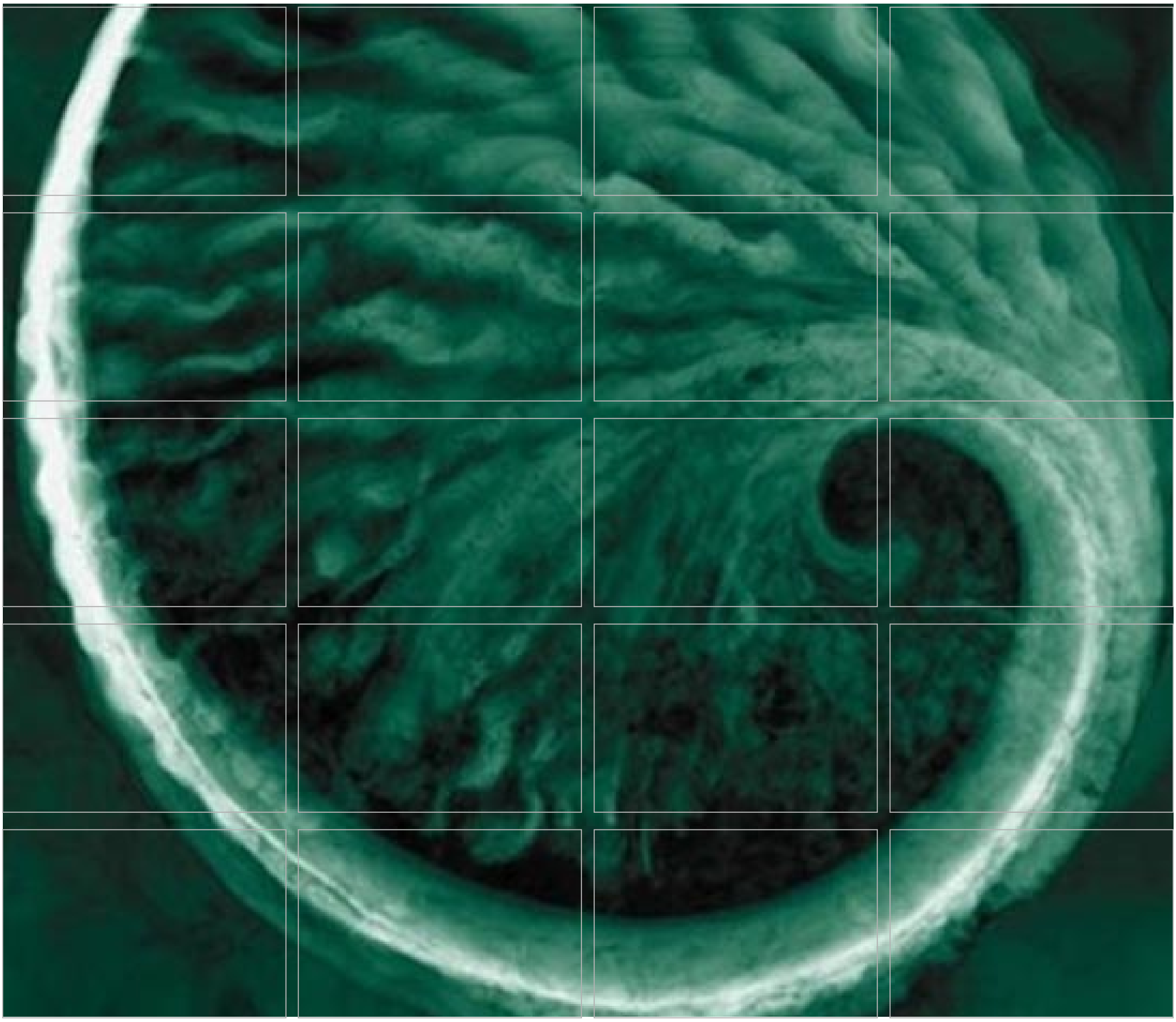

Impact of Energy from Waste and Recycling Policy on UK Greenhouse Gas Emissions

Defra

Final Report

January 2006

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CONTENTS

1 EXECUTIVE SUMMARY

This report examines the wider effects and impacts of waste-related policies on greenhouse gas emissions arisings from the life cycle of UK waste management systems. The policies considered include the EU Landfill Directive and those set out as recycling and composting targets in the national waste strategy for England and Wales, *Waste Strategy 2000.*

Waste management makes a significant contribution to UK emissions of greenhouse gases, in particular methane from landfills. Other forms of waste management (eg recycling or incineration with energy recovery) can result in net reductions of emissions of greenhouse gases through energy recovery or materials recycling.

The Government is implementing the EU Landfill Directive across the UK through various landfill allowance schemes to reduce quantities of biodegradable municipal waste disposed of to landfill, in accordance with targets. Within the framework of national waste strategies, the appropriate mix of waste management facilities in local areas will be a matter for local authorities.

A number of scenarios to investigate the range of likely responses to the EU Landfill Directive have been developed (*see Table 1.1*). The scenarios have been quantitatively assessed using a series of linked spreadsheets, combining the quantities and composition of arising waste streams, the management routes they are assumed to follow, and best estimates of greenhouse gas emissions for the activities involved in their management.

Table 1.1 Waste Management Scenarios Assessed

MSW Scenarios	**Scenario Definition**
Scenario 1	Baseline (2003/04) UK capacity for recycling, composting and energy from waste (EfW). All additional waste arisings over the period 2004-2045 will be landfilled.
Scenario 2	*Waste Strategy 2000* recycling and composting targets will be met. EfW capacity has been increased in order to meet UK landfill allowance targets .
Scenario 3	Elevated rates of paper recycling, windrow and kitchen waste composting and increased EfW capacity will be used to achieve UK landfill allowance targets.
Scenario 4	*Waste Strategy 2000* recycling and composting targets will be met. Anaerobic Digestion capacity for separately collected organic fractions has been increased, together with elevated EfW capacity, in order to meet UK landfill allowance targets.
Scenario 5	Elevated rates of green and kitchen waste recycling, predominantly via in-vessel composting (IVC), with co-composting of paper. Increased EfW capacity to reach UK landfill allowance targets.

MSW Scenarios	Scenario Definition
Scenario 6	*Waste Strategy 2000* recycling and composting targets will be met. MBT capacity (with MBT plant configured to stabilise wastes for landfill) has been increased in order to meet UK landfill allowance targets.
Scenario 7	*Waste Strategy 2000* recycling and composting targets will be met. MBT capacity (with MBT plant configured to produce RDF for combustion) has been increased in order to meet UK landfill allowance targets.
Scenario 8	*Waste Strategy 2000* recycling and composting targets will be met. Gasification capacity has been introduced in order to meet UK landfill allowance targets.
Scenario 9	A mix of waste treatment technologies will be used to achieve UK landfill allowance targets.
C&I Waste Scenarios	
Scenario 1	Baseline capacity for recycling and recovery (2002/03) with growth in waste arisings assumed to go to landfill.
Scenario 2	10% increased diversion from landfill per annum from 2005 to 2011/12. No change in diversion from 2011/12 onwards. It is assumed that all wastes diverted from landfill will be recycled.
Scenario 3	10% increased diversion from landfill per annum from 2005 to 2011/12. No change in diversion from 2011/12 onwards. It is assumed that all wastes diverted from landfill will be incinerated.

Scenarios quantify the likely effects of alternative responses on emissions of the following gases for the years 2005, 2010, 2015, 2020, 2030 and 2040:

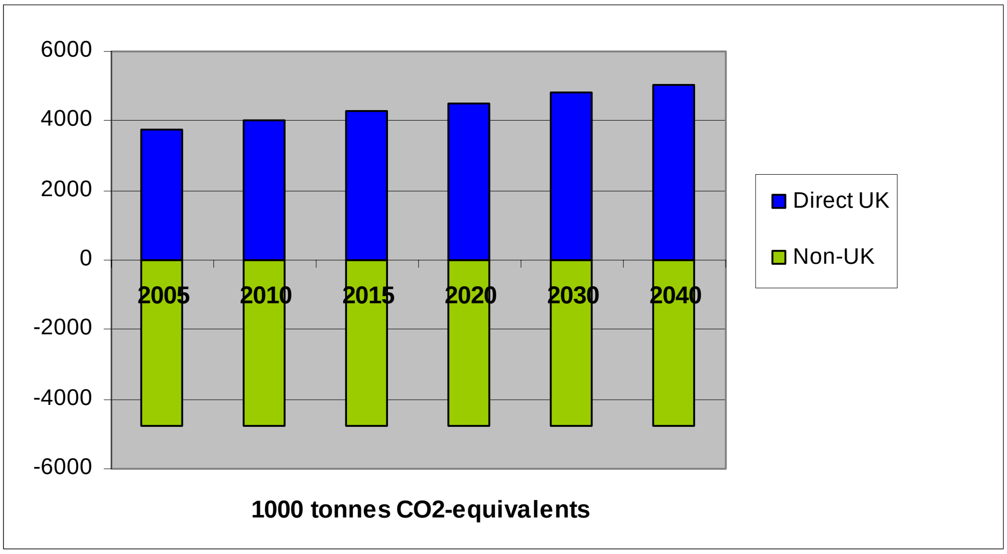
- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs); and
- sulphur hexafluoride (SF_6).

Greenhouse gas emissions have been translated, using standard charcterisation methods, into CO_2 equivalents to allow for a weighted comparison of emissions from alternative scenarios. In order to calculate estimates of greenhouse gas burdens in the UK, emissions have further been differentiated according to the likely location of their release, alternatively 'direct UK', or 'non-UK'.

Best estimates for greenhouse gas emissions associated with the baseline levels of waste treatment capacities for municipal solid waste (MSW) and commercial and industrial (C&I) waste streams are shown in *Figure 1.1* and *Figure 1.2* respectively. Both scenarios show a gradual increase in direct UK greenhouse gas emissions over the study period, predominantly associated with increased tonnages of waste sent for landfill.

Net non-UK greenhouse gas emissions are negative due to the offset benefits of recycling materials. These benefits appear as indirect emissions as the displacement of primary materials extraction and manufacture is assumed to occur outside of the UK system boundary.

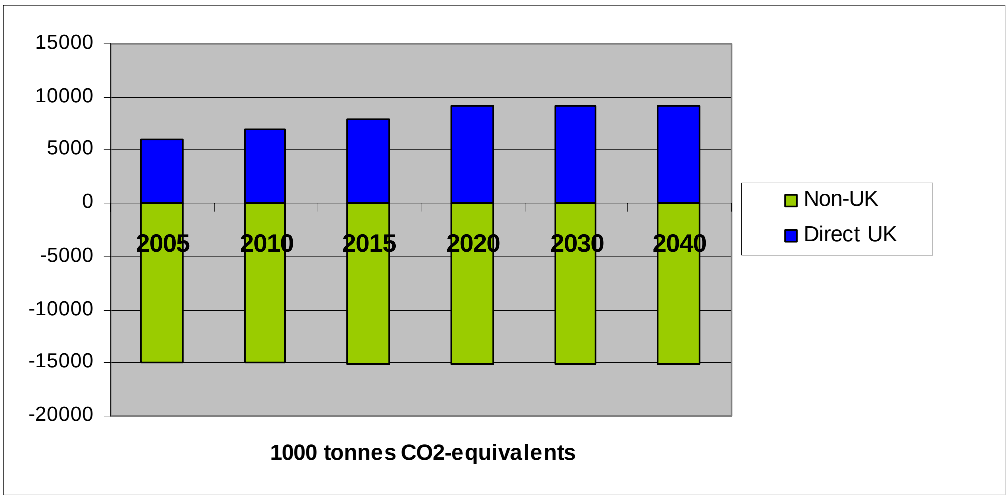
Figure 1.1 Baseline MSW Scenario Greenhouse Gas Emissions (Direct UK and Indirect)



MSW scenarios 2 to 9, each presenting an alternative option for meeting policy targets, exhibit greenhouse gas emission reductions in comparison with this baseline case. Estimates range from a 27% reduction in direct greenhouse gas emissions in 2020 for the high paper and card recycling scenario, to a 53% reduction in direct greenhouse gas emissions in 2020 for the high MBT with refuse derived fuel (RDF) production scenario.

In general, those scenarios comprising elevated levels of both recycling and energy recovery (mixed technology scenario, high EfW scenario, high paper and card recycling scenario, high MBT with RDF combustion scenario) show greater net greenhouse gas benefits.

Figure 1.2 *Baseline C&I Scenario Greenhouse Gas Emissions (Direct UK and Indirect)*



C&I scenarios 2 and 3, each presenting an alternative fate for the increased diversion from landfill assumed to result from increases in landfill tax, also exhibit greenhouse gas emission reductions in comparison with the C&I baseline case. The relative balance in performance between recycling and EfW scenarios shows a shift over time, with recycling favoured in the short term and EfW in the long term. This balance is heavily influenced by assumptions regarding commercial and industrial waste composition, however, for which only relatively poor data exist.

An assessment of the financial impacts of the waste management scenarios was carried out in addition to greenhouse gas quantifications. In accordance with HM Treasury Green Book, all future costs were discounted to present day prices (2005), at a discount rate of 3.5% per annum. *Figure 1.3* and *Figure 1.4* show the alternative collection, treatment costs of the MSW and C&I waste scenarios.

Figure 1.3 *Net Present Cost (£m) over Lifetime of Measures, Collection and Treatment: MSW Scenarios*

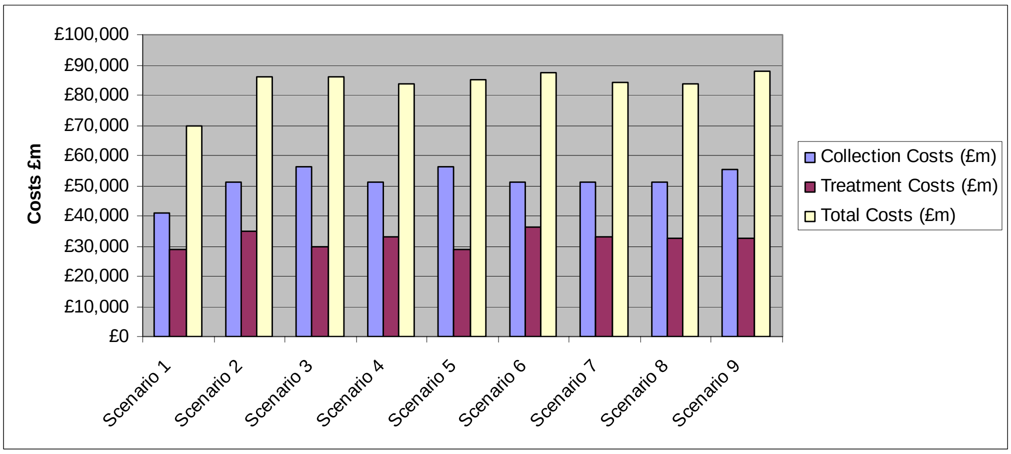
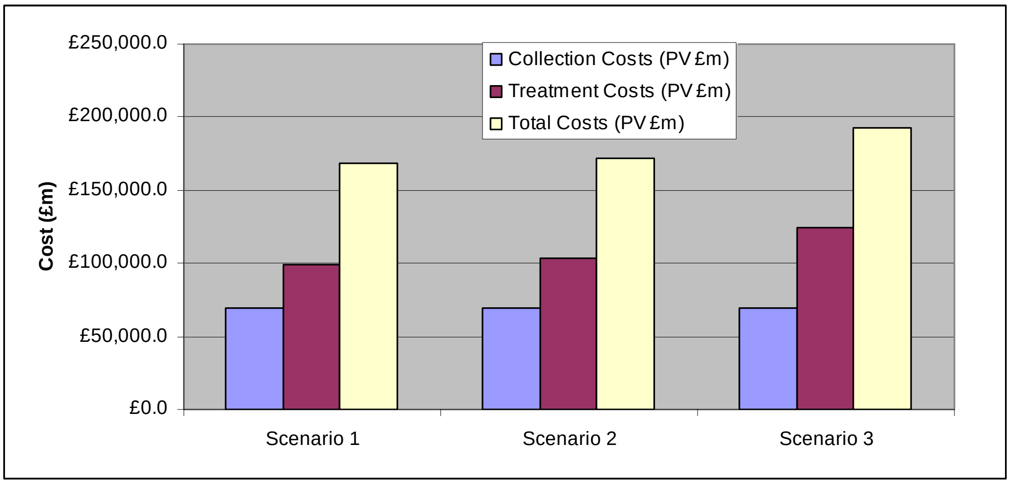
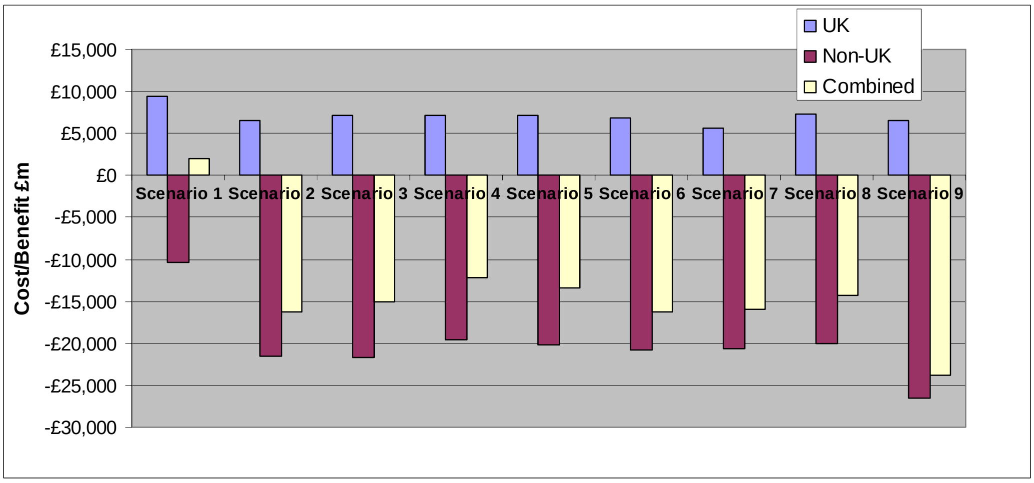


Figure 1.4 *Net Present Costs (£m) over Lifetime of Measures, Collection and Treatment: C&I Scenarios*



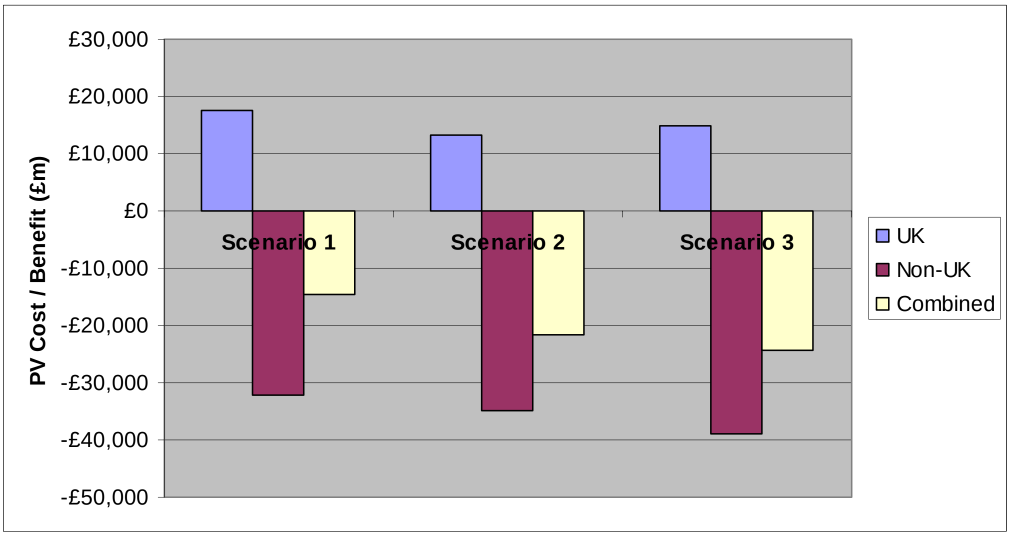
Efforts have also been made to place a monetary value on greenhouse gas emissions, reflecting the Social Cost of Carbon (SCC) (1). *Figure 1.5* and *Figure 1.6* present analyses of the costs of greenhouse gas emissions associated with MSW and C&I waste scenarios in terms of direct UK, non-UK and combined impacts. The presence of negative numbers indicates the benefits associated with avoiding greenhouse gas emissions through use of recycled materials, rather than relying on primary production of resources.

