

Dealing with Food Waste in the UK

Authors:

Dr Dominic Hogg, with Josef Barth, Konrad Schleiss and Enzo Favoino

March 2007

Report for:

Richard Swannell, WRAP

Prepared by:

Dominic Hogg, Josef Barth, Enzo Favoino and Konrad Schleiss

Approved by:

Joe Papineschi

Contact Details

Eunomia Research & Consulting Ltd

1 Kings Court

Little King Street

Bristol

BS1 4HW

United Kingdom

Tel: +44 (0)117 9450100

Web: www.eunomia.co.uk

Acknowledgements

Our thanks to Richard Swannell, Julian Parfitt, Linda Crichton and Ingrid Toleman for comments and prompts on earlier versions of this report.

Disclaimer

Eunomia Research & Consulting has taken due care in the preparation of this report to ensure that all facts and analysis presented are as accurate as possible within the scope of the project. However no guarantee is provided in respect of the information presented, and Eunomia Research & Consulting is not responsible for decisions or actions taken on the basis of the content of this report.

Executive Summary

In the context of the quest to move biodegradable municipal waste into more sustainable management routes, the low level of capture of food wastes in the UK is surprising. Despite the fact that food waste is one of the largest single fractions of the waste stream, it is estimated that only around 2% of the available amount is collected separately for composting or anaerobic digestion.

It is clear that there is a strong case to recycle more food and garden waste in the UK. By doing so we can make a significant reduction in the amount we are currently sending to landfill, helping the UK meet the terms of the EU landfill Directive. This also has greenhouse gas benefits and in time can make an important contribution to the UK's efforts to tackle climate change¹. In addition the treated material can be put to good use producing good quality compost for everything from parks and gardens to brownfield sites.

For local authorities the challenge is to find the most appropriate options to deliver an easy to use service which achieves good environmental outcomes and that is cost effective for local people. This report examines the options, their efficacy and their suitability. It also considers how different options can be integrated into existing collection infrastructure.

This report seeks to inform and to provide guidance on what is '*the most cost effective and environmentally sustainable ways of diverting household food waste from landfill that leads to the production of a saleable product*'. It builds on earlier work by assessing the financial and environmental costs and benefits of different approaches to biowaste management.²

This research finds that there is a genuine opportunity for the UK to take a lead in dealing with biowaste (i.e. food and garden waste) in Europe. It can learn from experience in other countries and manage biowaste more cost effectively and sustainably.

To do this it is important to count the cost of both the collection and processing of biowaste when considering management options. Each collection system has a different success rate in capturing biowaste, and different systems are more or less likely to increase the quantity collected from the household. For example, the quantity of biowaste collected in systems where garden waste collections are offered free of charge is higher than in systems where no such service is offered, or where there are constraints on the volume of material set out. Such considerations have implications for costs, and for diversion of material from the residual waste stream.

In considering the financial costs, the report finds:

1. Systems which include free garden waste collections tend to be more costly per household than those which target food waste *only*. In general, systems collecting garden waste, or mixed garden and food waste, *fortnightly* and free of charge, are more expensive than systems collecting food waste *weekly*. Encouraging householders to compost garden waste at home, where possible, reduces the risk of attracting extra material into the waste stream. Home composting promotion is also popular with gardeners, favourable on environmental grounds and can improve the economics of kerbside garden waste collections;

¹ *Carbon Balances and Energy Impacts of the Management of UK Wastes*. ERM and Golder Associates report for Defra.

² For the purposes of this, and the earlier report, biowaste is defined as garden waste and food wastes. It is recognised that composting and digestion systems are appropriate for treating other materials from household waste, but the focus is on food and garden wastes.

2. The additional cost associated with adding food waste to an existing free garden waste collection is significant. This is because the resulting mixture of food and garden waste must be treated by in vessel systems, which are more expensive than windrow composting of garden waste. In general this is a very expensive way of treating small amounts of food waste;
3. Collecting only food waste allows the processing costs to be minimised and can increase the capture rate. There is barely any difference in cost between the systems in which
 - a) all garden waste collected at household waste recycling centres (HWRCs) is composted in windrows, and food waste is digested anaerobically; and
 - b) all food waste and garden waste (collected at HWRCs) is composted at in-vessel systems.
 If the garden waste is processed by anaerobic digestion (AD) along with the food waste collected at kerbside, the costs are significantly higher. This is because windrow is a much cheaper way of treating garden waste than AD;
4. As the costs of residual waste management increase, so the benefits of separate biowaste collections increase, relative to the baseline (in which no biowaste is collected); and
5. Overall where home composting is promoted intensively by local authorities the financial costs of the biowaste management system are likely to be lower than in situations where this does not happen and it is a popular option for gardeners.

On environmental costs:³

1. If the system chosen for biowaste collection and treatment is separate collection of food waste coupled to anaerobic digestion, the environmental performance of the system is likely to be the best compared to all the other systems examined in this report.
2. The work re-affirms the results of earlier studies concerning the relative merits of open-air windrow composting, in-vessel composting and anaerobic digestion systems;
3. The performance of the systems relative to residual waste treatment is influenced by:
 - a. The quality of the residual waste treatment; and
 - b. The assumptions regarding the unit environmental damage costs³.

However, it seems that separate collection systems targeting biowaste are likely to show greater environmental benefits than collecting food and garden waste together.

These conclusions are subject to a number of caveats, and these were set out in more detail in other studies⁴. However, this work suggests the merits of an approach based on separate food waste collections, and the anaerobic digestion of this collected material. Collecting food waste separately from garden waste also enables anaerobic digestion to be integrated into the whole waste management system in a cost effective manner. This is because capital investments can be targeted at the material for which the investment is specifically required.

³ It was intended to seek to model thermophilic aerobic digestion (TAD) systems. However, it was felt that insufficient evidence of mass and energy balances, as well as emissions and costs, was available to enable reliable modelling of such systems using a feedstock of household food wastes.

⁴ Eunomia (2007) *Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis*, Banbury, Oxon: WRAP to be published in 2007

Food waste exhibits less seasonal variation than garden waste and therefore anaerobic digestion of this material should enable capacity utilisation to be higher.

In the light of these conclusions, the question arises as to the implications of treating biowaste with a high content of food waste. The report highlights the fact that there are both upsides and downsides to dealing with such input materials (known as feedstocks) when compared with processes dealing with garden waste and only small proportions of food waste:

- In the processing stage, the moisture content and fermentability of the wastes are important factors to be considered in the design and management of biological processes:
 - The high moisture content of food waste means that it needs structural material (such as garden waste or woodchips at around 50% by weight) in order to allow the aerobic process to take place; and
 - The high fermentability calls for processes with good exhaust air odour control in the aerobic phases;
 - In the case of anaerobic digestion, a key process management issue is to ensure a properly controlled feeding rate with well prepared feedstock to generate good biogas production;
- As regards product quality a higher proportion of food waste is likely to:
 - Increase the nutrient content compared to composts derived from garden wastes only;
 - Reduce contamination by inert materials (stones etc.);
 - Increase other impurities, such as plastic;

The salinity of the output material is likely to be higher in aerobic systems because food has a higher salt content than garden material and because there is a significant loss of water during in-vessel composting. This is a key point which is likely to mean that certain high value markets for the compost, such as horticulture, will not be available unless some form of blending (with other soil improvers) takes place. The potential for generating a product with lower salt content is much greater where AD processes are used. This is due to the fact that the soluble salts can in large part be removed in the dewatering phase following the digestion of the input material.

The report highlights experience in other countries with plants dealing with relatively high proportions of food waste. These examples show how, in different plants, some of the relevant issues are addressed in seeking to generate marketable outputs from food waste rich feedstocks (FWRFs). Some salient points emerge from these experiences:

- It is essential, if output products of a high quality are to be achieved, to ensure the collection system is communicated well with a good consultation process. A system which is acceptable and understood by the population will mean that impurities in the feedstock are minimised. This implies the use of convenient systems, and an approach which makes active participation easy for the householder;
- Where plants operate in proximity to agricultural markets, it is likely to be easier to find market outlets for typical products;
- It is helpful, if the aim is to reach high quality markets, for the plant to have direct links with those who will use the product, better still, for manufacturers of growing media to

be directly involved in the enterprise. In any event, some expertise in matters of compost marketing is extremely useful;

- Salinity of the product will not always mean that the compost cannot be used as a peat substitute. In the absence of this constraint, sufficient space for lengthy maturation is likely to be important;
- Combining anaerobic and aerobic steps within the treatment process can bring benefits. Integration of an additional digestion step for source separated kitchen waste can:
 - Increase capacity;
 - Reduce salinity of the output;
 - Significantly reduce odours, allowing post-digestion aerobic treatment to take place in open windrows without problems
 - Generate additional income through generation of energy,
- For digestion plants, thorough dewatering may be sufficient to render solid residues usable in agriculture (without a subsequent aerobic step), this will depend upon the input feedstock;
- Where an aerobic step is used following the digestion process, it can be useful to add bulking material to the process, especially where the food waste content of the feedstock is high;
- In some digestion plants, the liquid residue following dewatering may be usable as a liquid fertiliser. The salt content of fertiliser for use in agriculture is far less problematic than where the product is intended for use as (part of) a potting mix;
- Generally, the agricultural market is a major one for digestion products (liquid in particular). In continental Europe the market has a positive attitude towards the material because of its high fertiliser value and the (usually) low costs - the products are often made available free of charge. Arguably, the risk of not being able to reach high quality markets is lower for the solid products of digestion, but equally, the problems may be greater in urban areas in respect of the liquid residue. In these situations, process water can be partially recirculated, but some treatment of liquid residues is likely to be required.

In summary, therefore, the following points are clear:

- a) Both anaerobic digestion and in-vessel composting are suitable for processing food waste with a view to generating a saleable product;
- b) Anaerobic digestion is more favourable from an environmental perspective, primarily because the process produces methane which can be used to generate energy. Aerobic composting is a small net energy user; and
- c) In overall terms, the most cost-effective sustainable, and user friendly solution will depend upon how the collection and treatment systems are configured *jointly*. The design of collection and treatment should be considered together.

For some of the leading authorities in the UK in terms of recycling rates, decisions have already been made in respect of biowaste collection and treatment.

It has to be recognised that waste collection and treatment systems exhibit a considerable degree of 'path-dependence'. In other words, decisions made in the past can limit the menu of choices available in the future (or at least, they make some changes more difficult and

costly). Some adaptations are evidently possible in respect of treatment processes, whilst collection systems are also likely to be amenable to alteration.

The messages from this report are more immediately relevant for those considering, or seeking to implement, new systems for biowaste collection, particularly in more urban areas. Here, as long as adequate attention is paid to marketing strategies for the end products, and where collection and treatment systems are well integrated, consideration should be given to the possibility for collecting food waste separately for digestion. If these collection systems can be coupled to AD processes, it should prove possible to generate both energy, as electricity or heat, and quality products for use in various applications. The latter may require the use of blending (possibly with green waste or/and other materials), and working with companies with greater experience in producing and marketing products for specific end-users.

There is likely to be a considerable environmental dividend from a shift in this direction. If the 5.5 million tonnes of UK municipal food waste were targeted for separate collection, then the total quantity of electricity generated could be of the order 477-761 GWh per annum if the material was digested. This is equivalent to the electricity used by between 103,000 - 164,000 households, or 16-26% of the energy generated by wind power in the UK in 2005.⁵

Composting the same amount of material would utilise energy in the process. The net position in respect of greenhouse gases is likely to be such that routing the material through AD rather than composting will improve the position in respect of greenhouse gases to the tune of more than 0.22 - 0.35 million tonnes CO₂ equivalent (based on an assumption that the displaced source is gas fired electricity generation). If the same amount of material had been landfilled, savings increase to 1.6 - 3.6 million tonnes CO₂ equivalent, depending upon the performance of both the landfill and the digester.

AD plants that treat 100% food waste are rare at the moment, though many processes would happily receive such materials. What is being suggested here is to bring together leading-edge design of collection systems with state-of-the-art treatment systems. Some countries are using approaches to optimise collection systems, others are moving more towards digestion as an approach to biowaste treatment. Few are doing both. This report shows that the UK can learn from this experience and implement cost effective systems for the collection and management of biowastes which reduce greenhouse gas emissions and bring real environmental benefits.

⁵ Based on Digest of UK Energy Statistics 2006, http://www.dtistats.net/energystats/dukes06_c5.pdf

Contents

- Executive Summary ii**
- 1.0 Purpose of the Report 1**
- 2.0 From Challenge to Opportunity? 1**
- 3.0 Food Waste 2**
 - 3.1 How Much is There? 2
 - 3.2 How Much Can be Dealt with Through Waste Prevention?..... 4
 - 3.2.1 *Home Composting*..... 4
 - 3.2.2 *Source Reduction*..... 5
 - 3.3 What’s Left? 6
- 4.0 What are the Options?..... 6**
 - 4.1 Waste Prevention 6
 - 4.2 Approaches to Collection..... 7
 - 4.2.1 *How is Food Waste Being Collected Today?*..... 7
 - 4.3 Approaches to Treatment of Separately Collected Biowastes Including Food Wastes 10
 - 4.4 Approaches to Residual Waste Treatment..... 14
 - 4.5 Systems Modelled..... 15
- 5.0 Comparative Financial Performance 19**
- 6.0 Comparative Environmental Performance 24**
- 7.0 Products from Food Waste Rich Feedstocks (FWRFs)..... 30**
 - 7.1 Effects of FWRFs on Key Contaminants..... 30
 - 7.1.1 *Key Issues Regarding Different Feedstock Materials* 30
 - 7.2 Effects of Choice of Technology 39
 - 7.3 Process Issues 47
 - 7.3.1 *Composting*..... 48
 - 7.3.2 *Anaerobic Digestion* 48
 - 7.4 Risk Factors Associated With Food waste in Composting..... 49
 - 7.4.1 *Compost Quality?* 49
 - 7.4.2 *Compost Properties*..... 49
 - 7.4.3 *Compost Markets* 50
 - 7.4.4 *Process Problems Due to Insufficient Bulking Agents* 51
 - 7.4.5 *Perception of End Users* 51
 - 7.4.6 *Genetically Modified Organism Not Traceable in Compost and Digestion Products*
52
 - 7.4.7 *Digestion Residuals* 53
- 8.0 Conclusions..... 54**
 - 8.1 The Path Dependent Nature of Choice..... 54
 - 8.2 Energy from Food Waste? 57
 - 8.3 Caveats..... 58
 - 8.4 Moving Forward..... 58
- 9.0 References..... 58**

1.0 Purpose of the Report

In the WRAP Business Plan, a key objective for the Organics Programme is to identify:

*'the most cost-effective and environmentally sustainable ways of diverting household food waste from landfill that leads to the production of a saleable product. WRAP will focus particularly on food waste that cannot be practically dealt with by home composting.'*⁶

This report contributes to that objective through seeking to understand the possible approaches to collecting and treating biowastes, with a particular emphasis on food wastes.⁷ It follows previous research conducted for WRAP on the costs and benefits of waste collection and treatment options for biowaste management.⁸ It examines the comparative environmental performance of waste collection and treatment systems and then looks at some of the particular issues facing those local authorities, and their contractors, who seek to deal with materials which are relatively rich in food waste content at biowaste treatment plants. The report includes a number of case studies from other countries which seek to draw out some of the issues faced by plant operators in seeking to develop quality products from the collected biowaste.

2.0 From Challenge to Opportunity?

The Landfill Directive is rarely described as anything other than 'a challenge' to the management of waste in the UK. However, many are realising that it also provides a real opportunity. The opportunity lies in not simply improving the environmental performance of waste management, or in seeking to 'get closer' to the performance of other Member States in terms of recycling and composting. Rather, the opportunity lies in seeking to do things better, and smarter, than they have been done before. It is not just about 'catching up', but also, 'overtaking'.

The UK has the opportunity to make use of what is usually referred to as 'late-mover advantage'. Europe – and the rest of world – provides a rich laboratory of experience from which late-movers can learn, and so, adapt their strategies accordingly. Where biowaste management is concerned, this entails seeking the best *combinations* of collection *and* treatment in the context of the total waste management system.

For many authorities who are still currently reliant upon landfill as the principle route for dealing with residual waste, the looming targets for diversion of biodegradable material from landfill are already ensuring that the short-term focus of waste strategies is on how to improve the source separation of biowastes. Whilst garden waste collections have become far more prominent since the turn of the century, the

⁶ WRAP (2006) *Increasing Resource Efficiency, Reducing Carbon Emissions, WRAP Business Plan 2006-2008*, Banbury, Oxon: WRAP.

⁷ For the purposes of this, and the earlier report, biowaste is understood as covering garden waste and food wastes. It is recognised that composting and digestion systems are appropriate for treating other materials from household waste, but the focus is on food and garden wastes.

⁸ Eunomia (2007) *Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis*, Banbury, Oxon: WRAP to be published 2007.

separate collection of food wastes remains a largely peripheral activity with a small number of notable exceptions.

3.0 Food Waste

3.1 How Much is There?

Waste composition analyses repeatedly show that food waste is, if not *the* largest then, one of the largest single fractions of the household waste stream. Table 1 below shows that as far as we can discern, 18% or so of UK household waste is food waste (or around 216kg per household).⁹ The Table also shows the quantity of household waste which is composted in the different devolved administrations of the UK.

Of the total quantity that is composted, we have estimated the quantity of food waste within that total. This still tends to be a relatively small proportion because:

- Much of the biowaste collected separately for composting is garden waste collected at household waste recycling centres (HWRCs); and
- The majority of kerbside collections for biowaste are collecting garden waste only.

This enables an estimation to be made of the capture of food waste in the different administrations of the UK. The figures lie at around 1.3-2.8%. For the whole of the UK, the figure probably lies at around 2 %, and rising. How quickly this figure rises depends critically upon the systems used to collect food waste.

Table 1: Data and Performance Estimates for UK in Respect of Food Waste

	England 2004/5	Wales 2004/5	Scotland 2004/5	N. Ireland 2004/5	UK
Household Waste ('000 tonnes)	25,688	1,585	2,276	919	30,468
Composition of Food Waste (% hhld)	17.5%	18% ^a	18% ^b	19% ^c	17.6%
Quantity of Food Waste ('000 tonnes)	4,495	285	410	184	5,375
Total Quantity of Biowaste Composted	1,971,000 ^d	127,000	144,956	70,047	2,313,003
Estimated Quantity of Food Waste Composted	90,000 ^e	8,000 ^e	8,000 ^e	4,000 ^e	110,000 ^e
Proportion of Food Waste Captured (calculated from estimates) ^f	2.00%	2.80%	1.95%	2.17%	2.04%
Average Food Waste per Household per Year					216 kg

⁹ As the notes to the table indicate, the fraction reported as fines is also likely to contain a significant proportion of food waste within it.

Notes:

- ^a We have assumed a figure of 18% for Wales. The composition of municipal waste indicates a lower figure for municipal waste (15.7%) but this included a significant proportion of non-household waste.
- ^b SEPA gives a range of figures from Scottish local authorities for 'putrescibles' with an average of 28% and with an average for 'fines' of 7% (see note f below). We have estimated food waste at 18% of household waste.
- ^c Northern Ireland figures suggest a figure of 33% for all putrescibles in household waste. We have assumed that approximately 14% would be garden waste, leaving 19% as food waste
- ^d Calculated using the 2004/5 estimate from Defra for household waste recycled / composted and an estimate of the proportion of this that was 'compost' in 2004/5.
- ^e These are estimates and are based upon the view that a considerable proportion of waste collected for composting is 'pure garden waste' from CA sites and from 'garden waste only' collection systems. The authorities that include kitchen waste within their collection system tend, in the main, to co-collect kitchen waste with garden waste, typically on a fortnightly basis. This tends to keep kitchen waste captures quite low in proportion to garden waste.
- ^f Most composition studies report a 'fines' fraction. This fraction is likely to contain a reasonable proportion of food waste (the exact proportion depending upon the size of the fines fraction). For example, in recent work in West Sussex, it was clear that a sub-10mm fraction of residual waste consisted, in the main, of garden waste, food waste, soil, and dust like material.¹⁰ To the extent that the garden fraction is likely to be grass clippings, the proportion of fines which are food waste is likely to be highly seasonal. The contribution made by fines to the quantity of food waste has not been taken into account in the above table.

Sources:

England: Statistical Release: Municipal Waste Management Statistics 2004/5 (released March 2006); Julian Parfitt (2002) Analysis of Household Waste Composition and Factors Driving Waste Increases, December 2002.

Wales: National Statistics (2005) Municipal Waste Management Survey 2004-5: Results of the Survey for Wales, First Release, 16 December 2005; J. Poll et al (2003) The Composition of Municipal Solid Waste in Wales: A report for the Welsh Assembly Government, December 2003.

Scotland: SEPA (2005) Waste Data Digest 6, June 2006.

N. Ireland: NIEHS (2005) Municipal Waste Management: Northern Ireland, 2004/05 Summary Report, December 2005; DOENI (2006) Towards Resource Management: The Northern Ireland waste Management Strategy 2006-2020, Vol.2: Waste Stream Summaries. Quantities across the two studies are slightly different – we have used quantity data from the former and composition data from the latter.

UK: Household numbers from National Statistics Online (figure for 2004)

¹⁰ Network Recycling with Eunomia (2005) A Size Assay Study of Household Residual Waste as a Proposed Feedstock to an MBT Plant, Report for West Sussex County Council.

