.

Firstly, around 20 households in the September 2004 dataset that had been relegated from WRAP Enhanced to non-WRAP home composters were changed back to WRAP Enhanced. This has the effect of defining WRAP households on the basis of bin ownership rather than bin use, and allows for the possibility that owning a WRAP bin may result in a faster fill-rate of existing (non-WRAP) bins even before the WRAP bin comes into use. The revised results for Models G, H and J are presented in Table 17. Changing the classification households had virtually no effect on the diversion estimated for WRAP New Recruits, slightly increased the diversion estimate for non-WRAP households, and reduced the diversion estimate for Enhanced households by around 31 kg/hhld/yr, compared with the original models in Table 16.

**Table 17** Combined diversion factors (kg/hhld/year) with changes made to household classification

| Model | Waste stream | Non-WRAP HC | WRAP 2004 Enhanced | WRAP 2004 New Recruits |
|---|---|---|---|---|
| **G** | Residual waste – other compostables | -27.1 | -29.8 | -32.6 |
| **H** | Residual waste – garden waste | -25.7 | -31.4 | -14.7 |
| **J** | Garden waste – all compostable | 42.5 | -22.9 | -49.5 |
| | **All kerbside waste** | **-10.3** | **-84.2** | **-96.8** |

Negative values indicate diversion.

Secondly, the definition of compostable waste was broadened to include cooked or meat-based kitchen waste, soil, and 100% of fines. The original classification detailed in Table 11 was based upon that used by the Environment Agency. However, some households deliberately add soil to their compost as a way of activating the bin with bacteria that promote decay, significant quantities of soil may also be attached to plant roots discarded into home compost bins, and some households use soil in the layering process. The Agency assume that 50% of fines are biodegradable, but in practice it is possible that the majority of fines will be soil and fragments of food and garden waste. Cooked food is not recommended for home composting, but inevitably some of it does end up in home compost bins.

The revised results for Models G, H and J are presented in Table 18. Changing the definition of compostable waste had a greater effect on the results than changing the classification of households. There was little effect on the diversion estimated for WRAP New Recruits, but the diversion estimates for non-WRAP households were around 26 kg/hhld/yr higher than in the original model, and around 27 kg/hhld/yr higher for Enhanced households. This was not surprising, since broadening the definition of compostable waste affects all households rather than just 20 or so, and increases the amount of waste that can potentially be home composted.

**Table 18** Combined diversion factors (kg/hhld/year) with changes made to the definition of compostable waste

| Model | Waste stream | Non-WRAP HC | WRAP 2004 Enhanced | WRAP 2004 New Recruits |
|---|---|---|---|---|
| **G** | Residual waste – other compostables | -41.9 | -48.1 | -36.5 |
| **H** | Residual waste – garden waste | -23.6 | -46.0 | -11.7 |
| **J** | Garden waste – all compostable | 36.1 | -47.7 | -42.5 |
| | **All kerbside waste** | **-29.4** | **-141.9** | **-90.7** |

Negative values indicate diversion.

Finally, Models G, H and J were re-run with changes to both the classification of households and the definition of compostable waste. The results are presented Table 19. As expected, the diversion factors were broadly a combination of the changes observed in tables 17 and 18. Total diversion from kerbside collection were around 37 kg/hhld/yr higher than the original model (Table 16) for non-WRAP households, around 9 kg/hhld/yr lower for Enhanced households, and around 6 kg/hhld/yr lower for New Recruits. Overall, these changes are small compared with the broad confidence intervals around many of the individual diversion estimates, indicating that unexplained variation in waste presentation is a greater source of uncertainty than methodological assumptions.

**Table 19** Combined diversion factors (kg/hhld/year) with changes made to both household classification and definition of compostable waste

| Model | Waste stream | Non-WRAP HC | WRAP 2004 Enhanced | WRAP 2004 New Recruits |
|---|---|---|---|---|
| **G** | Residual waste – other compostables | -45.7 | -42.5 | -36.4 |
| **H** | Residual waste – garden waste | -30.8 | -34.0 | -11.6 |
| **J** | Garden waste – all compostable | 36.4 | -29.8 | -42.4 |
| | **All kerbside waste** | **-40.1** | **-106.3** | **-90.5** |

Negative values indicate diversion.

## 5.3 Extension of models to 2005

The final step of the modelling sought to extend the models presented in Section 5.2 to track the performance of WRAP-bin households over a 16 month period from June 2004 to September 2005. To do this, the analysis focused on a subset of 479 households that (i) had been successfully classified by Julian Parfitt in September 2004, (ii) had completed the questionnaire and the waste composition survey in June and September 2004 and again in September 2005, and (iii) had not had a change of occupancy in the intervening period (see Section 4.2 for details).

The analysis aimed to answer two questions:

1. Was the performance of Enhanced and New Recruit households in 2004 maintained or even improved in 2005?
2. Did households that bought WRAP bins in 2005 achieved similar levels of diversion to those that bought bins in 2004?

The first question was answered by testing for an interaction between composting behaviour and time, which would indicate that the diversion factors differed between 2004 and 2005. The second question was answered by including 2005 Enhanced and 2005 New Recruits as distinct categories in the household classification (see Table 2).

As before separate models were run for ResidualOCW, ResidualGW and compostable garden waste.

