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Use of home food digesters to reduce household waste

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European and UK legislation has led local authorities to implement waste prevention programmes and assess the options available for diverting waste from final disposal to landfill. Food waste is part of the waste stream where significant diversions can be made, with an estimated 6·7 Mt of such waste thrown out by UK households each year. One option available for managing food waste is the green cone (GC) food waste digester. The unit is installed at household level and is designed to accept all food waste including meat, fish and processed food. The unit heats up through solar gain and the waste in the GC is converted into water, carbon dioxide and a small amount of residue. This paper describes a project that directly investigated changes in waste by householders after they started using a GC food digester. A statistically significant reduction in waste was found, at a 99% confidence level, in households using a GC food digester. An average reduction of 2·1 kg of waste per household per week (from 11·2 to 9·1 kg) was seen in a sample of 68 new GC users compared with a sample of 1446 control, non-users.

1. INTRODUCTION

Local authorities throughout the UK are working towards meeting statutory recycling targets. The recycling rate has increased significantly over recent years, from only 7·5% of the waste stream being recycled in 1995[1] to 27% in 2005/06.[2] While it is important to increase levels of recycling, it is always considered preferable to follow the order of priority given in the waste hierarchy, that is, reduce, reuse, then recycle.[2] By generating less waste in the first place, fewer resources have to be spent on collecting, processing and disposing of waste. The importance of waste prevention is now being reflected in the Revised Waste Framework Directive wherein a target for member states to stabilise waste production by 2012 to levels produced in 2008 has been proposed. Moreover, the Thematic Strategy on the Prevention and Recycling of Waste requires member states to produce waste prevention plans.[3]

The *Waste Strategy for England 2007*[2] recognises the need to focus efforts on waste prevention. The strategy sets out a series of targets for reducing the amount of waste sent for final disposal (i.e. waste generated that is not reused, recycled or composted) from over 22·2 Mt in 2000 to 12·2 Mt by 2020—this is the equivalent of a reduction in annual household waste generation from 450 kg per capita in 2000 to 225 kg by 2020.

Local authorities throughout the UK are using a range of waste prevention initiatives to reduce quantities of waste delivered for final disposal. Examples include the promotion of reusable nappies, home composting, smart shopping, opting out of receiving junk or unwanted mail and donating items for reuse. Further information on current waste prevention initiatives and options is available in the literature.[4–6]

1.1. Food waste

A further approach is to minimise the food waste components of household waste (or catering waste) entering the collection stream through the provision of waste digesters. Food waste typically comprises 17–22% by weight of an average weekly waste bin,[7,8] and includes vegetables, fruit, cooked and processed foods, meat and fish.

Until 2003, local authorities in the UK were permitted to collect garden waste (organic matter including grass cuttings, prunings, fallen fruit, etc.) and food waste from households and then compost the material using open-air windrow systems. However, in 2001 an outbreak of foot and mouth disease led to the slaughter of some four million sheep, cattle and pigs.[9] The suspected cause of the outbreak was the feeding of unprocessed food waste to animals. As a consequence, under the Animal By-Products Order 1999 (amended in 2003), all food waste (catering waste), including source-separated material that could contain or have been in contact with meat or other products of animal origin, must now be disposed of in such a way that prevents its exposure to livestock and wild birds.[10] This had implications for local authorities—unless they had an enclosed composting facility, they could no longer continue to collect and compost food waste.

Based on the latest available data from the Composting Association, in 2004/05 only 7% of local authorities collected food waste along with garden waste from kerbsides; a further 3·5% offered a dedicated collection of food waste. At present, only 13% of sites accept food waste and it is estimated that 4 Mt was sent to landfill during 2004/05;[11] recent research by the Waste and Resources Action Programme (Wrap)[12] suggests this figure is far higher at 6·7 Mt. Diversion of this food waste from final disposal would result in significant economic savings from saved waste collection and processing costs along with associated environmental savings from reductions in transportation and greenhouse gas emissions from the degradation of food waste. Wrap

Desirable GC materials	Materials not suitable
Fish	Metal
Red meat and poultry	Wood
All bones	Plastic
Bread	Glass
Fruit, including peelings	Paper
Vegetables, including peelings	Straw
Dairy produce	Grass cuttings
Cooked food scraps	Hedge clippings
Crushed egg shells	Bulk oil
Tea bags	Disinfectant and bleaches
Animal excrement	Special treatment items

Table 1. Materials suitable for use in green cone waste digesters

estimates that 18 Mt of carbon dioxide emissions are generated from the disposal of food waste.[13]

A variety of systems have been developed to help residents manage their waste at home. The green cone (GC) waste digester was developed to manage food wastes and other biodegradable wastes such as animal excrement (see Table 1). There is some confusion that the GC is actually a home composting system, but unlike a composter, the role of the GC is to act as a digestion unit, that is, to provide a place for waste to degrade in an accelerated fashion rather than producing a compost material. Other differences between a GC and a home compost unit are summarised in Table 2.