The characteristics of food waste – it is both biodegradable (and hence, an obvious target for inclusion in strategies for dealing with the various Landfill Allowance Schemes (LASs)), and one of the largest fractions in the waste stream – suggest that it should be one of the major foci of waste strategies. Currently, the vast majority is collected in refuse and landfilled. Because of this, and as recycling of other materials improves, food waste appears to account for a growing proportion of residual waste. Some recent compositional studies suggest that in some areas, food waste may be as much as 40% of residual waste collected door-to-door.

3.2 How Much Can be Dealt with Through Waste Prevention?

Work we have undertaken for WRAP elsewhere indicates that the best way of dealing with biowastes is likely to be to home compost them. The work suggests that this is not necessarily the most preferred approach on *environmental* grounds, but taking into account both benefits *and* costs, the low costs of home composting suggest that it ought to have a role to play in the management of biowaste.¹¹

In addition, WRAP is working with leading retailers in implementing the Courtauld Commitment, part of which aims to reduce the amount of food waste arising in household bins. This relates to the fact that a considerable quantity of food waste is literally wasted food which has not been touched by the purchaser. Some other countries, notably South Korea, are also trying to address this problem.

3.2.1 Home Composting

Survey work by WRAP suggests that the background rate of home composting in Great Britain is around a third (of households with gardens).¹² Another survey with linked waste analysis showed that on average, those households involved in home composting deal with 24 kg of food waste per year in schemes who were not using bins supported by WRAP, and 42 kg of food waste in schemes which used WRAP-supported bins, supported by relatively high intensity promotional activity.¹³

Table 2 shows what may happen to the quantity of food waste being home composted under the following assumptions:

- 87% of households have gardens;
- 34% of these households are currently home composting;
- 53% of current usage is well-promoted and these households deal with 42kg of food waste in their home composters;
- Of the remaining 47% of households home composting:

¹¹ WRAP is now working with a range of partners to promote home composting and since the programme was started in 2004 has distributed more than 1 million subsidised composting bins. Households covered by WRAP's partner authorities amount to 63% of households in Scotland and around 53% of households in England.

¹² 2005 Exodus Survey commissioned by WRAP.

¹³ Information from WRAP report on Home Composting Diversion Models, July 2005. It is worth noting that this is still only around 20% of what is produced each year by each household – see Table 1 above.

- 50% compost 24kg per annum of food waste; and
- 50% compost no food waste;
- The proportion of those with gardens engaged in home composting increases in future from 34% to 60%; and
- All home composting participants achieve a level of home composting of food waste of 60kg per annum.

As the Table shows, this does make a dent in the quantity of food waste remaining in the waste stream. However, the additional 576 thousand tonnes dealt with under these assumptions has to be set against the quantity still in residual waste at present which we estimate at over 5.2 million tonnes. In other words, under these assumptions, which may be difficult to realise, home composting would still be dealing with only just over 10% of the food waste currently in the residual waste stream.

Table 2: Estimated Potential for Food Waste Reduction from Home Composting in Future

Parameter	Value
Total Households (2004)	24,700,000
Proportion of Households with Gardens (estimate)	87%
Current Situation	
<i>Background Home Composting Rate (as % of those with gardens)</i>	34%
<i>Proportion of Home Composters Dealing with No Food Waste</i>	23.50%
<i>Proportion of Home Composters Dealing with 24 kg Waste</i>	23.50%
<i>Proportion of Home Composters Dealing with 42kg Waste</i>	53%
Future Situation	
<i>Home Composting Rate</i>	60%
<i>Proportion of Home Composters Dealing with No Food Waste</i>	0.00%
<i>Proportion of Home Composters Dealing with 24 kg Waste</i>	0.00%
<i>Proportion of Home Composters Dealing with 42kg Waste</i>	0.00%
<i>Proportion of Home Composters Dealing with 60kg Waste</i>	100%
Current Quantity of Food Waste Home Composted (estimate, tonnes)	203,845
Possible Future Quantity of Food Waste Home Composted (estimate, tonnes)	773,604
Increase in Quantity Home Composted (tonnes)	569,759

3.2.2 Source Reduction

There is growing evidence that a considerable quantity of food waste consists not of residues or leftovers, but of food that has never been touched by the purchaser. Two surveys, one by the Prudential, and the other by Braun, suggest very high levels of waste due to households throwing away ‘past its sell-by-date’ food (cooked and uncooked). The degree to which elimination of this ‘excess waste’ would reduce the total quantity of food waste finding its way into the waste stream is unclear. The reports indicate levels of waste in financial terms, but not in terms of waste.

Table 3 shows the items which the survey carried out for the Prudential 'Soggy Lettuce' report suggested were being thrown away by households. Though the survey may not be statistically robust, and though it does not make clear how much of any given item is disposed in each week, it does suggest that considerable strides could be made through seeking to prevent wastage of food.

Relatively few campaigns of this nature have been run around the world. South Korea has been seeking to reduce the quantity of food wasted by its citizens. Culturally, it is seen as polite to leave food on the plate, whilst people hosting dinners are expected, out of custom, to supply vast feasts which have little prospect of being consumed.

In the UK, it might seem reasonable to assume that, over time, and with concerted action over that period, it might be possible to reduce food waste by something of the order of 10% of the total. However, it should not be expected that this could happen over night.

Table 3: Food Waste Items Thrown Away as Reported by Prudential Report

Item	% of people who throw the item away in an average week
Lettuce / bag of salad	61%
Loaf of bread	60%
Fruit	57%
Pint of milk	45%
Cooked meat	43%
Packet food e.g. biscuits	42%
Spreads and dips	37%
Cheese	33%
Prepared meals	24%
Fresh meat and fish	23%
Unfinished bottle of wine	17%

Source: Prudential (2004) *Soggy Lettuce Report 2004: Are We A Nation of Wasters?*

3.3 What's Left?

It would seem that waste prevention measures could have an important impact on food waste quantities. However, these measures are likely to take time to implement and take effect, and even if the results are as suggested, the quantity of food waste will still be well in excess of 4 million tonnes (or around 14% of the household waste stream).

The question is, how best to manage this remaining food waste?

4.0 What are the Options?

4.1 Waste Prevention

As discussed above, one key option for managing biowastes is home composting. Waste prevention 'at source' requires changes to customers' attitudes to food and to retailers approaches to marketing, and seems unlikely to happen in the short-term. Increasing home composting rates is entirely possible, and indeed, more likely to be

achieved swiftly. However, there are limits to what could be done related not least to the presence of gardens. As shown above, the quantity of food waste remaining is likely to remain significant for the foreseeable future. This suggests the need for alternative management approaches.

4.2 Approaches to Collection

A review of experience suggests different approaches to biowaste collection:

- In some countries such as Denmark, barely any food waste is collected separately for composting or digestion although garden waste is collected separately by municipalities. One which was collecting biowaste – Aarhus – used an opti-bag separation system to sort refuse from organics. Reported loss rates were high, and the approach incurred high costs. The high costs are most likely explained through reference to the costs of sorting equipment, the fact that the approach demands that refuse is collected at the same frequency as biowaste, and the fact that the vehicle stock is more expensive than it needs to be for the materials concerned. Aarhus has stopped using this system;
- In most ‘central European’ countries – Belgium, Netherlands, Austria, Germany, and Switzerland, all of whom rank amongst the lead performers in terms of reducing quantities of household residual waste – biowaste collection takes place using biobins, or biotonnes, which are typically wheeled bins. In some countries – notably Belgium and the Netherlands – so called GFT waste (vegetable, fruit and garden wastes) is targeted. In other areas, all food waste materials are targeted. Households are typically given kitchen caddies for use in the kitchen, sometimes with liners of paper bags, or occasionally, starch-based liners;
- In Italy, Catalunya, some other parts of Spain, and parts of Norway, many collection systems focus on the food waste fraction (see Box 1). The basic concept is to seek to avoid drawing garden waste into the collection system by offering small containers to households for the collection of food waste. Households are given caddies with liners of either paper or starch based bags. Where starch based liners are issued, caddies are more likely to be vented to aid evaporation of moisture. The material is typically collected in non-compacting trucks.

Different approaches to collection of food waste clearly exist, and there is considerable discussion as to which approach may be better in which circumstances.

4.2.1 How is Food Waste Being Collected Today?

In the majority of UK authorities, food waste is still being collected as part of refuse. Where food waste is collected separately from refuse, the tendency has been to incorporate the collection of food within an already existing garden waste collection. To the extent that there is a ‘typical’ model emerging, it is the separate collection of food and garden waste free of charge in wheeled bins on a fortnightly basis, with refuse collected fortnightly in the intervening weeks. We are not aware of any situations where the vehicle used is not a standard refuse collection vehicle (RCV) or an adaptation of this (for example, a Rotapress vehicle).

Some authorities are running collection schemes which target food waste specifically. These authorities include Ealing, Richmond, Preston, Mendip, South Somerset, Taunton Deane and West Somerset. Some of these authorities – Ealing, for example – operate user pays garden waste collections. The charging structures and the containment methods vary. In the Somerset districts and Ealing, the vehicles used are stillages as food waste is collected alongside dry recyclables. In Richmond, the vehicles used (at present) are compactors. In Preston the vehicles used are 7.5 tonne tippers with a specially designed boxed body and bin lift.

Box 1: Italian Experience With Intensive Food Waste Collections

The Italian experience with food waste collections is of interest since so many of the municipalities which are separating biowaste at source are doing so with a focus on food waste.

The traditional approach to waste collection in many parts of Italy was through the use of road containers for the collection of refuse. It was a natural development for some municipalities, therefore, to make use of road containers since the mid 1990s as a means to collect materials separately when interest in recycling and composting grew.

Road container systems for biowaste collection suffer three major drawbacks. First, they allow delivery of large quantities of material into the collection system (including from commerce and industry). Second, the 'open access' nature of them tends to increase the level of impurities in the segregated materials. Third, there is little opportunity to motivate participation by households so captures of recyclables/compostables are rather poor.

Concurrently, a number of municipalities have started to collect food waste through door-to-door collections, whilst more and more door-to-door collections for dry recyclables have also started. It was quickly realised that the targeted collection of food waste was particularly important for a number of reasons:

1. Food waste is a large proportion of the waste stream;
2. It is the most putrescible fraction of the waste stream so needs to be collected frequently. If it is targeted effectively, refuse can be collected less frequently with few problems and this can lead to more cost-effective provision of services;
3. It is a dense fraction which effectively compacts itself, so making it unnecessary to invest in expensive compaction vehicles;
4. It was possible to constrain the set out of garden waste (so limiting any undermining of home composting and keeping waste arisings down);
5. The purity of the collected waste was very high and so could be used to make high quality composts.

Door-to-door food waste collections have become the backbone of the most effective collection systems in Italy. Several small municipalities now achieve recycling rates of 70% (the highest are at 80%) without large quantities of garden waste being delivered into the collection system. Lecco Province in the North of Italy recently became the first Province of Italy to achieve a 50% recycling rate. Today, many Provinces have gone beyond 50%, with the best performers (Treviso and Lecco) achieving around 60%. Therefore, many new Waste Management Plans are considering 55 to 60% as their mid-term target for recycling and composting

In most cases where food waste is collected separately, the collection frequency is weekly. Not all of the authorities collecting food waste are collecting refuse fortnightly. Some collect refuse weekly and this is likely to depress captures of food waste. However, the shift to fortnightly refuse collection appears to be an emerging trend where food waste collections are implemented. In several cases where food waste is collected separately, the authorities offer a 'user pays' garden waste collection.

Across the UK, the proportion of households receiving any form of food waste collection is still relatively low. Defra estimated the percentage of English households receiving kerbside collection schemes, by material collected, in 2003/04. The figures

are shown in Table 4. The Defra figures show the proportion of households receiving collections for compostable materials. We have estimated, from this, the numbers receiving collections of garden waste, and the numbers receiving collections of food waste. We estimate the number receiving food waste collections to be between 10-15%, and though this is an estimate, it is based upon a good understanding of what is happening in the development of services generally.

Our own in-house review, and data from the ROTATE team at WRAP, suggests that some 50-60 authorities are now collecting food waste, with roughly one quarter of these collecting food waste through targeted collections (i.e. independently of any garden waste collection). This would suggest a similar estimate in terms of household coverage (given the number of local authorities across the UK).

It is worth comparing this with the number of households covered by paper and card collections. For this – the other major biodegradable fraction in the waste stream – the collection coverage is 65% of households. It could be argued that this rate does not apply for all paper and card, and that as with compostable wastes, specific fractions, for example, card, are not targeted so widely. On the other hand, the collection costs of card are likely to be somewhat higher (notwithstanding higher material revenues) owing to the material’s low bulk density. The point is that, of the major biodegradable fractions of waste which could be separately collected, food waste seems to be a blind spot for existing collection schemes.

Table 4: Percentage of Household Covered by Door-to-door Collections of Different Materials

Material	Percentage of households
Paper and card	65%
Glass	40%
Scrap metal & white goods	18%
Textiles	27%
Cans	41%
Plastics	12%
Co-mingled	24%
Other	9%
Compost	43%
Of which	
<i>Including Garden Waste</i>	42%
<i>Including Food waste</i>	10-15%

The suggestion is, therefore, that food waste is not being targeted to the extent that it could or should be given its significance in the waste stream, and its potential to contribute positively to strategies for complying with obligations under the LASs. This can be traced in part to historic concerns regarding animal by-products, and the way

these interacted with changes in waste policy (notably, the introduction of targets for recycling and composting).¹⁴

4.3 Approaches to Treatment of Separately Collected Biowastes Including Food Wastes

The majority of European experience has been based around the composting of collected biowastes. Composting is a relatively well understood process, and some of what were the more troublesome issues – related to, for example, odour management – can now be addressed rather better than they were in the past. The development of in-vessel techniques has also contributed to the improved management of processes with respect to exhaust air and process controls.

More recently, the anaerobic digestion of municipal waste has proved increasingly popular as a treatment for municipal waste. Some of the more recent installations in recent times (notably in Spain) have been for the treatment of residual wastes (or a mechanically separated fraction thereof). However, the rise in prominence of AD has been quite apparent in respect of source-segregated biowastes. This development has been notable in Germany and Switzerland (see Box 2), and in respect of co-digestion, it appears to be occurring in Austria.

Box 2: Key Information Regarding the Swiss Situation:

Since 1986, the use of compost derived from residual waste has been effectively forbidden by the limit values for certain metal contaminants. In the early days of the development of composting in Switzerland, the majority of 'biowaste' composting was based upon the use of garden waste as a feedstock. Since the 1990s the use of centralised AD has been developing. The first scaled-up installation was at Rümliang.

The economics of composting and AD plants are still driven very much by gate fees for the management of waste (around 90% or more of income is derived from gate fees). In this context, the financial driver to generate good quality products remains somewhat weak.

The principle selling point AD is the generation of energy. The income from energy sales varies from between Fr. 10. and 40.-, (£4.30 and £17.20^a), with most plants' income lying between Fr. 10. and 20.-, (£4.30 and £8.60^a). On the other hand, for many plants, income from the sale of compost or digestate might be close to zero if the plant operator has to pay for transport and spreading of the products.

Two treatment techniques are used in the main: "dry" AD plants with input dry matter content around 30%, and wet AD processes with input dry matter around 5 to 10%. One widely used process is a dry, horizontal plugflow process which needs a certain structure in the material. Dry processes are easily and more economically run at thermophilic (55 °C), temperature because there is less water to heat. Wet AD processes are usually run at mesophilic temperature (37 °C) and are therefore usually subject to a separate sanitization phase.

^a converted at average 2002 exchange rate (CHF 1 = £0.43)

¹⁴ For a discussion in the English context, see Eunomia (2007) *Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis*, Banbury, Oxon: WRAP to be published 2007.

In countries where the development has been most rapid, there appear to be some important reasons behind the shift:

- Concerns regarding the performance of older composting plants coming to the end of their life (especially where, in some more urban areas, problems of odour control were not addressed effectively)
- A desire to ensure renewable energy is generated from the materials concerned (supported in some cases by economic instruments aimed at fostering the development of renewable energy sources); and
- The improved performance of the technology itself (though there are still problems at some plants).

Within the UK, the treatment of biowaste is almost entirely through composting. Greenfinch has recently started treating mixed kitchen and garden waste at a plant in South Shropshire supported by Defra's New Technologies Demonstrator Programme. However, this plant remains the only AD facility treating source-segregated organic wastes in the UK (see Box 3).

Box 3: Greenfinch AD Plant in South Shropshire

The Greenfinch AD plant uses a wet process and operates at mesophilic temperature (37°C). The plant is designed to treat 5,000 tonnes per annum of combined food waste (including meat and cooked food) and garden waste. The material is collected from South Shropshire where wheeled bins are used to collect kitchen and garden waste. As in other UK authorities where this configuration is used, this tends to lead to high captures of garden waste and relatively low captures of food waste.

The company estimates that food waste may be as little as 5% of the total collected material, though it might be more typical for the material to account for 15% or so of the total material. The company would prefer to be dealing with pure food waste. The high garden waste content gives rise to problems with 'heavies' (stones and grit) since these are usually found where garden waste is collected (from garden sweepings etc.).



The current configuration of the facility is such that the material is sent to a pasteurisation tank between two digestion tanks. The material is raised to 71 °C for two hours.

The output from the plant is subjected to a basic screening, leading to the separation of a fibre of particle size >500µm and a liquid fraction. It is intended that the liquid will be stored prior to onward transport to a farm for use as liquid fertiliser. The solid residue is to be held in maturation bays before subsequent use. The approach to maturation is basic, and the solid residue is not subject to any post-digestion screening at present. This might be expected to hinder the ability of the plant to access higher value end-use markets

Biogas from the plant is sent to a CHP plant which produces electricity, process heat and surplus heat which is not currently used.

In addition, Earth Tech is planning to use Linde's dry digestion technology at Stornaway on the Isle of Lewis in the Western Isles to treat 20,000 tonnes of source-separated biowastes (including paper and card fractions).¹⁵ The plant is now operational and is currently seeking State Veterinary Service (SVS) approval.

Emerging technologies include thermophilic aerobic digestion (TAD), sometimes referred to as autothermal thermophilic aerobic digestion (ATAD). This is something of a hybrid between aerobic composting and anaerobic digestion, and indeed, although the process relies principally on degradation by thermophilic aerobic microbes, the process appears to involve some anaerobic bacteria and it is not well understood how the two types inter-relate. Further information is given in Box 4.¹⁶

Box 4: Thermophilic Aerobic Digestion

Thermophilic aerobic digestion (TAD) processes were pioneered in the 1960s, and have been applied since then for the treatment of, principally, sludges. In the 1960s, operation was mostly at a lab scale. In the 1970s, uncovered vessels were used, and in the 1980s and 1990s, insulated reactors became the norm, these providing greater potential for automated operation. Processes today tend to reach higher temperatures, and achieve higher digestion rates, than earlier designs. Some refer to the latest type of reactors as '2nd generation' systems.

The technology is based upon the use of a class of naturally abundant microbes that thrive at high temperature, and establishing a food source for the microbes and an oxygen supply that will allow them to self-generate their preferred high temperature growth conditions. It is generally accepted that there are still considerable gaps in our knowledge of the process though there are, at least for sludges, areas of agreement as to what the key operating criteria for the process should be.

Essentially, enclosed tanks are used to contain low-solids material which is mixed (imparting energy to the material) and has air injected using jet aeration so as to maintain aerobic conditions. Over time, systems have included control schemes for regulating aeration rates (i.e., variable pump and/or blower speeds, etc.) based either on timers, or on-line 'oxidation reduction potential' (ORP) monitoring. This allows sufficient variable oxygen delivery to maintain aerobic conditions (helping to limit odours, improves volatile solids destruction and improve temperature regulation) and helps to improve the control of foaming (which is expected in the process, and which in controlled quantities, is helpful in providing a thermal insulation layer).

One of the distinguishing features claimed for TAD systems is their relatively fast (compared with anaerobic digestion and conventional aerobic digestion) rate of reaction. The figure below shows performance on pet food processing. The y-axis shows the level of destruction of either fats or volatile solids (plotted in the figure). The x-axis indicates the retention time in the system (note that ATAD is used to denote Autothermal Thermophilic Aerobic Digestion, and is simply another acronym commonly used in the US for TAD systems).