For **ResidualOCW**, there was no statistically significant interaction between composting behaviour and time, indicating no evidence that the diversion factors observed in 2004 changed in 2005. Pooling the data across all three time periods, the following diversion factors were obtained:

**Table 20** Model K: Diversion factors for different types of composting households – ResidualOCW

| Group | Diversion factor* (kg/hhld/year) | Upper 95% CI | Lower 95% CI |
|---|---|---|---|
| Non-WRAP HC | -23.8 (-24.6) | 4.0 | -51.5 |
| WRAP 2004 Enhanced | -26.5 (-34.2) | 4.3 | -57.3 |
| WRAP 2005 Enhanced | -85.1 (NA) | -32.1 | -138.1 |
| WRAP 2004 New Recruits | -39.6 (-32.5) | -12.7 | -66.5 |
| WRAP 2005 New Recruits | -17.9 (NA) | 72.1 | -107.9 |

*difference in waste presentation compared with an identical non-composting household. Negative values indicate diversion. Values in brackets indicate diversion factors from Model G using 875 households in 2004.

Note that because Model K is based on data from 479 households in 2004 and 2005, the diversion factors for non-WRAP HC, 2004 Enhanced and 2004 New Recruits differ slightly from those in Model G. The confidence intervals on both 2005 Enhanced households and 2005 New Recruits are fairly wide because there are relatively few households in these categories, and consequently there is no statistically significant difference between these latter WRAP households and the original ones that bought their bins in 2004.

For **ResidualGW**, there was a statistically significant interaction between composting behaviour and time, yielding the following diversion factors:

**Table 21** Model L: Diversion factors (kg/hhld/yr)* for different types of composting households – ResidualGW

| Group | June 2004 | Sept 2004 | Sept 2005 |
|---|---|---|---|
| Non-WRAP HC | -10.4 | -30.3 | -73.4 |
| WRAP 2004 Enhanced | -33.9 | -39.3 | -2.9 |
| WRAP 2005 Enhanced | - | - | -50.5 |
| WRAP 2004 New Recruits | -33.0 | -14.9 | -105.8 |
| WRAP 2005 New Recruits | - | - | -30.0 |

*difference in waste presentation compared with an identical non-composting household. Negative values indicate diversion.

The data suggest that 2004 Enhanced households divert less waste in 2005 than in 2004, but that 2004 New Recruits divert more waste in 2005 than in 2004. These results should be treated with caution, however, as the interaction term is only marginally significant and the confidence intervals on these results are quite wide.

The diversion estimate for 2005 Enhanced households in their first year (51 kg/hhld/yr) was slightly higher than that for 2004 Enhanced households at the same stage (33-39 kg/hhld/yr), but this difference was not statistically significant. Similarly, the diversion estimate for 2005 New Recruits in their first year (30 kg/hhld/yr) was slightly higher than that for 2004 New Recruits at the same stage (15-33 kg/hhld/yr), but again this difference was not statistically significant. These results do suggest, however, that households that joined the WRAP scheme in 2005 showed similar levels of diversion to those that joined in 2004.

Finally, for compostable **garden waste** in separate kerbside collections, there was no statistically significant interaction between composting behaviour and time, indicating no evidence that the diversion factors observed in 2004 changed in 2005. Pooling the data across all three time periods, gave positive diversion factors, indicating that a reliable model could not be achieved.

# 6.0 Discussion

## 6.1 Adequacy of data

This study re-analysed data from two previous studies, which were funded by WRAP and undertaken by independent waste consultants. The datasets were supplied by WRAP electronically as Excel or SPSS spreadsheets and although generally well organised there were a number of data quality issues. The two main problems were:

- An inadequate description in the project reports of the way in which households were selected for inclusion, and to what extent each household participated. In particular, it was often not clear how many households did not present waste on the day of the waste composition survey. This posed problems in trying to define the target population, and in trying to quantify the effect of home composting.
- Questionnaire responses were frequently incomplete or inconsistent. Missing answers lead to gaps in the dataset and reduce the power of the analysis. Inconsistent answers raise uncertainties about the accuracy of the data used, for example, when attempting to classify households according to their home composting behaviour.

These data quality deficiencies were overcome by making assumptions about the way in which the data were collected and processed. For example, inconsistent responses were generally resolved by taking the first response to be the correct answer. To reduce these problems, it is recommended that future studies:

- Require contractors to produce a full and detailed description of the research methodology, such that a subsequent researcher could repeat the study and re-construct the results.
- Capture questionnaire responses electronically and undertake data validation on the doorstep so that errors and inconsistencies are less likely to occur and any problems can be rectified immediately.

## 6.2 Adequacy of models

The present study successfully verified and extended the home composting diversion factors estimated by Parfitt (2005). Specifically, the present study was able to focus on just the compostable component of residual and garden waste collections, and to obtain a direct estimate of the diversion achieved by WRAP New Recruits. Because the household-level multiple regression models were not constrained to align with any district-level models, the present study was often able to explain a greater proportion of variation in the data. For example, Parfitt's Models 2 and 3 explained just 12% of the variation in the quantity of waste presented, whereas Model G accounted for 20%. Similarly, the present study was able to utilise the observational data to produce reliable models of garden waste in the residual bin and in separate kerbside collections.

Set against these successes, the present study encountered a number of limitations, which are inherent in the household-level approach and therefore were experienced by Parfitt (2005) too. The primary limitation was the high variability in household-level data, which could not be explained adequately by any of the explanatory variables available to the present study. Although some of the models were successful in explaining 20% of the variation in the data, this is low in absolute terms and means that the models have poor predictive ability. One consequence of this was that the 95% confidence intervals surrounding the diversion estimates were often wide and sometimes spanned zero, making it difficult to conclude with certainty that home composting was effective in diverting waste from kerbside collections. A second consequence was that the ability of the models to test for seasonal and annual changes in diversion factors was low.