1.2. The green cone

The GC is a four-part plastic injection-moulded system comprising a digestion basket that is installed below ground and which forms the base for an above-ground double-walled solar chamber with an access lid (Figure 1). The design of the GC utilises solar heating in the double-walled chamber to facilitate and accelerate the aerobic decomposition process within the digestion basket. For the system to work effectively it should be installed to obtain maximum sunlight. Access to the GC is through a 20 cm diameter hole in the top of the unit, which is sealed with a hinged lid. An accelerator powder that contains bacteria can be added to assist the decomposition process.

Food waste that is placed into the GC is converted into water, carbon dioxide and a small amount of residue. In a well-operating system, the residue will occupy the bottom 25 cm of the digestion basket after decomposition of about 1 t of food waste; the resulting water constituent escapes to the surrounding

	Home composter	Green cone
Takes all food waste including meat, bones and dairy products ('non-compostable kitchen waste')	×	✓
Takes garden waste	✓	×
Requires good drainage	×	✓
Requires turning/mixing occasionally	✓	×
Installation requires digging a hole	×	✓

Table 2. Key differences between green cone and home compost unit

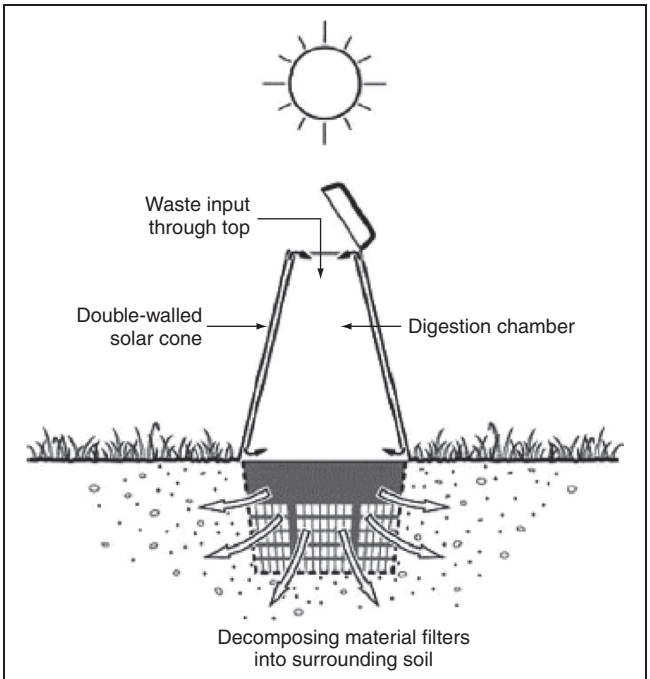

Figure 1. The green cone waste digester

soil. After about five years (the duration varies depending on the feedstock and use of the unit) this small quantity of residue must be removed and dug into garden sub-soil.

The GC is being promoted extensively throughout the UK as well as parts of North America. For example, in Aberdeenshire, Aberdeen City and Moray, 3702 GC units were sold in 2002–2005.[14] In Seattle, USA, 3600 units were distributed in a single day and 8000 households have purchased a GC over a period of 12 years.[15] West Sussex County Council conducted a trial of GCs in 2002 and launched a county-wide promotion in 2004 with the aim of having 50% of households with gardens using food waste digesters by 2015.[16] Despite the increasing profile of the GC unit, relatively few research studies into their performance (or those of home food digesters generally) have been undertaken. Those studies that are available are not able to provide results that have been tested for statistical significance.

Bench *et al.*[17] undertook a study in which households were provided with weighing equipment to monitor how much waste was being diverted into their GC. Sixty per cent of respondents stated that they had seen a reduction of 25–50% in the quantity of waste that they placed out for collection, and quantitative results showed that, on average, 2·7 kg per week was diverted. Other research has shown conflicting results, with rates of diversion varying from 2·2 to 6·5 kg per household per week (see Table 3[17–22]). However, many of the studies involved only small numbers of households, and residents were aware that their behaviour was being observed.

Local authorities are required to justify their spending. It is thus necessary to determine, with more certainty, the amount of waste that could be diverted through GCs so that their use could be considered against the cost of public subsidy. This paper reports on a systematic study of 1957 households who were offered GCs and whose residual waste was individually weighed for four weeks before and four weeks after GC installation.