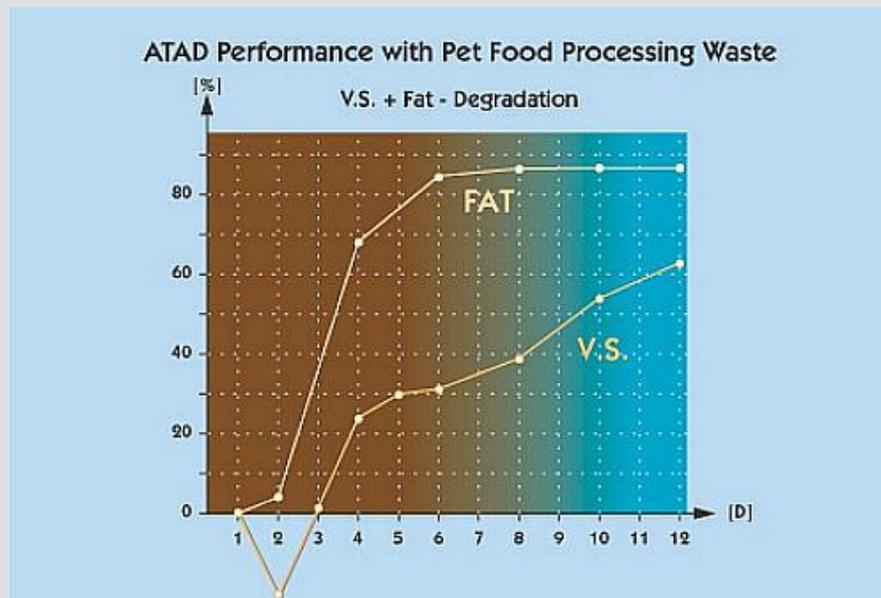
Levels of volatile solids destruction in excess of 50% appear to be achievable in short timeframes. Kelly et al¹⁷ argue that this implies that the size of reactors can be between one-sixth and one-half that

¹⁵ See <http://www.earthtech.co.uk/generic/featured.html>

¹⁶ The nomenclature of waste treatment facilities is becoming more colourful by the day. Our definition of TAD includes only those facilities that operate at a low solids content (and which effectively have no need for structural materials). Most existing systems appear to operate at below 10% solids content.

¹⁷ Harlan G. Kelly and Donald S. Mavinic (2003) *Autothermal Thermophilic Aerobic Digestion: Research Application and Operational Experience*, Paper for the WEFTEC 2003 Workshop, Los Angeles, October 2003.

required for anaerobic digestion. However, it remains to be seen whether this is transferable to food waste treatment. For example, existing digesters claim, especially for food waste rich feedstocks, rates of volatile solids destruction of 70%, and sometimes more, over retention periods of the order 3 weeks. It is not so clear, therefore, that TAD systems would offer major improvements in destruction rates



Source: Fuchs

This would mean that reactor volumes could be smaller than the equivalent for an anaerobic digestion process. Indeed, in some areas, the process has been selected for treatment of sludges for its potential to deliver cost and space savings over other conventional processes such as anaerobic or conventional aerobic digestion. It is also considered useful for ensuring good levels of pathogen destruction.

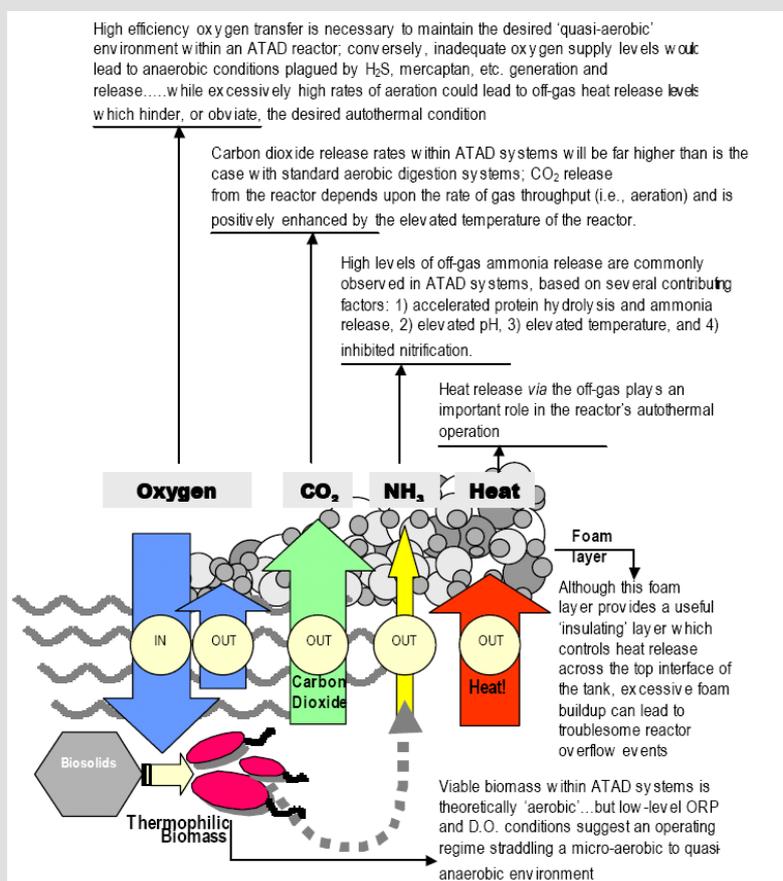
Within this work, some attempt has been made to generate credible mass and energy balances, as well as inventories of principle pollutants. This has not proved possible for a feedstock of household food waste. What is clear, however, is that:

- i) The process is likely to require additional water;
- ii) The process is a net user of energy (associated with mixing, aeration, and solids separation). No biogas is generated for subsequent use;
- iii) Assuming a clean, source-separated feedstock, solid and liquid residues are likely to be generated with solids having potential use in agriculture, and some of the liquid also having potential use as a liquid fertiliser. It is not clear how much water can be re-circulated and how much might need to be treated off-site;
- iv) The principle air emissions are likely to be carbon dioxide and ammonia, as with composting. This is shown in the Figure below. Some reduced sulphur compounds may be emitted as well as volatile organic compounds. The exhaust gas is usually treated in a biofilter to reduce ammonia and odours.
- v) Some processes make use of lime to maintain pH at appropriate levels, and some use flocculants in the dewatering stage.

Consequently, reflecting the nature of the emissions and the net use of energy, the environmental performance is likely to be more similar to that of composting than anaerobic digestion, though the additional water use may be considerable.

We have also tried to understand the likely cost implications of the process. Figures of the order £30-50 per tonne have been quoted but these have been difficult to verify. For the time being, we have assumed (until further evidence becomes available) that TAD systems have an environmental

performance close to that of composting, but that they could be more cost effective approaches to treating food waste since no additional structural material is required. Equally, they may have a role in stabilising digested materials, especially where space is a constraint.



Note: ATAD = Autothermal Thermophilic Aerobic Digestion; D.O. = dissolved oxygen; O.R.P. = oxidation-reduction potential

Source: Staton, Kevin L., James E. Alleman, Richard L. Pressley and Jim Eloff (2001) 2nd Generation Autothermal Thermophilic Aerobic Digestion: Conceptual Issues and Process Advancements, Proceedings of the WEF/AWWA/CWEA Joint Residuals and Biosolids Management Conference, Biosolids 2001: "Building Public Support"

4.4 Approaches to Residual Waste Treatment

Some may ask whether it makes sense to collect materials separately at all. Whilst it is known that the Landfill Directive requires a progressively declining quantity of biodegradable municipal waste to be sent to landfill, it might be argued that material could simply be collected as refuse for subsequent treatment.

A range of treatments for residual waste are being considered in the UK today. These include:

- Conventional grate incineration;
- MBT systems using both aerobic and anaerobic biological treatments, with the aim being to produce more than one of the following:
 - Dry recyclables;

- RDF;
- Biogas; and
- Stabilised biowaste (for landfilling or use as landfill cover);

The destiny of the RDF could be:

- Cement kilns;
 - Power plants; or
 - Dedicated thermal treatment facilities (including advanced thermal treatment facilities).
- Gasification / pyrolysis;
 - Systems incorporating autoclaves.

How some of these residual waste treatment systems compare with the options for source separation on financial and environmental grounds is discussed in Section 6.0.

It has been suggested – erroneously - that where mechanical biological treatment is being deployed for the treatment of residual wastes, it makes no sense to collect biowastes (and specifically, food wastes) separately. This exhibits a misunderstanding of the issue, and of the nature of how residual waste may change in the context of the development of source separation. This point is taken up in Box 5.

4.5 Systems Modelled

The systems modelled are described below and in Table 5.¹⁸ It should be noted that in all cases, the refuse collection frequency is halved where the biowaste collection is introduced. The significance of this is discussed in Box 6. It should be noted that in our modelling of costs, we have assumed that the anaerobic digestion process includes a dewatering stage followed by aerobic composting of the solid residue.

Box 5: Is There Any Point in Considering Food Waste Collections if Residual Waste is to be Treated Using MBT?

Mechanical-Biological Treatment (MBT) is a growing technology in the UK and the EU. The primary reason for its deployment resides in the possibility to deliver results, in terms of loss of biodegradability of landfilled waste, in a comparatively short time, and with scaling possible at relatively small sizes.

Some have suggested that if MBT is used for residual waste, it must effectively replace separate collection, given that it is, effectively, a process reliant upon the biological conversion of waste materials. This is untrue. Aerobic MBT processes are likely to remain functional as long as the putrescible fraction of residual waste is in excess of 10% or so. It has to be remembered that almost always, where food waste is being separately collected for composting or digestion, other materials (dry recyclables etc.) are usually being separately collected as well. This means that in order for this low level (10% putrescible materials in residual waste) to be reached, the rates of source separation have to be extremely high, and probably higher than those for other dry recyclables.

¹⁸ The systems, along with the associated mass flows, are described in more detail in a separate piece of work for WRAP, Eunomia (2007) *Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis*, Banbury, Oxon: WRAP to be published in 2007.

If it really was the case that MBT systems were reliant upon source separation of food wastes *not* being in place, one might reasonably ask why it is that MBT has developed most quickly in those countries where captures of biowaste have traditionally been highest (Austria and Germany). Its rapid development in Italy also occurs in the context of a parallel development of source separation.

There is empirical evidence that a declining proportion of organic materials in residual waste does not cause inconvenience. Indeed, where facilities are configured to produce a fuel, the output quantity (as a proportion of input materials) and its quality (related basically to calorific value of the outputs sent for thermal recovery) actually seems to improve, given the lower moisture of the input. For instance, some “biodrying” sites in Districts with well established kerbside schemes for food waste (around 50% overall separate collection rate) have reported over recent years around 45 % RDF by weight, and a calorific value around 18-20 MJ/kg. Indeed, far from causing problems, improved conditions for biodrying and subsequent refining seem to offset any concerns associated with the lower percentage of biological material to ‘fuel’ the process.

It remains true that outputs from MBT processes, to the extent that they are supposedly intended for use on land, are unlikely to meet the same quality standards as those from source separated materials. However, the importance of MBT relates much more to its intrinsic *flexibility* as a treatment option for residual waste. Many composting technologies across the EU have demonstrated possibilities for effective application to both composting and MBT. This often happens at the same site – so called “double duty sites” - where the intention is to progressively increase the share of material collected in segregated form for composting, and reduce the share of residual waste to be treated as MBT. It can be seen, therefore, that by taking advantage of MBT’s flexibility, the technology is clearly complementary to, rather than a substitute for, source separation.

It can be seen that for some of the systems, the same collection system is linked to different treatments of the collected biowaste. These treatment options are:

- Kerbside collected food waste, and garden waste collected from household waste recycling centres (HWRCs), all sent to in-vessel composting (IV) facility;
- Kerbside collected food waste, and garden waste collected from HWRCs, all sent to anaerobic digestion (AD) facility;
- Kerbside collected food waste sent to AD facility, and garden waste collected from HWRCs sent to open air windrow composting (OC).

This was done to see how the choice of different treatment routes would affect the system performance.

In addition to the systems modelled above, an ‘intermediate base case’ was modelled. To add realism to the approach, all the changes from the baseline collection system include an uplift in the capture of dry recyclables. The intermediate base case was modelled as the same system as the baseline, but with the level of capture of dry recyclables set the same as for the other systems. This enabled the cost and environmental comparisons to focus on changes in the collection and treatment of biowaste. The intermediate base case is effectively used as the comparator against which the performance of other systems is measured.

All systems were modelled for the case where gardens average greater than (>) 200m², and for the case where the gardens average less than (<) 200m². This affects mass flows, and hence, relative costs under the different collection systems. We show the results of the financial modelling for both cases, but the environmental

performance concentrates on the > 200m² case. The modelling for the < 200m² case is essentially very similar.¹⁹

Table 5: Collection Model Description Summaries

	Dry recycling	Biowaste	Refuse	Biowaste Treatment
Base case BC	Fortnightly 240l bin, capture norm, 5% reject	None	Weekly 240l	
garden only G OC	Fortnightly 240l bin, capture high, 5% reject	Fortnightly (alternating) 240l	Fortnightly (alternating) 240l	open air windrow (with HWRC-collected garden waste) (OC)
all biowaste G+K IV	Fortnightly 240l bin, capture high, 5% reject	Fortnightly garden and kitchen (alternating) 240l for those with gardens, kerbside bucket for those without.	Fortnightly (alternating) 240l	all doorstep collected to in vessel composting (IV), HWRC collected garden waste to OC
kitchen only (kitchen AD, HWRC green windrow) K AD/OC	Fortnightly 240l bin, capture high, 5% reject	Weekly, kitchen caddy & kerbside bucket	Fortnightly (alternating) 240l	food waste to anaerobic digestion (AD) , HWRC garden waste to OC
>200 kitchen only (IVC) K IV	Fortnightly 240l bin, capture high, 5% reject	Weekly, kitchen caddy & kerbside bucket	Fortnightly (alternating) 240l	all (incl HWRC-collected garden waste) to IV
>200 kitchen only (AD) K AD	Fortnightly 240l bin, capture high, 5% reject	Weekly, kitchen caddy & kerbside bucket	Fortnightly (alternating) 240l	all (incl HWRC collected garden waste) to AD
>200 kitchen plus (kitchen AD, HWRC green windrow) K+ AD/OC	Fortnightly 240l bin, capture high, 5% reject	Weekly, kitchen caddy & kerbside bucket. Intensive home composting promotion.	Fortnightly (alternating) 240l	food to AD HWRC garden to OC
>200 kitchen plus K+ IV	Fortnightly 240l bin, capture high, 5% reject	Weekly, kitchen caddy & kerbside bucket. Intensive home composting promotion.	Fortnightly (alternating) 240l	all (incl HWRC-collected garden waste) to in vessel composting (IV)
>200 kitchen plus (AD) K+AD	Fortnightly 240l bin, capture high, 5% reject	Weekly, kitchen caddy & kerbside bucket. Intensive home composting promotion.	Fortnightly (alternating) 240l	all (incl HWRC collected garden waste) to AD

Note: This table refers to the analyses that were conducted with garden sizes of >200 m²

Reflecting the limited information available on TAD systems, these have not been modelled. However, some information can be gleaned from the analysis of one assumes that, on the basis of available evidence:

- the financial costs are likely to be similar – marginally lower – than for the case where kitchen waste is collected separately, and where the kerbside collected food waste is digested, with the garden waste from the civic amenity site being dealt with through open air windrows (K AD/OC and K+AD/OC);

¹⁹ Details of the approach can be found in Eunomia (2007) *Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis*, Banbury, Oxon: WRAP published in 2007.

- the environmental performance is likely to be similar to the situation where kitchen waste is collected separately, but it is then mixed with garden waste from civic amenity sites before being composted (K IV, K+ IV)

Box 6: The Importance of Refuse Collection Frequency

The analysis of financial costs has assumed, in all cases, that the frequency of refuse collection is reduced relative to the baseline. This is clearly important in the analysis of financial costs. On a per household basis, the costs of refuse collection are not halved when the frequency is halved, but on a per household basis, refuse collection costs might be expected to fall to between 65%-75% of the level of costs at the higher (weekly) frequency.

This approach to optimising costs is important in the context of the operation of the overall system. The effect on costs is not simply limited to the change in refuse *collection* costs. The approach has been shown to increase the capture of biowaste *and* dry recyclables, thereby reducing the quantity of material (and costs of) disposal, though increasing the costs (in per household terms) of collecting and treating biowaste and dry recyclables.

The system effects are important. Effectively, in the absence of charging systems (which can be used to influence collection frequency), changing the frequency of refuse collection increases capture rates of targeted recyclables and reduces the costs of the refuse collection and disposal system. Partly for these reasons, the measure is gaining in popularity as local authorities face up to the task of improving performance under cost constraints.

Key to public acceptance though is engagement with the residents prior to roll-out of reduced rate residual waste collection, consultation on the proposed approach which must ensure food waste is regularly removed, and include monitoring to check performance.

Key to public acceptance, though, are the following factors:

- a) Comprehensive coverage of recyclables, including those materials which occupy large volumes (cardboard and plastic bottles);
- b) An average weekly container volume for separately collected materials which is adequate to allow consumers to maximise their recycling;
- c) Frequent removal of putrescible items, such as food;
- d) Engagement with the residents prior to roll-out; and
- e) Support, especially during the roll-out period, for households experiencing difficulties

Systems that work well have tended to respond positively to householder feedback

Note: See also WRAP (2005) Alternate Week Collections: Guidance for Local Authorities

Several different approaches to disposal of residual waste were examined:

1. Landfilling with future rates of landfill tax applied;
2. Incineration of waste (electricity only);
3. Incineration of waste (CHP);
4. MBT of waste with energy generation from RDF in fluidised bed incinerator;
5. MBT of waste with energy generation from RDF in cement kiln;
6. MBT using basic stabilisation technology.

The total financial costs of the waste management system were modelled for all the different biowaste collection and treatment systems listed in Table 5 using a single level of disposal cost. The figure chosen was £75 per tonne. Justification for the use of this figure is given in Annex 1, but it is believed to be quite a low 'shadow cost' of

disposal for authorities which are currently without any form of residual waste treatment available to them (other than landfill). In addition, environmental modelling of the waste management system was undertaken so as to compare the net environmental costs of the systems.

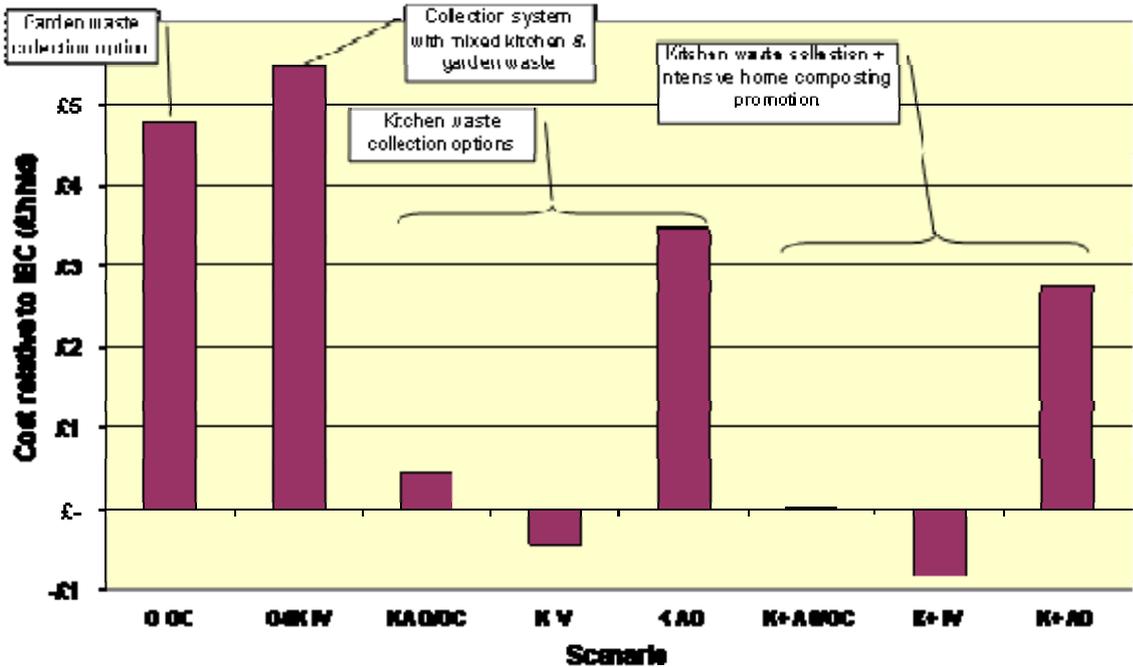
5.0 Comparative Financial Performance

The costs of the different systems are shown in Figure 1. There are a number of key points which follow from the modelling. These are discussed in what follows:

1. Systems which include the free collection of garden waste tend to be more costly than those which target food waste *only*. In general, systems collecting garden waste free of charge, or garden and food waste together, on a fortnightly basis are more expensive than systems collecting food waste only on a weekly basis.