Figure 1.5 *Present Value Cost/Benefit of Greenhouse Gas Emissions (£m) Over Lifetime of Measures: MSW Scenarios*



(1) As discussed in Clarkson and Deyes (2002). *Estimating the Social Cost of Carbon Emissions.* HM Treasury and GES Working Paper 140. London

Figure 1.6 Present Value Cost/Benefit of Greenhouse Gas Emissions (£m) Over Lifetime of Measures: C&I Scenarios



Results have shown that adopting a strategy to implement the EU Landfill Directive, or divert C&I wastes from landfill, will have a subsequent beneficial impact on levels of greenhouse gas emissions. *Table 1.2* and *Table 1.3* indicate scenario waste treatment spending above the baseline case per tonne of greenhouse gas (carbon dioxide or equivalent) avoided.

Table 1.2 Additional Waste Management Cost above Baseline Case (Scenario 1) per Tonne GHG Avoided: MSW Scenarios

	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7	Scenario 8	Scenario 9
UK	£258	£339	£279	£316	£307	£170	£305	£289
Non-UK	£69	£68	£71	£74	£81	£66	£68	£54
Combined	£43	£47	£48	£49	£48	£39	£42	£36

Table 1.3 Additional Waste Management Cost above Baseline Case (Scenario 1) per Tonne GHG Avoided: C&I Scenarios

	Scenario 2	Scenario 3
UK	£48	£415
Non UK	£76	£176
Combined	£29	£118

2 INTRODUCTION

2.1 BACKGROUND TO THE PROJECT

The UK has a legally binding target under the Kyoto Protocol to reduce emissions of a basket of six greenhouse gases (carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) to 12.5% below base year levels over the commitment period from 2008 to 2012. It also has a domestic goal of reducing carbon dioxide to 20% below 1990 levels by 2010.

The Government is currently conducting a review of its UK Climate Change Programme (CCPR). The Programme contains a package of polices and measures to meet the Kyoto commitment and the 20% goal, as well as to prepare the UK to make more significant cuts in the longer term.

Waste management makes a significant contribution to UK emissions of greenhouse gases. All waste management activities lead to the production of some greenhouse gases. The landfilling of wastes, in particular, contributes to methane emissions, a significant greenhouse gas. Reducing the UK's reliance on landfill is therefore central to the Government's new draft waste strategy.

Other forms of waste management can result in net reductions in greenhouse gas emissions. A key part of the Government's strategy is the promotion of the waste hierarchy: reduction; re-use; recycling; recovery; and, finally, disposal. In practice, this means that, where waste is produced, it is important that value is recovered from it, be it through recycling, composting or recovery of energy, for example through energy from waste (EfW). EfW, and other energy recovery processes, have the additional benefit of acting to provide a renewable source of electricity. This not only has implications for climate change, but also for UK energy security.

The Government is implementing the EU Landfill Directive across the UK through various landfill allowance schemes to reduce quantities of biodegradable municipal waste disposed of to landfill, in accordance with targets. Within the framework of national waste strategies, the appropriate mix of waste management facilities in local areas will be a matter for local authorities.

This study builds on previous work relating to the likely effects on UK greenhouse gas emissions of a range of scenarios for UK waste management policy (in particular relating to EfW and recycling). The study has been completed in time for consideration under the CCPR and will contribute to the review of national waste strategies.

2.2 *Study Aims and Objectives*

The primary aim of the study was to update quantitative assessments on the implications of waste management policies (including recycling, composting and energy from waste) for UK emissions of greenhouse gases.

To this effect, the study's overall objective was to quantify, for a range of scenarios, the likely effects of national-level waste management targets, and other relevant Government policies, on emissions of the following gases for the years 2005, 2010, 2015, 2020, 2030 and 2040:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs); and
- sulphur hexafluoride (SF_6).

Further, specific objectives were to:

- review recent research on the effects of waste management policies on greenhouse gas emissions and from these studies and data sources to produce a best estimate of greenhouse gas emissions;
- estimate the financial costs and benefits associated with waste management scenarios; and
- identify the key sensitivities and risks that will affect these assessments.

3 DEVELOPMENT OF SCENARIOS FOR THE ESTIMATION OF TOTAL GHG EMISSIONS IN THE UK

A number of scenarios to investigate the range of likely responses to UK waste management policies have been developed. The scenarios have been quantitatively assessed using a series of linked spreadsheets, combining the quantities and composition of arising waste streams, the management routes they are assumed to follow, and greenhouse gas emissions for the activities involved in their management (discussed further in *Section 4*).

The scenarios have been designed to incorporate a range of current waste management options, including:

- recycling;
- composting;
- energy from waste (EfW);
- mechanical biological treatment (MBT), with stabilisation of waste, or production of a refuse derived fuel (RDF);
- gasification; and
- landfill.

Other elements also incorporated within the waste management system include:

- transport within the different waste management routes, including waste collection;
- operation of transfer stations; and
- operation of materials recovery facilities (MRFs).

A series of key modelling assumptions formed the basis of scenario development and assessment and are outlined in the following sections:

- current waste arisings and management;
- waste composition;
- waste growth; and
- waste policy context (type and amount of waste to be diverted from landfill, method of management, compliance with legislative targets).

3.1 *CURRENT WASTE ARISINGS AND MANAGEMENT*

Two streams of waste arisings have been assessed:

- municipal solid waste (MSW); and
- commercial and industrial (C&I) waste.

3.1.1 *Management Routes*

For the purposes of the study, a 'standard' management system has been modelled for all waste arisings and scenarios. This assumes that all separately collected dry recyclables are source-separated and passed via a clean MRF/bulking point prior to recycling/reprocessing. All other residual wastes, and wastes designated for composting, pass via a transfer station before reaching an appropriate treatment facility.

This model may not be representative of all the waste collection and management systems employed in the UK, as there are many variants. Different levels of contamination associated with separated materials and different efficiencies in processing and conversion will have implications for greenhouse gas emissions estimates. There is also likely to be significant variation in the financial costs of systems employed in different areas. However, the generic system modelled is considered typical and ensures consistent modelling between the various scenarios.

3.1.2 *MSW Arisings and Management*

Current MSW arisings data have been provided by Defra, based on published Municipal Waste Management Survey (MWMS) data, detailing arisings in England for 2003/04. It was assumed that English arisings represent 85.7% of the total for the UK [(1)] and UK arisings were calculated accordingly.

Data show that, across the UK in 2003/04, 35.269 million tonnes of MSW were produced, approximately 18% of which was recycled or composted, 74% landfilled and 8% incinerated.

3.1.3 *C&I Waste Arisings and Management*

The Environment Agency has recently updated it National Waste Production Survey (NWPS) (2002/03), examining waste production across England in a substantial sample of businesses across various sectors. The NWPS survey data have not yet been published, but provisional figures are used for this study. It was assumed that English arisings represent 85.7% of the total for the UK [(2)] and UK arisings were calculated accordingly.

Data show that, across the UK in 2002/03, 79.238 million tonnes of C&I waste were produced, approximately 35% of which was recycled, 3% was composted, 4% thermally treated and the remainder sent for land disposal, recovery or transfer [(3)].

(1) Defra, pers comm., England GVA proportion.
(2) Defra, pers comm., England GVA proportion.
(3) For the purposes of modelling, wastes managed via each of these alternative routes was assumed to be landfilled.

3.2 *WASTE COMPOSITION*

3.2.1 *MSW Composition*

Baseline data for waste composition have been taken and adapted from: *The Composition of Municipal Waste in Wales.* National Assembly for Wales (NAW)/AEAT Technology - December 2003. The proportion of biodegradable material in each waste fraction has been estimated by ERM. Assumed average MSW composition and biodegradable content is shown in *Table 3.1*.

Table 3.1 MSW Waste Composition

Waste Fraction	% Composition in MSW	% Biodegradability
Paper/Card	21.0%	100%
Kitchen Waste*	17.8%	100%
Garden Waste	12.7%	100%
Textiles	1.8%	50%
Fines	5.2%	50%
Miscellaneous. Combustible	12.1%	50%
Other, Miscellaneous Wastes**	10.8%	35%
Ferrous Metals	4.7%	0%
Non-Ferrous Metals	0.8%	0%
Glass	5.8%	0%
Plastic Dense	4.5%	0%
Plastic Film	2.8%	0%
Total	**100.0**	**65%**

* includes 'other' organics (2.1%)

** includes WEEE (2%) and Specific Hazardous Household Waste Items (including all batteries) (0.813%)

Residual waste composition will change as materials are separated from the waste stream for recycling and composting. Similarly, composition will change following pre-treatment processes, such as MBT. The modelling carried out has taken into account these changes in residual waste composition.

3.2.2 *C&I Waste Composition*

Baseline data for C&I waste composition have been based on the Environment Agency's NWPS data for 2002/03. The compositional data are limited as a further breakdown for the substantial categories, 'other mixed general wastes (combustible and non-combustible) could not be determined and limited material analysis is provided. The proportion of biodegradable material in each waste fraction has been estimated by ERM. The composition and biodegradable content assumed for C&I waste is shown in *Table 3.2*.

Table 3.2 Assumed C&I Waste Composition

Waste Fraction	% Composition	% Biodegradability
Paper	12.7%	100%

Waste Fraction	% Composition	% Biodegradability
Food / animal waste	9.3%	100%
Ferrous metals	4.3%	0%
Non-ferrous metals	1.1%	0%
Other mixed general waste (non-combustible)	47.8%	0%
Other mixed general waste (organic)	24.8%	100%
Total	**100%**	**47%**

3.3 *WASTE GROWTH*

3.3.1 *MSW Forecasts*

Growth in MSW production is generally believed to be a function of two factors: increase in the numbers of households in a specific area; and growth in mean waste production per household, as a result of changing patterns of consumption. Since statistics regarding waste arisings are generally poor, the relationship between these two factors is not clearly defined and can not be predicted reliably.

The average rate of UK waste growth over the past six years was 2.5% and over the past three years was 1.3% (1).

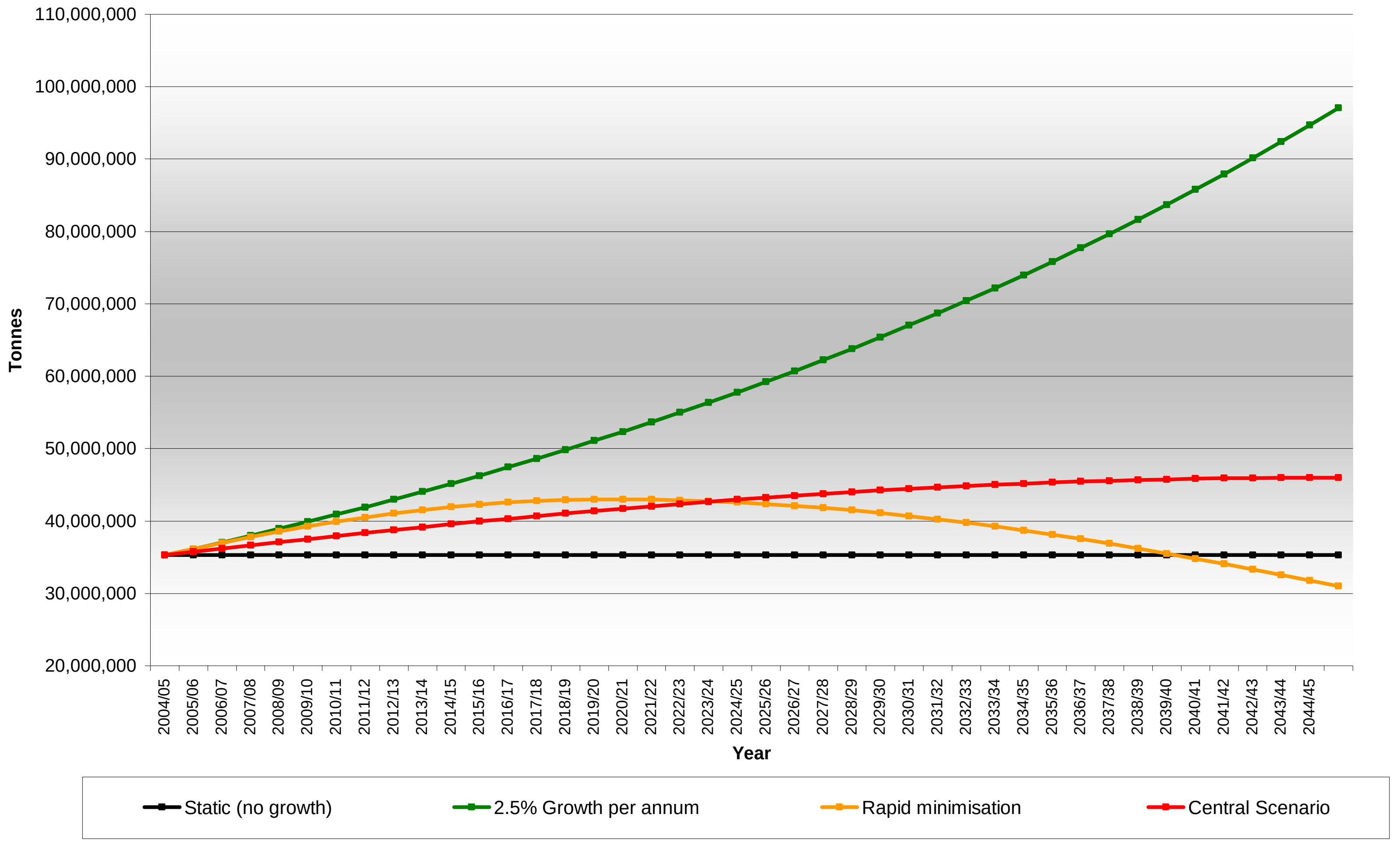
Four alternative growth scenarios for MSW are presented in *Figure 3.1* overleaf:

- **Forecast 1 -** a forecast of no growth in MSW arisings (static);
- **Forecast 2 -** a forecast of MSW arisings based on a constant 2.5% increase per annum, in line with the average growth rate over the past six years;
- **Forecast 3 –** a forecast demonstrating the affect of a rapid decrease in growth rate following, for example, the implementation of waste minimisation policies. This assumes a decrease in growth rate from 2.5% per year in 2005, reaching static growth in 2020. From 2020 onwards it is assumed that waste production will decline steadily at a rate reaching a maximum decline of -2.5% in 2045; and
- **Forecast 4 –** a central scenario, examining the impact of a conservative growth over the period, allowing for the impact of increasing waste management costs and waste minimisation efforts on growth rates. This assumes a steady decline in growth rate from 1.3% in 2005 (the historic 3-year UK growth rate), reaching static growth by 2045.

For the purposes of this study the central scenario was modelled.

(1) Defra Waste Statistics Division, pers comm.

Figure 3.1 MSW Growth Forecasts



3.3.2 *C&I Waste Forecasts*

There is a common opinion that C&I waste production is linked to economic growth. However, the relationship cannot be confirmed by the available statistics, making forecasting of C&I waste arisings difficult.

Estimates of value added growth by sector have been determined using information provided by the Defra REEIO model. This predicts industrial and commercial sectors to grow at different rates over the period 2004 - 2020. Current best estimates of growth in these sectors are:

- industrial sector growth (2004 – 2020) - 1.6% per annum; and
- commercial sector growth (2004 – 2020) – 2.6% per annum.

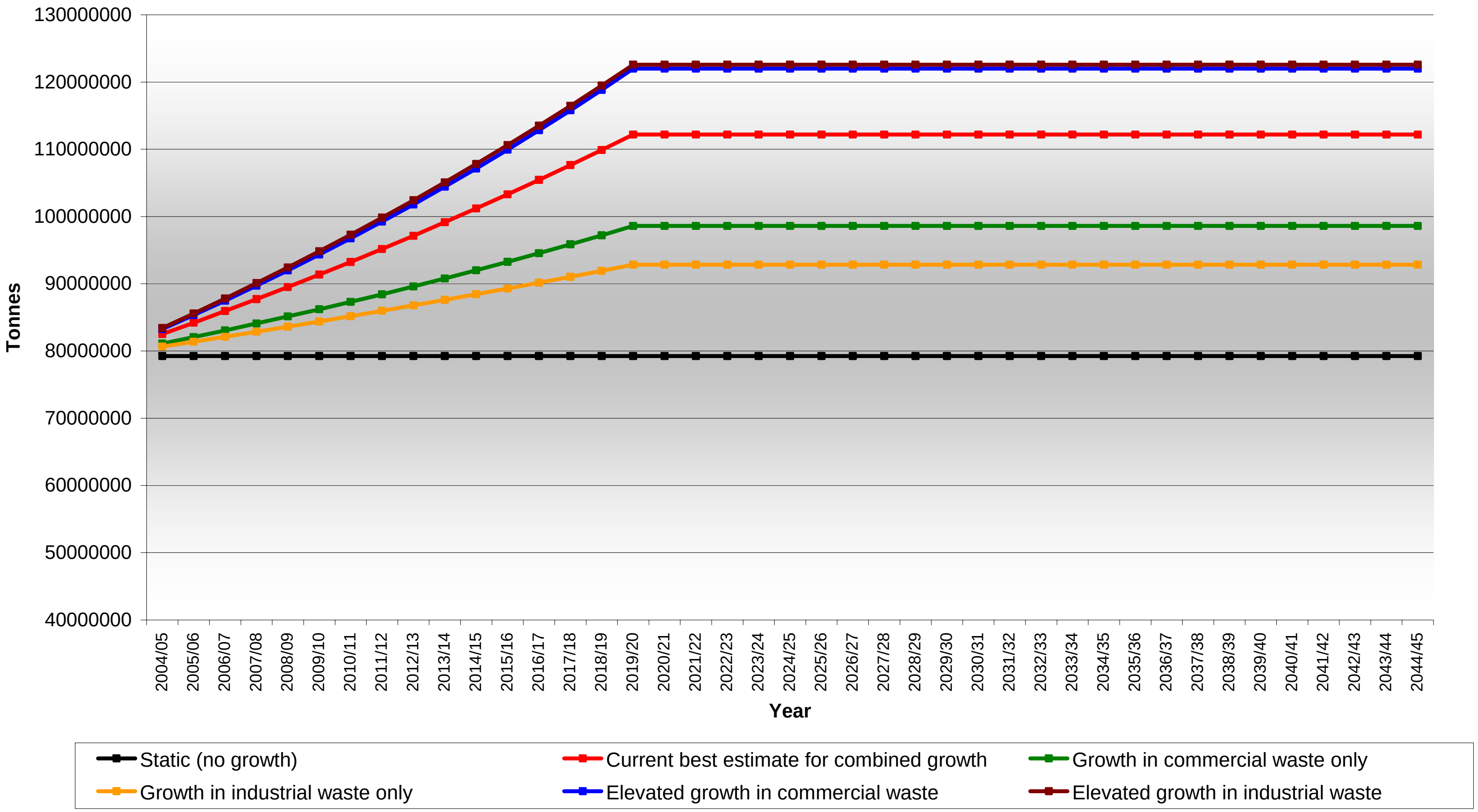
These estimates of economic growth have been used as a basis for forecasting waste growth, on the assumption that waste arisings for the industrial and commercial sectors will increase in accordance with predicted value added growth in each sector. Predictions are not made further than 2020, however, and there exists no evidence base on which a forecast past this period can be made.

Six alternative growth scenarios for C&I waste are presented in *Error! Reference source not found.* overleaf. All scenarios assume growth in C&I waste arisings until 2020 and static growth from this point forward:

- **Forecast 1 -** a forecast of no growth in C&I arisings (static);
- **Forecast 2 –** a forecast of growth in C&I waste arisings in line with current best estimates of economic growth (commercial – 2.6%, industrial – 1.6%);
- **Forecast 3 –** a forecast of growth in commercial waste arisings only, in line with current best estimates of economic growth (2.6% per annum). For this scenario, it was assumed that there would be no growth in the industrial sector;
- **Forecast 4 –** a forecast of growth in industrial waste arisings only, in line with current best estimates of economic growth (1.6% per annum). For this scenario it was assumed that there would be no growth in the commercial sector;
- **Forecast 5 –** a forecast of an elevated growth in commercial arisings (3.6% per annum), assuming that economic growth in this sector exceeds predictions. For this scenario, growth in industrial waste is assumed to increase in line with current best estimates of economic growth (1.6% per annum); and
- **Forecast 6 –** a forecast of an elevated growth in industrial arisings (2.6% per annum), assuming that economic growth in this sector exceeds predictions. For this scenario, growth in commercial waste is assumed to increase in line with current best estimates of economic growth (2.6% per annum); and

For the purposes of this study, the central, best estimate scenario of 2.6% growth in commercial waste and 1.6% growth in industrial waste per annum (to 2020) was modelled.

Figure 3.2 C&I Waste Growth Forecasts



3.4 *Waste Policy Context*

3.5 *EU Landfill Directive*

The EU Landfill Directive [(1)] aims to deal with the social, environmental and economic impacts of landfill over its whole life cycle. The Directive's principal objective is to prevent, or reduce as far as possible, the negative effects of landfilling waste on the environment and on human health. Accordingly, it introduces a number of restrictions on the type and quantities of waste that may be landfilled in the future. As a result, alternative management routes will need to be found for wastes that can no longer be landfilled.