## 6.3 Home composting diversion in context

The present study presents evidence that home composting can divert significant quantities of BMW from kerbside residual and garden waste collections. However, CA sites, which receive around 20% of all household waste and 40% of total household garden waste (Defra 2006/07 estimate based on WasteDataFlow returns), were not considered in the present study and consequently the reported diversion factors will under-estimate the total quantity of household waste diverted from landfill by an unknown amount. CA sites are commonly used to dispose of periodic extra loads of garden waste that cannot be disposed of by home composting or kerbside collections, and are particularly likely to receive bulky items and woody materials that are not easily composted.

Measuring diversion from CA sites is notoriously difficult. Although the 2004 questionnaire asked householders about their use of CA sites, Parfitt (2005) found no significant relationship between use of CA sites and kerbside waste collection, and no quantitative data was made available in the present study. WasteDataFlow contains

information on waste stream entering CA sites and can be incorporated into district-level models, but relating this to the home composting behaviour of the local population is difficult because it is not possible to account for cross-boundary movement of waste (whereby households in one WCA take waste to a CA site in a neighbouring WCA).

The present study analysed data from 2004 and 2005. Since 2004 there has been a significant expansion of kerbside collections of garden waste in some areas. The proportion of total household garden waste collected at kerbside has risen from around 29% in 2003/04 to around 60% in 2006/07, and the total quantity of garden waste collected from household sources in England has risen from 1.36 million tonnes in 2003/04 to over 3.1 million tonnes in 2006/07 (J. Parfitt, *pers. comm.*). An important question is to what extent has the expansion of kerbside collections affected the amount of garden waste composted at home? Households may use kerbside collection instead of home composting, or may use kerbside collections only for excess loads of garden waste that would otherwise be left to rot in the garden, put in the residual bin, or taken to CA sites.

The present study found that households that used a separate garden waste collection put on average 22 kg/hhld/year less garden waste in their residual bin, but that the amount of garden waste diverted by home composting was unaffected by the use of a separate garden waste collection. This result suggests that garden waste collections tend to complement rather than compete with home composting as a way of reducing the quantity of residual waste collected at the kerbside. Furthermore, there was evidence that WRAP home composting households presented less garden waste for separate collection than non-composting and non-WRAP home composting households. Thus, although it is not possible to quantify the impact of separate garden waste collections on home-composting activities, the results of the present study indicate that home composting may continue to divert significant quantities of waste from kerbside collection even in local authorities offering free garden waste collections.

## 6.4 Recommendations for future studies

The 2004 and 2005 datasets analysed in this study represent snapshot observational studies of residual and green waste composition and home composting behaviour. This type of study reduces the effect of seasonal variation by collecting waste samples intensively over a short period of time. The downside of this approach is that the quantity of waste presented by individual households can vary considerably from week-to-week, leading to high unexplained variation in any resulting diversion models and wide confidence intervals on estimated diversion factors. Future studies should explore the merits of conducting repeated surveys of the same households to average out this temporal variation.

Another difficulty with snapshot studies is the high variation in waste presentation among households, which is not always adequately explained by factors such as the number and age of people in the household and garden size. An alternative approach might be to conduct an experiment on home-composting households by measuring the amount of BMW that they present for kerbside collection, and then denying them access to their compost bins and recording the change in the quantity of BMW presented. Appropriate controls could be devised to take account of possible changes in behaviour as a result of their being monitored.

Ultimately, a multi-level approach that combines household- and district-level modelling, as conducted by Parfitt (2005), would appear to offer the best prospect for evaluating the effectiveness of home composting.

## 6.5 Conclusions

The goals of the present study were to (i) verify Parfitt's (2005) household-level models of home composting diversion, (ii) provide additional insight into how those diversion factors were derived, (iii) extend the modelling approach to consider garden waste in residual and garden waste collections, and (iv) track the performance of WRAP-bin households over a 16 month period.

Parfitt's (2005) household level models were verified as being a true representation of the data.

New regression models were constructed to better understand the performance of different home composting groups, to test the assumption that diversion factors are not seasonal, and to provide a better fit to the data, particular for garden waste. Diversion factors were produced for three groups of home composting households:

- Non-WRAP home composters – those that home composted without a WRAP bin;
- WRAP Enhanced - those households that composted prior to receiving their WRAP bin;
- WRAP New Recruits - those household that did not home compost prior to receiving their WRAP bin.

Analysis of waste composition and questionnaire data collected in 2004 from nine local authorities produced the following diversion factors (negative values indicate diversion and bold indicates significantly different from zero):

Table 22: Diversion factors achieved in household-level modelling (2005)

| Waste stream | Non-WRAP HC | WRAP Enhanced | WRAP New Recruits |
|---|---|---|---|
| Residual waste – other compostables | **-24.6** | **-34.2** | **-32.5** |
| Residual waste – garden waste | -22.4 | **-37.4** | -14.7 |
| Garden waste – all compostable | 43.8 | -43.4 | -49.4 |
| **All kerbside waste** | -3.2 | **-115.0** | **-96.6** |

Overall, non-WRAP home composters showed no significant diversion from kerbside collections, although this effect was mainly due to a large positive (but not statistically significant) diversion factor for compostable garden waste cancelling out a large negative (and statistically significant) diversion factor for residual waste. WRAP Enhanced households were estimated to divert a total of 115 kg/hhld/yr, of which around 112 kg/hhld/yr was attributable to the enhanced effect of participating in the WRAP home composting scheme. This diversion factor is much larger than the 40 – 80 kg/hhld/yr estimated by Parfitt (2005) for Enhanced households and to a large degree reflects the fact that the present study has explicitly assessed diversion from separate garden waste collections. Finally, WRAP New Recruits were estimated to divert a total of 97 kg/hhld/yr, which suggests that households new to home composting can achieve levels of diversion comparable to experienced home composters within just six months of participating in the WRAP scheme. This result was considerably lower than the 180-340 kg/hhld/yr estimated by Parfitt (2005) using district-level modelling.