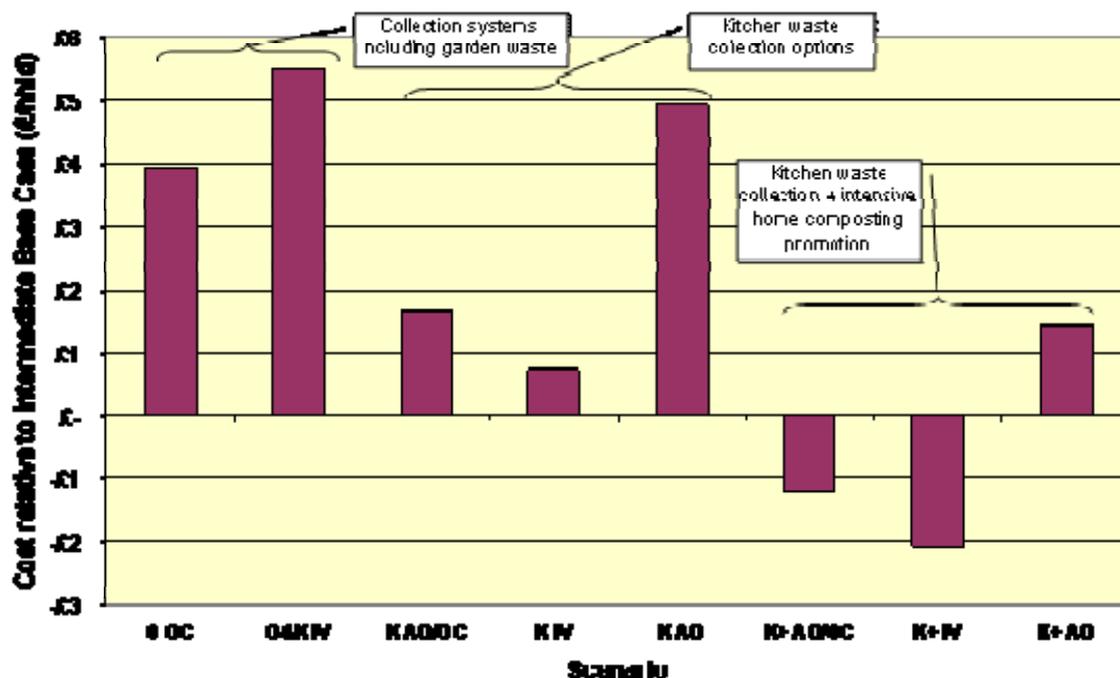
The situation is highlighted in Figure 1 (for areas with smaller gardens) and Figure 2 (for areas with larger gardens). The key reason for this is that additional waste is being pulled into the formal waste collection system through the provision of a service which is free at the point of provision. The implications of this additional tonnage are – perhaps for obvious reasons – greater for those areas where gardens are, on average, larger. These are areas where the quantity of additional material likely to enter the collection system is greater. These are also areas which might seek to implement such systems because they are likely to achieve higher recycling rates.

Figure 1: Cost Differentials Relative to the Intermediate Base Case for each Scenario with Residual Waste at £75 per tonne (areas with smaller gardens)



Note: See Table 5 for the key to labels on the Scenario axis

Figure 2: Cost Differentials Relative to the Intermediate Base Case for each Scenario with Residual Waste at £75 per tonne (areas with larger gardens)



Note: See Table 5 for the key to labels on the Scenario axis

2. The additional cost associated with adding food waste to an existing garden waste collection is significant even though food waste captures are likely to be low if the collection frequency is fortnightly.

The addition of food waste to an existing garden waste scheme requires the treatment of all the collected material in an in-vessel composting facility. The higher is the ratio of collected garden waste to collected food waste, the less effective the capital spend (on the in-vessel facility) becomes. It should also be pointed out that the facility needs to be designed to accommodate peak, not average, throughputs so the seasonality of garden waste flows can further reduce the efficiency of capital spend;

3. Where food waste only is targeted, there is little difference in cost between the systems in which
 - a) all garden waste is composted in windrows, and food waste is digested; and
 - b) all kitchen and garden waste is composted at in-vessel systems.

Both systems are cheaper than systems collecting garden waste free of charge. This is an important observation since local authorities have traditionally viewed anaerobic digestion as an expensive alternative to composting. Looked at superficially, digestion is, indeed, likely to be more expensive (and it has been modelled with higher unit (per tonne) costs in this work). However, the costs of treating biowaste have to be considered in the context of a clear

understanding of which materials are being sent to which type of biowaste treatment facility (see Box 7).

Some (not all) digestion systems are capable of treating food waste without mixing with structural materials. Composting systems do not share this property, so inevitably, the collection of food waste – whether by itself, or along with garden waste – necessitates diverting some material from lower cost windrows to higher cost in-vessel facilities because of the animal by-products legislation. This ‘leverage’ effect is especially high where food waste is collected alongside garden waste in free collections operating fortnightly (where captures of food waste tend to be low, but where all material must still be in-vessel composted). The same effect – of increasing system costs by treating garden waste in more capital intense systems - is shown through considering the K AD and K+ AD scenarios. In these cases, both the kerbside collected kitchen waste and the HWRC collected garden waste are treated through AD. The difference in cost relative to the K AD/OC and K+ AD/OC scenarios, respectively, is around £3 per household;

4. **As the costs of residual waste management increase, so the incremental costs of the collection systems which recycle more material fall relative to the baseline (in which no biowaste is collected).**

This is clearly important as local authorities confront the end of the ‘cheap disposal’ era. The workings of the LATS, and of the landfill tax, imply that the effective costs of disposal which local authorities will be considering for biodegradable municipal waste are likely to be exceeding £70 per tonne (sometimes considerably) in future, with the possible exception of some of those authorities where incineration facilities have already been constructed. As disposal costs rise, so the benefits of avoiding disposal rise also. This is a key parameter governing the economics of separate collection.

Where food waste collections are accompanied by active promotion of home composting, system costs have the potential to be lower than baseline costs once disposal costs (including transport) reach a figure of £70 per tonne or so (which, for many local authorities, they already have done, or they very soon will). The effect of increasing disposal costs is somewhat less pronounced in the cases where garden waste is collected free of charge, and where food waste is added to a fortnightly garden waste collection. The reasons for this are related to previous points. The additional costs of garden waste collections relate in part to new material entering the system (and not to higher disposal costs). Similarly, the incremental cost of treating food waste once it is collected alongside garden waste is (where the garden waste was previously windrowed) related to:

- i. The difference in price between in-vessel composting and open-air windrowing; and
- ii. The ratio of garden waste to food waste in the collected material.

The higher both of these are, the greater is the implied incremental cost for treating the newly collected food waste. Since this can be quite high, then avoiding disposal has less (financially) to recommend it (since disposal may be cheaper).

5. Where home composting is promoted intensively, local authorities will save money

In most local authorities, the issue of waste growth has become a key issue, not least because of the fact that all growth makes meeting obligations under the LAS more difficult (irrespective of the nature of the waste growth).

Consequently, there is renewed emphasis on waste prevention strategies. The tension between 'levels of the hierarchy' – do we collect biowaste or do we promote as much home composting as possible? – is sometimes played out against the backdrop of a discussion regarding landfill targets. Yet on the basis of costs, promotion of home composting still seems to make financial sense.

Box 7: Treatment Costs – the Influence of the ABPR

If only garden waste is collected, the material can be sent for open-air windrow composting. The costs of this are typically low, at around £20 per tonne.

If local authorities then seek to add food waste into the same collection system, then the material collected must be treated in enclosed composting facilities, a requirement of the Animal By-products Regulations. Enclosed systems could be either enclosed composting systems or anaerobic digestion systems. The former are likely to cost upwards of £30 per tonne whilst the latter might cost upwards of £50 per tonne (though obviously, costs are scale- and technology-dependent).

Suppose one assumes figures of £35 per tonne and £50 per tonne. Suppose also that an authority is operating a fortnightly collection of garden waste against the backdrop of fortnightly residual waste collections. Let us assume that around 200 kg per household/year – not untypical where garden waste collections are free of charge – are being collected.

The introduction of food waste collections is assumed to realise an additional 50kg per household of food waste. This is far less than is available, but reflects the assumption that fortnightly collections of food waste lead to relatively low captures – 25% or so – of the available material, which appears to be a reasonable estimate based UK experience. Once food waste is added to the collection, the whole mix of material is to be treated in an in-vessel composting facility. What is the cost of dealing with the food waste?

The calculation is carried out in Table 6. Effectively, this highlights the way in which co-collection of garden and food waste has a ‘multiplier effect’ on treatment of biowaste. The relatively large quantities of garden waste have to be treated in the same system as the relatively small quantity of food waste. Although the headline cost for treatment is £35.00 tonne, the cost of treating the incremental tonnage is effectively £95 per tonne.

This is an expensive means of treating additional biowaste and highlights one of the problems of the dynamics of the way in which collection services evolve. It also illustrates why this might be a particular issue in two-tier areas. WCAs will probably see relatively little change in collection costs. WDAs, on the other hand, will see significant changes in treatment costs. In our example, these more than double for a 25% increase in treated material.

Table 6: Change in Costs for Biowaste Treatment in a move from Garden Waste Only Collections to Co-collection of Kitchen and Garden Wastes

	Before food waste collection (windrow)	After food waste addition (in-vessel)
Garden waste collected (kg/hhld)	200	200
Food waste collected (kg/hhld)	0	50
Costs of treating garden waste (£/hhld)	£4.00	£7.00
Costs of treating food waste (£/hhld)	£ -	£1.75
Total costs of treating biowaste (£/hhld)	£4.00	£8.75
Change in cost (£/hhld)		£4.75
Implied treatment cost for food waste added (£/tonne)		£95.00

This picture is an evolving one. Some authorities are finding difficulties in obtaining planning permission for open-air windrow sites, and one view is that all biowastes may need to be composted in enclosed facilities in future. In these circumstances, and as markets mature, it may be that, as in some other countries, different gate fees are charged for different materials with, typically, garden waste being charged at a lower rate than food waste at the same facility (because of the less problematic nature of the material). This would also become more likely if structural materials became more scarce.

Box 8: Aren't the Capital Costs of Digestion Systems Prohibitive?

The majority of studies which have reviewed the costs of anaerobic digestion and the costs of composting indicate a higher capital cost for anaerobic digestion. Typically, the unit capital costs of the order 50% (or more) higher than for aerobic composting.

Evidently, one of the issues facing compost plants is the necessity to have a feedstock which incorporates sufficient structural material to make the process technically viable. This implies, typically, making use of garden waste or similar material as a means of providing structure.

For many local authorities, the possibility still exists for treating garden waste through lower cost open-air windrow systems. Consequently, the efficiency of any additional capital investment might be seen partly in terms of the ability of the new capital to treat material which could not otherwise be treated. This is where AD, with the potential to handle much wetter mixes, may display some advantages are not always apparent at first glance. The additional capital spend is effectively targeted more closely at that component – food waste – for which it is essentially necessary.

Another issue is of some significance in respect of links to the type of collection system. Unless wastes with the opposite seasonality can be found, the seasonality of garden waste collections makes it difficult to ensure very high levels of capacity utilisation over an annual cycle. Once again, this has the potential to reduce the capacity utilisation over a given year unless appropriate adaptations are made. This is more likely to be problematic where kitchen and garden wastes are co-collected.

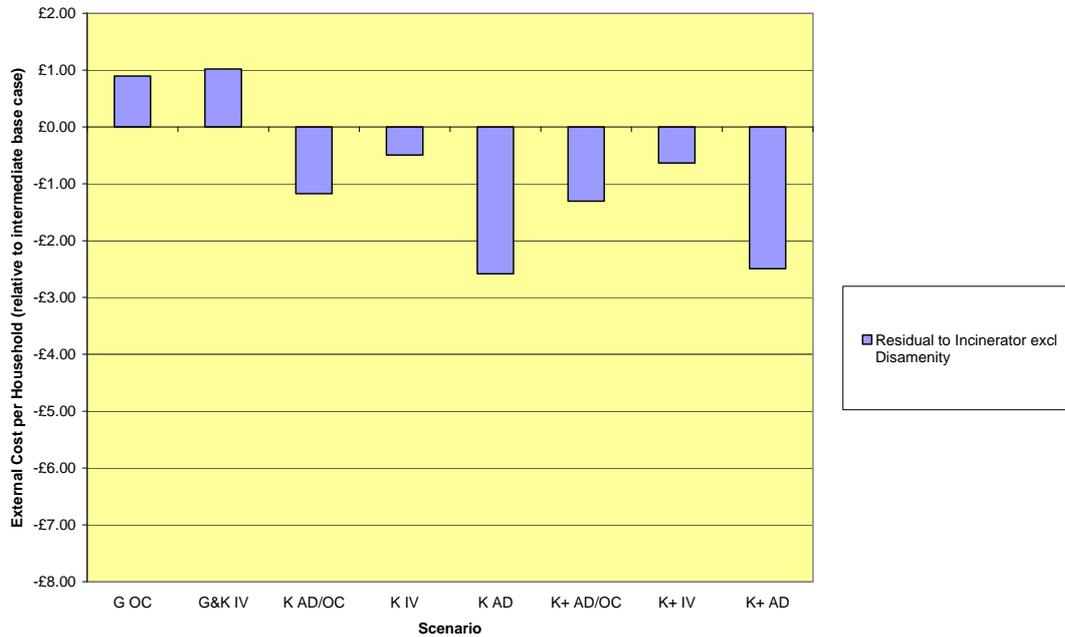
6.0 Comparative Environmental Performance

The comparative environmental performance of the systems is illustrated below. In all cases, we have shown the results using two sets of damage costs (referred to here as high and low). Details of the assumptions regarding offsets are as in previous work for WRAP.²⁰ In the case of MBT processes generating RDF for combustion in a cement kiln, it is assumed that the fuel displaces coal on a one-for-one basis. This is the best possible assumption for this type of treatment.

The first case (Figure 1 and Figure 2) shows the differential external costs (the performance relative to the Base Case) for an incinerator generating electricity only. For both sets of damage costs, the best performing systems are those where food waste is collected, and in these cases, the performance improves as the proportion of material sent to AD increases.

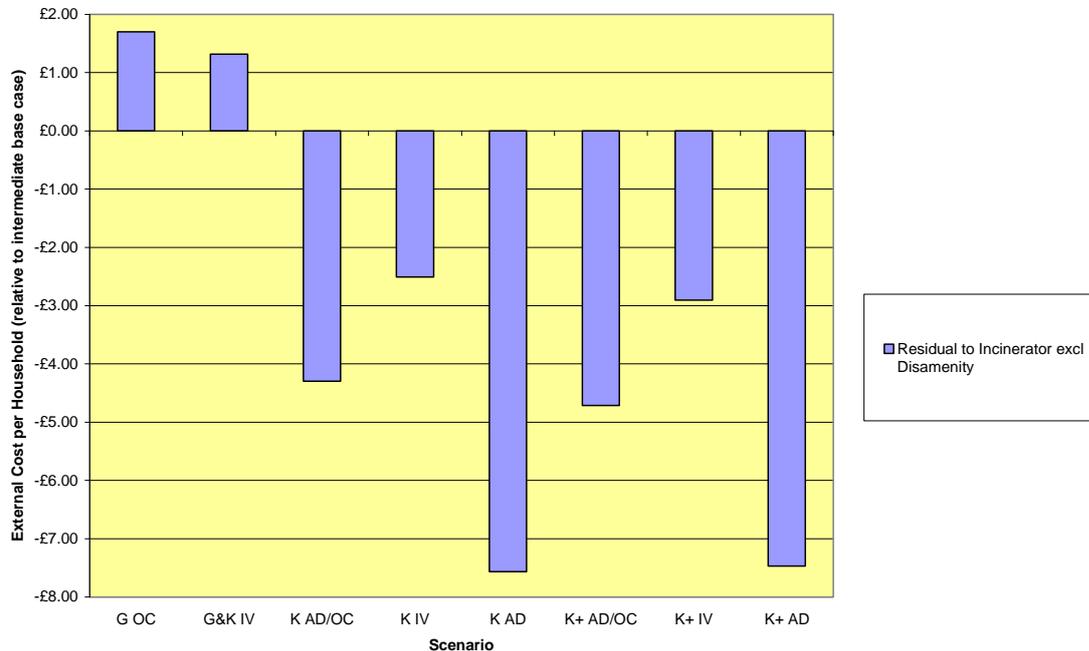
²⁰ Eunomia (2007) *Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis*, Banbury, Oxon: WRAP to be published in 2007.

Figure 1: Differential External Costs (low) of Different Separate Collection Systems, Residual to Incinerator with Electricity Only (relative to no separate collection, £/hhld)



Note: See Table 5 for the key to labels on the Scenario axis

Figure 2: Differential External Costs (high) of Different Separate Collection Systems, Residual to Incinerator with Electricity Only (relative to no separate collection, £/hhld)



Note: See Table 5 for the key to labels on the Scenario axis

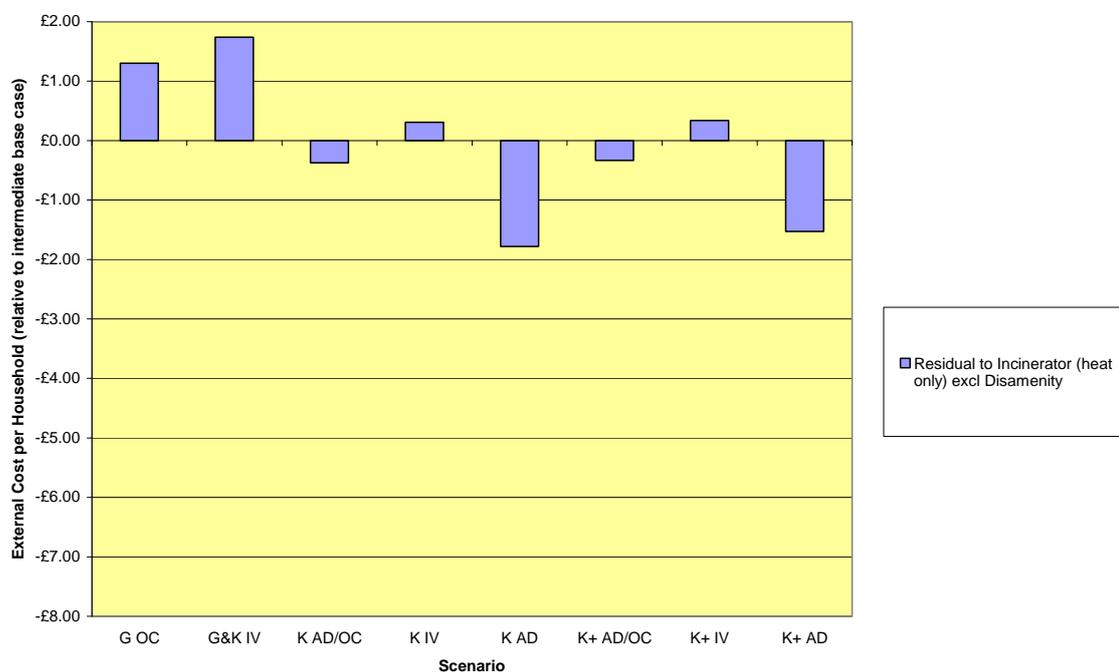
The next case (Figure 3 and Figure 4) shows the performance relative to what is probably the most efficient form of incineration, an incinerator generating heat only at

a net efficiency of 90% (measured relative to net calorific value). The performance of the residual waste system is improved, and this means that for the food waste systems where the material is sent for composting, the net environmental performance is possibly marginally worse than the residual waste system.

Figure 5 and Figure 6 illustrate performance where the background residual treatment is an MBT process sending RDF to a fluidised bed incinerator (FBI) generating electricity only. This residual waste system performs similarly to the case of the incinerator generating electricity only.

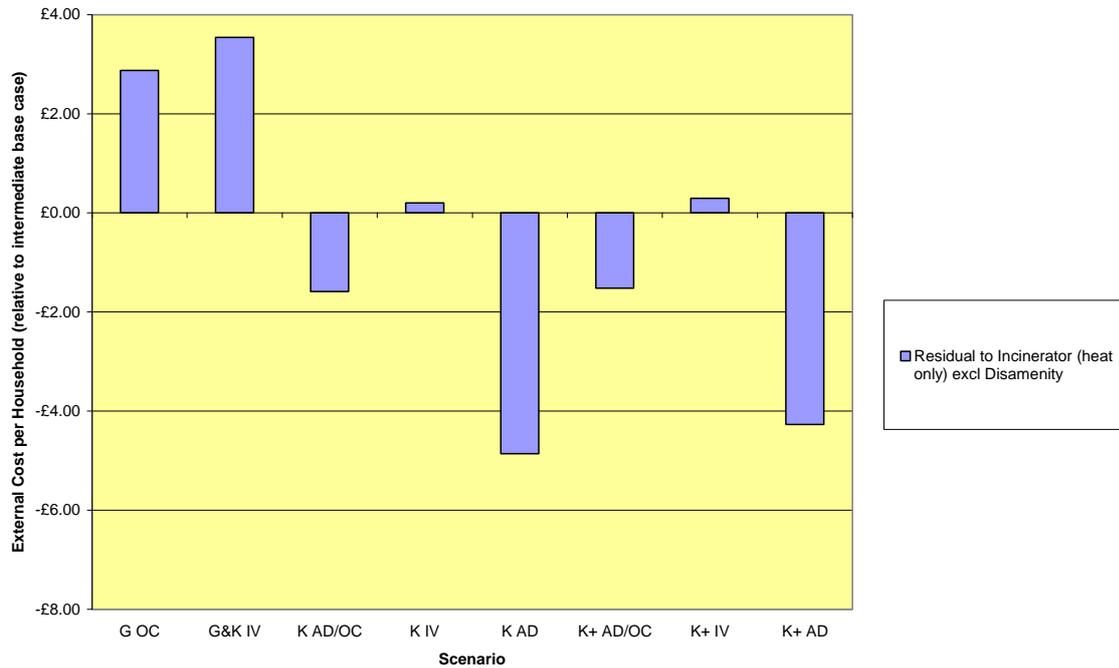
Finally, in the case of a stabilisation facility (Figure 7 and Figure 8) the level of damage costs does not affect the fact that the food waste collections fare best notably where coupled to digestion systems.