Article 5 of the Directive progressively limits the quantity of biodegradable municipal waste (BMW)[(2)] that can be landfilled, with the aim of reducing the emission of gases that affect the global climate and leachate that might pollute groundwater.

In the UK, BMW has been interpreted as the biodegradable fraction of those wastes under the control of waste collection and disposal authorities (municipal solid waste). Key Directive provisions for local authorities relate to the gradual reduction of BMW going to landfill going to landfill and the promotion of alternatives such as recycling, composting and EfW. To this effect, the Directive contains three national-level targets aimed at reducing the amount of BMW disposed to landfill:

- by 2010: reduce the amount of BMW landfilled to 75 percent of that produced in 1995 [(3)];
- by 2013: reduce the amount of BMW landfilled to 50 percent of that produced in 1995; and
- by 2020: reduce the amount of BMW landfilled to 35 percent of that produced in 1995.

These limits on landfilling BMW will act as the major driving force behind UK Government waste management policy.

3.5.1 *Landfill Allowances*

Landfill allowance schemes have been developed in order to ensure that the UK will meet targets for BMW diversion. Schemes differ according to nation, and key features of each are presented in *Table 3.3*.

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(1) Council Directive 99/31/EC on the Landfill of Waste, European Commission (1999).

(2) The Directive defines BMW as that which is capable of undergoing anaerobic or aerobic digestion, such as food and garden waste, paper and cardboard.

(3) These dates include the four-year derogation available to the UK because of the proportion of MSW landfilled in the baseline year of 1995.

Table 3.3 Comparison of the Landfill Allowance Schemes in England, Wales, Scotland and Northern Ireland

	ENGLAND	**WALES**	**SCOTLAND**	**NORTHERN IRELAND**
Name of Scheme	Landfill Allowance Trading Scheme	Landfill Allowances Scheme	Landfill Allowances Scheme	Landfill Allowances Scheme
Biodegradable content of municipal waste	68%	61%	63%	71%
Introduction of the scheme	1 April 2005	1 October 2004	1 April 2005	1 April 2005
Trading of allowances	Trading is permitted although not obligatory.	No trading of allowances	Trading will be permitted from 2008. Before 2008, waste disposal authorities may be able to swap allowances, at the discretion of the Executive.	No trading of allowances. Transfer of allowances between authorities permitted.
The Landfill Directive targets for each of the countries (tonnes of biodegradable municipal waste)	2009/10 – 11,200.00 2012/13 – 7,460.00 2019/20 – 5,220.00	2009/10 – 710,000 2012/13 – 470,000 2019/20 – 330,000	2009/10 – 1,320,000 2012/13 – 880,000 2019/20 – 620,000	2009/10 – 470,000 2012/13 – 320,000 2019/20 –220,000
Scheme Year	1 April to 31 March	1st scheme year: 1 October 2004 to 31 March 2005. Subs. 1 April to 31 March	1 April to 31 March	1 April to 31 March
Allocation of allowances to authorities	2005/06 to 2019/20	2005/06 to 2009/10	Allocated till 2009/10	Allocated only for 2005/06
Intermediate targets (2006/07 to 2008/09)	Back-end loaded trajectory	Linear progression	Linear progression to 1.5mt in 2006/07 and from 2006/07 to 2009/10	Linear progression
Maximum amounts of biodegradable municipal waste to be sent to landfill prior to 2009 (tonnes)	2005/06 – 15,200,000 2006/07 – 14,530,000 2007/08 – 13,640,000 2008/09 – 12,530,000	2004/05 – 550,000 2005/06 – 1,035,000 2006/07 – 970,000 2007/08 – 905,000 2008/09 – 840,000	2005/06 – 1,800,000 2006/07 – 1,500,000 2007/08 – 1,440,000 2008/09 – 1,380,000	2005/06 – 669,885 2006/07 – 655,545 2007/08 – 641,235 2008/09 - 626,925
Monitoring Authority	The Environment Agency	The Environment Agency	Scottish Protection Environment Agency (SEPA)	Environment and Heritage Service

Source: http://www.defra.gov.uk/environment/waste/localauth/lats/pdf/lats-comparanalysis.pdf. Accessed on 1/10/05 at 12:00

For the purpose of modelling, a combined UK landfill allowance has been determined, based on the pooled targets of individual nations, as shown in *Table 3.4*.

Table 3.4 Combined UK Landfill Allowance (BMW Allowed to Landfill)

Year	England	Wales	Scotland	Northern Ireland	Total
2006	15196000	1035000	1800000	669885	**18700885**
2007	14530000	970000	1500000	655544	**17655544**
2008	13642000	905000	1440000	641235	**16628235**
2009	12532000	840000	1380000	626925	**15378925**
2010	**11200000**	**710000**	**1320000**	**473925**	**13703925**
2011	9953333	630000	1173333	469937	**12226603**
2012	8706667	550000	1026667	465950	**10749284**
2013	**7460000**	**470000**	**880000**	**315950**	**9125950**
2014	7140000	450000	842857	302409	**8735266**
2015	6820000	430000	805714	288868	**8344582**
2016	6500000	410000	768571	275327	**7953898**
2017	6180000	390000	731429	261768	**7563197**
2018	5860000	370000	694286	248245	**7172531**
2019	5540000	350000	657143	234704	**6781847**
2020	**5220000**	**330000**	**620000**	**221164**	**6391164**

3.6 *RECYCLING AND COMPOSTING TARGETS*

In order to comply with the Landfill Directive BMW diversion targets, national waste strategies for England & Wales, Scotland and Northern Ireland establish recycling and composting targets for municipal solid waste. They recognise that an essential part of achieving landfill allowances is the drive towards a higher level of recycling and composting of household waste.

For the purpose of this study, recycling and composting targets in the Government-published *Waste Strategy 2000*, the national strategy for England & Wales, are assumed to apply across the UK, as this strategy applies to the bulk of MSW arisings across the UK (greater than 80%). These targets are:

- by 2005: recycle or compost at least 25% of household waste;
- by 2010: recycle or compost at least 30% of household waste; and
- by 2015: recycle or compost at least 33% of household waste.

3.7 LANDFILL TAX

The Landfill Tax was introduced in October 1996 as a tax on disposal of waste to landfill. With the objective of changing behaviour, encouraging waste minimisation and diversion away from landfill to treatment, it was initially set at a level designed to reflect the externalities of disposal excluded from the market price of landfill.

In July 1997, the Government published its Statement of Intent on Environmental Taxation which made clear its aim to reform the tax system, over time, to move the burden of tax from 'goods' to 'bads', and to increase incentives to reduce environmental damage and encourage innovation to meet higher environmental standards. Consequently, in 1998, the rate of landfill tax was raised to £10 a tonne for active wastes and an escalator introduced at £1 per tonne per year.

The landfill tax currently stands at £18 per tonne for active wastes and £2 per tonne for inert wastes. In its review of practical and cost-effective measures for waste management in England, *Waste Not, Want Not*, the Strategy Unit recommended that the level of landfill tax be raised to £35 per tonne in the medium term. In November 2002, the Chancellor's pre-budget statement proposed that the landfill tax escalator should increase to £3 per tonne per year from 2005/6, towards the medium term rate of £35/tonne. This was subsequently confirmed in the 2003 budget.

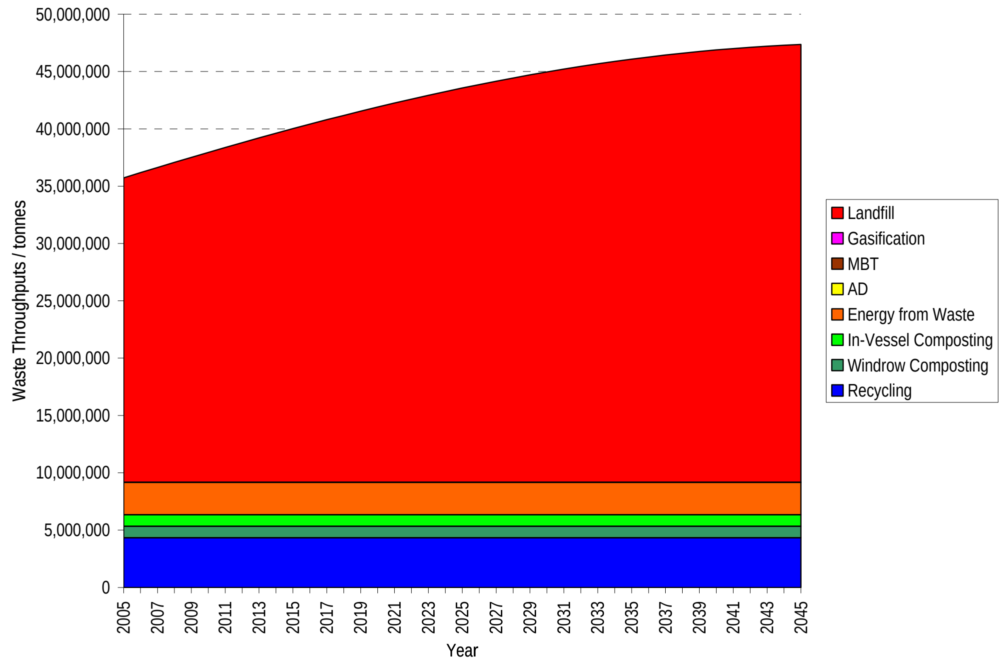
3.8 SCENARIO DESCRIPTIONS

3.8.1 *MSW Scenarios*

Nine scenarios, including the baseline case, have been developed for the management of MSW. The range of scenarios selected enables investigation of the use of alternative technologies to achieve UK landfill allowance targets between 2006 and 2020 under the projected levels of growth. For all scenarios (with the exception of the baseline), it has been assumed that the recycling and composting targets set out in *Waste Strategy 2000* will be achieved.

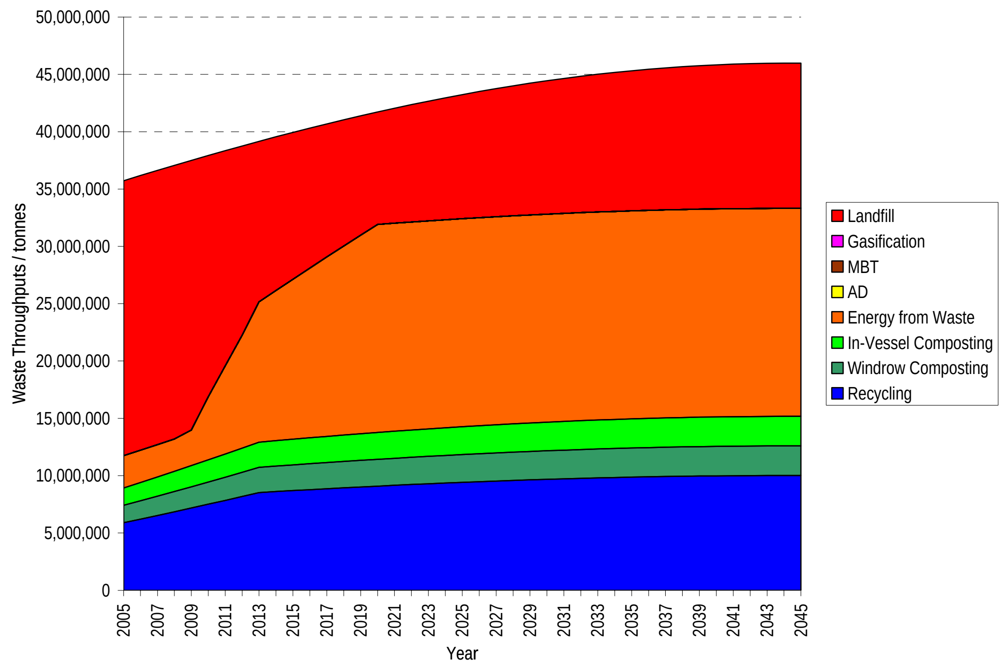
The scenarios for MSW management are shown in *Figure 3.3* to *Figure 3.11.*

Figure 3.3 *Scenario 1 – Baseline (2003/-04) Recycling and EfW Capacity*



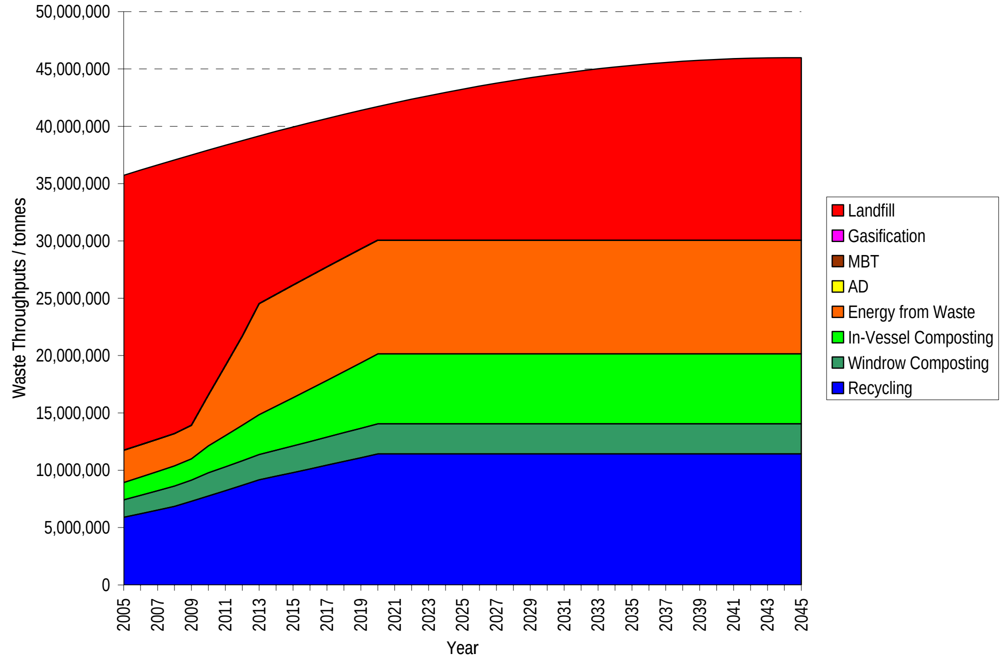
This scenario assumes the baseline (2003/04) UK capacity for recycling, composting and EfW, and assumes that all additional waste arisings over the period 2005-2045 will be landfilled.

Figure 3.4 *Scenario 2 – High EfW*



This scenario assumes the *Waste Strategy 2000* recycling and composting targets will be met (with 2003/04 proportional breakdown of materials recycled and composted in England [1]). EfW capacity has been increased in order to meet UK landfill allowance targets.

Figure 3.5 *Scenario 3 – High Paper and Card Recycling*

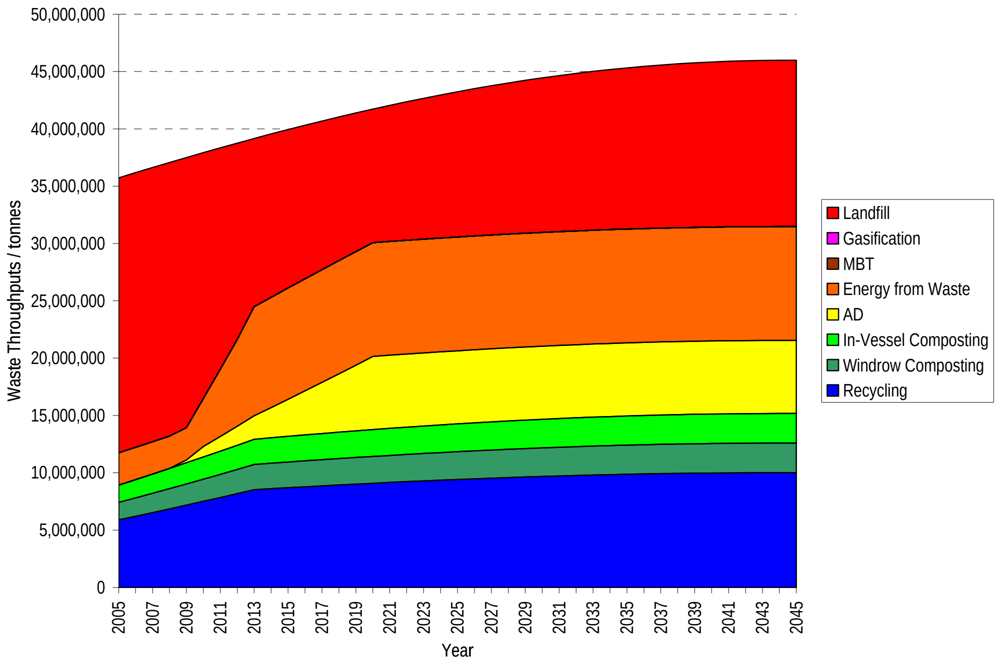


This scenario assumes that an elevated rate of paper recycling (reaching 65% capture) will be used to achieve BMW diversion. Levels of windrow and kitchen waste composting have also assumed to be increased (reaching 65% capture) alongside paper recycling. The outcomes of initial modelling highlighted that high paper recycling with increased green and kitchen composting together would be insufficient to meet landfill allowance targets. It was assumed that EfW capacity would be increased to reach sufficient levels of BMW diversion.

With increased tonnages of recycling and composting, this scenario exceeds *Waste Strategy 2000* targets across the assessment period. Beyond 2020, it was assumed that waste treatment capacities would remain static, with additional growth in waste arisings being sent to landfill only.

(1) recycling 68% (37% paper, 26% rubble, 14% ferrous metals, 3%, non-ferrous metals, 17% glass, <1% plastics), composting 32% (Environment Agency MWMS, 2003/04)

Figure 3.6 Scenario 4 – High Anaerobic Digestion

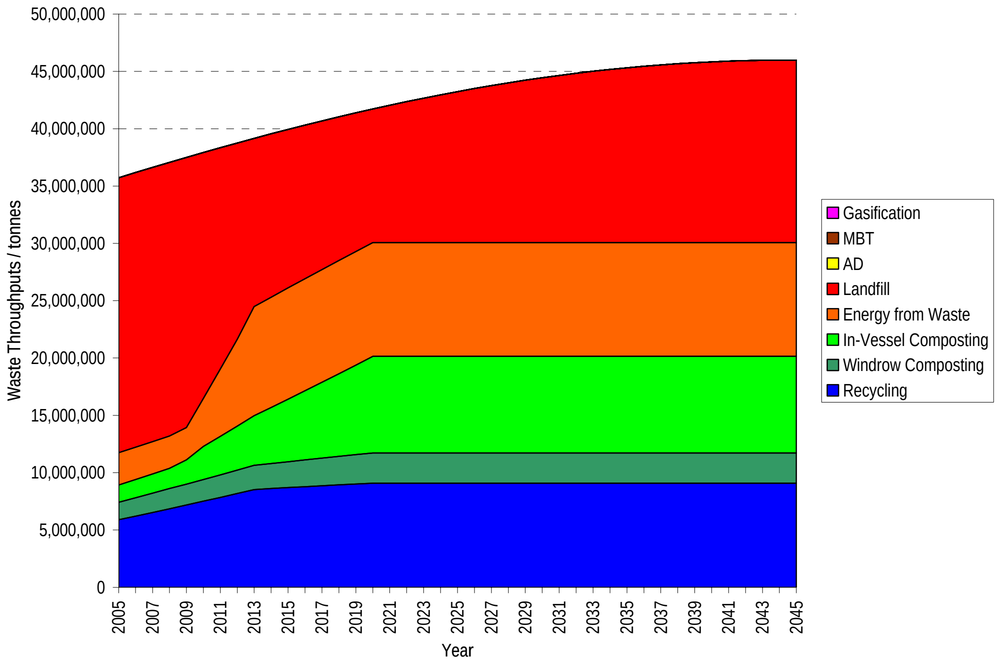


This scenario assumes the *Waste Strategy 2000* recycling and composting targets will be met (with 2003/04 proportional breakdown of materials recycled and composted in England [(1)]). AD capacity for separately collected organic fractions (green waste, kitchen waste and paper/card) has been increased, reaching a maximum 65% capture for each fraction, to maximise BMW diversion.

The outcomes of initial modelling highlighted that high separation and digestion of these fractions alone would be insufficient to meet landfill allowance targets. It was assumed that EfW capacity would be increased to reach sufficient levels of BMW diversion.