There was no evidence that diversion factors differed between summer and autumn, although the high variability in the data made detecting for such interactions difficult.

Finally, there was only limited evidence that the performance of New Recruits and Enhanced households changed after they had had their WRAP bins for more than a year. There was also no evidence that New Recruits and Enhanced households that bought a WRAP bin later on were any more or less effective in diverting waste than those that bought a bin at the beginning of the scheme.

## References

Hyder (2006) WRAP composting report (Project DV53041). 12 April 2006, pp. 46.

Parfitt (2005) Home composting diversion models. WRAP report, 2 August 2005, pp. 74.

WRAP (2008) Synopsis of WRAP home composting research and diversion estimates. WRAP note January 2008.

WRAP (2009) Home composting diversion: district level modelling. July 2009

# Appendix 1: Final Model Outputs

Model A: Parfitt Model 1 (taken from Parfitt 2005, pp 56-57)

**Descriptive Statistics**

| | Mean | Std. Deviation | N |
|---|---|---|---|
| Rtotalf | 12.2994 | 6.78455 | 861 |
| home composting for more than 1 year? mar05 | .3438 | .47525 | 861 |
| total garden area (sq m) march05 | 311.3849 | 218.35227 | 861 |
| household size (persons) mar05 | 2.6016 | 1.17945 | 861 |
| kerbside ~ number of materials | 2.5377 | 1.85084 | 861 |
| use kerbside for GW? | .2207 | .41494 | 861 |
| wheeled_bin | .6945 | .46087 | 861 |

**Model Summary[b]**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .478[a] | .228 | .223 | 5.98030 |

a. Predictors: (Constant), wheeled_bin, household size (persons) mar05, home composting for more than 1 year? mar05, kerbside ~ number of materials, total garden area (sq m) march05, use kerbside for GW?

b. Dependent Variable: Rtotalf

**ANOVA[b]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 9043.437 | 6 | 1507.240 | 42.144 | .000[a] |
| | Residual | 30542.477 | 854 | 35.764 | | |
| | Total | 39585.914 | 860 | | | |

a. Predictors: (Constant), wheeled_bin, household size (persons) mar05, home composting for more than 1 year? mar05, kerbside ~ number of materials, total garden area (sq m) march05, use kerbside for GW?

b. Dependent Variable: Rtotalf

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 7.450 | .738 | | 10.101 | .000 |
| | home composting for more than 1 year? mar05 | -1.669 | .443 | -.117 | -3.766 | .000 |
| | total garden area (sq m) march05 | .005 | .001 | .152 | 4.824 | .000 |
| | household size (persons) mar05 | 1.465 | .174 | .255 | 8.405 | .000 |
| | kerbside ~ number of materials | -.702 | .122 | -.192 | -5.769 | .000 |
| | use kerbside for GW? | -1.853 | .542 | -.113 | -3.422 | .001 |
| | wheeled_bin | 3.364 | .448 | .229 | 7.507 | .000 |

a. Dependent Variable: Rtotalf

# Regression analysis

Response variate: reg1TotalResidualWaste
Fitted terms: Constant + reg2HCmore_than_year + reg3Garden_size + reg4Persons_per_household + reg5Number_material_dry_recyclin + reg6Use_kerbside_garden_waste + reg7Wheeled_bin_refuse

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 7 | 19229. | 2746.97 | 75.42 | <.001 |
| Residual | 1742 | 63450. | 36.42 | | |
| Total | 1749 | 82679. | 47.27 | | |

Percentage variance accounted for 22.9
Standard error of observations is estimated to be 6.04.

## Estimates of parameters

| Parameter | estimate | s.e. | t(1742) | t pr. |
|---|---|---|---|---|
| Constant | 6.673 | 0.584 | 11.42 | <.001 |
| reg2HCmore_than_year | -1.440 | 0.316 | -4.56 | <.001 |
| reg3Garden_size | 0.002576 | 0.000655 | 3.94 | <.001 |
| reg4Persons_per_household | 1.592 | 0.122 | 13.07 | <.001 |
| reg5Number_material_dry_recyclin | -0.2371 | 0.0975 | -2.43 | 0.015 |
| reg6Use_kerbside_garden_waste | -1.613 | 0.385 | -4.19 | <.001 |
| reg7Wheeled_bin_refuse 1 | 3.726 | 0.354 | 10.52 | <.001 |
| reg7Wheeled_bin_refuse Unknown | 8.225 | 0.983 | 8.37 | <.001 |

Parameters for factors are differences compared with the reference level:

| Factor | Reference level |
|---|---|
| reg7Wheeled_bin_refuse | 0 |

# Regression analysis

Response variate: RTot_NC
Fitted terms: Constant + reg2HCmore_than_year + reg3Garden_size + reg4Persons_per_household + reg5Number_material_dry_recyclin + reg6Use_kerbside_garden_waste + reg7Wheeled_bin_refuse

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 7 | 7185. | 1026.41 | 32.82 | <.001 |
| Residual | 1742 | 54483. | 31.28 | | |
| Total | 1749 | 61668. | 35.26 | | |

Percentage variance accounted for 11.3
Standard error of observations is estimated to be 5.59.