Figure 3: Differential External Costs (low) of Different Separate Collection Systems, Residual to Incinerator with Heat Only (relative to no separate collection, £/hhld)



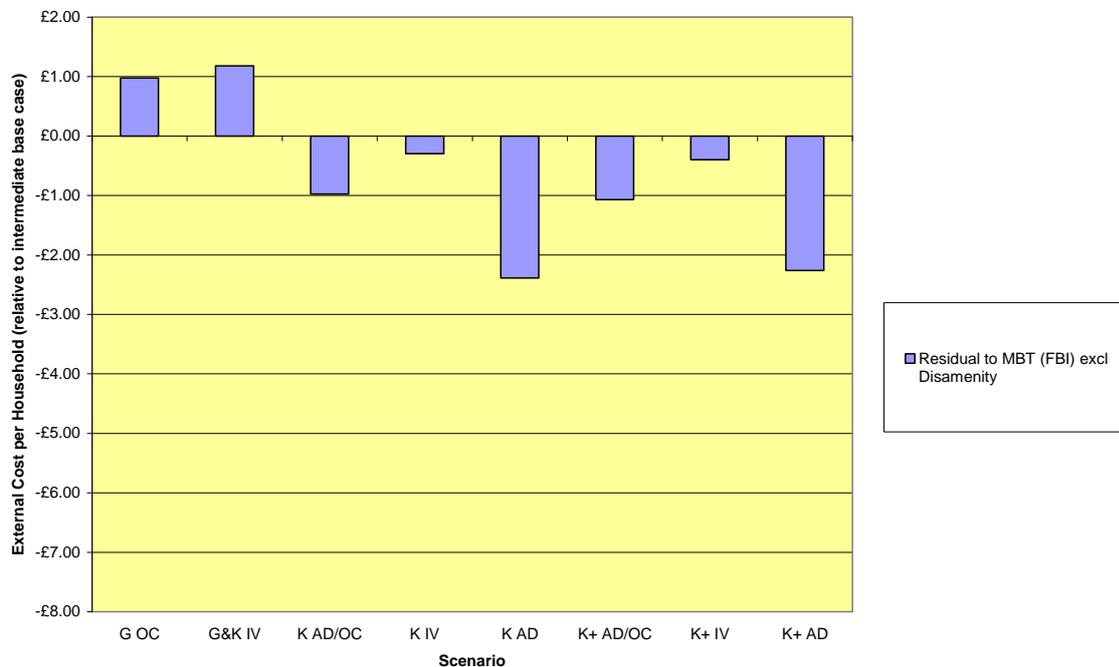
Note: See Table 5 for the key to labels on the Scenario axis

Figure 4: Differential External Costs (high) of Different Separate Collection Systems, Residual to Incinerator with Heat Only (relative to no separate collection, £/hhld)



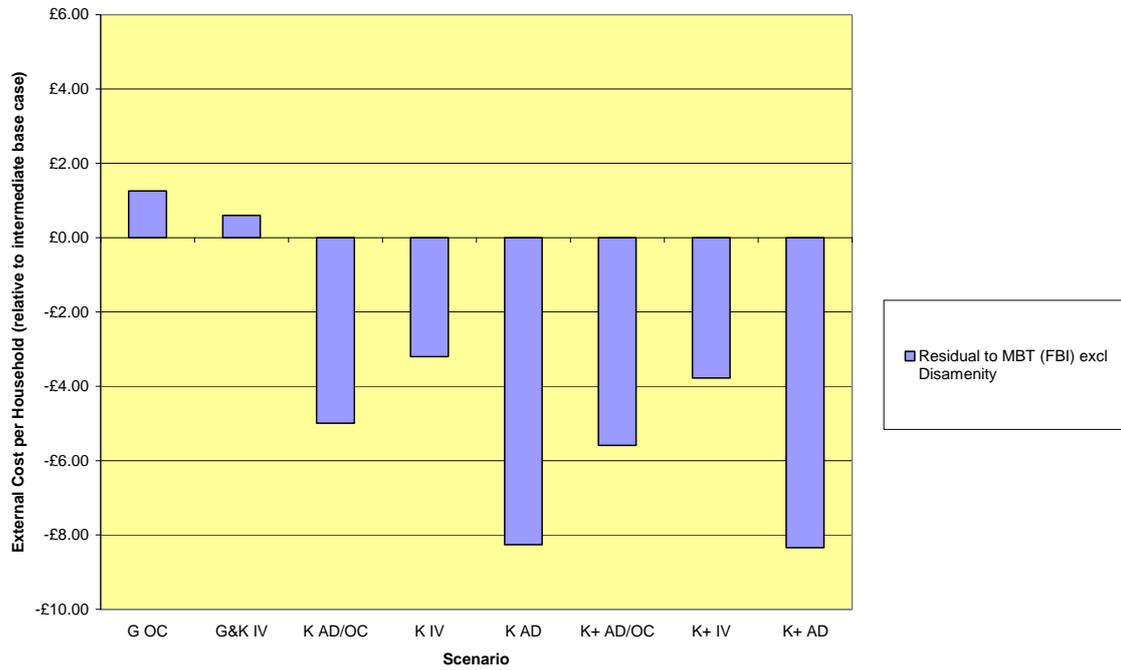
Note: See Table 5 for the key to labels on the Scenario axis

Figure 5: Differential External Costs (low) of Different Separate Collection Systems, Residual to MBT (RDF to FBI) (relative to no separate collection, £/hhld)



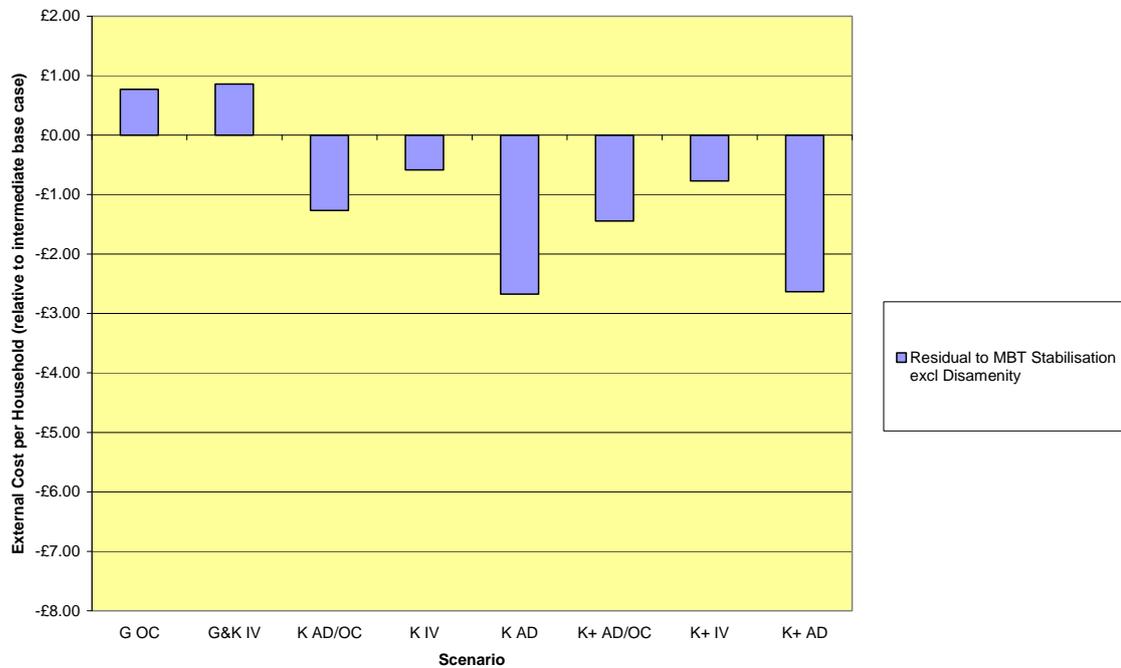
Note: See Table 5 for the key to labels on the Scenario axis

Figure 6: Differential External Costs (high) of Different Separate Collection Systems, Residual to MBT (RDF to FBI) (relative to no separate collection, £/hhld)



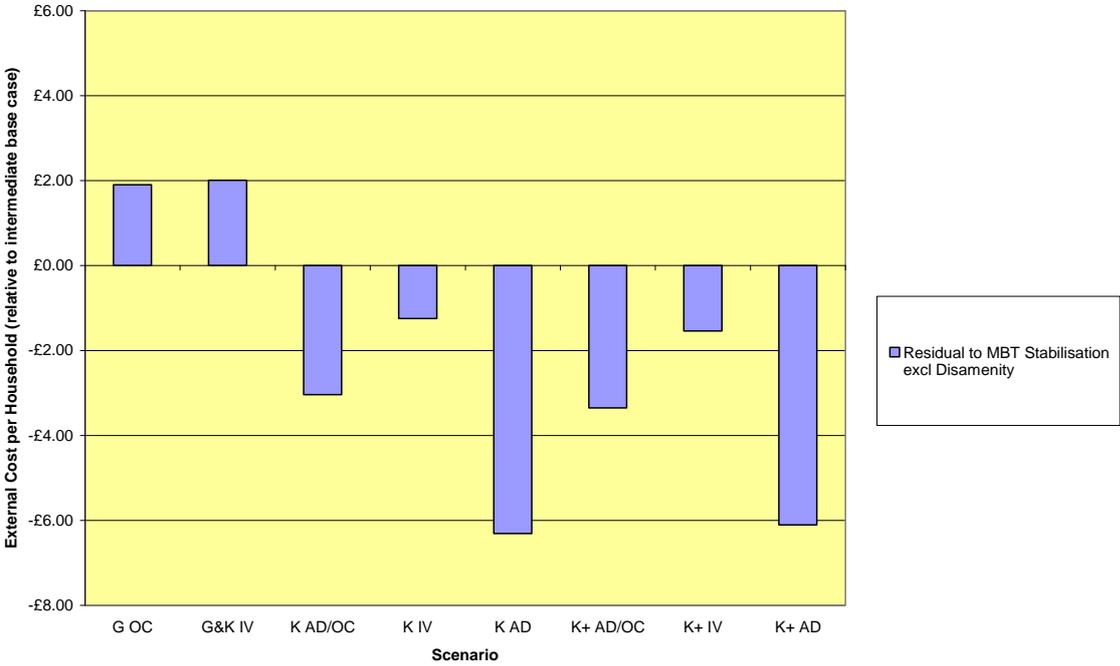
Note: See Table 5 for the key to labels on the Scenario axis

Figure 7: Differential External Costs (low) of Different Separate Collection Systems, Residual to MBT (Stabilisation) (relative to no separate collection, £/hhld)



Note: See Table 5 for the key to labels on the Scenario axis

Figure 8: Differential External Costs (high) of Different Separate Collection Systems, Residual to MBT (Stabilisation) (relative to no separate collection, £/hhld)



Note: See Table 5 for the key to labels on the Scenario axis

There are various points which arise from these data. The key ones are:

1. If the system chosen for biowaste collection and treatment is food waste coupled to anaerobic digestion, the environmental performance of the system is likely to be the best;
2. The work re-affirms the results of earlier studies concerning the relative merits of open-air windrow composting, in-vessel composting and anaerobic digestion systems. The Figures show that the environmental benefits increase as one moves from the K IV scenario to the K AD/OC and K AD scenarios. In other words, as progressively more material is digested, the benefits increase;
3. The performance of the systems relative to residual waste treatment is influenced by:
 - c. The quality of the residual waste treatment; and
 - d. The assumptions regarding the unit damage costs.

When damage costs are low, the benefits are of the order £2-3 per hhld per annum. When damage costs are high, the benefits increase to £4-8 per hhld per annum;

4. The additional material collected where free garden waste collections are in place is decisive in the analysis of environmental performance. Free garden waste collections do not perform well for this reason.

These conclusions are subject to a number of caveats, and these are elaborated upon further in earlier work for WRAP.²¹ However, they suggest the merits of an approach based upon food waste collections, and anaerobic digestion of the collected material. Collecting food waste separately from garden waste also enables digestion to be integrated into the management system in a cost effective manner.

7.0 Products from Food Waste Rich Feedstocks (FWRFs)

The main experiences with compost in the UK until now have been with feedstocks derived from garden waste only, or garden waste along with relatively small proportions of food waste. This partly reflects the nature of the collection systems in place, in which the captures of food waste relative to garden waste have tended to be, by and large, low. The question then arises as to how composts derived from FWRFs are likely to vary, relative to those which are derived from garden waste. This section draws on previous work undertaken on behalf of WRAP.²² As with other sections of the report, we have been unable to acquire sufficient information concerning TAD systems to understand whether issues might be similar to those which arise with composting processes, or digestion processes.

7.1 Effects of FWRFs on Key Contaminants

A review of German plants classified plants on the basis of the different feedstocks. They compared outputs from garden waste compost plants with plants containing differing proportions of waste from household collected biobins. In Germany, most of the collections for biowaste target both food waste and garden waste, but the influence of variable charging systems may, in some cases, imply that households have a financial incentive to compost at home. However, generally, a higher proportion of biobin waste might be assumed to lower the proportion of garden waste in the overall mix.

A review of the effect on various parameters of increasing the proportion of biobin waste led to the tendencies shown in Table 7. These tendencies are not completely supported by other studies. For example, with respect to metallic contaminants, Austrian studies show that for some metals (Cd, Cr and Ni) biobin composts are less contaminated. An Italian study shows that biobin composts have lower Cr content, whilst a Belgian study suggests garden waste composts have lower levels of all relevant metals.

7.1.1 Key Issues Regarding Different Feedstock Materials

From the point of view of marketing composts for different markets, the following points are probably the key ones:

²¹ Eunomia (2007) *Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis*, Banbury, Oxon: WRAP to be published in 2007.

²² Josef Barth (2005) *Product and Application Differences of Compost and AD-Residues Based on Different Raw Materials, Treatment Technologies and Collection Areas*, Report ORG0023, Banbury, Oxon: WRAP.

1. The organic matter content of composts is not influenced in any statistically significant manner by increasing proportions of food waste material. There is only a slight tendency towards higher average levels;
2. As the proportion of food waste increases, so the content of the main nutrients (N, P, K) tends to increase;

Table 7: Trends in the Development of Compost Properties on Account of Increasing Portions of Biobin Material in the Input Mix

Compost property / parameter	Tendency of Mean Values of the Parameter Resulting from Increasing Proportion of Biobin Material
Organic matter	(+) = tendency to increase
Total nitrogen	+ = assured increase
C:N-ratio	- = assured decrease
Total phosphate	+ = assured increase
Total potassium oxide	+ = assured increase
Total magnesium oxide	o = unchanged
Alkaline effective components	o = unchanged
Salt content	+ = assured increase
pH value	o = unchanged
Lead	(+)= tendency to increase
Cadmium	o = unchanged
Chromium	o = unchanged
Copper	+ = assured increase
Nickel	(-) = tendency to decrease
Mercury	(+)= tendency to increase
Zinc	+ = assured increase
Impurities	+ = assured increase
Stones > 2 mm	- = assured decrease
Germinable seeds and sprout parts	o = unchanged

Source: Josef Barth (2005) *Product and Application Differences of Compost and AD-Residues Based on Different Raw Materials, Treatment Technologies and Collection Areas*, Report ORG0023, Banbury, Oxon: WRAP.

3. Increasing proportions of food waste seems to lead to slight increases in metallic elements, though different studies arrive at different conclusions for some metals, notably chromium (which may be present at higher levels in

garden waste composts). However, the increases are regarded as acceptable from a precautionary perspective;²³

4. As the proportion of food waste rises, so salt content increases, sometimes significantly;
5. At the same time, the C:N ratio decreases;
6. Physical impurities other than stones usually increase; but
7. The presence of stones tends to fall.

Physical parameters influence the way compost products are prepared and marketed. Additional portions of food waste material lead to a contradictory effect whereby stones, closely associated with the green waste fraction, decrease significantly, but other impurities increase. For this reason, additional measures in plants treating higher portions of food waste material may be needed so as to ensure a clean feedstock, e.g. education of the citizens, careful design of the collection system, control of containers, exclusion of parts of the collection area, additional sorting and screening in the plants. Besides odours, impurities - especially glass and plastic - are the most likely factor to give rise to negative reactions on the part of customers.

The significant increase in salt content (KCl) and nutrient content (N, P, K) of compost as a consequence of higher proportions of food waste limits the chances for compost to be marketed into the high value-added markets e.g. for potting soils or for growing media. Source material from urban areas can create compost with 12 g KCl/l and more, which is far in excess of German limits for "substrate" compost (< 5 g KCl/l) which is qualified for an admixture in growing media.²⁴ One alternative approach to obtain a product suitable for higher value markets is to mix the compost derived from feedstocks with higher food waste content with green waste compost which is essentially lower in salt.

In summary, the change in feedstocks does not affect the compost quality significantly where the content of key metallic elements is concerned. Only characteristics such as salt content (KCl) and nutrient content (N, P, K) are affected in a major way. Green composts and mixed material composts show lower contents and are more suitable for use as a component for the production of growing media in the high value-added markets. These markets are not so much 'out of reach' for composts derived from FWRFs as they are 'more difficult to break into'.

Some experiences with composting at plants where the food waste fraction is relatively high are given in Box 9 to Box 12. These examples show how compost plants make adaptations to ensure that the high proportion of food waste does not

²³ See, for example, Amlinger, F. Pollak, M, and Favoino, E (2004) *Heavy Metals and Organic Compounds from Wastes Used as Organic Fertilisers*, Final Report to the European Commission, ENV.A.2/ETU/2001/2004, July 2004; Rahel C. Brandli, Thomas Kupper, Reinhard Furrer, Franz X. Stadelmann and Joseph Tarradellas (2005) Persistent Organic Pollutants in Source-Separated Compost and Its Feedstock Materials—A Review of Field Studies, *Journal of Environmental Quality*, Vol.34, No.3, May-June 2005, pp.735-60.

²⁴ Josef Barth (2005) *Product and Application Differences of Compost and AD-Residues Based on Different Raw Materials, Treatment Technologies and Collection Areas*, Report ORG0023, Banbury, Oxon: WRAP.

compromise the potential for achieving a marketable product quality, sometimes with blending being the basis for successful marketing.

Box 9: Approach to Composting of Wastes in Wangerland/Wiefels



This facility was constructed in 1996 and has a capacity of 40,000 tonnes per annum. The investment costs were around €10 Million, excluding real estate and development. The treatment process uses agitated bays and a Thyssen-Dynacomp™ corkscrew-like turning device (see below).



The plant is located in a rural district in the middle of the area with the largest animal population in Germany, and where there is a corresponding surplus of animal manure. This allows for the marketing of negligible quantities of compost into agriculture. To develop alternative markets, and following some market research, the owner of the composting plant constructed the Flormaris Potting Soil and Growing Media plant in close proximity. A significant proportion of the compost produced is processed into growing media, and other highly specialised products for professional and hobby gardeners.

The composting plant consists of a reception hall, the decomposition hall, the biofilter, a partly roofed site for subsequent decomposition and storage, a special area for preparation of fine product, an additional area for pure green waste composting and a sales point for selling final products ex works.

An essential portion of the composts produced is used as mixed components for the production of potting soils and growing media in the earthen works nearby. Therefore it is essential that compost is absolutely free from foreign matter. For this purpose a complex fine preparation plant has been installed. Quantities of the shredded green waste from the green waste composting can be added over a controlled separated conveyor belt. In this way, the desired mixing conditions/ratios between green waste and biowaste, so as to produce final products with varying nutrient content, can be achieved.

The feedstock for the composts is separately collected biowastes²⁵ and green wastes (brown bin) from the region of Friesland (Northern Germany), Wittmund and the city of Wilhelmshaven. Additional green waste collections are made in spring and autumn. On account of the scattered settlement structure of the region (high portion of single houses and two family houses with gardens), and the positive acceptance of the population, the biowaste is of very high-quality and scarcely differentiated from pure green wastes regarding foreign matters, salt and nutrient contents (comparable to pure green waste). It is, therefore, available for higher-value added uses of composts when potting soils and growing media will be produced.

Depending on the intended application, the material stays in the decomposition hall for 8 to 12 weeks. The material goes into subsequent decomposition via different conveyor belts in the outer storage area. After the maturation process, there is a screening step with a mobile screen, after which the materials are stored in a covered area.

On account of the high-class utilisation of the largest part of the compost production in the connected Flormaris Potting Soils and Growing Media Plant, the remaining foreign matter/impurities have to be removed by an additional fine preparation (costs €420,000 in 1998). These impurities include glass, wires, foils and especially wooden pieces, which will cut through the packaging and create problems with the professional potting machines of the gardeners.

Around 60 % of the production is delivered to the neighbouring Flormaris Potting Soil and Growing Media Plant and used in 10 of the 15 different products offered by Formaris (www.flormaris.de) replacing peat to a greater or lesser extent. The professional products range in value up to €85 / m³. The residual 40 % compost production is mainly sold in various grain sizes as bulk material directly to landscapers and hobby gardeners at between €10 - 35 /tonne.



This result shows that for this composting plant the tremendous efforts in high quality, additional products and marketing are compensated by the acceptance on the market and market prices.

Nevertheless it is a risky situation when quality problems occur and become obvious, with negative results for the consumer confidence (especially the professional ones). Most of the German compost plants can rely on agriculture as a matter of security for compost sales, sometimes with negative revenue, but the storage area can be cleared within a short period of time if necessary. This is more difficult for the Wiefels case because of the surplus of manure in the area, and has led to focus on high quality outputs.