(1) recycling 68% (37% paper, 26% rubble, 14% ferrous metals, 3%, non-ferrous metals, 17% glass, <1% plastics), composting 32% (Environment Agency MWMS, 2003/04)

Figure 3.7 Scenario 5 – High Green and Kitchen Waste Composting with Increased Paper Composting

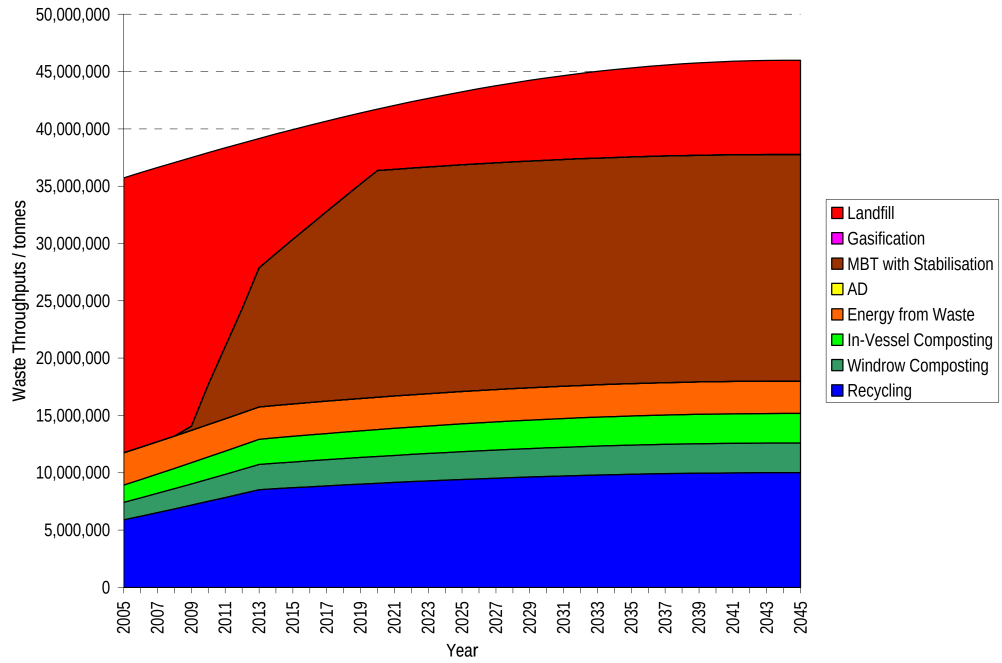


This scenario assumes an elevated rate of green and kitchen waste recycling (reaching 65% capture), predominantly via in-vessel composting (IVC), to capture the kitchen waste stream. To maximise the capture of organic material it has been assumed that paper will be collected for co-composting with green and kitchen waste via the IVC process (together with paper recycling, reaching a total of 65% capture).

The outcomes of initial modelling highlighted that high composting alone would be insufficient to meet landfill allowance targets. It was assumed that EfW capacity would be increased to reach sufficient levels of BMW diversion.

With increased tonnages of recycling and composting, this scenario exceeds *Waste Strategy 2000* targets across the assessment period. Beyond 2020, it was assumed that waste treatment capacities would remain static, with additional growth in waste arisings being sent to landfill only.

Figure 3.8 Scenario 6 – High MBT with Stabilisation for Landfill

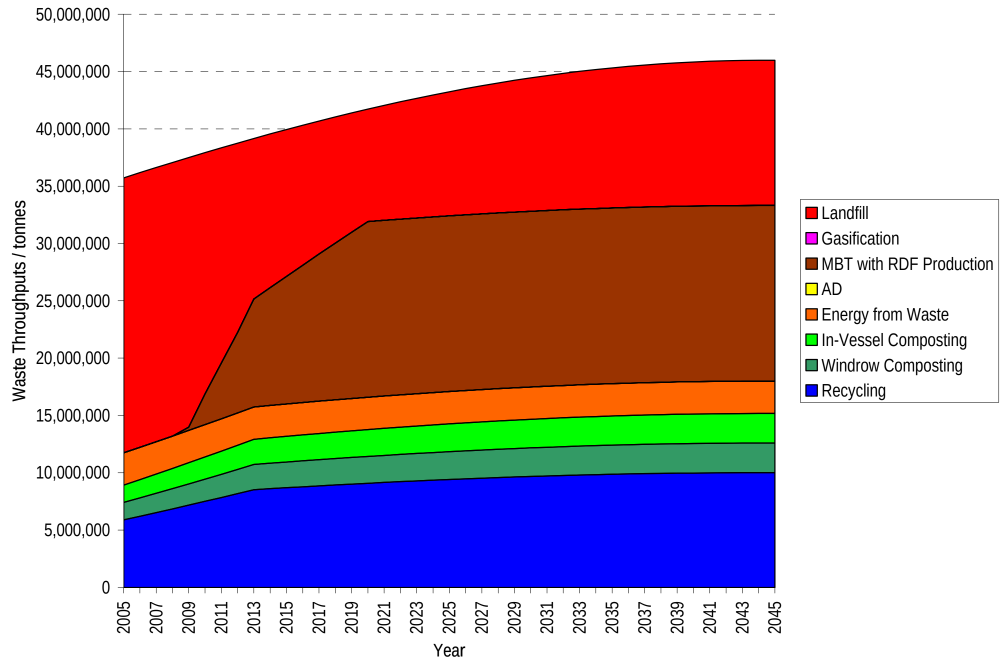


This scenario assumes the *Waste Strategy 2000* recycling and composting targets will be met (with 2003/04 proportional breakdown of materials recycled and composted in England [(1)]). MBT capacity (with MBT plant configured to stabilise wastes for landfill [(2)]) has been increased in order to meet UK landfill allowance targets.

(1) recycling 68% (37% paper, 26% rubble, 14% ferrous metals, 3%, non-ferrous metals, 17% glass, <1% plastics), composting 32% (Environment Agency MWMS, 2003/04)

(2) Assuming the processes achieves a 75% reduction in biodegradable content. The recent report by Juniper (*Mechanical-Biological-Treatment: A Guide for Decision Makers. Processes, Policies and Markets.* Juniper Consultancy Services, March 2005) reports an estimated performance range of 24 % to approx 90% BMW diversion for MBT plant configured to stabilise waste for landfill. An upper estimate within this range was taken.

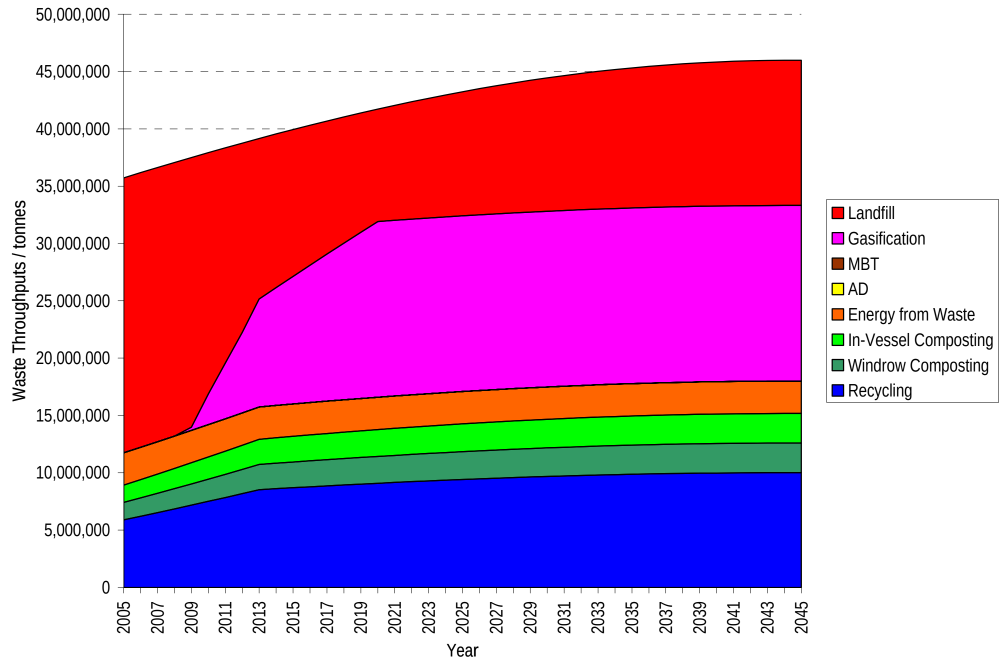
Figure 3.9 Scenario 7 - High MBT with RDF Production



This scenario assumes the *Waste Strategy 2000* recycling and composting targets will be met (with 2003/04 proportional breakdown of materials recycled and composted in England [(1)]). MBT capacity (with MBT plant configured to produce RDF for combustion) has been increased in order to meet UK landfill allowance targets.

(1) recycling 68% (37% paper, 26% rubble, 14% ferrous metals, 3%, non-ferrous metals, 17% glass, <1% plastics), composting 32% (Environment Agency MWMS, 2003/04)

Figure 3.10 Scenario 8 – High Gasification



This scenario assumes the *Waste Strategy 2000* recycling and composting targets will be met (with 2003/04 proportional breakdown of materials recycled and composted in England (1)). Gasification capacity has been introduced in order to meet UK landfill allowance targets.

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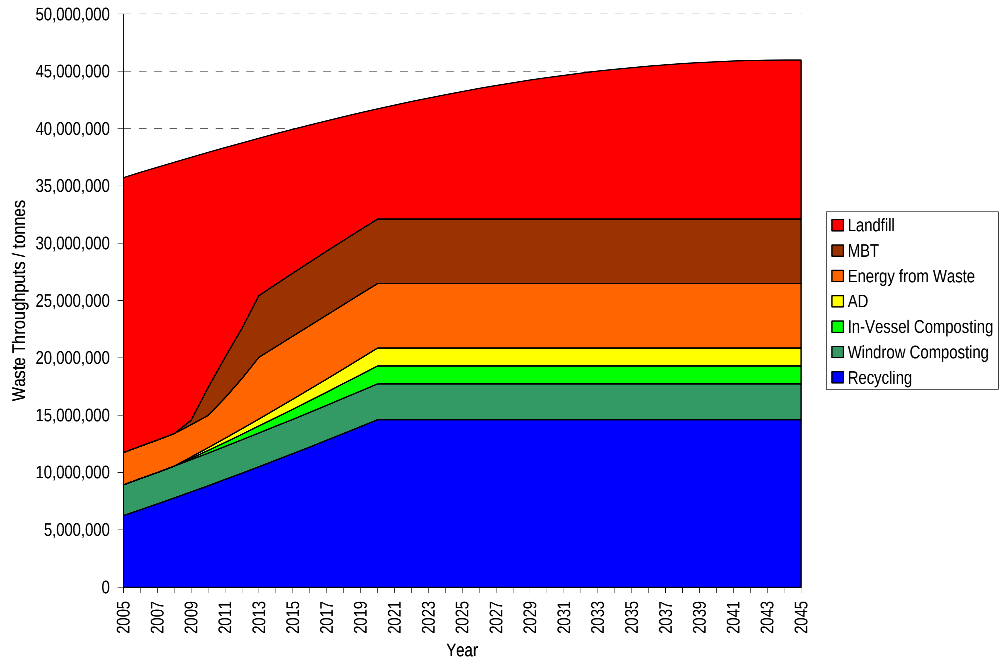
(1) recycling 68% (37% paper, 26% rubble, 14% ferrous metals, 3%, non-ferrous metals, 17% glass, <1% plastics), composting 32% (Environment Agency MWMS, 2003/04)

Figure 3.11 Scenario 9 – Mixed Technology Scenario



This scenario assumes that a mixture of waste treatment technologies will be used in order to meet UK landfill allowance targets.

It was assumed that recycling and composting (including composting through anaerobic digestion) rates would reach 50% by 2020 (1). EfW and MBT (with MBT plant configured to produce RDF for combustion) capacities were then increased, in equivalent proportions, to reach sufficient levels of BMW diversion.

With increased tonnages of recycling and composting, this scenario exceeds *Waste Strategy 2000* targets across the assessment period. Beyond 2020, it was assumed that waste treatment capacities would remain static, with additional growth in waste arisings being sent to landfill only.

3.8.2 C&I Waste Scenarios

Three scenarios are proposed for the management of C&I waste. Scenarios have been developed to investigate potential responses to increases in landfill tax:

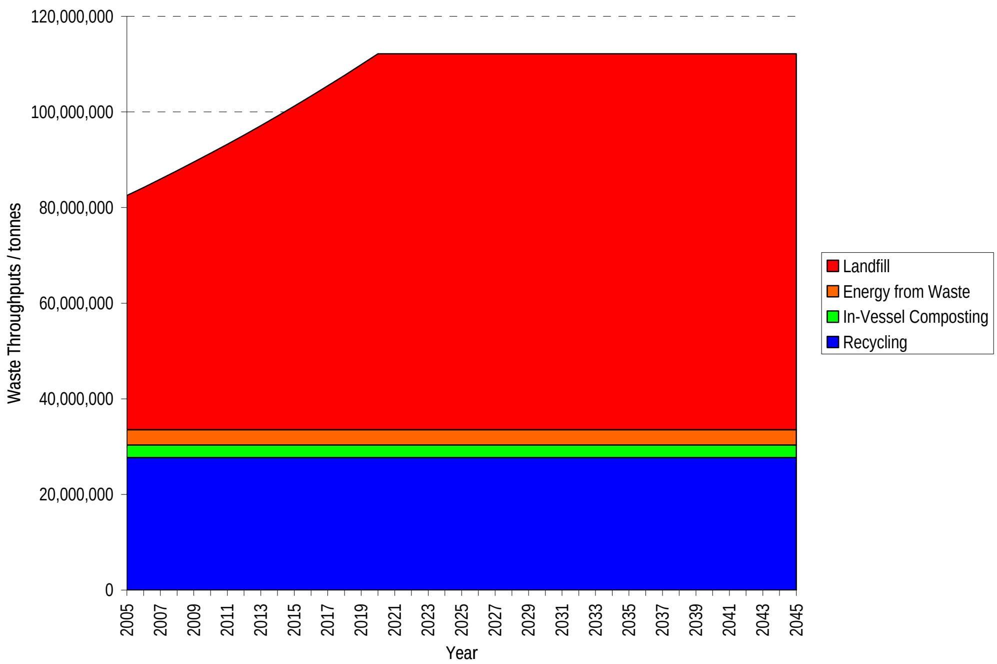
- **Scenario 1** - baseline capacity for recycling and recovery (2002/03) with growth in waste arisings assumed to go to landfill;
- **Scenario 2** - 10% increased diversion from landfill per annum from 2005 to 2011/12. No change in diversion from 2011/12 onwards. It was assumed that all wastes diverted from landfill will be recycled; and

(1) 50% is a high recycling & composting rate, in comparison with current, *Waste Strategy 2000*, targets, but one commonly cited in waste authority strategies and so is considered a reasonable basis for this scenario.

- **Scenario 3** - 10% increased diversion from landfill per annum from 2005 to 2011/12. No change in diversion from 2011/12 onwards. It was assumed that all wastes diverted from landfill will be incinerated.

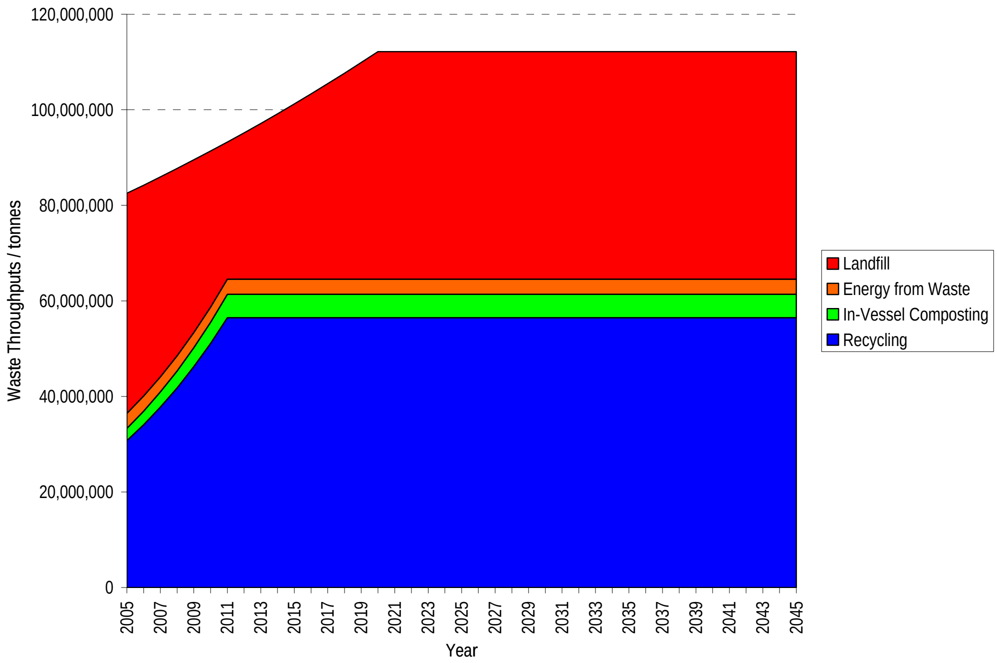
The scenarios for C&I waste management are shown in *Figure 3.12* to *Figure 3.14*.

Figure 3.12 C&I Scenario 1 – Baseline (2002/03) Recycling and EfW Capacity



This scenario assumes the baseline (2002/03) UK capacity for recycling, composting and thermal treatment of C&I waste, and assumes that all additional waste arisings over the period 2003-2045 will be landfilled.

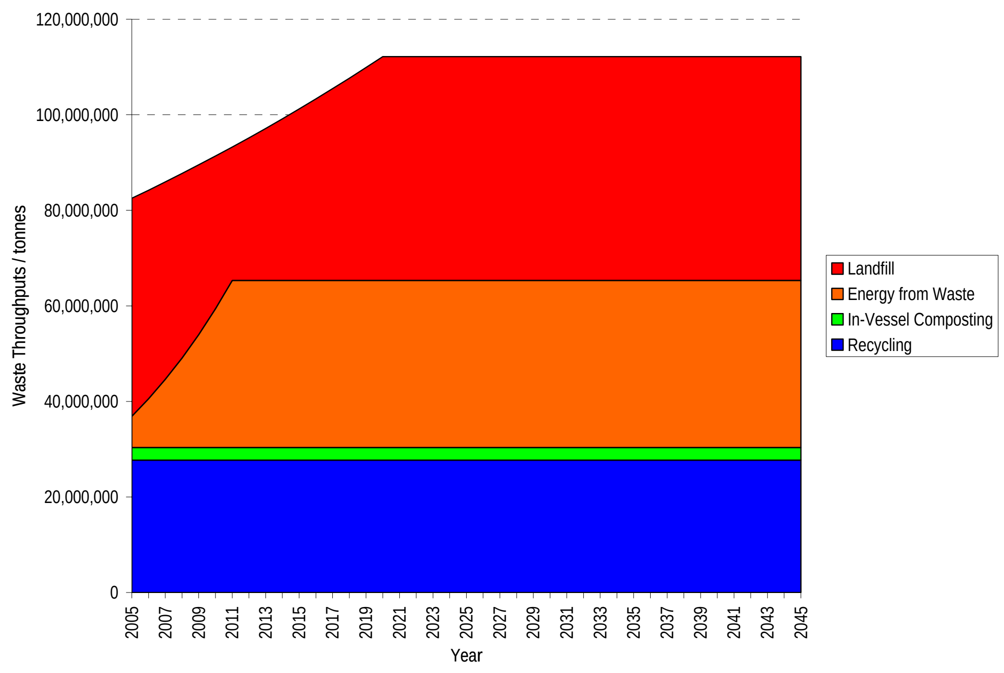
Figure 3.13 C&I Scenario 2 – Increased Recycling



This scenario assumes that baseline diversion rates (2002/03) increase at a rate of 10% per annum, from 2005 to 2011/12. It was further assumed that the increased tonnage diverted will be recycled/composted (with 2002/03 proportional breakdown of materials recycled and composted (1)). Where fractional arisings were insufficient to meet this recycling need (for example, insufficient paper, ferrous and non-ferrous metals arising in the waste stream to reach increased recycling rates), it was assumed that additional recycling would be apportioned from the category, mixed general waste (non-combustible). This category comprised almost 50% of C&I recycling in England in 2002/03.

(1) recycling 90% (33% paper, 4% combustible general waste, 49% non-combustible general waste, 11% ferrous metals, 3%, non-ferrous metals), composting 10% (Environment Agency NWPS, 2002/03)

Figure 3.14 C&I Scenario 3 – Increased EfW



This scenario assumes that baseline diversion rates (2002/03) increase at a rate of 10% per annum, from 2005 to 2011. It was further assumed that the increased tonnage diverted will be sent to EfW facilities for processing.

4 QUANTIFYING GREENHOUSE GAS EMISSIONS FROM WASTE MANAGEMENT PROCESSES

A life cycle approach has been used to assess the greenhouse gas emissions associated with waste management operations in the UK. A number of activities in the waste management life cycle may be responsible for emitting or avoiding releases of greenhouse gases. These activities include:

- waste transport (eg to transfer stations, MRFs);
- waste treatment (eg via EfW, MBT, gasification processes);
- recycling and composting; and
- waste disposal (landfilling).