## Estimates of parameters

| Parameter | estimate | s.e. | t(1742) | t pr. |
|---|---|---|---|---|
| Constant | 2.627 | 0.541 | 4.85 | <.001 |
| reg2HCmore_than_year | -0.892 | 0.293 | -3.05 | 0.002 |
| reg3Garden_size | 0.000723 | 0.000607 | 1.19 | 0.233 |
| reg4Persons_per_household | 1.295 | 0.113 | 11.48 | <.001 |
| reg5Number_material_dry_recyclin | -0.0114 | 0.0903 | -0.13 | 0.900 |
| reg6Use_kerbside_garden_waste | -0.369 | 0.356 | -1.04 | 0.300 |
| reg7Wheeled_bin_refuse 1 | 2.181 | 0.328 | 6.64 | <.001 |
| reg7Wheeled_bin_refuse Unknown | 5.164 | 0.911 | 5.67 | <.001 |

Parameters for factors are differences compared with the reference level:

| Factor | Reference level |
|---|---|
| reg7Wheeled_bin_refuse | 0 |

# Regression analysis

Response variate: RTot_C
Fitted terms: Constant + reg2HCmore_than_year + reg3Garden_size + reg4Persons_per_household + reg5Number_material_dry_recyclin + reg6Use_kerbside_garden_waste + reg7Wheeled_bin_refuse

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 7 | 4044. | 577.74 | 25.91 | <.001 |
| Residual | 1742 | 38842. | 22.30 | | |
| Total | 1749 | 42886. | 24.52 | | |

Percentage variance accounted for 9.1
Standard error of observations is estimated to be 4.72.

## Estimates of parameters

| Parameter | estimate | s.e. | t(1742) | t pr. |
|---|---|---|---|---|
| Constant | 4.046 | 0.457 | 8.85 | <.001 |
| reg2HCmore_than_year | -0.549 | 0.247 | -2.22 | 0.027 |
| reg3Garden_size | 0.001854 | 0.000512 | 3.62 | <.001 |
| reg4Persons_per_household | 0.2964 | 0.0953 | 3.11 | 0.002 |
| reg5Number_material_dry_recyclin | -0.2255 | 0.0763 | -2.96 | 0.003 |
| reg6Use_kerbside_garden_waste | -1.243 | 0.301 | -4.13 | <.001 |
| reg7Wheeled_bin_refuse 1 | 1.545 | 0.277 | 5.57 | <.001 |
| reg7Wheeled_bin_refuse Unknown | 3.061 | 0.769 | 3.98 | <.001 |

Parameters for factors are differences compared with the reference level:

| Factor | Reference level |
|---|---|
| reg7Wheeled_bin_refuse | 0 |

# Regression analysis

Response variate: Residual_OCW
Fitted terms: Constant + reg2HCmore_than_year + reg3Garden_size + reg4Persons_per_household + reg5Number_material_dry_recyclin + reg6Use_kerbside_garden_waste + reg7Wheeled_bin_refuse

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 7 | 1579. | 225.57 | 21.46 | <.001 |
| Residual | 1742 | 18309. | 10.51 | | |
| Total | 1749 | 19888. | 11.37 | | |

Percentage variance accounted for 7.6
Standard error of observations is estimated to be 3.24.

## Estimates of parameters

| Parameter | estimate | s.e. | t(1742) | t pr. |
|---|---|---|---|---|
| Constant | 2.476 | 0.314 | 7.89 | <.001 |
| reg2HCmore_than_year | -0.402 | 0.170 | -2.37 | 0.018 |
| reg3Garden_size | 0.001022 | 0.000352 | 2.91 | 0.004 |
| reg4Persons_per_household | 0.6441 | 0.0654 | 9.84 | <.001 |
| reg5Number_material_dry_recyclin | -0.1829 | 0.0524 | -3.49 | <.001 |
| reg6Use_kerbside_garden_waste | -0.359 | 0.207 | -1.74 | 0.083 |
| reg7Wheeled_bin_refuse 1 | 0.070 | 0.190 | 0.37 | 0.714 |
| reg7Wheeled_bin_refuse Unknown | 0.199 | 0.528 | 0.38 | 0.707 |

Parameters for factors are differences compared with the reference level:

| Factor | Reference level |
|---|---|
| reg7Wheeled_bin_refuse | 0 |

# Regression analysis

Response variate: Residual_cGW
Fitted terms: Constant + reg2HCmore_than_year + reg3Garden_size + reg4Persons_per_household + reg5Number_material_dry_recyclin + reg6Use_kerbside_garden_waste + reg7Wheeled_bin_refuse

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 7 | 2233. | 318.95 | 25.53 | <.001 |
| Residual | 1742 | 21767. | 12.50 | | |
| Total | 1749 | 23999. | 13.72 | | |

Percentage variance accounted for 8.9
Standard error of observations is estimated to be 3.53.