²⁵ Biowaste is the typical mixture of kitchen and garden waste collection in the biobin. The mixture can be from nearly 100 % of food waste in the months January and February to 70 % of garden waste in spring (mostly grass) and autumn (cleaning the gardens). The yearly average depends from the collection area of the composting plant but should be between 30 to 50 %.

Box 10: Approach to Composting of Food Wastes in Dortmund



The Dortmund composting plant is located in the middle of the Ruhr-District, the most crowded area in Germany. The owner, the municipal waste management company of Dortmund, offers waste management services to 590,000 inhabitants including separate collection and treatment of organic wastes at a composting plant with a capacity of 22,000 tonnes per annum. The total required area is 18,000 m², and the distance to the next dwelling is 500 metres.

The total investment in 1992 was relatively high at €11 million because besides the decomposition hall and its equipment, the whole plant was designed for scaling up to 40,000 tonnes per annum, which affects the plant finances negatively. The necessary tipping fees, which may be in excess of €70 per tonne, are, however, covered in an overall waste fee for the inhabitants. Some manually operated and some technical sorting processes are used to get the amount of impurities down to a reasonable extent.

The technology concept is based on the Thyssen-Dynacomp™ corkscrew-like turning device in a decomposition hall with two agitated bays. The floors of these bays are divided into 14 compartments, which can be moistened and aerated (positive / negative) in different ways during the 8 (fresh compost) to 12 weeks decomposition phase. This is controlled by a computer, and changes are triggered according to maturation stage and temperature. The system provides the necessary intensive aeration to deal with a comparatively wet source material.

The plant exclusively collects so-called biowaste material from the households by a bi-weekly collection via biobins (carts). Dortmund is one of the big cities in Germany where the town centre is successfully included in the collection. The catchment area consists of more or less exclusively urban districts. Some parts of the town are excluded from the collection system (e.g. where there are only high-rise buildings). In this catchment area, the collection situation leads to a comparably high portion of 85 % food waste, 5 % market wastes and only 10 % of green/garden waste. In January and February the garden waste portion can go down to as low as 3 %. Despite considerable information and effort in respect of public relations, the amount of impurities – most of all plastic – is important and can reach as high as 10 %.

This very wet source material requires additional bulky material from outside in order to obtain a reasonable C:N ratio and enough structural material in the feedstock. The structural material is obtained in the form of oversized residues from the screening process at a separate green waste composting plant, which is operated on a former landfill. The wooden bulky material was added in the first two years of the operation of the biowaste plant on the basis of density measurements. However, now the wheel loader drivers know the periods of the year and the catchment districts well enough to add the structural material (which is stored at the biowaste plants) on the basis of experience.

After several weeks in the decomposition hall the finished compost is discharged from the pile via the Dynacomp device. Subsequently, there is a mobile screen with screen sizes according to the area of application.

The annual production of compost amounts to around 10,000 tonnes. A significant part (40 %) of the compost will be picked up for free by the owners of two large farms. This is picked up in the form of fresh compost with a low level of maturity. 30 % (0 - 25 mm grain size) is used in major restoration projects in former coal mines in the area with sales prices up to €5 per tonne. 20 % is used as fine compost (0 to 10 mm grain size) in public greens and 10 % (0 to 10 mm) is used by hobby gardeners with sales prices up to €10 per tonne.

This case can be seen as a very successful one under the constraints of the urban situation with a very wet feedstock. It also shows that the constraints on separate collection and composting can be overcome even in big cities.

The risk factors in this situation are the limited markets in the urban area. Final products based on standard qualities and with mainly food waste as the source material can only enter the lower value mass markets. In Dortmund, there is a fortuitous situation which exists with 2 farms and the ongoing restoration projects. Nevertheless, creating new markets with a standard food waste based product (high salt and nutrient content which restricts the use in mixtures) is more difficult, especially if the desire is to enter the market for high price, highly specialized products, and more so, where the plant is run by a municipality owned enterprise (where expertise in matters of compost marketing tends not to be so extensive).

Box 11: Approach to Composting Food Waste at the “ECOPROGETTO” compost site in Venezia, Italy

The composting site is located in Marghera, the industrial district of Venice. Its distance from the city is 4 km, and it is 1 km to nearest dwellings. The site has a permit to treat 72,500 tonnes per annum. It processed 62,250 tonnes in 2005, of which 38,800 tonnes were food waste, and 23,450 tonnes were garden waste

A third of the food waste is collected through kerbside collection using small buckets for houses, and bins at high-rise buildings. Two-thirds are collected through a bring scheme using side-loading of containers permanently on the road. Collection frequencies are twice weekly for the kerbside collection, and 3 times weekly for road containers. The site accepts food waste collected both in biobags and normal PE bags, although the former is preferred.

The process is performed through a 7 days' treatment in bioboxes (HerHof type) followed by 15 days in an enclosed post-treatment stage using turned windrows.



This is then followed by a 45 day curing stage which takes place in a covered (i.e. with a roof) but not fully enclosed area. Overall, the retention time in areas provided with odour treatment systems is 3 weeks. The odour treatment system is the patented HerHof technology LARA (self-regenerative thermal purification of air).



Reportedly, the good stability which is achieved after the 7 days' treatment in bioboxes does not require any particular adaptation of process management in the post-treatment and curing stage. The post-treatment does not adopt forced aeration, and management of the process is basically performed through daily turning of windrows.

The key adaptation to ensure good process performances is the input mixture, which is kept around 50% / 50% (food waste / bulking materials). Wooden rejects from previous process cycles are sufficient to make up for the lower quantity of garden waste, relative to food waste. This is also facilitated through appropriate grinding of garden waste, which is performed through a hammer mill, and leads to a coarse size of output such that the percentage of wooden rejects is increased. In addition, the comparatively short process time (70 days) increases the percentage of rejects relative to the product.

The end product in 2005 amounted to 19,300 tonnes, most of which is used free of charge by farmers in farmlands. According to an agreement with the farmers' association, farmers have to pick up and haul the product at their own expense which implies that they value the product at least as high as its cost of transportation.

According to managers' opinion, the limitation for marketing as a peat substitute, is simply the lack of space to provide for a longer maturation. The managers have a long tradition in the production and sale of composted products as peat substitutes (which they blend and bag under their own brand).

Even today, the site managers report that to date, some 10% of the end product (around 4-5,000 m³ out of some 40,000 m³) is chosen for use by producers of potting mixes, who thereafter stockpile the product on their own premises in order to gain better maturity and stability. This implies that, once the maturity problem is overcome, other factors (namely salinity) do not constitute an overly binding constraint. The product is then blended with peat and sold as a potting mix.

Box 12: The “BERCO” compost site in Calcinatè (BG)

The BERCO site is located in Calcinatè, the industrial district of small town in Bergamo Province. It is situated 1.5 km from the town, and 200 metres from the nearest dwellings.

The site has a permit to treat 67,000 tonnes per annum. It processed 53,520 tonnes in 2005, 27,480 tonnes of which were food waste, and 26,040 tonnes were garden waste.

All the food waste is collected through kerbside collection (small buckets and carts at high-rise buildings) in biobags and the collection frequency is one or two times a week.

The process includes a 45-50 day treatment in enclosed windrows which are aerated through turning, followed by a 45-50 day curing phase in an area which is not enclosed, but is under a roof. The material is frequently stored for 1 year before refining. Overall, the retention time in areas provided with odour treatment systems is 45-50 weeks. The odour treatment system is a chemical double phase acid/base scrubber.

Reportedly, the good level of stability which is achieved after the 45-50 day treatment in the enclosed shed does not require any particular adaptation of process management in the curing stage. The management of the process is basically performed through daily turnings of windrows.

The compost is stocked in huge piles (up to 10 metres high) for 1 year in order to gain a high level of maturity and stability. It is then double refined (mesh size 8 cm and 8 mm, see middle picture below) and mixed with several media such as peat, perlite, clay etc in different blends, before being bagged (see right-most picture below) and sold.



Shredding garden waste



Refining composted product



Bagging finished product

The key adaptation to ensure good process performances is the input mixture, which is kept around 50/50 (food waste / bulking materials). Wooden rejects from previous process cycles are sufficient to make up for the lower quantity of garden waste, relative to food waste. This is also achieved through appropriate shredding of garden waste (see left-most picture above).

The end product in 2005 amounted to 50,000 m³. The interesting feature of this plant is that Berco owns a business which produces potting mixes, and this is located in the same site as the composting plant. 90% of the composted product is used directly for the production of growing media. 10% of the product is sold to farmers for direct application to soil at 20 €/tonne. Berco is the only Italian brand that has been awarded the Ecolabel for a growing media.

7.2 Effects of Choice of Technology

As discussed above, and as the examples show, composts derived from FWRFs are not fundamentally limited in their potential market outlets, though some constraints – in terms of salt content – and some possible advantages – in terms of nutrient content – exist.

It was argued above that AD provides a superior environmental outcome for the treatment of biowastes, and food waste in particular. Whilst – as the examples from Dortmund and Venezia clearly show – the composting process is limited in the proportion of food waste that can be accepted in the feedstock (see Section 7.3.1), where AD processes are concerned, the proportion of food waste in the input feedstock can increase to 100%. This is not true for all AD processes. In particular, dry, horizontal plug flow systems also require structural material to prevent material moving through the digester like a liquid. In addition, although this remains theoretically possible, in practice, there appear to be very few examples where a facility accepts food wastes, and food wastes *only*.

Where digestion is chosen as the technology of choice, it is usual for the material to undergo some form of dewatering once it emerges from the fermentation vessel. The nature and extent of the dewatering process varies from process to process (and potentially, according to location and markets). However, usually, a liquid and a solid residue are obtained.

The separation of the liquid from the solids makes possible the removal of much of the salt content of the residue into the liquid stream. This implies that the two products can usually be characterised as:

- A more saline liquid with high nutrient content; and
- A less saline solid residue, still with reasonable nutrient content.

Depending upon plant location, the liquid may find useful application in agriculture as a fertiliser. Mineral fertilisers typically have a relatively high salt content so the higher salt content of the liquid is not usually problematic for farmers. As regards the solid residuals, the interesting point is that the removal of salts in the dewatering phase implies that the remaining material might be more capable of finding higher value-added markets than composted material from the equivalent feedstock. On the other hand, digestion residuals are not as stable as mature composts and they usually need to undergo at very least some basic maturation, and in more advanced cases, it is common to deploy a secondary processing step through aerobic composting before marketing the end product (much depends on the end markets being developed). Post-composted digestion residuals may be

Table 8 shows some of the characteristics of liquid digestion residuals in plants processing differing proportions of manure and collected biowaste. Only where high levels of manure are present do copper and zinc present problems, whilst the nutrient content for N, P, K is up to 3 times higher than comparable levels in compost from plants treating mostly biobin material. This highlights the potential value of this stream as an organic fertiliser, especially for agricultural purposes.

As regards the solid residuals, the interesting point is that the removal of salts in the dewatering phase implies that the remaining material might be more capable of

finding higher value-added markets than composted material from the equivalent feedstock. On the other hand, digestion residuals are not as stable as mature composts and they usually need to undergo at very least some basic maturation, and in more advanced cases, it is common to deploy a secondary processing step through aerobic composting before marketing the end product (much depends on the end markets being developed). Post-composted digestion residuals may be

Table 8: Mean contents of nutrients and heavy metals in liquid digestion residuals in Germany

Category*	No	Total nutrient content (% dm)				Heavy metal content (mg/kg dm)						
		N	P ₂ O ₅	K ₂ O	MgO	Pb	Cd	Cr	Cu	Ni	Hg	Zn
1 *	107	7,00	3,11	6,58	0,92	12,8	0,47	20,5	241	27	0,15	633
2 *	45	5,93	4,24	3,85	1,38	30,0	0,51	15,6	102	17,5	0,15	426
3 *	28	2,65	1,64	3,35	0,89	25,5	0,46	21,9	54,8	14,4	0,12	248
Nutrient values for FWRf compost material						Limits for the German RAL quality label						
		1,40	0,74	1,20	0,92	150	1,5	100	100	50	1,0	400

Notes:

No. refers to sample number

Cat 1 = > 50 % animal manure - < 50 % biobin material

Cat 2 = 20 to 50 % animal manure - 50 to 80 % biobin material

Cat 3 = < 20 % animal manure - > 80 % biobin material

more suitable – because of lower salinity (because of salt removal through dewatering) - for use in specialised potting mixes than compost from the same feedstock. The examples of Pinerolo and Pratteln indicate that, particularly when solid digestate is composted along with other structural materials following the digestion process, or when the digestate is blended with other products, use in higher value applications is clearly possible (see Box 15 and Box 17).

If, after solid / liquid separation, the liquid digestate is added into the composting process (which may be a strategy suitable for areas where no agricultural market exists, and where there is a desire not to have to tanker off waste liquors), then the risk of higher salt concentration again arises. This may be a problem if the intention is to market the end product for use in greenhouses and as substrate.

A key issue is to have a clear idea of the product being developed, and to have good control of production, with the intention of marketing the right product into the correct application.

Some of these issues are highlighted in the examples which follow (see Box 13 to Box 18). These also highlight differing approaches to dealing with the liquid residues following dewatering. In some cases, this is put to beneficial use, whilst in others, it is

treated at waste water treatment plants (usually in the more urban cases, and where such facilities are close by). It should be noted that although it is possible to treat, at AD plants, material that is 100% food waste, such systems are rare. Their rarity relates as much to the collection system as to the treatment system. Both targeted food waste collections and AD systems for source separated biowastes are 'in the minority'.

Box 13: Approach to Digestion of FWRP at Biogas and Composting Plant of Weissenfels

The plant was constructed in 1999 as a drum composting plant system using Envital technology (estimated capital cost €7.5 million, excluding costs of land) with a capacity of 12,000 tonnes per annum for biowaste from households. In 2004, the plant underwent an enlargement using a dry digestion step for 2,700 tonnes per annum for €2.7 million.



The main reasons for the AD enlargement decision were the odour problems (linked to the plant location), the lack of treatment capacity and the composition of biowaste. It was not possible to treat biowaste with the high portion of food waste long enough in the drums to take the material through the very odorous first decomposition phase.

93 % of the raw material is biowaste from households, collected fortnightly using biobins. 7% are garden and park residues which are directly delivered to the plant (some of which was previously composted at small decentralised compost sites further afield).

Now after the enlargement with the new process, the incoming biowaste is mixed and homogenized in 3 Envital drums. During the 3 days retention time, the hydrolysis phase starts. After screening and sorting the material is delivered to a buffer storage tank in order to be discharged continuously into the fermenter whilst adding process water. The process operates in the thermophilic range and the retention time is 10 - 15 days. The discharged digestate from the fermenter is dewatered and then post composted in 2 steps. The first phase of 5 - 7 days takes place in 2 Envital drums, the second phase takes 5 to 7 weeks in windrows, which are not enclosed, but covered by a roof.

The integration of the additional digestion step showed several advantages:

- 20% increase of the capacity
- No longer any problems resulting from the occasionally high proportion of food waste
- After digestion, the material emits significantly less odours compared with the original process where the active step was only the drum treatment, so now it can be post-composted in open windrows without any problems
- AD creates additional income, and has led to a reduction in the specific treatment costs from €77 to €65 per tonne of input. 2.3 million KWh electricity per year is expected to be sold as renewable energy in to the electricity grid at a price of €0.11/KWh.

The plant produces RAL quality assured compost in 2 grain sizes, 0-10 mm which accounts for 85% of production and 0-25 mm for 15% of production. 80% of the compost is given to farmers free of charge ex works, 15% is given free of charge to the municipality for use on public greens and 5 % is sold to private customers for €5 to 15 /tonne. There are no market problems.

Box 14: Approach to Digestion at Boden, Germany

The 1-step wet anaerobic digestion plant in Boden was built in 1995 initially for 28,000 tonnes per annum. It was enlarged in 2000 to a capacity of 57,000 tonnes per annum (through installing an additional pulper and fermenter, and introducing a three-shift operation). The total investment cost was €12 million (excluding real estate and development), and treatment costs are €60 to 75 per tonne.



The technology includes a hygienisation step (heating 1 hour 70 °C) in order to guarantee the fulfilment of the ABP Regulations, an intensive dewatering and a first waste water purification. 80 % of the final waste water is transported to a sewage treatment plant.



95 % of the raw material comes from a fortnightly, separately collected biobin collection running in the rural districts of the Northern Taunus which is a very rural area with some large towns. 5 % of the input is food and catering waste from markets and restaurants and is delivered by professional collectors and dealers of this material.

The solid digestate is quality controlled and achieves the German RAL quality label for solid digestion residues.

The total output of the plant is dewatered intensively so that the final product has the appearance and visual composition of a fresh compost. A contract (€1 to 2 per tonne) exists with an agricultural services company, which has to collect from the plant, to sell and to spread all the solid digestate at its own risk. The service company has contracts with farmers.

No marketing problems occur, and there is a growing demand for the material because of the high quality, its good spreading properties, and the valuable nutrient content set against increasing mineral fertilizer prices.

The liquid fraction after dewatering is pre-purified and partly used in the wet process again. The surplus is transported to sewage treatment plants. The energy is sold at typical values for renewable electricity in Germany (€0.10/kWh) to an energy supply company as green energy.

This AD plant demonstrates a very cost effective AD solution, avoiding an additional post composting step. The sales prices for energy and the gate fees further enable a positive financial situation given the size, throughput and cost of the plant.

Box 15: Box: The “ACEA” compost site in Pinerolo (TO)

A site owned by ACEA, which combines anaerobic digestion and aerobic composting, is located in Pinerolo, Torino Province. It is located less than 1 km from the town, and less than 300 metres from the closest households.



Food waste constitutes more than 90% of the input material to the digestion process. The material is collected both through kerbside collection and road container schemes. The collection is managed in different ways so that no single collection frequency or containment system (in terms of bags for use by households) can be singled out.

The anaerobic treatment is carried out in two reactors (operating capacity of 55,000 tonnes per annum) using a semi dry (12% total solids) thermophilic process for 14 days. The digested residue is sieved at 12 mm mesh size and dewatered using a filter press to produce a 70% moisture solid digestate. The total amount of solid digestate produced is 10,000-12,000 tonnes per annum. Some 20% of the liquid digestate remaining from the filter press is reused in the anaerobic digestion process whilst 80% (80,000 m³/year) is delivered to the waste water treatment plant (which is also owned by ACEA).

All the solid digestate is aerobically processed in a mixture following the addition of bulking material. The mixing ratio is typically 50/50 (by weight) but it may be adjusted according to various needs, including an evaluation of the heavy metal concentration in the digestate. The active composting phase is carried out in enclosed windrows using forced aeration, and mechanical turning. The processing time is 28 days, and the exhaust air is treated using a biofilter. The material is then cured for 65 days in covered bays. No critical steps are faced during the processing of digestate. It may be worth noting that ACEA has been composting anaerobic digestion residues from sludge since 2001.

The composted product amount in 2005 was around 5,000 tonnes. It was mainly sold as semi finished product for the production of potting mixes at 5-8 €/ton. The remaining 1,000 t was sold to farmers for application to crop the typical price being around 20 €/t. In coming years, compost production is foreseen to double due to a major increase in input material at the composting plant.



Box 16: Approach to Digestion of Biowaste in Rümlang, Switzerland

The AD plant in Rümlang (near Zurich) uses Kompogas technology. The plant is a dry, horizontal plug-flow process which operates at thermophilic temperature (55°C). It has been operating since 1992.

The plant serves a community of around 45,000 inhabitants. The collection system in the area is one which includes both kitchen and garden waste collected together through weekly kerbside collections. The waste is collected in wheeled bins. Some waste is also delivered direct from catering facilities and from industry, including a major retailer, Migros. The plant has a capacity of around 9,000 tonnes. About 50% of the capacity is associated with the biowaste collection, and about 50% of the capacity is from catering and industry (incl. food waste). Consequently, the feedstock is likely to be around 70% 'food-like' wastes.

The investment costs for the plant were 7 million Swiss Francs (£2.8 million^a) including the costs of land in an industrial zone. Treatment costs are around 140 Swiss Francs (£62^b) per tonne.

The residue is dewatered to produce a solid and a liquid product. Per tonne of input, the plant produces around 500l (350kg) of solid residue and 450l of liquid, though these figures vary with the moisture content of the feedstock. Around 50% of the output is liquid fertiliser. The solid product is subjected to a simple maturation process, and the product is usually taken by farmers within a period of weeks. The solid and liquid products are used in the main for agricultural purposes (more than 90% is used by farmers). No net revenue is received by the plant after spreading the residue on the fields. There has been no problem with the marketing of the product (though the company would prefer a higher price).

The plant produces around 100m³ biogas per tonne of input, of which around 60% is methane. An interesting aspect of the plant is that cooperation with the retailer Migros has led to Migros sending their vegetable waste to Kompogas and using the biogas to power their trucks (a promotional video had the strap-line 'salad as a fuel'). www.kompogas.ch/en/index.html



^a converted at average 1992 exchange rate (CHF 1 = £0.40)

^b converted at current exchange rate (CHF 1 = £0.439)

Box 17: Approach to Digestion of Pratteln, Switzerland

The plant at Pratteln, in the suburbs of Basel, has recently commenced operation. It is another Kompogas plant (dry, horizontal plug flow) and operates at thermophilic temperatures. However, the plant is of more modern design than at Rumlang and also operates with a sanitisation pre-treatment to deal with liquid wastes from industry (133 °C for 20 minutes). In addition, a covered area has been designed for composting the solid residue following the digestion phase.