The greenhouse gas emissions associated with all of these activities have been estimated and a greenhouse gas benefit has been attributed to the recovery of energy and the displacement of materials through recycling, where this occurs. The processes upstream of waste management have not been studied in detail.

In order to quantify the emissions from each of these activities, emission factors (EFs) were determined. Emission factors are defined as the mass of greenhouse gas released / avoided for every tonne of waste with a particular composition arising in a specific activity in the waste management life cycle, for example, x g of CO_2 emitted for every tonne of plastic waste incinerated. EFs were calculated for each of the 'basket of six' greenhouse gas emissions (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) for each process within the waste management system.

Prior to scenario analysis, EFs were converted to CO_2 equivalents to allow for a weighted comparison of emissions for the greenhouse gases emitted / avoided from the various activities in the waste management life cycle. Standard characterisation factors of global warming potential (GWP) were applied in order to convert emissions to CO_2 equivalents. GWPs for each of the basket of six emissions are listed in *Table* 4.1.

Table 4.1 Global Warming Potentials (100-year time scale)

Greenhouse Gas	Global Warming Potential
CO_2	1
CH_4	21
N_2O	310
HFCs	-
PFCs	-
SF_6	23900

Source: IPCC, 1995

The emission factors calculated for each process within the waste management chain are detailed in *Section 4.2.*

4.1 DIRECT UK / NON-UK EMISSIONS

In order to calculate estimates of greenhouse gas burdens in the UK, emissions were differentiated according to the likely location of their release, alternatively 'direct UK', or 'non-UK'.

A number of assumptions have been made regarding these categories for each process within the waste management chain. For example, the production of all fuels (with the exception of natural gas) is assumed to take place outside of the UK, whereas fuel use and electricity generation are assumed to take place within the UK. Emissions from each process were then apportioned accordingly.

Figure 4.1 summarises the boundaries for direct UK, and non-UK systems, and the processes that fall within each. *Table 4.2* further details the key processes occurring within each boundary.

Figure 4.1 UK and Non-UK Emissions Boundaries

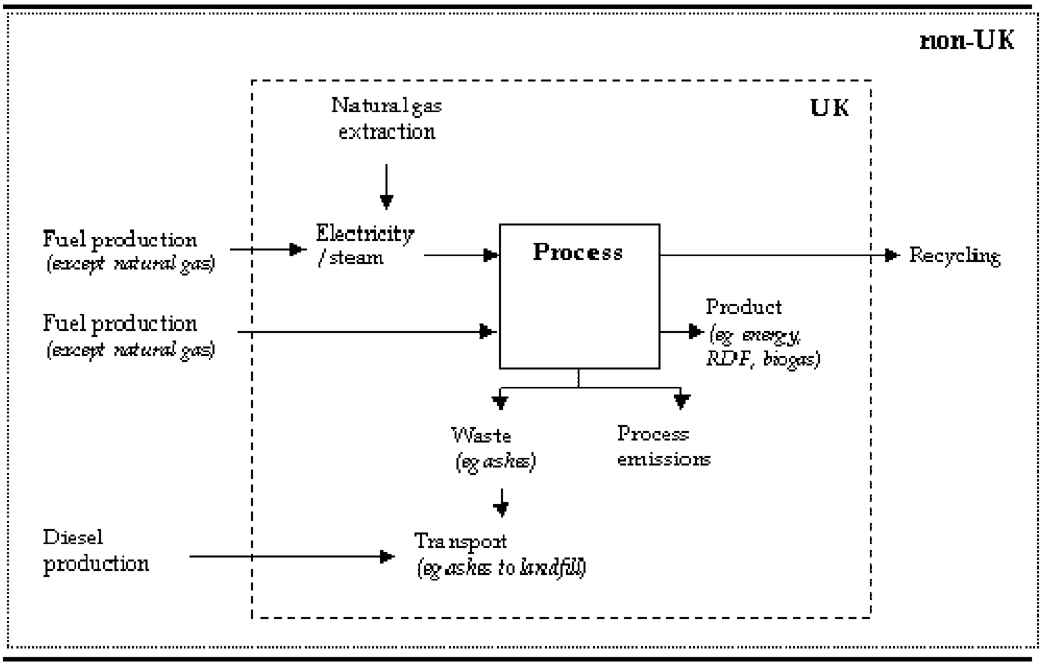


Table 4.2 UK/Non-UK Process Emissions

Direct UK Emissions	Non-UK Emissions
Fuel use	Fuel extraction and production (except natural gas)
Electricity generation	Production of primary material displaced by recycling activities
Natural gas extraction	Other materials production
Process emissions from waste treatment options	
Transport emissions	

4.2 EMISSION FACTORS

EFs for each activity in the waste management life cycle were determined, and subsequently used to quantify scenario greenhouse gas profiles. EFs were calculated using a series of steps:

1. Resource EFs (greenhouse gas emissions per tonne of diesel produced, per kWh of electricity generated, per tonne of virgin material displaced through recycling, per tonne-kilometre of waste transported, etc) were sourced from published life cycle inventory databases. These factors are presented in *Table 4.3* to *Table 4.5* (1).
2. The resource inputs (tonnes of diesel, kWh of electricity, tonne-kilometres of residues transported, etc), useful outputs (tonnes of material separated for recycling, kWh electricity recovered, etc) and direct greenhouse gas emissions associated with the management of one tonne of waste were determined for each treatment process (MRF, composting, EfW, MBT, etc), using representative data for the UK (2).
3. Direct process emissions and those associated with resource consumption / material recycling / energy recovery were combined to give a total greenhouse gas EF for each treatment process. These factors are presented in *Table 4.6*.

4.2.1 *Energy Emission Factors*

EFs for the production of diesel and electricity, and their use in waste treatment processes, have been taken from published sources (3). Those for electricity production and distribution change over time, taking into account predicted changes in UK grid electricity mix (4), and are based upon the DTI's latest energy projection data (2005). Projections are made for electricity mixes

(1) Further detail regarding the source of data and assumptions made can be found in *Annex A*.
(2) Further detail regarding the source of data and assumptions made can be found in *Annex A*.
(3) Refer to *Annex A* for further details.
(4) Taken from the updates to the Environment Agency's WISARD tool (ERM, (2005). WRATE Electricity Database Manual. Environmental Resources Management. Unpublished.)

from 2005 to 2020. With no further data available, it was assumed that UK grid electricity would remain of the same mix from 2020 onwards (1).

The combustion of waste in thermal treatment processes, such as EfW and gasification, is widely used to recover energy from wastes with an appropriate calorific value. Energy is recovered as heat, and either used directly, or, more commonly at the large scale, for generating electricity. For the purposes of modelling, it has been assumed that the greenhouse gas benefits of energy recovery occurs as a result of offsetting electricity generation according to UK marginal electricity mix.

A conservative assumption, that marginal (offset) electricity is comprised 100% gas (CCGT) across the study period, was made and EFs for marginal electricity were calculated accordingly.

Table 4.3 Emission Factors for Energy Production and Use

Process	Release	2005	2010	2015	2020	Long term
Diesel production and use	Direct UK	3.15	3.15	3.15	3.15	3.15
(kg CO_2-equivalents/kg)	Non-UK	0.51	0.51	0.51	0.51	0.51
Electricity production and distribution	Direct UK	0.54	0.50	0.53	0.53	0.53
(kg CO_2-equivalents/kWh)	Non-UK	0.047	0.039	0.035	0.026	0.026
Marginal (offset) electricity production	Direct UK	0.46	0.46	0.46	0.46	0.46
(kg CO_2-equivalents/kWh)	Non-UK	0.001	0.001	0.001	0.001	0.001

4.2.2 *Recycling Emission Factors*

The separation of materials for recycling has greenhouse gas benefits through offsetting the requirement for virgin materials. The substitution of recovered materials for virgin material often confers considerable energy savings, as shown in *Table 4.4*. These EFs have been taken from published sources (2) and represent the greenhouse gas benefits of substituting the production of virgin material for the use of secondary materials.

(1) 16% coal/thermal other/waste, 0.2% oil, 3.8% gas (non-CCGT), 55% gas (CCGT), 8.6% nuclear, 2.2% renewables thermal, 12% wind and 1.6% hydro/renewable other.
(2) Refer to *Annex A* for further details.

Table 4.4 *Emission Factors for Recycling Offset*

Material	Release	Emission Factor (kg CO_2 equivalents/ tonne)
Paper and card	Non-UK	-496
Textiles	Non-UK	-7869
Ferrous metals	Non-UK	-434
Non-ferrous metals	Non-UK	-11634
Glass	Non-UK	-762
Plastic, dense	Non-UK	-2324
Plastic, film	Non-UK	-1586
Gravel	Non-UK	-2.74
Compost	Non-UK	-16.2

4.2.3 *Transport Emission Factors*

Waste transport may be categorised according to the following routes of movement:

- transport of waste from household to waste transfer site / MRF / bulking point;
- transport of recyclables from MRF to reprocessor; and
- transport of residual waste from transfer site to treatment facility / landfill.

It has been assumed that, in the transport of waste, all waste fractions cause equivalent emissions per km travelled (through vehicle use), such that the only variable is the mass of the waste transported. Further, for the purposes of the study, it has been assumed that transport of waste for transfer / treatment / disposal is all via road.

ERM's experience of assessing waste transport in the UK has suggested that the typical distances travelled by wastes are as follows:

- recycling collections: 2 km per tonne of waste collected;
- residual waste collections: 1.5 km per tonne of waste collected;
- transport to recovery / composting / landfill: 30 km per tonne of waste treated; and
- transport to reprocessors / recyclers: 100 km per tonne of waste landfilled.

EFs for the transport of wastes via each route were calculated using published data sources (1) and are presented in *Table 4.5*.

(1) Refer to *Annex A* for further details.

Table 4.5 Emission Factors for Transportation

Process	Release	Transport from Household to MRF (kg CO_2 equiv/tonne waste transported)	Transport from MRF to Reprocessor (kg CO_2 equiv/tonne waste transported)	Transport from Household to Transfer Station (kg CO_2 equiv/tonne waste transported)	Transport from Transfer Station to Treatment Facility (kg CO_2 equiv/tonne waste transported)
Refuse collection vehicle	Direct UK	0.49		0.37	
	Non-UK	0.15		0.11	
Bulk transport	Direct UK		10.23		3.07
	Non-UK		4.64		1.39

4.2.4 Waste Management Emission Factors

EFs for all activities in the waste management chain are shown in *Table 4.6*. The approach taken is such that these EFs represent greenhouse gas emissions resulting from:

- production and use of fuels;
- generation of electricity;
- direct treatment process emissions;
- offset emissions through materials recycling and energy recovery (where relevant);
- transport of residues to landfill (where relevant); and
- transport of materials to recycling and composting facilities (where relevant).

For some processes, factors differ according to the fraction of waste treated. This occurs where the outputs of a treatment process differ according to the properties of the material processed. For example, waste plastics have a higher calorific value than minerals or putrescible materials and so offer a greater potential for energy recovery.

All data and assumptions used to calculate emission factors are presented in *Annexes A, B* and *D*.

Table 4.6 Emission Factors for Waste Treatment Processes (kg CO_2 Equivalents/Tonne of Waste Processed)

Process	Release	Paper/ Card	Kitchen Waste	Garden Waste	Textiles	Fines	Misc. Combustible	Misc. Non-Combustible	Ferrous Metals	Non-Ferrous Metals	Glass	Plastic Dense	Plastic Film
Transfer Station	Direct UK	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	Non-UK	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
MRF	Direct UK	15			15			15	15	15	15	15	15
	Non-UK	-494			-7868			-1.2	-433	-11632	-761	-2322	-1585
EfW	Direct UK	-392	-124	-124	219	132	202	41	15	15	-46	1119	991
	Non-UK	-0.18	0.41	0.41	-0.44	0.42	-0.42	0.49	-429	-11629	0.58	-1.28	-0.99
Gasification	Direct UK	-360	-76	-76	244	180	228	91	70	70	6.6	1121	1001
	Non-UK	5.1	5.8	5.8	4.9	5.8	4.9	5.9	-424	-11623	5.9	4.0	4.3
Anaerobic Digestion	Direct UK	6.9	6.9	6.9									
	Non-UK	-2.3	-2.3	-2.3									
Windrow Composting	Direct UK	16		16									
	Non-UK	-3.2		-3.2									
In-Vessel Composting	Direct UK	18	18	18									
	Non-UK	-6.2	-6.2	-6.2									
MBT with RDF combustion	Direct UK	-338	-75	-75	94	119	83	56	59	59	-1.8	678	598
	Non-UK	3.3	3.9	3.9	3.0	3.9	3.0	4.0	-425	-11625	4.1	2.2	2.4
MBT with stabilisation	Direct UK	116	79	79	91	64	89	57	59	59	50	49	49
	Non-UK	4.1	4.1	4.1	4.1	4.1	4.1	4.12	-425	-11625	4.2	4.2	4.2
Landfill	Direct UK	272	121	121	171	61	165	32	2.9	2.9	6.0	2.9	2.9
	Non-UK	0.25	0.36	0.36	0.32	0.41	0.33	0.46	0.46	0.46	0.46	0.46	0.46

5.1 MSW SCENARIOS

Estimates of the affect of different MSW management scenarios on both direct UK greenhouse gas emissions and potential indirect emissions are presented in *Figure 5.1* to *Figure 5.18* and *Table 5.1* to

Table 5.27. A summary of comparative emissions for all scenarios is shown in *Figure 5.19*.

Results are presented as an aggregated CO_2 equivalent emission for ease of interpretation. Inventories of individual greenhouse gas emissions by scenario are presented in *Annex C*. Whilst a number of the treatment processes examined resulted in emissions of all greenhouse gases, it was found, in general, that carbon dioxide was the largest contributor to scenario greenhouse gas emission profiles. This is with the exception of landfill, for which methane was the predominant greenhouse gas emitted.

5.1.1 *Scenario 1 – Baseline (2003/-04) Recycling and EfW Capacity*

Figure 5.1 Baseline Scenario Greenhouse Gas Emissions (Direct UK and Indirect)

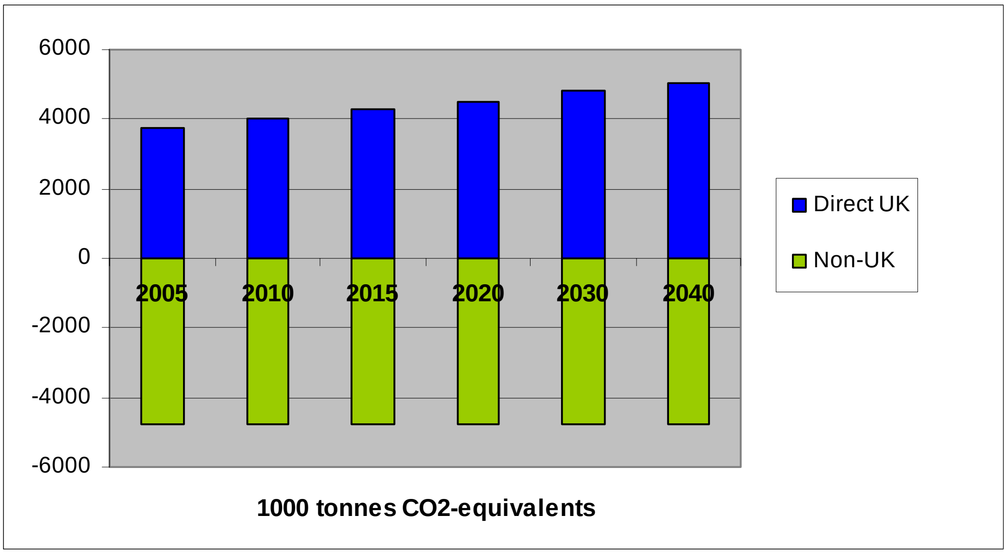


Figure 5.2 Baseline Scenario Greenhouse Gas Emissions (Total)

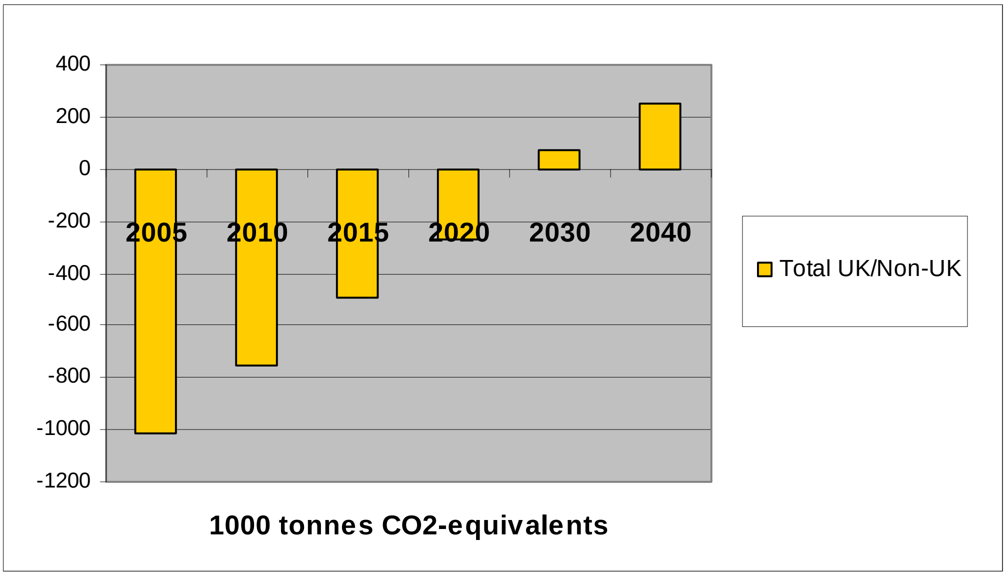


Table 5.1 Baseline Scenario Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	108	115	122	128	138	142
Transfer station	64	66	72	76	81	84
Transport to and from MRF	46	46	46	46	46	46
MRF including recycling	66	62	65	65	65	65
EfW with recovery of metals (incl transport to reprocessor)	58	53	49	46	42	40
Windrow composting	16	16	16	16	16	16
In-vessel composting	18	17	18	18	18	18
Landfill (direct CH_4 emissions and energy recovery)	3350	3625	3875	4098	4437	4610
Total	**3727**	**4000**	**4264**	**4492**	**4842**	**5021**

Table 5.2 Baseline Scenario Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	47	50	53	56	60	62
Transfer station	8	8	8	8	8	9
Transport to and from MRF	21	21	21	21	21	21
MRF including recycling	-4334	-4335	-4336	-4337	-4337	-4337
EfW with recovery of metals (incl transport to reprocessor)	-484	-495	-506	-515	-526	-531
Windrow composting	-3	-3	-3	-3	-3	-3
In-vessel composting	-6	-6	-6	-6	-6	-6
Landfill (direct CH_4 emissions and energy recovery)	10	10	11	12	13	13
Total	**-4743**	**-4751**	**-4758**	**-4764**	**-4770**	**-4772**

Table 5.3 Baseline Scenario Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	2010	2015	2020	2030	2040
Direct UK	3727	4000	4264	4492	4842	5021
Non-UK	-4743	-4751	-4758	-4764	-4770	-4772
Total UK / Non-UK	-1016	-751	-494	-272	72	248

The baseline scenario shows a gradual increase in direct UK greenhouse gas emissions over the study period, predominantly associated with increased tonnages of waste sent for landfill. Non-UK greenhouse gas emissions appear negative due to the offset benefits of recycling materials. The displacement of primary materials extraction and manufacture is assumed to occur outside of the UK system boundary.

For the scenario as a whole, greenhouse gas emissions from waste treatment and disposal activities are significantly lower than the benefit attributed to the displacement of primary material and energy production. As a result, net greenhouse gas emissions are negative for the majority of years modelled. In 2040 and beyond, emissions associated with the landfilling of significant quantities of waste outweigh the greenhouse gas benefits of recycling and energy recovery and a GHG impact is seen. The magnitude of this impact is directly dependent on assumptions made regarding future waste growth, however.