## Estimates of parameters

| Parameter | estimate | s.e. | t(1742) | t pr. |
|---|---|---|---|---|
| Constant | 1.570 | 0.342 | 4.59 | <.001 |
| reg2HCmore_than_year | -0.147 | 0.185 | -0.79 | 0.428 |
| reg3Garden_size | 0.000832 | 0.000383 | 2.17 | 0.030 |
| reg4Persons_per_household | -0.3477 | 0.0713 | -4.87 | <.001 |
| reg5Number_material_dry_recyclin | -0.0427 | 0.0571 | -0.75 | 0.455 |
| reg6Use_kerbside_garden_waste | -0.884 | 0.225 | -3.92 | <.001 |
| reg7Wheeled_bin_refuse 1 | 1.475 | 0.208 | 7.11 | <.001 |
| reg7Wheeled_bin_refuse Unknown | 2.863 | 0.576 | 4.97 | <.001 |

Parameters for factors are differences compared with the reference level:

| Factor | Reference level |
|---|---|
| reg7Wheeled_bin_refuse | 0 |

# Regression analysis

Response variate: Residual_OCW
Fitted terms: Constant + Comp + RTot_NC + NinH + House + TimePeriod + Local_Authority

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 20 | 4138. | 206.885 | 22.71 | <.001 |
| Residual | 1729 | 15751. | 9.110 | | |
| Total | 1749 | 19888. | 11.371 | | |
| Change | 1 | 21. | 21.095 | 2.32 | 0.128 |

Percentage variance accounted for 19.9
Standard error of observations is estimated to be 3.02.

## Estimates of parameters

| Parameter | estimate | s.e. | t(1729) | t pr. |
|---|---|---|---|---|
| Constant | 3.074 | 0.375 | 8.20 | <.001 |
| Comp NonWRAPHC | -0.473 | 0.195 | -2.42 | 0.015 |
| Comp WRAP2004Enhanced | -0.657 | 0.230 | -2.86 | 0.004 |
| Comp WRAP2004NewRecruit | -0.625 | 0.204 | -3.07 | 0.002 |
| RTot_NC | 0.1869 | 0.0130 | 14.34 | <.001 |
| NinH | 0.4302 | 0.0689 | 6.25 | <.001 |
| House Bungalow | -0.550 | 0.246 | -2.23 | 0.026 |
| House Flat | -1.17 | 2.15 | -0.55 | 0.586 |
| House Other | -1.85 | 2.16 | -0.86 | 0.392 |
| House Semi | -0.700 | 0.184 | -3.80 | <.001 |
| House Terraced | -0.992 | 0.370 | -2.68 | 0.007 |
| House Unknown | -0.234 | 0.352 | -0.67 | 0.506 |
| TimePeriod Jun04 | -0.825 | 0.144 | -5.72 | <.001 |
| Local_Authority Enfield | -0.447 | 0.374 | -1.20 | 0.232 |
| Local_Authority Fareham | -1.006 | 0.356 | -2.83 | 0.005 |
| Local_Authority G.Yarmth | -0.078 | 0.360 | -0.22 | 0.829 |
| Local_Authority Halton | -1.142 | 0.345 | -3.31 | <.001 |
| Local_Authority Hyndburn | -1.141 | 0.361 | -3.16 | 0.002 |
| Local_Authority Kennet | 0.026 | 0.371 | 0.07 | 0.944 |
| Local_Authority N. Lincs | 0.100 | 0.370 | 0.27 | 0.787 |
| Local_Authority Wigan | -0.163 | 0.372 | -0.44 | 0.661 |

Parameters for factors are differences compared with the reference level:

| Factor | Reference level |
|---|---|
| Comp | NonHC |
| House | A-Detached |
| TimePeriod | A-Sept04 |
| Local_Authority | Christch |

# Regression analysis

Response variate: Residual_cGW
Fitted terms: Constant + Comp + NinH + Age + House + TimePeriod + Local_Authority + AreaHardStanding + AreaLawn

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 22 | 3909. | 177.68 | 15.27 | <.001 |
| Residual | 1727 | 20090. | 11.63 | | |
| Total | 1749 | 23999. | 13.72 | | |
| Change | 0 | 0. | * | | |

Percentage variance accounted for 15.2
Standard error of observations is estimated to be 3.41.

## Estimates of parameters

| Parameter | estimate | s.e. | t(1727) | t pr. |
|---|---|---|---|---|
| Constant | 0.242 | 0.685 | 0.35 | 0.724 |
| Comp NonWRAPHC | -0.431 | 0.224 | -1.92 | 0.055 |
| Comp WRAP2004Enhanced | -0.720 | 0.262 | -2.75 | 0.006 |
| Comp WRAP2004NewRecruit | -0.283 | 0.231 | -1.23 | 0.221 |
| NinH | -0.2137 | 0.0808 | -2.65 | 0.008 |
| Age | 0.2412 | 0.0706 | 3.42 | <.001 |
| House Bungalow | -0.465 | 0.282 | -1.65 | 0.099 |
| House Flat | 3.61 | 2.44 | 1.48 | 0.140 |
| House Other | -1.77 | 2.45 | -0.72 | 0.469 |
| House Semi | -0.697 | 0.217 | -3.21 | 0.001 |
| House Terraced | -0.945 | 0.428 | -2.21 | 0.027 |
| House Unknown | -0.760 | 0.401 | -1.89 | 0.058 |
| TimePeriod Jun04 | 0.358 | 0.163 | 2.19 | 0.029 |
| Local_Authority Enfield | 0.067 | 0.427 | 0.16 | 0.876 |
| Local_Authority Fareham | 1.942 | 0.408 | 4.76 | <.001 |
| Local_Authority G.Yarmth | 1.892 | 0.415 | 4.56 | <.001 |
| Local_Authority Halton | -0.200 | 0.399 | -0.50 | 0.617 |
| Local_Authority Hyndburn | -0.418 | 0.416 | -1.01 | 0.315 |
| Local_Authority Kennet | -0.196 | 0.420 | -0.47 | 0.640 |
| Local_Authority N. Lincs | 2.281 | 0.420 | 5.44 | <.001 |
| Local_Authority Wigan | 3.129 | 0.426 | 7.34 | <.001 |
| AreaHardStanding | -0.00411 | 0.00129 | -3.19 | 0.001 |
| AreaLawn | 0.001288 | 0.000622 | 2.07 | 0.039 |