Reference	Year of study	Location	Number of households	Waste diverted to green cone: kg/week per household
Todd[18]	2001	West Oxford	32	2·4
Jones[19]	2002	Moray	63	2·9
TWBC[20]	2003	Telford	5	6·5
Bench *et al.*[17]	2005	West Sussex	48	2·7
Gysin[21]	2005	Dorset	95	3·9
RBC[22]	2005	Rugby	50	2·2

Table 3. Previous green cone studies

2. METHODOLOGY

In summer 2005, the University of Brighton in partnership with West Sussex County Council set out to determine whether the use of GC food digesters by householders in West Sussex could be correlated with a significant reduction in residual household waste set out for disposal. Data were collected using two methods.

(*a*) Waste placed out by householders for collection was weighed for four consecutive weeks before and four consecutive weeks after use of a GC (at least a month was allowed between the two periods for users to 'settle in'). It was hypothesised that those changing to GC use would have a reduced residual waste set out for collection.
(*b*) The composition of residual (black bag) waste of a sample of householders was analysed in detail both before and after the onset of GC use. These data were used to test the hypothesis that there would be reductions in specific waste materials that could be processed in GCs for those households that were using them compared with those that were not.

As the effects looked for were small, it was known from the outset that incorrect data from only two or three households could mask true effects. It was necessary to be certain whether every household used to test the hypotheses was using the GC or not. To this end, a programme of face-to-face questionnaires was carried out with householders. All householders in the sample were approached; not all were available (even after three visits) or willing to answer. Households whose use of the GC was unknown were discounted from the data set. However, the initial sample size was sized to take account of these and other 'wastages'.

2.1. Overview

The trial was conducted in an area where GCs had not previously been promoted. The sample consisted of approximately 500 households from the first half of a given daily collection round over four different collection days (i.e. 2000 in total). Rounds in four different villages or towns were chosen, and measurements started on 14 June 2005 for four weeks (phase 1). The second set of four-week measurements (phase 2) started on 6 September 2005. In both phases, in the fifth week, residual waste was taken from approximately 200 households for detailed analysis.

Normal waste collection was suspended each morning as university researchers went along the route weighing waste from *every* house using portable electronic scales. After 3–4 h, council collection crews came in to collect the waste. The first half of the round was specifically chosen to ensure that all households would have their waste set out; those on the second half of the round might not have put their waste out until much later, causing many gaps in the data sets.

Following phase 1, all households were offered free (including delivery) GCs to arrive within 2–3 weeks. The offers were made during visits to each household or via flyers if personal contact could not be made. All were delivered by the middle of July. The target number of 350 households was exceeded, with 392 households requesting GCs.

In the fifth week of phase 1, 175 households had their black bags removed and waste was analysed by material type; 275 households were similarly analysed in the fifth week of the post-GC period (phase 2). Of the 275 households in phase 2, 51 were later found to have installed and used their GCs; 108 were definitely not using GCs and these were used as controls. The study only used data from those households *definitely* known to have have/have not installed and used their GCs.

2.2. Kerbside weighing

Surveyors used portable electronic industrial scales with an accuracy of 1 g to weigh waste at the kerbside of targeted households before collection. The waste was weighed in the containers used by each household since it was not feasible (noise disturbance, time constraints, etc.) to remove the waste from the container prior to weighing. At some point (e.g. later in the day after they had been emptied) the weights of the empty containers were recorded and noted for future reference and calculations. In cases where several houses used the same waste container (e.g. council-issued wheeled bins), the same weight was used for all relevant households. Any extra waste set out, for example, beside the containers but in plastic bags, was recorded separately in each case.

2.3. Waste compositional analysis

For compositional analysis, bags were removed from the kerbside of each targeted household and placed in a large sack labelled with a reference number. These were then removed to a sorting site where surveyors weighed them, separated the contents into the categories listed in Table 4 (based on Defra guidance[23]) and noted the weight of each category for each reference number. The data were then analysed.

3. RESULTS

3.1. Changes in average weight of waste

Residual waste weights for each household for each week were averaged over phase 1 and again over phase two. For each household (1446 did not use the GC; 68 were known to have started using the GC), the difference between average phase 1 and phase 2 weights was calculated.