5.1.2 *Scenario 2 – High EfW*

Figure 5.3 Scenario 2 Greenhouse Gas Emissions (Direct UK and Indirect)

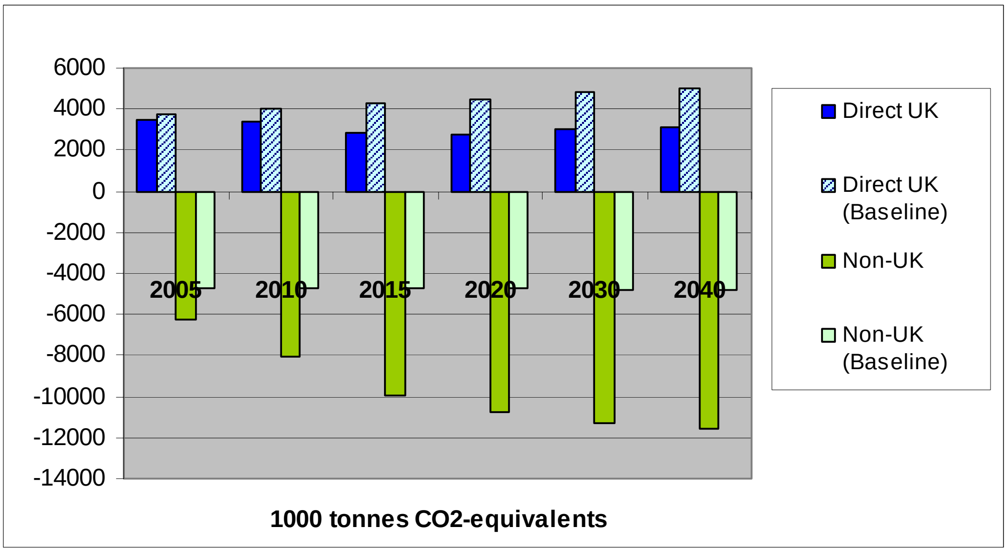


Figure 5.4 Scenario 2 Greenhouse Gas Emissions (Total)

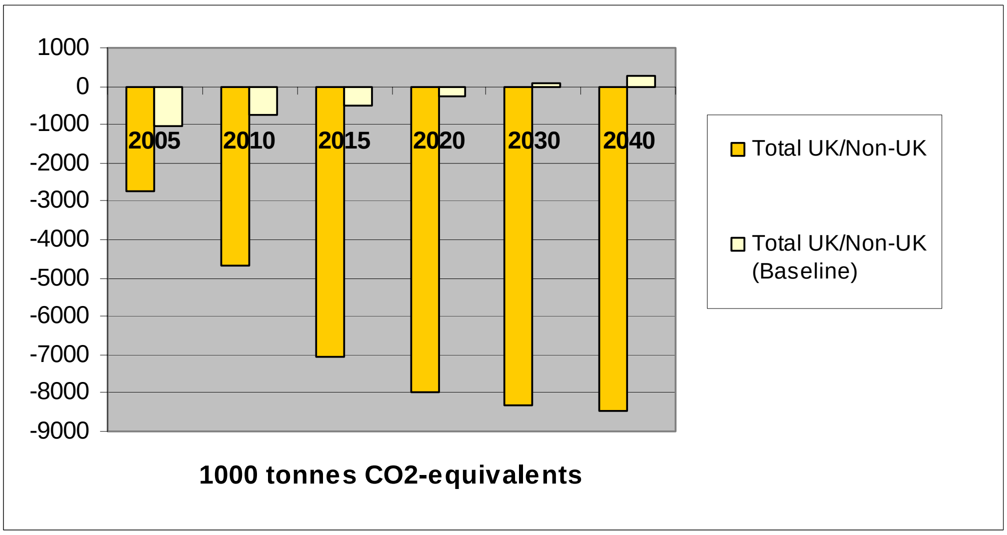


Table 5.4 *Scenario 2 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)*

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	102	104	107	112	119	123
Transfer station	61	60	63	66	70	73
Transport to and from MRF	63	80	93	97	104	107
MRF including recycling	90	107	143	136	145	149
EfW with recovery of metals (incl transport to reprocessor)	97	254	753	980	980	980
Windrow composting	24	30	35	37	39	40
In-vessel composting	27	34	41	41	44	45
Landfill (direct CH_4 emissions and energy recovery)	3045	2687	1643	1258	1492	1611
Total	**3510**	**3357**	**2865**	**2727**	**2993**	**3128**

Table 5.5 *Scenario 2 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)*

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	45	46	47	49	52	54
Transfer station	8	7	7	7	7	8
Transport to and from MRF	28	36	42	43	46	48
MRF including recycling	-5900	-7517	-8709	-9099	-9693	-9996
EfW with recovery of metals (incl transport to reprocessor)	-399	-619	-1303	-1696	-1696	-1696
Windrow composting	-5	-6	-7	-7	-8	-8
In-vessel composting	-9	-12	-14	-15	-16	-16
Landfill (direct CH_4 emissions and energy recovery)	9	8	5	4	4	5
Total	**-6224**	**-8058**	**-9933**	**-10715**	**-11302**	**-11603**

Table 5.6 *Scenario 2 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)*

	2005	2010	2015	2020	2030	2040
Direct UK	3510	3357	2865	2727	2993	3128
Non-UK	-6224	-8058	-9933	-10715	-11302	-11603
Total UK / Non-UK	-2714	-4700	-7068	-7988	-8310	-8474

The high EfW scenario shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with reduced tonnages of waste sent for landfill. It further shows greatly increased offset benefits occurring outside of the UK system. This results from increased materials recycling to meet *Waste Strategy 2000* targets and additional metals recovery from the EfW process.

5.1.3 *Scenario 3 – High Paper and Card Recycling*

Figure 5.5 Scenario 3 Greenhouse Gas Emissions (Direct UK and Indirect)

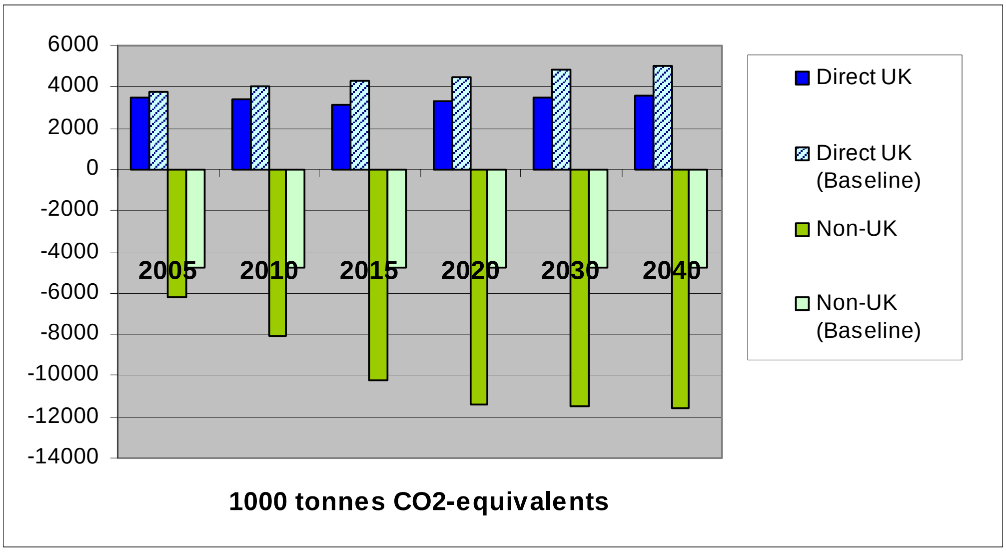


Figure 5.6 Scenario 3 Greenhouse Gas Emissions (Total)

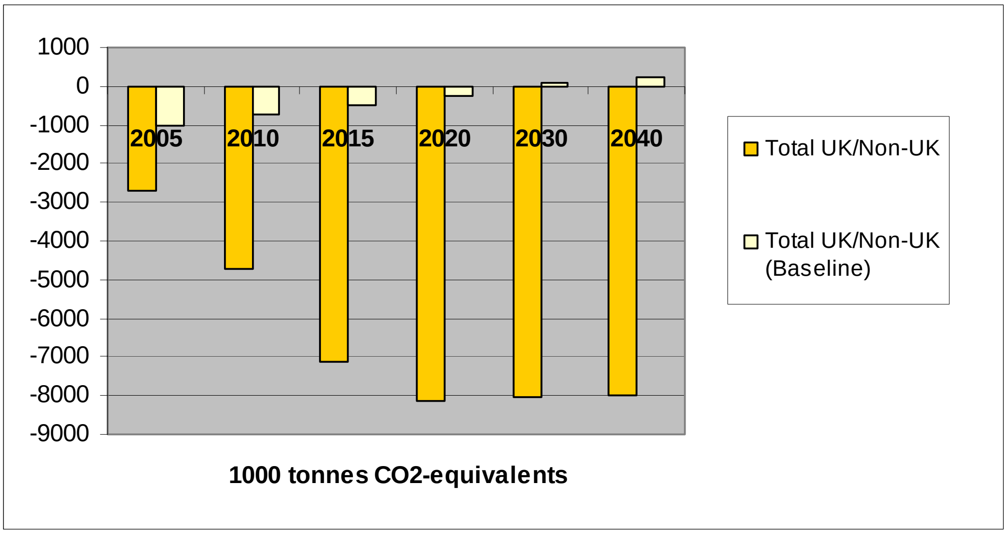


Table 5.7 Scenario 3 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	102	104	103	104	113	118
Transfer station	61	59	61	61	67	70
Transport to and from MRF	63	83	105	122	122	122
MRF including recycling	90	110	161	171	171	171
EfW with recovery of metals (incl transport to reprocessor)	97	238	886	1346	1189	1122
Windrow composting	24	32	37	41	41	41
In-vessel composting	27	41	76	107	107	107
Landfill (direct CH_4 emissions and energy recovery)	3045	2703	1685	1329	1656	1824
Total	**3510**	**3370**	**3098**	**3281**	**3467**	**3575**

Table 5.8 Scenario 3 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	45	45	45	45	50	52
Transfer station	8	7	7	6	7	7
Transport to and from MRF	28	37	47	55	55	55
MRF including recycling	-5900	-7636	-9252	-10254	-10254	-10254
EfW with recovery of metals (incl transport to reprocessor)	-399	-513	-1040	-1202	-1332	-1388
Windrow composting	-5	-6	-7	-8	-8	-8
In-vessel composting	-9	-15	-26	-39	-39	-39
Landfill (direct CH_4 emissions and energy recovery)	9	8	5	4	5	6
Total	**-6224**	**-8073**	**-10222**	**-11392**	**-11517**	**-11570**

Table 5.9 Scenario 3 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	**2010**	**2015**	**2020**	**2030**	**2040**
Direct UK	3510	3370	3098	3281	3467	3575
Non-UK	-6224	-8073	-10222	-11392	-11517	-11570
Total UK / Non-UK	-2714	-4703	-7124	-8111	-8050	-7995

The high paper and card recycling scenario shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with reduced tonnages of waste sent for landfill.

The scenario performs less well than the high EfW scenario in terms of direct UK emissions. This is, in part, due to the impact of increased source-separation of organic materials on the energy recovery potential from residual waste. With a relatively lower proportion of combustible material in residual waste, EfW plant can recover less energy and so are awarded less offset greenhouse gas benefit.

Further, the majority of benefits associated with both paper/card recycling and composting are assumed to occur outside of the UK. The scenario accordingly shows an elevated non-UK greenhouse benefit, in comparison with scenario 2 for the majority of years assessed. Scenario 2 performs marginally better in 2040 due to additional recycling tonnages to meet *Waste Strategy 2000* targets.

5.1.4 Scenario 4 – High Anaerobic Digestion

Figure 5.7 Scenario 4 Greenhouse Gas Emissions (Direct UK and Indirect)

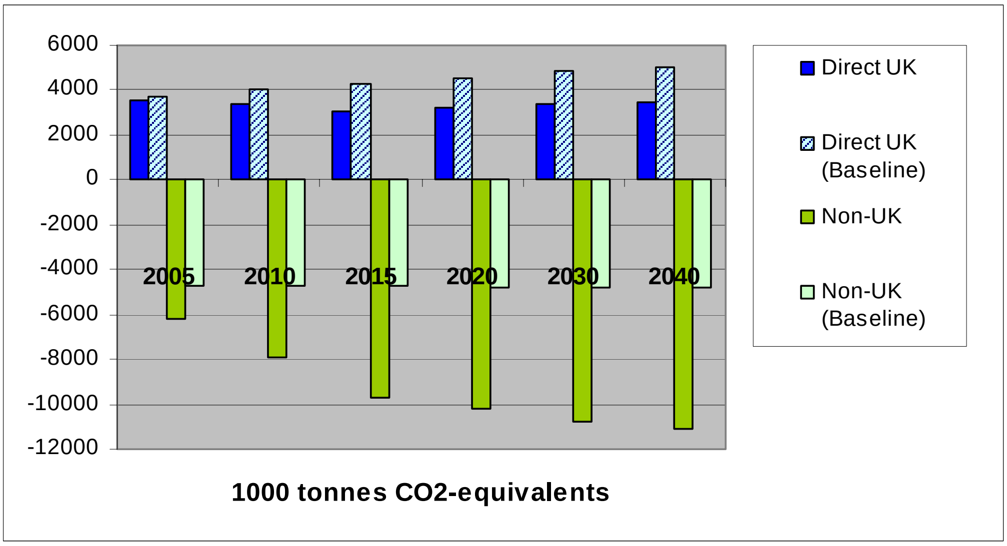


Figure 5.8 Scenario 4 Greenhouse Gas Emissions (Total)

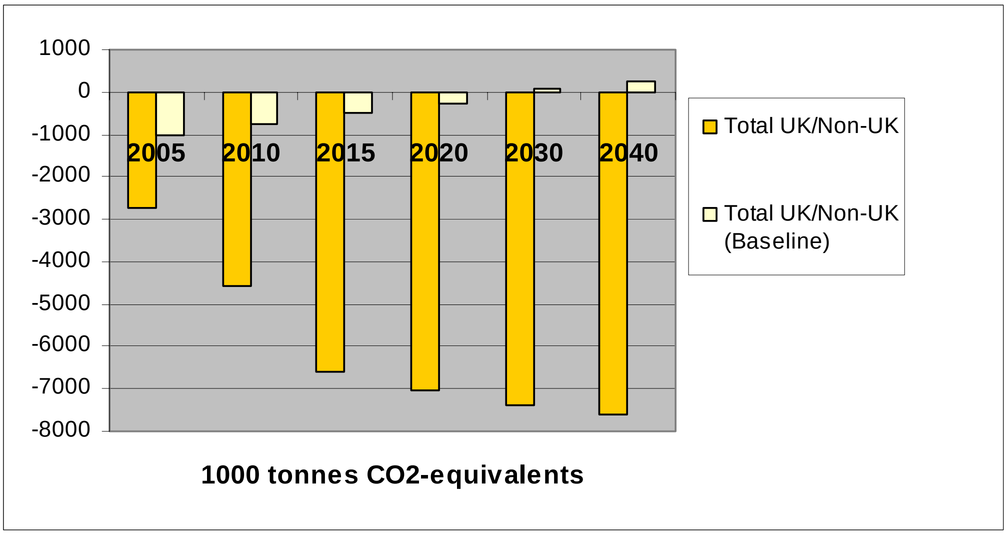


Table 5.10 Scenario 4 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	102	104	107	112	119	123
Transfer station	61	60	63	66	70	73
Transport to and from MRF	63	80	93	97	104	107
MRF including recycling	90	107	143	136	145	149
EfW with recovery of metals (incl transport to reprocessor)	97	235	904	1373	1308	1278
Anaerobic digestion	0	5	26	42	42	42
Windrow composting	24	30	35	37	39	40
In-vessel composting	27	34	41	41	44	45
Landfill (direct CH_4 emissions and energy recovery)	3045	2698	1672	1311	1532	1646
Total	**3510**	**3354**	**3067**	**3215**	**3403**	**3504**

Table 5.11 Scenario 4 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	45	46	47	49	52	54
Transfer station	8	7	7	7	7	8
Transport to and from MRF	28	36	42	43	46	48
MRF including recycling	-5900	-7517	-8709	-9099	-9693	-9996
EfW with recovery of metals (incl transport to reprocessor)	-399	-487	-1031	-1202	-1181	-1171
Anaerobic digestion	0	-2	-8	-17	-17	-17
Windrow composting	-5	-6	-7	-7	-8	-8
In-vessel composting	-9	-12	-14	-15	-16	-16
Landfill (direct CH_4 emissions and energy recovery)	9	8	5	4	5	5
Total	**-6224**	**-7928**	**-9668**	**-10238**	**-10804**	**-11095**

Table 5.12 Scenario 4 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	2010	2015	2020	2030	2040
Direct UK	3510	3354	3067	3215	3403	3504
Non-UK	-6224	-7928	-9668	-10238	-10804	-11095
Total UK / Non-UK	-2714	-4574	-6602	-7022	-7400	-7590

The high anaerobic digestion scenario shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with reduced tonnages of waste sent for landfill.

The anaerobic digestion scenario performs less well than the high EfW scenario in terms of direct UK emissions, as the anaerobic digestion process recovers less electricity per tonne of waste processed than EfW (see *Annex A*) and accordingly is awarded a lower offset greenhouse gas benefit. Further, there are implications associated with increased source-separation of organic materials on the energy recovery potential from residual waste in EfW plant. With a relatively lower proportion of combustible material in residual waste, EfW plant can recover less energy and so are awarded less offset greenhouse gas benefit.

5.1.5 *Scenario 5 – High Green and Kitchen Waste Composting with Increased Paper Composting*

Figure 5.9 Scenario 5 Greenhouse Gas Emissions (Direct UK and Indirect)

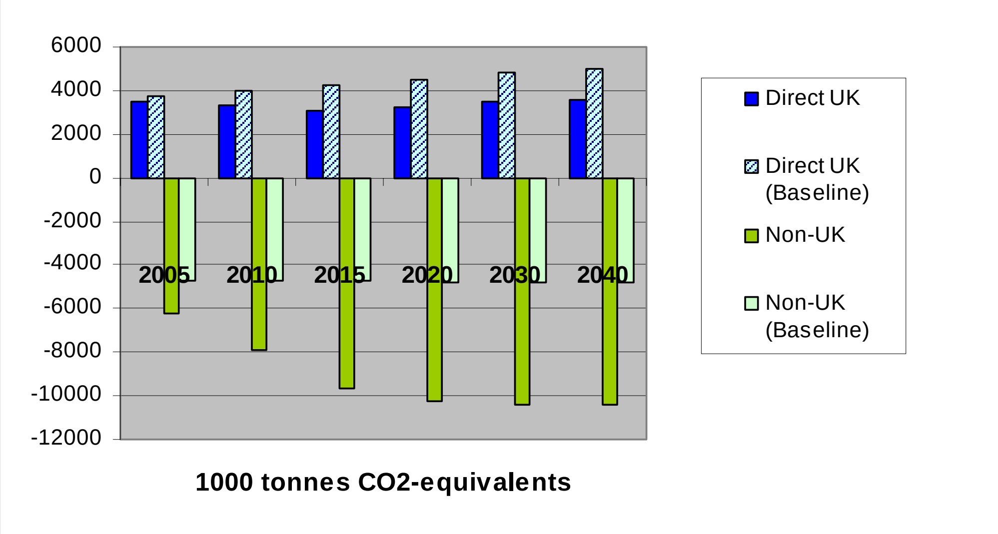


Figure 5.10 Scenario 5 Greenhouse Gas Emissions (Total)

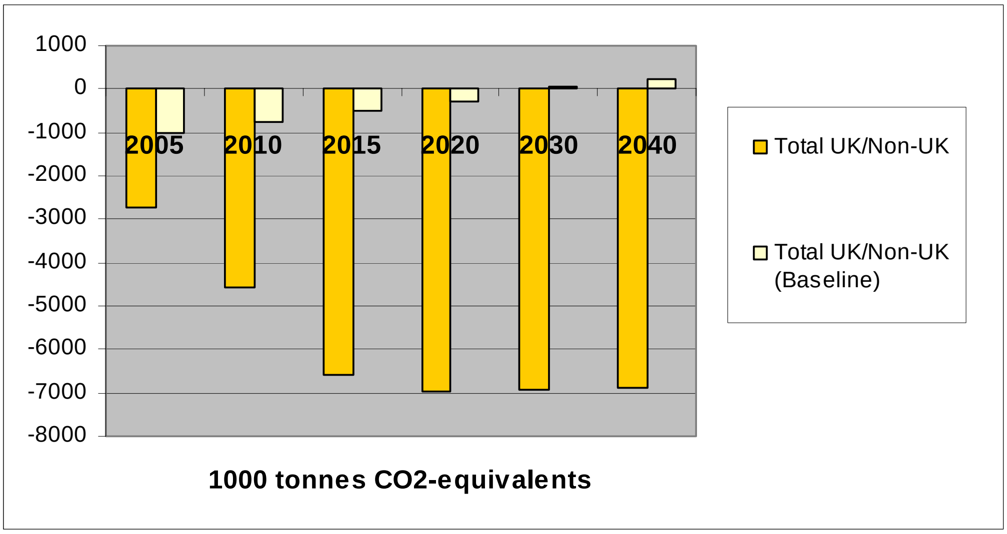


Table 5.13 Scenario 5 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	102	104	107	112	121	126
Transfer station	61	60	63	66	72	74
Transport to and from MRF	63	80	93	97	97	97
MRF including recycling	90	107	143	136	136	136
EfW with recovery of metals (incl transport to reprocessor)	97	237	893	1346	1189	1122
Windrow composting	24	30	36	41	41	41
In-vessel composting	27	50	99	148	148	148
Landfill (direct CH_4 emissions and energy recovery)	3045	2692	1681	1329	1656	1824
Total	**3510**	**3360**	**3100**	**3275**	**3461**	**3569**

Table 5.14 Scenario 5 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	45	46	47	49	53	55
Transfer station	8	7	7	7	7	8
Transport to and from MRF	28	36	42	43	43	43
MRF including recycling	-5900	-7517	-8709	-9099	-9099	-9099
EfW with recovery of metals (incl transport to reprocessor)	-399	-487	-1031	-1202	-1332	-1388
Windrow composting	-5	-6	-7	-8	-8	-8
In-vessel composting	-9	-18	-34	-53	-53	-53
Landfill (direct CH_4 emissions and energy recovery)	9	8	5	4	5	6
Total	**-6224**	**-7932**	**-9680**	**-10260**	**-10384**	**-10438**

Table 5.15 Scenario 5 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	2010	2015	2020	2030	2040
Direct UK	3510	3360	3100	3275	3461	3569
Non-UK	-6224	-7932	-9680	-10260	-10384	-10438
Total UK / Non-UK	-2714	-4572	-6581	-6985	-6924	-6869

The high composting scenario shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with reduced tonnages of waste sent for landfill.