Parameters for factors are differences compared with the reference level:

| Factor | Reference level |
|---|---|
| Comp | NonHC |
| House | A-Detached |
| TimePeriod | A-Sept04 |
| Local_Authority | Christch |

# Regression analysis

Response variate: GWTotal_C
Fitted terms: Constant + Comp + House + Age + TimePeriod + Local_Authority + AreaFlowerbeds + AreaHardStanding + AreaLawn

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 16 | 2146. | 134.15 | 3.14 | <.001 |
| Residual | 823 | 35174. | 42.74 | | |
| Total | 839 | 37320. | 44.48 | | |
| Change | 0 | 0. | * | | |

Percentage variance accounted for 3.9
Standard error of observations is estimated to be 6.54.

## Estimates of parameters

| Parameter | estimate | s.e. | t(823) | t pr. |
|---|---|---|---|---|
| Constant | -2.10 | 1.58 | -1.33 | 0.184 |
| Comp NonWRAPHC | 0.843 | 0.658 | 1.28 | 0.200 |
| Comp WRAP2004Enhanced | -0.834 | 0.796 | -1.05 | 0.295 |
| Comp WRAP2004NewRecruit | -0.950 | 0.675 | -1.41 | 0.160 |
| House Bungalow | 0.128 | 0.843 | 0.15 | 0.879 |
| House Other | -1.15 | 4.72 | -0.24 | 0.808 |
| House Semi | -1.623 | 0.651 | -2.49 | 0.013 |
| House Terraced | -2.78 | 1.16 | -2.40 | 0.017 |
| House Unknown | 0.19 | 1.27 | 0.15 | 0.879 |
| Age | 0.414 | 0.184 | 2.25 | 0.025 |
| TimePeriod Jun04 | 0.890 | 0.451 | 1.97 | 0.049 |
| Local_Authority Enfield | 3.450 | 0.923 | 3.74 | <.001 |
| Local_Authority Halton | 2.338 | 0.865 | 2.70 | 0.007 |
| Local_Authority Hyndburn | 3.420 | 0.903 | 3.79 | <.001 |
| AreaFlowerbeds | 0.01171 | 0.00612 | 1.91 | 0.056 |
| AreaHardStanding | -0.01198 | 0.00443 | -2.70 | 0.007 |
| AreaLawn | 0.00362 | 0.00243 | 1.49 | 0.137 |

Parameters for factors are differences compared with the reference level:

| Factor | Reference level |
|---|---|
| Comp | NonHC |
| House | A-Detached |
| TimePeriod | A-Sept04 |
| Local_Authority | Christch |

# Regression analysis

Response variate: Residual_OCW
Fitted terms: Constant + Age + AreaFlowerbeds + AreaHedgesShrubs + AreaLawn + Comp + House + Local_Authority + NinH + Tenant + TimePeriod

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 27 | 2000. | 74.07 | 6.47 | <.001 |
| Residual | 1320 | 15113. | 11.45 | | |
| Total | 1347 | 17112. | 12.70 | | |
| Change | 0 | 0. | * | | |

Percentage variance accounted for 9.9
Standard error of observations is estimated to be 3.38.

## Estimates of parameters

| Parameter | estimate | s.e. | t(1320) | t pr. |
|---|---|---|---|---|
| Constant | 4.276 | 0.785 | 5.45 | <.001 |
| Age | -0.1592 | 0.0830 | -1.92 | 0.055 |
| AreaFlowerbeds | -0.00447 | 0.00162 | -2.76 | 0.006 |
| AreaHedgesShrubs | 0.00617 | 0.00262 | 2.35 | 0.019 |
| AreaLawn | 0.001180 | 0.000685 | 1.72 | 0.085 |
| Comp NonWRAPHC | -0.457 | 0.272 | -1.68 | 0.093 |
| Comp WRAP2004Enhanced | -0.509 | 0.302 | -1.68 | 0.093 |
| Comp WRAP2004NewRecruit | -0.761 | 0.264 | -2.88 | 0.004 |
| Comp WRAP2005Enhanced | -1.636 | 0.520 | -3.14 | 0.002 |
| Comp WRAP2005NewRecruit | -0.344 | 0.883 | -0.39 | 0.697 |
| House Bungalow | -0.579 | 0.318 | -1.82 | 0.069 |
| House Flat | -0.47 | 2.00 | -0.23 | 0.815 |
| House Other | -2.12 | 2.46 | -0.86 | 0.389 |
| House Semi | -0.696 | 0.249 | -2.80 | 0.005 |
| House Terraced | -1.116 | 0.554 | -2.01 | 0.044 |
| House Unknown | -0.416 | 0.504 | -0.82 | 0.410 |
| Local_Authority Enfield | 0.211 | 0.457 | 0.46 | 0.645 |
| Local_Authority G.Yarmth | 0.150 | 0.412 | 0.36 | 0.716 |
| Local_Authority Halton | 0.064 | 0.415 | 0.15 | 0.878 |
| Local_Authority Hyndburn | -0.725 | 0.440 | -1.65 | 0.100 |
| Local_Authority Kennet | 0.740 | 0.432 | 1.71 | 0.087 |
| Local_Authority N. Lincs | 1.456 | 0.435 | 3.35 | <.001 |
| Local_Authority Wigan | 1.062 | 0.466 | 2.28 | 0.023 |
| NinH | 0.5267 | 0.0882 | 5.97 | <.001 |
| Tenant Tenant | 0.278 | 0.390 | 0.71 | 0.477 |
| Tenant Unknown | 1.975 | 0.775 | 2.55 | 0.011 |
| TimePeriod Jun04 | -0.719 | 0.219 | -3.29 | 0.001 |
| TimePeriod Sept05 | 0.074 | 0.246 | 0.30 | 0.764 |