For data of this type, simple averages are not suitable, and more sophisticated statistical techniques are needed. For example, on average, GC users' residual waste decreased by 2·1 kg in phase 2, while that of the control group (i.e. non-GC users) increased by 0·2 kg. However, in both cases the uncertainty in the

Primary material category	Example
Cardboard	Card packaging, board packaging, liquid cartons, other card
Compostable kitchen	Home-compostable kitchen waste, e.g. vegetable scraps, tea leaves
Dense plastic	Clear and coloured plastic bottles, food packaging, other dense plastic
Electrical equipment	Old household goods, e.g. kitchen appliances, radios, electronic toys
Ferrous metal	Beverage cans, food cans, other cans, other ferrous
Fines	Material less than 10 mm, including soils
Garden waste	–
Glass	Glass bottles and jars
Hazardous	Household and car batteries, chemicals, identifiable clinical, other potentially hazardous
Miscellaneous combustibles	Treated wood, untreated wood, furniture, carpet and underlay
Miscellaneous non-combustibles	Construction and demolition, masonry, ceramics
Non-compostable kitchen	Non-home-compostable kitchen waste, e.g. meat, fish, bones, cooked foods, dairy products
Non-ferrous metal	Beverage cans, foil
Paper	Newspaper and magazines, other recyclable paper, paper packaging
Plastic film	Packaging plastic film, plastic bags
Textiles	Clothes, shoes, linen
Disposable nappies	–

Table 4. Categories of waste used in this study

measurements was around 4 kg. A more appropriate statistical test was thus used—in this case, a two-tailed *t*-test for two samples known to have different variances. This gave the result that the two samples were different at a high confidence level of 99% (Table 5).

3.2. Changes in waste composition

Changes in composition of the residual waste before and after use of a GC was determined through detailed composition analysis of 153 and 159 households in phase 1 and phase 2 respectively. The analysis allowed comparison of the amounts of different materials in the residual waste of GC users and non-users. The average quantity of waste set out for collection in phase 1 was 9 kg per household per week (Table 6). In phase 2, the average weight of residual waste placed out by those households that had installed a GC was 7·9 kg per week; in the same period the control group (i.e. households that had not installed a GC) set out 9·2 kg waste per week.

The only category of residual material that can be placed in a GC but not in a composter is non-compostable food material such as meat and cooked food. This category thus represents exactly those materials that should be reduced in the waste stream of GC users who also have composters. On average, the households studied generated 1·5 kg per week of non-compostable food waste in phase 1; this was reduced to 0·5 kg per week for GC users in phase 2. A two-tailed *t*-test showed this result to be highly statistically significant at the 99% confidence level. For comparison, the control households generated 1·1 kg of such waste per week in phase 2.

Regarding all materials desirable for a GC, 3 kg per household per week was generated in phase 1. In phase 2, this reduced to 1·7 kg per week for households using a GC; the control group remained consistent at 3·1 kg.

	Households using GC in phase 2	Control (households without a GC)	Valid *t*-test?
Number of households	68	1446	
Difference in residual waste phase 2 − phase 1: kg/week	−2·1	+0·2	Yes, 99% confidence level
Standard deviation	4·3	3·9	

Table 5. Differences in averages of residual weights set out in the two phases

4. CONCLUSIONS

In trials conducted in Sussex, UK, the use of green cone food digesters was studied to determine if a statistically significant reduction of residual waste set out by households could be achieved. The study showed that households using GCs achieved a reduction in their set-out waste when compared with a control group, to a 99% confidence level. On average, residual waste set out for collection was reduced by 2·1 kg per week per household.

	Phase 1 baseline data	Phase 2 GC installed	Phase 2 control (non-GC households)
Number of households	153	51	108
Average residual waste: kg/household/week	9	7·9	9·2
Non-compostable kitchen: kg/household/week	1·5	0·5	1·1
Standard deviation	2·2	0·7	1·6
Compostable kitchen: kg/household/week	1·4	1·2	2·1
Total GC-desirable material: kg/household/week	3·0	1·7	3·1

Table 6. Comparison of composition of residual waste set out for collection

From a detailed composition analysis of the waste, households using a GC were found to set out less 'non-compostable food materials' than those not using a GC, to a 99% confidence level. The average difference was found to be 0·6 kg per week.

No statistically significant reduction was found for the categories of compostable food waste or garden waste. Although food digesters can, in principle, take some waste from these categories, in this study they did not appear to be affected. It is considered that most households using food digesters already use composting units for these categories.

The results suggest that the GC food waste digester is an effective option to reduce the amount of food waste being sent for disposal. Previous studies were unable to reach this conclusion as the level of waste reduction cannot be shown to be significant without very large sample sizes; this study is the first to report such statistical significance.

The result is key to those working to divert household waste from the general waste stream, with waste reduction being placed higher on the waste hierarchy than recycling or city composting. For the first time, this research provides a clear indication that food digesters work to reduce residual household waste, along with a measure of that reduction. Local authorities can use this information to determine the relative benefits of promoting food digesters against other waste diversion techniques. However, it must be noted that the success of the method will depend on the attitude of the public, the availability of gardens and appropriate weather conditions.

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