The scenario performs less well than the high EfW scenario in terms of direct UK emissions. This is, in part, due to the impact of increased source-separation of organic materials on the energy recovery potential from residual waste. Further, the majority of benefits associated with composting are assumed to occur outside of the UK.

The scenario shows a reduced non-UK greenhouse benefit in comparison with scenario 3 (high paper/card recycling), as offsetting the production of peat (assumed offset for compost recycling) results in a lower greenhouse gas benefit than paper/card recycling.

5.1.6 *Scenario 6 – High MBT with Stabilisation for Landfill*

Figure 5.11 Scenario 6 Greenhouse Gas Emissions (Direct UK and Indirect)

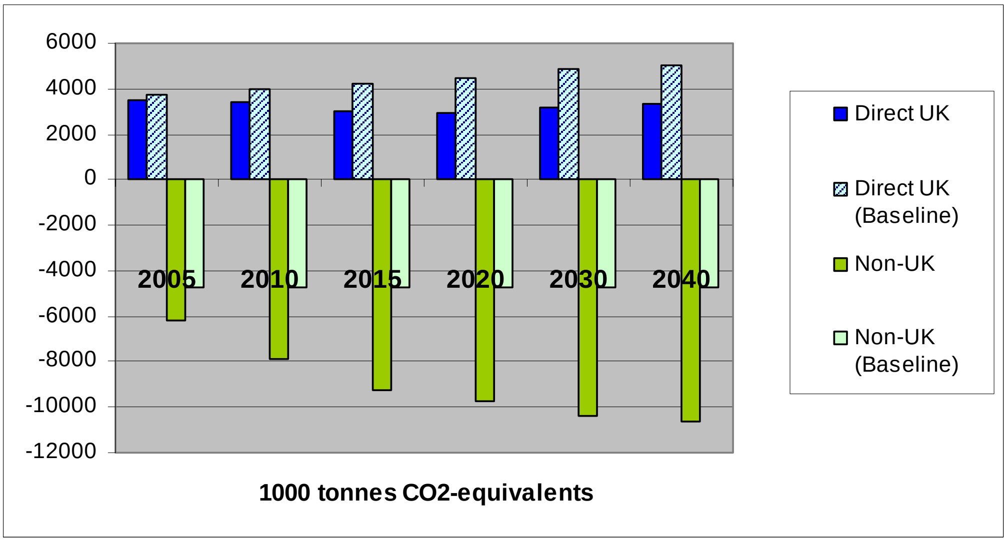


Figure 5.12 Scenario 6 Greenhouse Gas Emissions (Total)

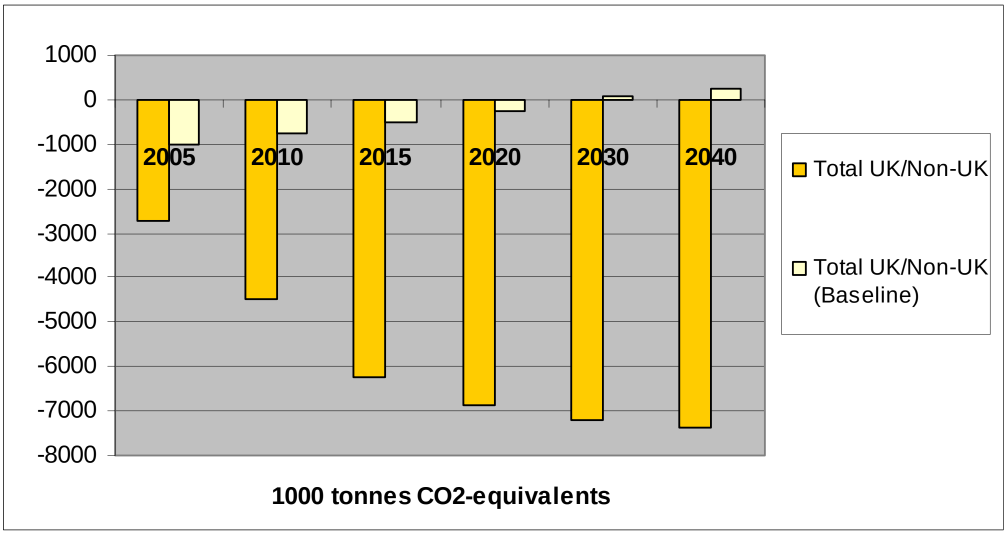


Table 5.16 Scenario 6 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	102	104	107	112	119	123
Transfer station	61	60	63	66	70	73
Transport to and from MRF	63	80	93	97	104	107
MRF including recycling	90	107	143	136	145	149
EfW with recovery of metals (incl transport to reprocessor)	97	130	152	152	152	152
Windrow composting	24	30	35	37	39	40
In-vessel composting	27	34	41	41	44	45
MBT Stabilisation with recovery of metals (incl transport to reprocessor)	0	268	1145	1572	1572	1572
Landfill (direct CH_4 emissions and energy recovery)	3045	2587	1228	688	921	1041
Total	**3510**	**3400**	**2994**	**2901**	**3166**	**3302**

Table 5.17 Scenario 6 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	45	46	47	49	52	54
Transfer station	8	7	7	7	7	8
Transport to and from MRF	28	36	42	43	46	48
MRF including recycling	-5900	-7517	-8709	-9099	-9693	-9996
EfW with recovery of metals (incl transport to reprocessor)	-399	-317	-264	-264	-264	-264
Windrow composting	-5	-6	-7	-7	-8	-8
In-vessel composting	-9	-12	-14	-15	-16	-16
MBT Stabilisation with recovery of metals (incl transport to reprocessor)	0	-121	-345	-489	-489	-489
Landfill (direct CH_4 emissions and energy recovery)	9	7	3	2	3	3
Total	**-6224**	**-7877**	**-9240**	**-9774**	**-10361**	**-10662**

Table 5.18 Scenario 6 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	**2010**	**2015**	**2020**	**2030**	**2040**
Direct UK	3510	3400	2994	2901	3166	3302
Non-UK	-6224	-7877	-9240	-9774	-10361	-10662
Total UK/Non-UK	-2714	-4477	-6246	-6873	-7195	-7360

The high MBT with stabilisation scenario shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with reduced tonnages of waste sent for landfill and diversion of biodegradable material from landfill.

The high MBT with stabilisation scenario performs less well than the high EfW or high MBT with RDF production scenarios in terms of direct UK emissions, as the stabilisation process does not recover energy and so is awarded no offset benefit.

5.1.7 *Scenario 7 – High MBT with RDF Production*

Figure 5.13 Scenario 7 Greenhouse Gas Emissions (Direct UK and Indirect)

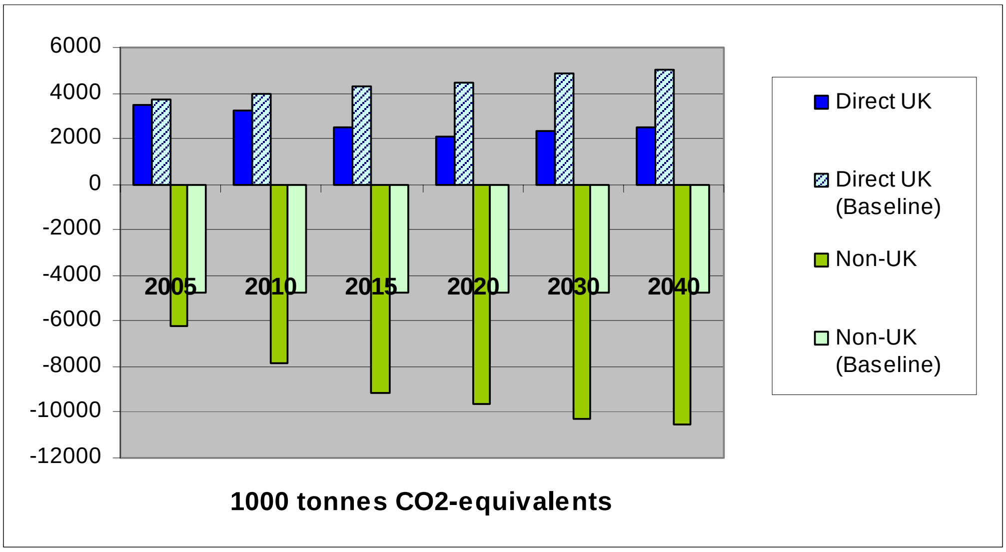


Figure 5.14 Scenario 7 Greenhouse Gas Emissions (Total)

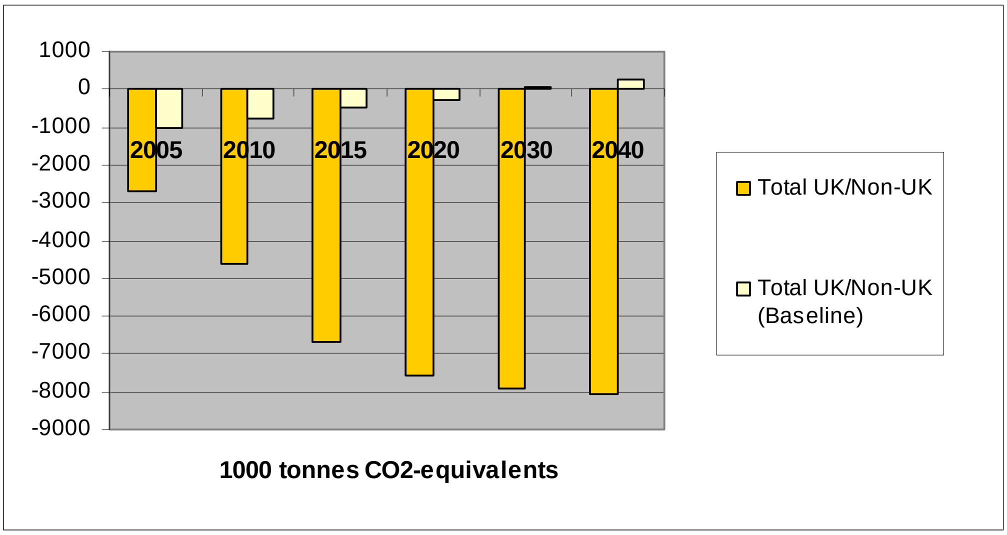


Table 5.19 Scenario 7 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	102	104	107	112	119	123
Transfer station	61	60	63	66	70	73
Transport to and from MRF	63	80	93	97	104	107
MRF including recycling	90	107	143	136	145	149
EfW with recovery of metals (incl transport to reprocessor)	97	130	153	152	152	152
Windrow composting	24	30	35	37	39	40
In-vessel composting	27	34	41	41	44	45
MBT with RDF combustion and recovery of metals (incl transport to reprocessor)	0	15	196	187	187	187
Landfill (direct CH_4 emissions and energy recovery)	3045	2687	1643	1258	1492	1611
Total	**3510**	**3248**	**2470**	**2087**	**2353**	**2489**

Table 5.20 Scenario 7 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	45	46	47	49	52	54
Transfer station	8	7	7	7	7	8
Transport to and from MRF	28	36	42	43	46	48
MRF including recycling	-5900	-7517	-8709	-9099	-9693	-9996
EfW with recovery of metals (incl transport to reprocessor)	-399	-317	-264	-264	-264	-264
Windrow composting	-5	-6	-7	-7	-8	-8
In-vessel composting	-9	-12	-14	-15	-16	-16
MBT with RDF combustion and recovery of metals (incl transport to reprocessor)	0	-95	-276	-390	-390	-390
Landfill (direct CH_4 emissions and energy recovery)	9	8	5	4	4	5
Total	**-6224**	**-7851**	**-9169**	**-9673**	**-10260**	**-10561**

Table 5.21 Scenario 7 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	2010	2015	2020	2030	2040
Direct UK	3510	3248	2470	2087	2353	2489
Non-UK	-6224	-7851	-9169	-9673	-10260	-10561
Total UK / Non-UK	-2714	-4603	-6699	-7586	-7908	-8072

The high MBT with RDF production scenario shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with reduced tonnages of waste sent for landfill.

The high MBT with RDF combustion scenario performs favourably in comparison with the high EfW scenario in terms of direct UK emissions, as the EfW process produces greater direct emissions of CO_2 than the MBT with RDF combustion process (see *Annex A*).

5.1.8 Scenario 8 – High Gasification

Figure 5.15 Scenario 8 Greenhouse Gas Emissions (Direct UK and Indirect)

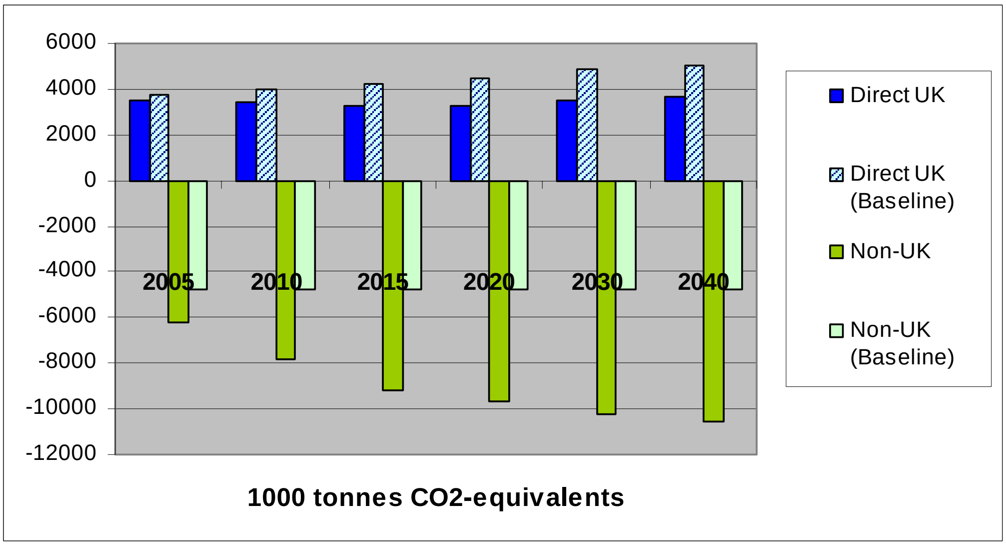


Figure 5.16 Scenario 8 Greenhouse Gas Emissions (Total)

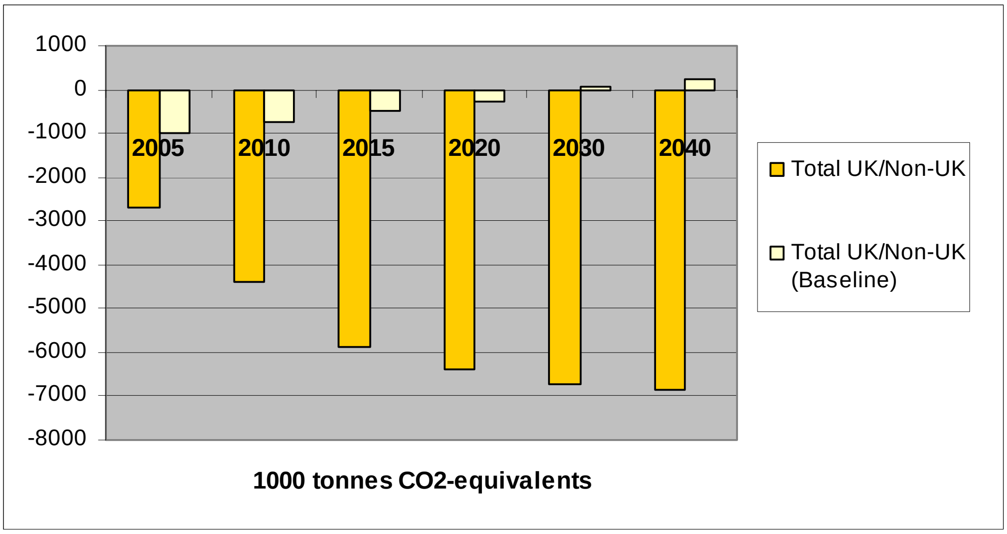


Table 5.22 Scenario 8 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	102	104	107	112	119	123
Transfer station	61	60	63	66	70	73
Transport to and from MRF	63	80	93	97	104	107
MRF including recycling	90	107	143	136	145	149
EfW with recovery of metals (incl transport to reprocessor)	97	130	152	152	152	152
Gasification with recovery of metals (incl transport to reprocessor)	0	212	995	1366	1366	1366
Windrow composting	24	30	35	37	39	40
In-vessel composting	27	34	41	41	44	45
Landfill (direct CH_4 emissions and energy recovery)	3045	2687	1643	1258	1492	1611
Total	**3510**	**3445**	**3259**	**3265**	**3531**	**3667**

Table 5.23 Scenario 8 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	45	46	47	49	52	54
Transfer station	8	7	7	7	7	8
Transport to and from MRF	28	36	42	43	46	48
MRF including recycling	-5900	-7517	-8709	-9099	-9693	-9996
EfW with recovery of metals (incl transport to reprocessor)	-399	-317	-264	-264	-264	-264
Gasification with recovery of metals (incl transport to reprocessor)	0	-91	-257	-367	-367	-367
Windrow composting	-5	-6	-7	-7	-8	-8
In-vessel composting	-9	-12	-14	-15	-16	-16
Landfill (direct CH_4 emissions and energy recovery)	9	8	5	4	4	5
Total	**-6224**	**-7847**	**-9151**	**-9650**	**-10237**	**-10538**

Table 5.24 Scenario 8 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	**2010**	**2015**	**2020**	**2030**	**2040**
Direct UK	3510	3445	3259	3265	3531	3667
Non-UK	-6224	-7847	-9151	-9650	-10237	-10538
Total UK/Non-UK	-2714	-4401	-5892	-6384	-6707	-6871

The high gasification scenario shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with reduced tonnages of waste sent for landfill.

The high gasification scenario performs less well than the high EfW and high MBT with RDF combustion scenarios in terms of direct UK emissions, as the gasification process is relatively less efficient, consuming greater quantities of both electricity and fuel per tonne of waste processed than the alternative combustion processes.