Parameters for factors are differences compared with the reference level:

| Factor | Reference level |
|---|---|
| Comp | NonHC |
| House | A-Detached |
| Local_Authority | Christch |
| Tenant | A-Owner |
| TimePeriod | A-Sept04 |

# Regression analysis

Response variate: Residual_cGW
Fitted terms: Constant + Age + AreaFlowerbeds + AreaHardStanding + Comp + GWUse + Local_Authority + NinH + Tenant + TimePeriod + Comp.TimePeriod

## Summary of analysis

| Source | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| Regression | 27 | 2644. | 97.92 | 7.77 | <.001 |
| Residual | 1323 | 16670. | 12.60 | | |
| Total | 1350 | 19314. | 14.31 | | |
| Change | 10 | 91. | 9.14 | 0.72 | 0.703 |

Percentage variance accounted for 11.9
Standard error of observations is estimated to be 3.55.

## Estimates of parameters

| Parameter | estimate | s.e. | t(1323) | t pr. |
|---|---|---|---|---|
| Constant | 0.737 | 0.787 | 0.94 | 0.349 |
| Age | 0.2243 | 0.0856 | 2.62 | 0.009 |
| AreaFlowerbeds | -0.00280 | 0.00151 | -1.86 | 0.063 |
| AreaHardStanding | -0.00211 | 0.00142 | -1.48 | 0.138 |
| Comp NonWRAPHC | -0.582 | 0.436 | -1.34 | 0.182 |
| Comp WRAP2004Enhanced | -0.755 | 0.503 | -1.50 | 0.133 |
| Comp WRAP2004NewRecruit | 0.287 | 0.445 | 0.64 | 0.520 |
| Comp WRAP2005Enhanced | -0.972 | 0.577 | -1.68 | 0.092 |
| Comp WRAP2005NewRecruit | -0.576 | 0.944 | -0.61 | 0.542 |
| GWUse 1 | -0.477 | 0.282 | -1.69 | 0.091 |
| Local_Authority Enfield | -0.761 | 0.455 | -1.67 | 0.095 |
| Local_Authority G.Yarmth | 1.103 | 0.416 | 2.65 | 0.008 |
| Local_Authority Halton | -0.870 | 0.429 | -2.03 | 0.043 |
| Local_Authority Hyndburn | -1.075 | 0.450 | -2.39 | 0.017 |
| Local_Authority Kennet | -0.696 | 0.440 | -1.58 | 0.114 |
| Local_Authority N. Lincs | 2.110 | 0.442 | 4.77 | <.001 |
| Local_Authority Wigan | 1.640 | 0.468 | 3.51 | <.001 |
| NinH | -0.1645 | 0.0909 | -1.81 | 0.070 |
| Tenant Tenant | -0.629 | 0.399 | -1.58 | 0.115 |
| Tenant Unknown | -1.327 | 0.809 | -1.64 | 0.101 |
| TimePeriod Jun04 | 0.398 | 0.349 | 1.14 | 0.255 |
| TimePeriod Sept05 | 0.570 | 0.403 | 1.42 | 0.157 |
| Comp NonWRAPHC .TimePeriod Jun04 | 0.382 | 0.589 | 0.65 | 0.517 |
| Comp NonWRAPHC .TimePeriod Sept05 | -0.829 | 0.754 | -1.10 | 0.272 |
| Comp WRAP2004Enhanced .TimePeriod Jun04 | 0.103 | 0.702 | 0.15 | 0.883 |
| Comp WRAP2004Enhanced .TimePeriod Sept05 | 0.700 | 0.735 | 0.95 | 0.341 |
| Comp WRAP2004NewRecruit .TimePeriod Jun04 | -0.347 | 0.630 | -0.55 | 0.582 |
| Comp WRAP2004NewRecruit .TimePeriod Sept05 | -1.747 | 0.665 | -2.63 | 0.009 |
| Comp WRAP2005Enhanced .TimePeriod Jun04 | | | | |

| | | | |
|---|---|---|---|
| 0 | * | * | * |
| Comp WRAP2005Enhanced .TimePeriod Sept05 | | | |
| 0 | * | * | * |
| Comp WRAP2005NewRecruit .TimePeriod Jun04 | | | |
| 0 | * | * | * |
| Comp WRAP2005NewRecruit .TimePeriod Sept05 | | | |
| 0 | * | * | * |

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