The collection of household waste is through the fortnightly collection of kitchen and garden waste using wheeled bins. Only about one third of the plant's 15,000 tonnes per annum capacity is taken up by household biowaste. The other two-thirds comes from catering and industry (including food retailers) and some from other compost plants. Leureko, who run the plant, run 4 more composting plants. Materials sent to these plants which may give rise to odour problems are forwarded to the AD-plant (enabling a win-win situation for both the composting and AD-plant). As Pratteln has started operation quite recently, there is some spare capacity so it is easy to add material to the digester.

Despite the additional complexity (relative to the plant at Rumlang), the capital costs of the plant were CHF 11 million (£4.9 million) and the gate fees are £53 per tonne.

Leureko is responsible for marketing the products of the plant. The digestate is dewatered and around 50% of the total is liquid. Some of this is used as liquid fertiliser but most of it is used in the composting process following the digestion phase. This helps to reduce the water requirement at the AD / compost plant. The treatment time post-digestion is to be around 6 weeks so further maturation is required to deliver a sufficiently mature product for use in various substrates.

More than 60% of the product is used for horticultural purposes. The rest is used in agriculture. Leureko is a professional horticultural company with considerable areas devoted to greenhouse cultivation. However, it is also keen to test the quality of the liquid product as a fertiliser.

Farmers pay less than the spreading costs, but they pay Fr. 2 to 4.-/m³ (£0.86 to £1.72/m³ ^a). In horticulture the digestate is part of the substrate mix and does not have a specific price. There have been no problems marketing the product. Leureko has been using and selling compost products for more than 10 years.

The biogas fuel is used to power cars. The biogas generated is expected to be similar to the case of Rumlang.

<http://www.ebl.ch/energie/innovation/index.php> (in German)

www.bio-power.ch/

www.leureko.ch/

^a converted at average 2002 exchange rate (CHF 1 = £0.43)

Box 18: Approach to Digestion of FWRF in Silvaplana

Silvaplana is an area of St Moritz, a mountainous tourist area around 1,800m above sea level. The plant started operation in 2005. It is a wet AD process operating at mesophilic temperature (37C). The food waste material is subjected to a pre-treatment at 70 °C for 1 hour for hygienisation purposes.

Around 1,000 tonnes of food waste is collected from restaurants and hotels, and this exhibits strong seasonal peaks. The collection takes place 1-3 times per week in 30 litre bins. In summer, some grass clippings are included. However, there is no wood waste of any form allowed since the wood floats in the digester and creates problems. In addition, an equal quantity of manure from farms is collected for digestion.



The investment costs for the plant were around CHF 1 million (£0.43 million^a). Collection and treatment together cost CHF 180 per tonne (£77.4 per tonne^a), the treatment alone costing CHF 100 per tonne (£43 per tonne^a).

A dewatering stage separates the liquid from the solids. Around 10% of the residue is solid and 90% is liquid. The solid residue is subjected to a type of drying process in a drum which gives a dry fibrous material (digestate) which is not subsequently composted. Genesys is trying to find a viable way for composting the solid residue, but has not been successful so far.

The materials are used in agriculture. Though no problems are anticipated in making use of the material, for which there is no revenue received, there is limited experience because the plant has not been operating for long.

www.genesys.ch/biogasanlagen_agrigas_gastro.php

^a converted at average 2002 exchange rate (CHF 1 = £0.43)

7.3 Process Issues

The choice of treatment for biowaste needs to be considered alongside the proposed approach to collection, and the likely outcomes in terms of materials to be treated. The successfully targeted collection of food wastes may imply the need for treatment of FWRFs, and specific issues arise in respect of process management in such circumstances.

7.3.1 Composting

For composting, key process issues where FWRFs are concerned relate to the moisture content of the input material, the structure of the feedstock and the degree of dynamism of the composting system (whether or not there is physical turning for aeration). The key is to ensure the feedstock is mixed so as to provide the necessary structure, and sufficiently low moisture content, to prevent clogging of airspaces in the process under consideration. It may be possible, depending upon the nature of the process, to treat feedstocks with more than 50% food waste content as long as the system is sufficiently dynamic.

Another key issue is that of odour control. Where FWRFs are in use, the issue of odour control becomes much more critical than in the case where only garden waste is composted, or in cases where, for example, kitchen and garden waste are collected in one container, and where food waste accounts for 15% or less of the input mix. Without adequate attention to the issue of odour control, such plants are likely to give rise to complaints. Proper process management and control becomes more critical where FWRFs are concerned.

7.3.2 Anaerobic Digestion

Some process management issues for anaerobic digestion, where the feedstock has a high proportion of food wastes, are also of relevance. Evidently, odour control is potentially problematic, though it is generally held that the fully enclosed nature of the system reduces these. On the other hand, the reception stage clearly remains important, whilst the point at which waste is discharged from the digester may give rise to some odour-related issues.

In the case where the feedstock is effectively 100% food wastes, one view has been that two-stage systems are more suitable for the treatment of such highly fermentable materials. This is because staging the process avoids the accumulation of acids, which inhibit later stages in the digestion process. However, this may be overcome in one-stage processes through the thorough mixing of materials prior to their being fed to the digester, and through ensuring continuous (or very regular) feeding of material into the digester.

Some digestion processes are characterized as 'dry' systems (between 28 - 35% dry matter). Where materials are too dry, water can be added to the system. Where the mix is too wet, which may be the case with material with a high proportion of food wastes, some dry material may need to be added in some dry systems. Most notably, in horizontal plugflow processes, there is no mixing of the different layers and it is important that newly introduced material does not "overtake" material introduced into the digester earlier. If this happens, then the material is likely to be less well sanitized (in proper operating conditions, the material is exposed for 14 and more days to temperatures of about 55 °C) and the volatile solids reduction, and hence biogas production, will also be lowered.

A key process management issue is to ensure a properly controlled feeding rate with well prepared feedstock to generate good biogas production. Control of the process is through measurement of temperature, gas production and gas quality (methane content). In the starting phase (when the plant is being commissioned), it is likely to be necessary to measure, in addition, the short-chain (smaller than C₅) volatile fatty

acids at the end of the digestion process (to ensure the digestion is more or less complete).

Wet processes operate in the range 5-10% dry matter. Because of the energy requirement for heating the additional water, these tend to operate at mesophilic temperatures 37 °C and are fully mixed. The lower temperatures imply that there is a much reduced effect in terms of sanitization, and feedstock which requires sanitization (such as food wastes) must be pretreated in the appropriate manner (usually) before being sent to the fermenter.

7.4 Risk Factors Associated With Food waste in Composting

The following sub-sections cover the key risks which exist in the case where the feedstock material for treatment is a FWR as oppose to, for example, garden waste.

7.4.1 Compost Quality?

Compost quality in its basic meaning is not significantly affected by the amount of food waste in the feedstock, certainly as far as composting practice in Europe is concerned. Large and sustainable markets are generally only secured for quality controlled / quality assured compost products which are supported by some form of quality assurance system (QAS), such as PAS100 in the UK. This can help to develop a standard for an accepted compost quality appropriate for the market. 'Composts' failing to meet this standard should not be considered because they will not have a sustainable market, and may jeopardise market prospects for higher quality composts also derived from waste. In the UK, one way of achieving this would be to ensure that materials falling outside this specification did not count towards recycling and composting targets.

The amount of food waste in biowaste does not appear to have a statistically significant impact on the quality of compost. This is highlighted in Section 7.1. Quality, in this respect, refers mainly to the level of contamination by metallic elements and impurities. Therefore, the achievement of standards related to these parameters should not be seen as a major risk in professional composting.

7.4.2 Compost Properties

Compost properties vary considerably with the use of different source materials. More food waste leads to higher salt content and higher nutrient content in the final compost compared to compost which is derived from a feedstock containing more (or only) garden waste. Higher salinity can harm the roots of young plants, so food waste compost can usually only be used in professional cultivation in small quantities, or more realistically, as part of a blended product. This should be somewhat less of an issue with quality digestate since the dewatering step can effectively lead to (incomplete) removal of soluble salts in the liquid residue.

Whether this constitutes 'a risk' is debatable. Most of the European QASs require application recommendations and information, which accompany the sales of compost products. If this is properly managed, then it becomes the responsibility of the customer to consider the appropriate product. The issue is that the market for end product is narrowed, and that particular efforts will be required to market composts with significant food waste content into higher value markets. This may be

more important in more urban contexts, with limited agricultural outlets, though other markets may also be available locally.

7.4.3 Compost Markets

FWRFs can become a risk if local 'mass markets' for a composting plant are not available. The case study of Dortmund shows the risks in this respect. The situation in that case – where the output for compost is dependent upon two farmers and some restoration projects – indicates a degree of vulnerability in respect of agricultural outlets, but that a sustainable market for large composting plants can be found even where such outlets do not exist. The key, though, is to 'tap into' markets for large quantities of material to secure outlets for the end product. In the Dortmund case, restoration projects are an important outlet. The urban context allows for a limited range of tools to influence the nature of the source material, or to create products and outlets in the highly specialized, high price market of mixtures, potting soils and growing media.

In urban areas it is difficult to 'compensate' for the loss of some mass markets like agriculture, though opportunities for land restoration / remediation may exist (albeit not always for the long-term). Alternatives are more likely to be found through delegating the compost marketing activity to regional / national compost vendor companies (which exist in Europe in the form of big waste management companies such as Essent Milieu in the Netherlands, or Remondis in Germany).

The mass market for the food-waste based composting plants can become the source of an additional risk when it comes to the plant's financial position. Strong competition in agricultural markets *can* lead to quite high "negative" sales prices. In these situations, the composting plant has to support compost sales to farmers by such an amount of money that it starts to have an impact of the total economy of the plant.

In response to this, more and more composting plants try to reduce their dependency on the sometimes "costly" agricultural market by seeking to improve the quality of their product and by creating mixtures for the high specialized markets for landscaping and hobby gardening. These mixtures may be derived from different ratios of compost from FWRFs and green waste compost.

The Wiefels case study above showed one approach to finding a niche in the high price market. Based on the high quality of their product, and by starting to co-operate with a growing media producer, this becomes a more sustainable, lower risk solution. This approach creates a positive image for the plant and for the product, and brings with it reasonable revenues. Nevertheless, the absence of agricultural or other mass markets results in a risk too. As a matter of security composting plants ideally have channels to "market" large amounts of standard quality compost (i.e., compost passing a specific quality standard, such as PAS100) within a very short period of time, whilst seeking to derive higher values through creating products to more tailored specifications.

A low risk approach suggests, therefore, some product development on the part of the composting plants for the high value, specialized markets, and the simultaneous marketing of product into some mass/high volumes outlets which can be used as necessary. Most of the successful German composting plants have created over the

years this two pronged approach. It is an approach with which WRAP is very familiar in respect of most secondary materials markets, including the products of biological treatments, and this is one of the key objectives of WRAP's Organics Programme.

7.4.4 Process Problems Due to Insufficient Bulking Agents

Compost plants (and some digestion plants) treating FWRFs depend widely on additional sources of woody, structural materials. The process can compensate for the lack of structure (and high moisture content), and the low C/N ratio only to a certain extent. Static processes have more problems than dynamic processes, the latter having the possibility to increase the turning frequency. Modular systems such as tunnel composting systems allow the treatment of batches differently in respect of differing intensities of aeration (and the potential to switch the flow of air from a blowing to a sucking action and vice versa may also be helpful to force air through the biomass).

Nevertheless all composting processes need a minimum addition of 25 % of structural material to add to a food waste feedstock, and probably rather more if the system is based around aerated static piles. If only food waste is being collected on a frequent basis at kerbside, this could come from the collection of garden waste at CA sites, or from seasonal collections from the doorstep, or from external sources (other green waste composting plants). In most cases, plants are aware of their needs and plan for their sources, or store the material for the winter months (reflecting seasonally high ratios of food waste collected to collection of garden waste).

Developments in Germany highlight this as a potential 'risk factor', possibly more correctly viewed as an opportunity. There, the increasing interest in renewable energy from biomass treatment makes it wise to consider the possibility that woody biomass – a source of structural materials – may be channelled increasingly towards biomass power plants in future. There is a major difference for a waste collector if they are being paid for the woody material at a biomass plant instead of having to pay gate fees (albeit low ones) at a composting plant. Some composting plants in Germany now face problems in securing enough structural material at a reasonable price.

This is a small but increasingly important reason for the growing interest in anaerobic digestion processes. Many AD processes require no structural material. This type of development would support even more strongly the concept of separate collections for food waste and for garden waste.

7.4.5 Perception of End Users

Problems of perception can arise in respect of two main areas:

1. Odour perception during raw material collection and / or treatment, or with the final product; and
2. Impurities in the final product

Regarding 1, FWRFs tend to have a higher moisture content and can give rise to anaerobic fermentation early in the process, emitting the corresponding unpleasant odours. Intensive odour emissions will tend to generate a negative perception of the compost. To overcome this situation collections can be increased in frequency (e.g.

weekly) and biodegradable plastic bags or paper bags can be used in kitchen bins. Both approaches are fully costed in the preferred option in this report.

Odour emissions from the treatment operation seem to be a critical issue for compost plants all over Europe. Not only are odorous plants obviously bad neighbours, but potential customers tend to be of the opinion that a malodorous plant cannot manufacture good products. Besides the technology itself, the management of the plant is decisive e.g. by using the appropriate mixing ratio between FWRF and structural material in the winter months (or in periods where large quantities of grass are collected). Digestion in an enclosed reactor exhibits certain advantages when it comes to odour emission management.

Regarding point 2 above, a higher proportion of food waste collected by biobins in Central Europe may result in larger amounts of impurities, especially plastics. To keep impurities down to reasonable levels (below 3 to 5%) additional sorting may be necessary for wet anaerobic digestion processes. Various technologies (e.g. magnetic and ballistic separators, density separators, windsifters, disk screens) exist which can help to reduce the impurities. Continuous provision of information and education of citizens can also help in this respect.

Plastics and glass are the most critical impurities when it comes to end user perception. Coloured impurities are easy to detect in compost and lead to a “waste” association by private customers. Professional customers see problems in the manual handling (glass pieces affect hand labour while potting) or in the use of their further handling technologies (potting machines are sensitive to large wooden pieces and plastics). In addition they do not wish to sell products with contaminated compost to their customers.

In order to improve the impurity situation the German Compost Quality Assurance Association BGK established a new parameter for plastics in 2006. The existing 0.5% (by weight) limit value for plastics was not sufficient, because 0.5 % plastic film was considered too lax a limit to guarantee positive consumer responses. The new parameter “area ratio” measures the area covered by the plastic pieces and foils of a sample in the lab (max. 20% of a page DIN A4). Around 20% of German compost plants have problems meeting this new standard. Larger pieces of plastic film often correlate with feedstocks with a high proportion of food waste because households wish to have an easy-to-use system (without mess and odours) and so use plastic bags. The provision of starch based biobags may help to reduce this problem.

In addition plastic content reflects the quality of the organic waste treatment and the management of the plants. Those plants which are carefully managed and aim for quality processing and quality products are more likely to invest in the removal of impurities and in education of the population in the catchment area.

7.4.6 Genetically Modified Organism Not Traceable in Compost and Digestion Products

There may be some concerns among some organic farmers in the UK that composts / digestates derived from FWRFs are contaminated by genetically modified organisms (GMOs).

In the UK, the current position is that potential users of compost derived from food wastes need to have exercised due diligence to ensure absence of contamination of the feedstock by GMOs. The Soil Association is not aware of any organic farmer using compost with food waste from households in the feedstock, though some are using material with food waste from processors. It should be noted that this position holds true irrespective of the relative proportion of food waste in the feedstock. Any food waste in the feedstock is likely to raise this as a concern (so feedstocks with small proportions of food waste are also captured by this rule).

This situation may be reviewed pending outcomes of research currently underway at the Abertay Centre for the Environment in Dundee. This is looking at the effect of composting on proteins, and on the potential for horizontal transport of genetic material to soil micro-organisms. An initial report is expected in the Autumn with a final report in the first half of next year.

Some work concerning this matter has been undertaken (albeit in a different way) in Germany, where the German Compost Quality Organisation (BGK) carried out tests in July 2004. None of the typical DNA sequences typical of GMOs have been detected in any of the analysed samples of compost.

Additional investigations regarding the composting of transgenic plants, carried out by the Federal Institute for Agriculture (FAL) at Braunschweig, Germany (and ordered by the Federal Ministry of Environment), demonstrated that the plant DNA and also the recombinant genes were decomposed during the hot decomposition phase and were eliminated as a result. Another two year long study on genetically modified corn plants also showed that recombinant genes were eliminated during the hot decomposition phase within 8 days. Following this, the recombinant DNA sequence was detected neither in tomatoes nor in mushrooms which were cultivated using the compost.

According to these researchers, high temperatures in composting plants appear to induce an intensive biological degradation in the decomposition process. It is argued that germinable materials (seeds, pollen etc.) are decomposed during the composting process in such a way that further distribution of genetically modified plant genes is difficult, if not impossible.

In general, therefore, the GMO issue is no longer regarded as an argument against the use of compost in organic farming in Germany. Slightly more detail is offered in Annex 2.

7.4.7 Digestion Residuals

No additional risk factors are present for plants which digest FWRFs. The liquid fraction and the solid fraction show very low levels of heavy metals and a high nutrient content. Generally, the agricultural market is a major one for digestion products (for liquid residues in particular). The sector generally takes a favourable view of the material because of its high fertiliser value and the (usually) low costs (the products are often made available free of charge).

Arguably, the risk of not being able to reach high quality markets is lower for solid products from digestion, but equally, the problems may be greater in urban areas in respect of the liquid residue.

In addition, one can note that:

- Odour problems appear to be less of a problem at digestion facilities;
- However, odorous end products may be more a problem for the solid residues from anaerobic digestion plants than at composting plants. This is why, for example, the German Compost Quality Assurance Organisation (BGK) established criteria by which those laboratories accredited for analysis have to evaluate digestate samples according to their potential to give rise to odours. The 3 level odour classification “pleasant”, “neutral”, “unpleasant” allows only a qualitative evaluation, but it can lead (in those cases where unpleasant smells are reported) not to the withdrawal of the quality label, but to an additional consultation by the BGK; and
- Fewer problems are likely to arise from the absence of bulking agents at some (not all) AD plants, though careful attention to the rate of feeding of the digester is required in order to ensure process stability.

8.0 Conclusions

This study demonstrates that:

1. In terms of financial costs, separate collection systems which target food wastes are likely to be the most cost-effective;
2. In terms of environmental performance, the systems which perform best are those which route a higher proportion of the collected biowaste into digestion processes;
3. The quality of composts / digestates derived from FWRFs shows some variation from the qualities expected from garden waste composts. However, there are ‘pros’ and ‘cons’ in this regard;
4. With due attention to local circumstances and market realities, plants treating FWRFs can overcome risks associated with the additional food waste content in the collected biowaste.

These issues are important as the UK looks to comply with obligations under the Landfill Directive. The English waste strategy consultation indicates the need to capture a growing proportion of the household waste stream for recycling and composting. Though food waste is one of, if not the largest, fraction of the waste stream, it remains the case that it is barely touched by separate collection systems in England. In Wales, Scotland and Northern Ireland, food waste also remains a ‘cinderella material’, barely captured, yet needing to be managed more sustainably if targets and penalties are to be met and avoided, respectively.

8.1 The Path Dependent Nature of Choice

For some of the leading authorities in the UK in terms of recycling rates, decisions have largely been made in respect of biowaste collection and treatment. The highest combined recycling and composting rates are found in areas where garden waste is collected free of charge.

The options available to local authorities are dependent on the infrastructure that is currently in place. The work in this report suggests that benefits may arise from, for example, promotion of home composting, and introducing targeted food waste

collections, with processing infrastructure being adapted accordingly (on the basis of what already exists). This emphasises the path dependent nature of the decisions to be made in respect of collection and treatment. Even so, some adaptations – as, for example, at Weissenfels – are possible in respect of treatment processes, whilst collection systems are also likely to be amenable to adaptation.

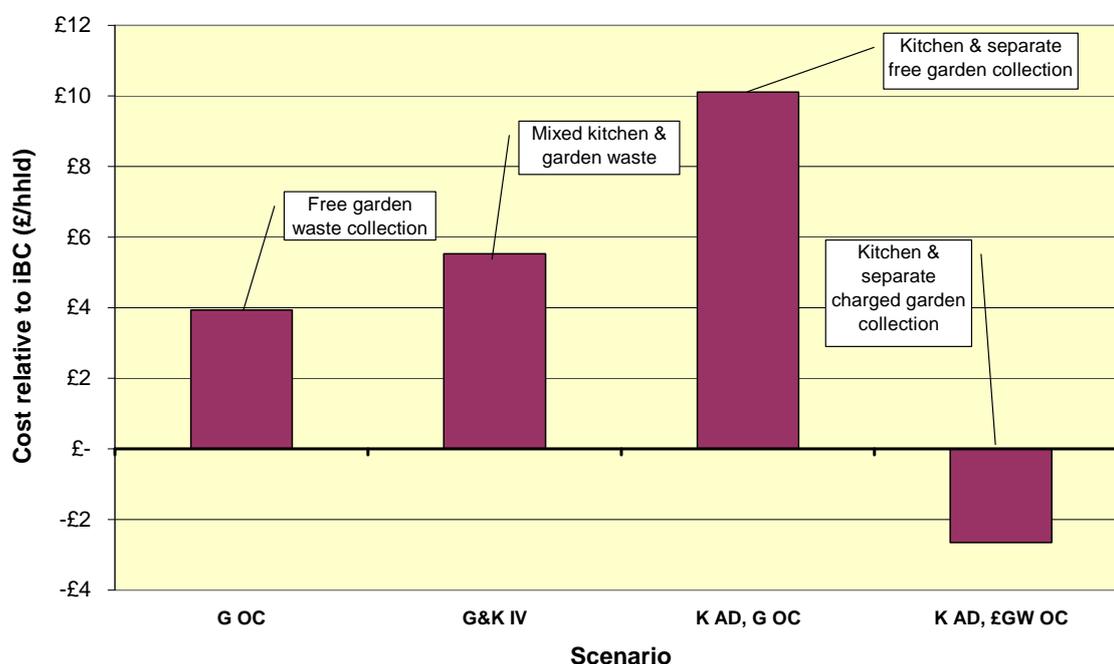
Given the starting position of many local authorities in the UK, some additional modelling was undertaken to show the difference in cost between alternative options for collecting food waste, as compared with the situation where garden waste is collected free of charge. The results are shown in Figure 9²⁶.

This shows that if local authorities are currently collecting free garden waste, then:

- if food waste is simply added to the garden waste collection scheme, the costs increase but the increase in recycling rate is relatively low, with correspondingly small reduction in residual waste per household
- if a separate food waste collection (weekly) is added alongside the free (fortnightly) garden waste collection, the increase in recycling rate is much higher and the residual waste per household is smaller. The costs are modelled with the food waste being digested and the garden waste being composted in windrows. The cost increase is significant;
- if methods are introduced which reduce the amount of garden waste collected fortnightly, and if a separate free (weekly) food waste collection is introduced, it seems possible (though this is based upon a number of assumptions) that the food waste can be digested, and the garden waste windrowed, at a reduced cost to the local authority. The methods of reducing the amount of garden waste collected include:
 - intensive promotion of home composting;
 - limiting the size and number of containers (bins or sacks) that are collected;
 - charging for the collection of garden waste, but if this approach is chosen then consultation with local residents is essential before any change to service is made. If the decision is made to charge, then the reasons for this have to be communicated very clearly to local residents. It will also be important to consider the impact of this decision on local recycling rates. As illustrated in Table 9 this approach will reduce the recycling and composting rate.

²⁶ See Table 5 for the key to labels on the scenario axis

Figure 9: Costs of Alternative Approaches to Collecting Biowastes, Including Food Wastes, as Compared with System Collecting Free Garden Waste Only



Note: See Table 5 for the key to labels on the Scenario axis

Table 9: Performance of Different Biowaste Collection Systems Including Garden Waste

	G OC	G&K IV	K AD, G OC	K AD, £GW OC
Recycling and Composting Rate	37.7%	41.9%	48.4%	44.7%
Residual Waste per Household (kg)	714	655	562	561

Other messages in the report are more immediately relevant for those considering, or seeking to implement new systems for biowaste collection, particularly in more urban areas. Here, as long as adequate attention is paid to marketing strategies for the end products, and where collection and treatment systems are well integrated, consideration ought to be given to the possibility for collecting food waste separately for digestion. If these collection systems can be coupled to AD processes, it should prove possible to generate both energy and quality products for use in various applications. The latter may require the use of blending (possibly with garden waste or/and other materials), and working with companies with greater experience in producing and marketing products for specific end-users.

8.2 Energy from Food Waste?

If food waste is targeted for separate collection, a considerable quantity of energy could be generated through digesting the material. Assuming:

- 60% capture across the UK;
- Generation of biogas ranging from 110-170 m³ per tonne of waste;²⁷
- Methane content of biogas = 60%; and
- Conversion to electricity at 30% efficiency in a gas engine;²⁸
- Parasitic load of 50-70 kWh per tonne;²⁹

then the total energy generated would be of the order 477-761 GWh per annum if the material was digested (see Table 10).

Composting the same amount of material would utilise energy in the process. The composting process would almost certainly lead to some time-limited sequestration of carbon, but the net position in respect of greenhouse gases is likely to be such that routing the material through AD rather than composting will improve the position in respect of greenhouse gases to the tune of more than 0.18 – 0.29 million tonnes CO₂ equivalent (based on an assumption that the displaced source is gas fired electricity generation).³⁰

²⁷ These figures were quoted by suppliers in a recent study (see Eunomia (2004) *Feasibility Study Concerning Anaerobic Digestion in Northern Ireland*, Final Report for Bryson House, ARENA Network and NI2000).

²⁸ This is a conservative figure for modern gas engines whose generation efficiency is likely to be closer to 40%. For example, Baky and Eriksson assume an efficiency of 38% with 52% of the energy content of the gas potentially available as useful heat (A. Baky and O. Eriksson (2003) *Systems Analysis of Organic Waste Management in Denmark*, *Environmental Project No. 822*, Copenhagen: Danish EPA).

²⁹ These figures may be on the high side, and are intentionally conservative. Studies frequently deal with this issue by assuming a percentage of the methane generated is used to generate energy for use at the plant. Baky and Eriksson assumed a figure of 5% (A. Baky and O. Eriksson (2003) *Systems Analysis of Organic Waste Management in Denmark*, *Environmental Project No. 822*, Copenhagen: Danish EPA). Finnvenden et al assumed that electricity consumed in the process was very low at 31 MJ/ton organic household waste (or around 9kWh per tonne (Goran Finnvenden, Jessica Johansson, Per Lind and Asa Moberg (2000) *Life Cycle Assessments of Energy from Solid Waste*, Forskningsgruppen for Miljostrategiska Studier, FMS 137, August 2000)

³⁰ This is based upon an assumption that the emissions associated with electricity generation from combined cycle gas turbines in the UK are 382g/kWh (see Annex 1 of D. Hogg (2006) *A Changing Climate for Energy from Waste*, Final Report to Friends of the Earth, for details).

Table 10: Possible Energy Generated from Digesting Source Separated Food Waste in the UK

Parameter	Low Value	High Value
Biogas yield (m ³ per tonne waste)	110	170
Percentage methane	60%	60%
Calorific value of biogas	660	1020
Electricity generated (@ 30% efficiency) (kWh/tonne)	198	306
Parasitic Load (kWh/tonne)	50	70
Net Generation (kWh/tonne)	148	236
Tonnes Food Waste	5375000	
Capture of Food Waste	60%	
Total Energy Generated (GWh)	477	761

8.3 Caveats

The analysis in this report is based in large part on previous work for WRAP. That work makes clear the limitations of any form of assessment and appraisal process where complex systems – such as municipal waste management – are concerned³¹. Suffice to say that given our imperfect, albeit expanding knowledge of the area of investigation, this appraisal represents ‘work in progress’. Even so, the financial and environmental appraisals are suggestive, and they indicate a direction of preference in respect of both approaches to collection and the approach to biowaste treatment. The key will be to seek to bring both aspects of this system together in future.

8.4 Moving Forward

As indicated above, it is rare to find AD plants where the feedstock is 100% food waste (though many processes would happily receive such high proportions). On the other hand, what is being suggested here is to bring together leading-edge design of collection systems with state-of-the-art treatment systems. Some countries are using approaches to the optimisation of collection systems, others are moving more towards digestion as an approach to biowaste treatment. Few are doing both. This is a genuine opportunity for the UK to take a lead in the management of biowaste and to use its late-mover advantage to leap-frog over the erstwhile ‘leading nations’ in managing biowaste more sustainably.

9.0 References

Amlinger, F., M. Pollak and E. Favoino (2004) *Heavy Metals and Organic Compounds from Wastes Used as Organic Fertilisers*, Final Report to the European Commission, ENV.A.2/ETU/2001/2004, July 2004;

³¹ Eunomia (2007) *Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis*, Banbury, Oxon: WRAP to be published in 2007

- Baky, A., and O. Eriksson (2003) *Systems Analysis of Organic Waste Management in Denmark*, *Environmental Project No. 822*, Copenhagen: Danish EPA.
- Barth, Josef (2005) *Product and Application Differences of Compost and AD-Residues Based on Different Raw Materials, Treatment Technologies and Collection Areas*, Report ORG0023, Banbury, Oxon: WRAP.
- Brandli, Rahel C., Thomas Kupper, Reinhard Furrer, Franz X. Stadelmann and Joseph Tarradellas (2005) *Persistent Organic Pollutants in Source-Separated Compost and Its Feedstock Materials—A Review of Field Studies*, *Journal of Environmental Quality*, Vol.34, No.3, May-June 2005, pp.735-60.
- Defra (2006) *Statistical Release: Municipal Waste Management Statistics 2004/5* (released March 2006).
- Dijkgraaf, E., and Gradus, R. (2003) *Cost Savings of Unit-Based Pricing of Household Waste: the Case of the Netherlands*. Rotterdam: OCFEB.
- DOENI (2006) *Towards Resource Management: The Northern Ireland waste Management Strategy 2006-2020, Vol.2: Waste Stream Summaries*.
- Eunomia (2004) *Feasibility Study Concerning Anaerobic Digestion in Northern Ireland*, Final Report for Bryson House, ARENA Network and NI2000.
- Eunomia (2006) *Managing Biowastes from Households in the UK: Applying Life-cycle Thinking in the Framework of Cost-benefit Analysis*, Banbury, Oxon: WRAP.
- Finnvenden, Goran, Jessica Johansson, Per Lind and Asa Moberg (2000) *Life Cycle Assessments of Energy from Solid Waste*, Forskningsgruppen for Miljostrategiska Studier, FMS 137, August 2000.
- Hogg, D. (2006) *A Changing Climate for Energy from Waste*, Final Report to Friends of the Earth.
- Kelly, Harlan G., and Donald S. Mavinic (2003) *Autothermal Thermophilic Aerobic Digestion: Research Application and Operational Experience*, Paper for the WEFTEC 2003 Workshop, Los Angeles, October 2003.
- National Statistics (2005) *Municipal Waste Management Survey 2004-5: Results of the Survey for Wales*, First Release, 16 December 2005
- Network Recycling with Eunomia (2005) *A Size Assay Study of Household Residual Waste as a Proposed Feedstock to an MBT Plant*, Report for West Sussex County Council.
- <http://www.earthtech.co.uk/generic/featured.html>
- NIEHS (2005) *Municipal Waste Management: Northern Ireland, 2004/05 Summary Report*, December 2005
- Parfitt, Julian (2002) *Analysis of Household Waste Composition and Factors Driving Waste Increases*, December 2002.
- Poll, J., et al (2003) *The Composition of Municipal Solid Waste in Wales*, Report for the Welsh Assembly Government, December 2003.
- Prudential (2004) *Soggy Lettuce Report 2004: Are We A Nation of Wasters?*

SEPA (2005) *Waste Data Digest 5*, July 2005.

Staton, Kevin L., James E. Alleman, Richard L. Pressley and Jim Eloff (2001) *2nd Generation Autothermal Thermophilic Aerobic Digestion: Conceptual Issues and Process Advancements*, Proceedings of the WEF/AWWA/CWEA Joint Residuals and Biosolids Management Conference, Biosolids 2001: "Building Public Support"

WRAP (2006) *Increasing Resource Efficiency, Reducing Carbon Emissions*, WRAP Business Plan 2006-2008, Banbury, Oxon: WRAP.

A.1.0 What Are the Avoided Costs of Treatment / Disposal?

In any analysis of the economics of, or the business case for, additional investment in separate collection systems, the case for additional action tends to rest significantly on the assumption concerning the level of the avoided cost of disposal. In fact, what matters is the avoided *marginal* cost of disposal.

Different local authorities will generally face different circumstances in this regard:

1. For some local authorities, the avoided marginal cost of disposal may be zero. This would be the case where 'put-or-pay' type contracts are in place.
2. For those authorities with non-landfill residual waste treatment facilities in place, then depending upon the nature of the contract ((and the potential benefits derived from, for example, freeing up capacity for other would-be users) the marginal avoided costs is either:
 - a. The avoided cost of treatment plus any revenue gain from sale of free capacity;
 - b. The avoided cost of treatment; or
 - c. The avoided cost of disposal plus the associated value of the improved balance in landfill allowances.

Much depends on the plant capacity and the nature of the contracts in place.

3. Finally, for those with no non-landfill residual waste treatment in place, the marginal avoided cost of disposal is likely to be either
 - a. The avoided cost of treatment; or
 - b. The avoided cost of disposal plus the associated value of the improved balance in landfill allowances

Once again, much depends upon plant capacity and the nature of the contracts in place.

In the context of collection systems, contract lengths may be of the order 7 years. For those authorities where the avoided marginal cost relates to landfill gate fees (including tax) plus related allowance values, this is equal to:

Gate fee + tax + value of allowances

Over a given contract period, then the value of gate fees plus allowances can be tolerably well estimated in present value terms for each year. What is less obvious is how to calculate the value of allowances over a given contract period. This is because under the LATS, forward prices are unlikely to be revealed since the market is forced into an extraordinary situation of balance in the target years. For this reason, forward trading is unlikely to occur across target years. This means that price formation will be non-existent beyond 2008/9 at the current time, and beyond 2011/12 once we reach 2009/10. In short, allowance values are characterised by enormous uncertainty beyond the year 2008/9.

Under a given profile for allowances, it is of course possible estimate the present value in any given year. It is also possible to estimate the annualised unit value of an allowance over the period. In effective recycling systems, residual waste will tend to have a biodegradable content of marginally less than 68%. Consequently, over the contract period, given an estimated profile for allowance values, it is possible to calculate an annualised present value of:

$$\text{Landfill gate fee} + \text{landfill tax} + (0.65 * \text{landfill allowance value})$$

The first two terms are likely to approach £55 in real terms at the end of the decade (the tax is not indexed for inflation). The third depends upon the profile of allowance values being used, but is likely to lie between £13-£50. In short, avoided marginal disposal costs are likely to lie somewhere between £68-105, with little understanding as to what might be a 'best guess' in this range.

For residual waste treatments, the contract values for residual waste treatment appear to be rising. Much depends, therefore, on whether authorities already have non-landfill residual waste treatments in place, or whether they have procured them recently, or are going to procure them in future. Unit prices in recent contracts are moving towards the £100 per tonne level. This can be compared with the unit prices at some of the older incinerators in England which lie in the £30s or £40s. It should be noted that even in those cases where contract gate fees with local authorities are low, the potential benefit from freeing up capacity may be much greater than the gate fee alone. The potential may exist, depending upon ownership arrangements and contracts, to sell freed up capacity, so that the marginal benefit of avoiding disposal is a combination of the avoided cost and the additional revenue so derived. It seems reasonable to assume that with non-landfill residual waste treatments moving towards £100 per tonne, and with the value of avoided landfill disposal plus allowances lying between £68-105, then the benefits of avoiding disposal may still be very high.

The study has used an avoided marginal cost of disposal of £75 per tonne. In the context of the discussion above, this seems likely to under-, rather than over-state the financial case for additional recycling (especially of biodegradable material). Even so, the case is made for some, albeit not all, systems on this basis.

It must finally be recognised that for many authorities, the avoided marginal cost of disposal is not associated with a non-landfill treatment. The available capacity in the market overall, and the lengthy lead-times in procurement, planning and commissioning, imply that many authorities face a marginal avoided cost which is determined by landfill gate fees, landfill tax, and the uncertain element that is the value of landfill allowances.

Some risk-averse authorities are effectively operating on the basis of an assumption that allowance values will approximate to the level of fines in the years 2009/10 to 2012/13, sometimes beyond. In this context, the financial case for most actions involving the recycling or composting of biodegradable material can easily be made, albeit the case may be justified only for short period of time. This is another area where the uncertainties created by the LATS may combine with the risk-averse nature of local authorities to bring about perverse strategies which appear justified over a short-term period, but whose value is questionable over the longer-term.

A.2.0 Testing of Compost for the Presence of GMOs

Against the backdrop of queries and questions coming from member organisations and authorities, the German Compost Quality Organisation (BGK) arranged, in July 2004, to analyse composts for the presence of genetically modified organisms (GMO). The analysis was carried out by the Agricultural Investigation and Research Organisation (LUFA-ITL), Institute for Animal Health and Food Quality GmbH, Kiel, Germany.

A.2.1 Test Results

In all, 8 samples of 500 g each were submitted to a GMO-Screen Standard Test. The test substrates consisted of fresh and mature composts and digestion products of different structures (Table A-1). Indications of a genetic modification were tested by "screening" the samples using genetic probes to trace those typical DNA-sequences, which can be found in almost all the admitted genetically modified organisms, e.g. the so called CaMV 35S-promotor sequence, the NOS terminator or the NPT II-gen. These are regulator genes used by molecular biologists in order to incorporate the information for the desired properties (e.g. herbicide resistance) at a defined point in the genetic make-up of the plant.

None of the typical DNA sequences were shown to be present in any of the analysed samples. The results of the test on the composts and digestion products investigated are shown in the Table A-1.

Table A-1: Results of Investigations into Presence of GMO-related DNA Sequences

Treatment plants	Product	Result
Sample plant 1	Fresh compost	No proof
Sample plant 2	Mature compost	No proof
Sample plant 3	Fertigkompost	No proof
Sample plant 4	Fresh compost	No proof
Sample plant 5	Mature compost	No proof
Sample plant 6	Fresh compost	No proof
Sample plant 7	Digestion product solid	No proof
Sample plant 8	Mature compost	No proof

The screening method used was very sensitive. If a sample indicates a positive result during screening, then with a further investigation the kind of the GMO and species can be determined or at least narrowed down (GMO-rape, maize, soya). After that quantification is possible.

If, in the context of further investigations, there is positive proof, as a rule the result should be confirmed once more. All doubts must be removed that identical sequences from the natural environment might have entered the sample. For example, the 35 S-Gen could have been transmitted into the sample by a soil bacterium (such as *Agrobacterium tumefaciens*) leading to an erroneous positive result regarding the presence of a GMO.

A.2.2 GMO Decomposition tests

Investigations on the composting of transgenic plants, carried out by the Federal Institute for Agriculture (FAL) at Braunschweig, Germany, ordered by the Federal Ministry of Environment, showed that plant DNA and also, recombinant genes, are decomposed during hot decomposition and thus eliminated (UBA text 11/2000 "Investigations Genetic Transfer at Decomposition of genetically modified herbicide resistant corn plants", research report 296 33 905, ISSN 0722-186X).

Corresponding investigations had been carried out previously in a two year study at the Federal Research Institute for Agriculture using genetically modified corn plants. Test plants had been the BASTA®-herbicide resistant corn plants (Liberty Link, Anjou 285, Prestige LL) of Hoechst Schering AgrEvo GmbH. The recombinant gene was eliminated during hot decomposition within 8 days. Following this, the recombinant gene was detected neither in tomatoes nor in mushrooms which have been cultivated on the compost.

Despite the very high level of metabolic activity displayed by compost microflora from various bacteria and yeast groups, no transfer of plant genes to microorganisms could be detected. This was taken as proof that there was no difference between microflora in composts from genetically modified plants and composts from plants containing no GMO.

In summary, the research team of the FAL determined that composting is a safe method for the treatment and utilisation of residues from transgenic plants from households or agriculture. As long as composting is carried out in line with good practice, feedstocks containing genetically modified material can be supplied to composting processes without any problems. High temperatures in composting plants induce an intensive biological degradation during the decomposition process. It can be assumed that germinable materials (seeds, pollen etc.) are decomposed during the composting process in such a way that further distribution of genetically modified plant genes is rendered practically impossible. In this respect, the German Biowaste Ordinance (BioAbfV) (in common with compost standards in several other countries) contains indirect regulations (guide value for the content of germinable seeds and sprouting plant parts).

It must be pointed out that the regulations of the EU Eco Ordinance (VO EG 2092/91 together with VO (EG) 1804/1999) for organic farming say that even the unintentional application of genetically modified organisms (e.g. through biological and plant wastes) is forbidden. On January 22nd, 2003 a meeting with stakeholders at the German Ministry of Consumer Protection (BMVEL) concluded that the requirement for the prohibition of the utilisation of genetically modified organisms is effectively fulfilled if during composting, no GMO are used (e.g. composting accelerators) and no commercial/industrial wastes are used resulting from the production of, or with,

GMO. A guarantee of the non-existence of GMO in separately collected biowastes from private households, which could have been produced from or with GMO, was deemed to be effectively rendered irrelevant on account of absence of proof that such material survived the composting process.

A.2.3 Further Information Regarding the Investigations:

Landwirtschaftliche Untersuchungs- und Forschungsanstalt Institut für Tiergesundheit und Lebensmittelqualität GmbH (LUFÄ-ITL), Gutenbergstr. 75-77, 24116 Kiel, Tel.: 0431/12 28-0, Fax: 0431/12 28-498, E-mail: zentrale@lufa-itl.de, Internet: www.lufa-itl.de

Further information regarding the GMO decomposition tests:

UBA-Text 11/2000 "Untersuchungen zum Gentransfer bei der Kompostierung gentechnisch veränderter herbizidresistenter Maispflanzen", Forschungsbericht 296 33 905, ISSN 0722-186X (KE)