5.1.9 *Scenario 9 – Mixed Technology Scenario*

Figure 5.17 Scenario 9 Greenhouse Gas Emissions (Direct UK and Indirect)

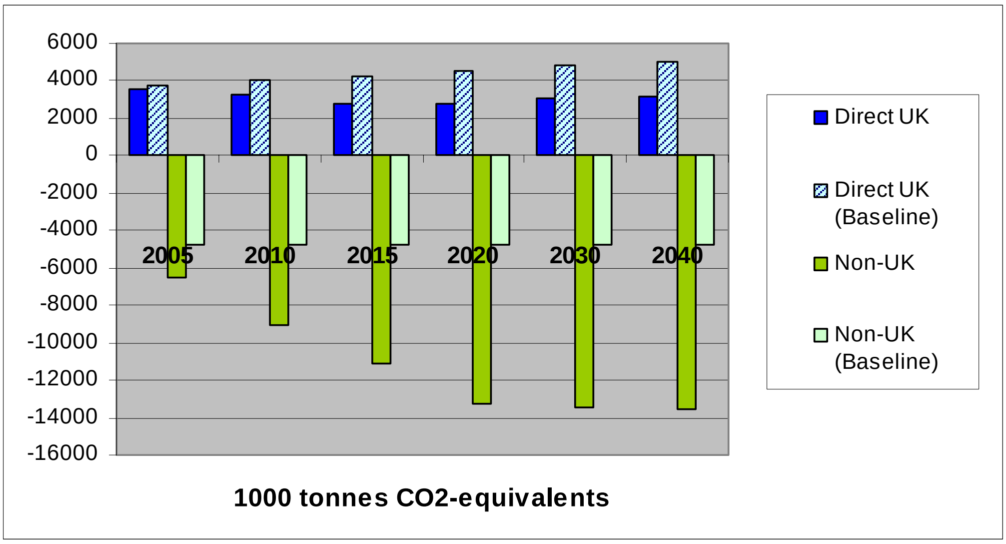


Figure 5.18 Scenario 9 Greenhouse Gas Emissions (Total)

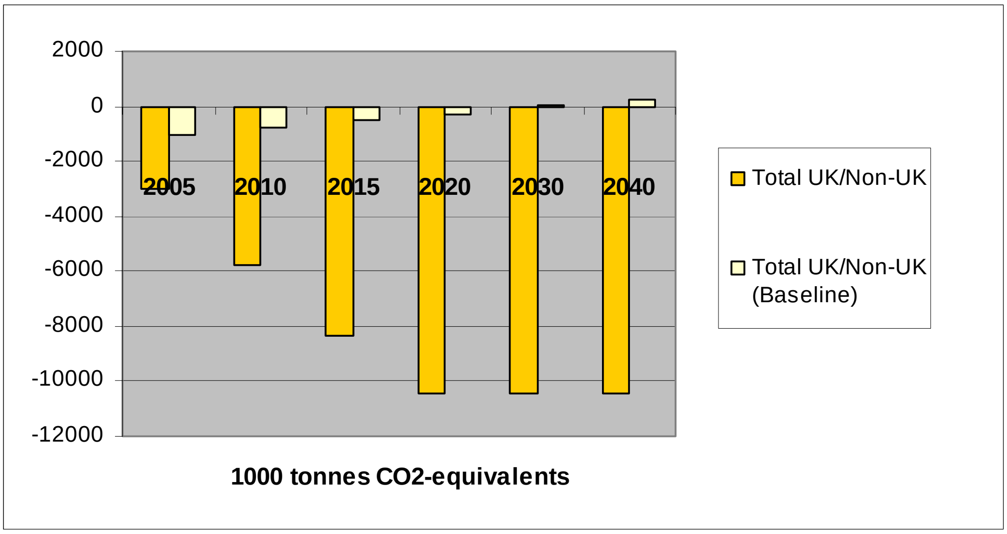


Table 5.25 Scenario 9 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	101	100	97	93	102	107
Transfer station	60	57	57	55	60	63
Transport to and from MRF	67	95	125	156	156	156
MRF including recycling	95	126	192	218	218	218
EfW with recovery of metals (incl transport to reprocessor)	97	148	443	677	596	561
Anaerobic digestion	0	1	6	10	10	10
Windrow composting	42	45	47	49	49	49
In-vessel composting	0	4	16	28	28	28
MBT with RDF combustion and recovery of metals (incl transport to reprocessor)	0	24	164	302	254	233
Landfill (direct CH_4 emissions and energy recovery)	3047	2620	1596	1220	1561	1736
Total	**3511**	**3220**	**2725**	**2809**	**3035**	**3162**

Table 5.26 Scenario 9 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	44	44	42	41	45	47
Transfer station	7	7	6	6	6	7
Transport to and from MRF	30	42	56	70	70	70
MRF including recycling	-6257	-8859	-10581	-13267	-13267	-13267
EfW with recovery of metals (incl transport to reprocessor)	-369	-208	-430	-86	-231	-293
Anaerobic digestion	0	-1	-2	-4	-4	-4
Windrow composting	-9	-9	-10	-10	-10	-10
In-vessel composting	0	-1	-5	-10	-10	-10
MBT with RDF combustion and recovery of metals (incl transport to reprocessor)	0	-34	-187	-29	-97	-126
Landfill (direct CH_4 emissions and energy recovery)	9	7	5	3	4	5
Total	**-6544**	**-9012**	**-11106**	**-13286**	**-13493**	**-13582**

Table 5.27 Scenario 9 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	2010	2015	2020	2030	2040
Direct UK	3511	3220	2725	2809	3035	3162
Non-UK	-6544	-9012	-11106	-13286	-13493	-13582
Total UK / Non-UK	-3034	-5791	-8381	-10477	-10458	-10420

The mixed technology scenario shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with reduced tonnages of waste sent for landfill.

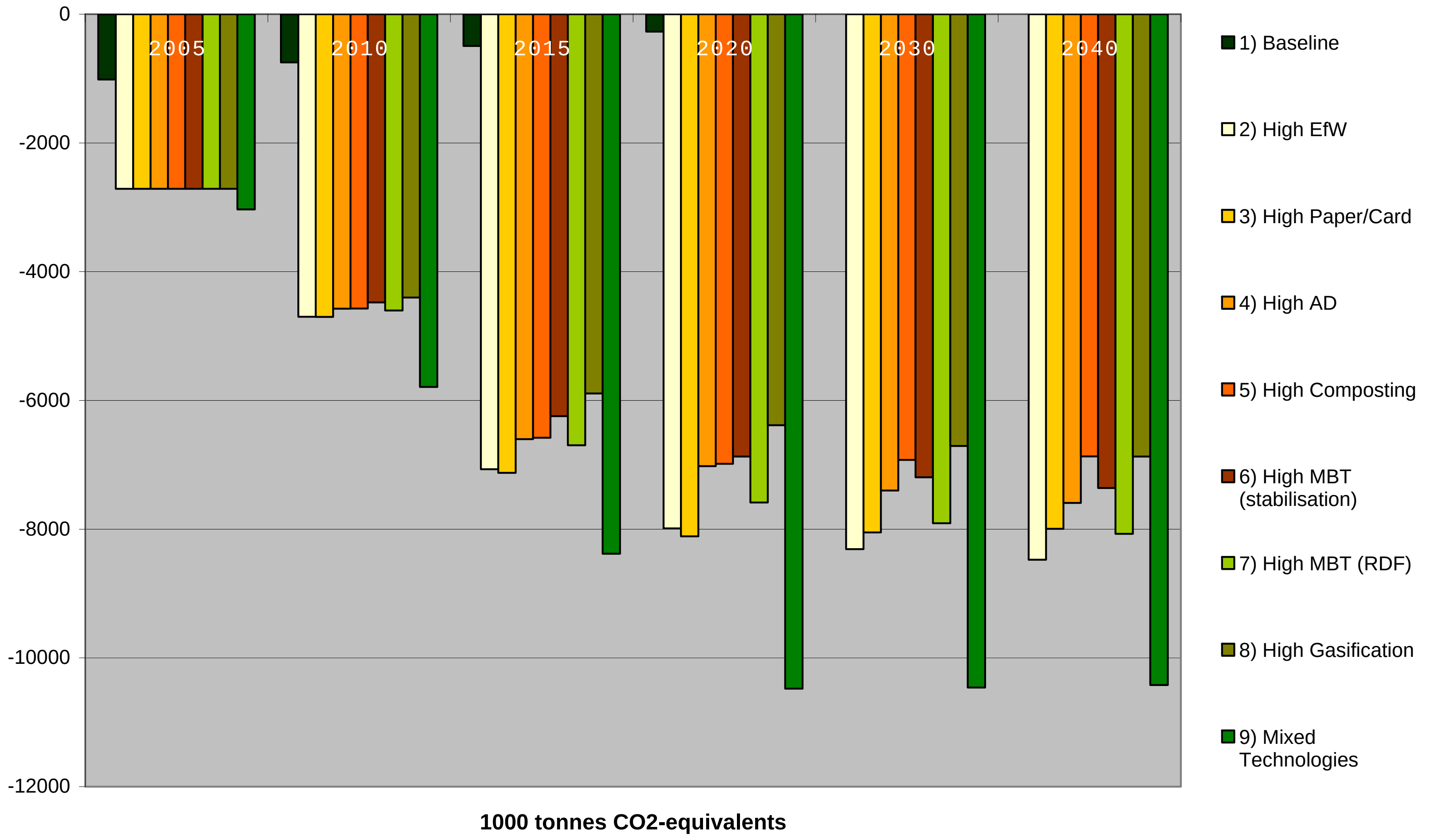
The mixed technology scenario further shows non-UK greenhouse benefits in excess of all other scenarios. This occurs predominantly due to the increased rates of source-separated recycling that this scenario assumes.

5.1.10 Summary Results

Figure 5.19 shows total (direct and indirect) greenhouse gas emissions for each of the scenarios assessed.

Results of modelling show that overall scenario greenhouse emission profiles are dominated by the offset benefits attributed to materials recycling and energy recovery. As a result, net greenhouse gas emissions are negative. It follows that those scenarios showing elevated levels of both recycling and energy recovery (mixed technology scenario, high EfW, high paper and card recycling, high MBT with RDF combustion) show greater net greenhouse gas benefits.

Figure 5.19 MSW Scenarios - Comparative Greenhouse Gas Emissions (Total Direct and Indirect)



5.2 C&I WASTE SCENARIOS

Estimates of the affect of different C&I waste management scenarios on both direct UK greenhouse gas emissions and potential indirect emissions are presented in *Figure 5.20* to *Figure 5.25* and *Table 5.28* to *Table 5.36*. A summary of comparative emissions for all scenarios is shown in *Figure 5.26*.

Results are presented as an aggregated CO_2 equivalent emission for ease of interpretation. Inventories of individual greenhouse gas emissions by scenario are presented in *Annex C*. Whilst a number of the treatment processes examined resulted in emissions of all greenhouse gases, it was found, in general, that carbon dioxide was the largest contributor to scenario greenhouse gas emission profiles. This is with the exception of landfill, for which methane was the predominant greenhouse gas emitted.

5.2.1 *C&I Scenario 1 – Baseline (2002/03) Recycling and EfW Capacity*

Figure 5.20 Baseline C&I Scenario Greenhouse Gas Emissions (Direct UK and Indirect)

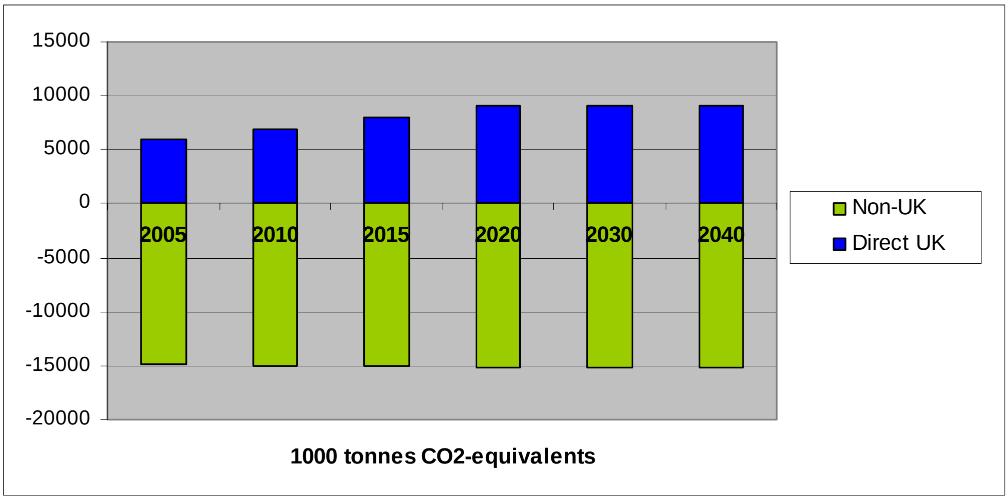


Figure 5.21 Baseline C&I Scenario Greenhouse Gas Emissions (Total)

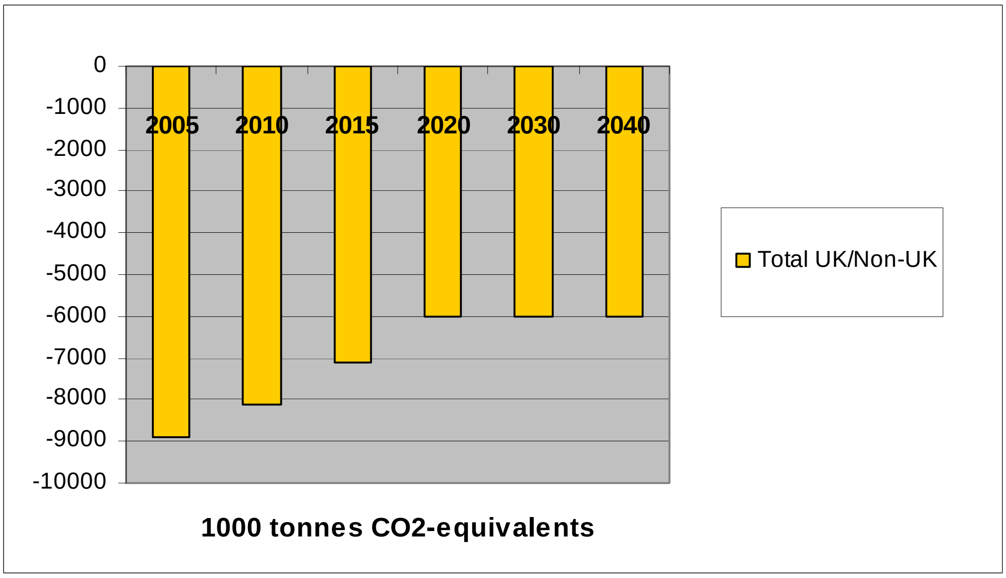


Table 5.28 Baseline C&I Scenario Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	188	218	252	290	290	290
Transfer station	112	125	149	171	171	171
Transport to and from MRF	297	297	297	297	297	297
MRF including recycling	423	395	456	414	414	414
EfW with recovery of metals (incl transport to reprocessor)	230	201	177	157	157	157
In-vessel composting	47	46	48	47	47	47
Landfill (direct CH_4 emissions and energy recovery)	4719	5620	6624	7744	7744	7744
Total	**6016**	**6901**	**7961**	**9119**	**9119**	**9119**

Table 5.29 Baseline C&I Scenario Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	82	95	110	127	127	127
Transfer station	14	15	17	18	18	18
Transport to and from MRF	132	132	132	132	132	132
MRF including recycling	-14989	-14994	-14997	-15002	-15002	-15002
EfW with recovery of metals (incl transport to reprocessor)	-160	-258	-338	-404	-404	-404
In-vessel composting	-16	-16	-17	-17	-17	-17
Landfill (direct CH_4 emissions and energy recovery)	19	22	26	30	30	30
Total	**-14918**	**-15003**	**-15066**	**-15116**	**-15116**	**-15116**

Table 5.30 Baseline C&I Scenario Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	2010	2015	2020	2030	2040
Direct UK	6016	6901	7961	9119	9119	9119
Non-UK	-14918	-15003	-15066	-15116	-15116	-15116
Total UK/Non-UK	-8902	-8102	-7104	-5997	-5997	-5997

The baseline C&I scenario shows a gradual increase in direct UK greenhouse gas emissions over the study period, predominantly associated with increased tonnages of waste sent for landfill.

Non-UK greenhouse gas emissions associated with C&I wastes appear negative due to the offset benefits of recycling materials. As with the MSW scenarios, the displacement of primary materials extraction and manufacture is assumed to occur outside of the UK system boundary.

5.2.2 *C&I Scenario 2 – Increased Recycling*

Figure 5.22 C&I Scenario 2 Greenhouse Gas Emissions (Direct UK and Indirect)

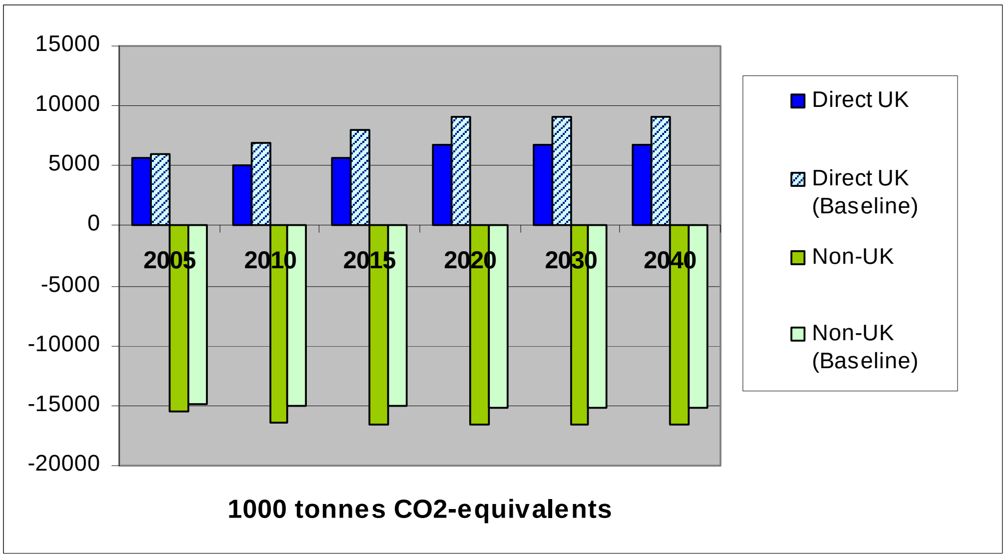


Figure 5.23 C&I Scenario 2 Greenhouse Gas Emissions (Total)

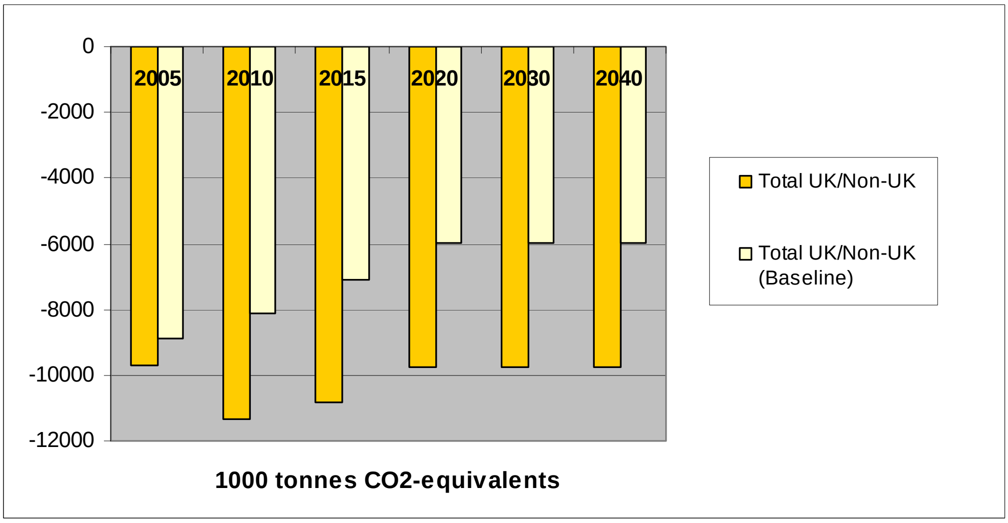


Table 5.31 C&I Scenario 2 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	178	138	154	191	191	191
Transfer station	106	79	91	113	113	113
Transport to and from MRF	329	547	605	605	605	605
MRF including recycling	469	728	930	843	843	843
EfW with recovery of metals (incl transport to reprocessor)	267	297	241	194	194	194
In-vessel composting	53	89	104	100	100	100
Landfill (direct CH_4 emissions and energy recovery)	4334	3172	3659	4780	4780	4780
Total	**5736**	**5050**	**5696**	**6827**	**6827**	**6827**

Table 5.32 C&I Scenario 2 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from Transfer Station	78	60	67	84	84	84
Transfer station	13	9	10	12	12	12
Transport to and from MRF	147	244	270	270	270	270
MRF including recycling	-15481	-16208	-16254	-16266	-16266	-16266
EfW with recovery of metals (incl transport to reprocessor)	-171	-448	-613	-661	-661	-661
In-vessel composting	-18	-32	-36	-36	-36	-36
Landfill (direct CH_4 emissions and energy recovery)	18	12	14	18	18	18
Total	**-15416**	**-16361**	**-16542**	**-16580**	**-16580**	**-16580**

Table 5.33 C&I Scenario 2 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	2010	2015	2020	2030	2040
Direct UK	5736	5050	5696	6827	6827	6827
Non-UK	-15416	-16361	-16542	-16580	-16580	-16580
Total UK / Non-UK	-9680	-11312	-10846	-9753	-9753	-9753

C&I scenario 2 shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with lower tonnages of waste sent for landfill.

This increased recycling scenario performs favourably over the increased EfW scenario (C&I scenario 3) in terms of direct UK emissions, as the EfW process emits significant quantities of CO_2. The scenario further performs less well than might be expected in terms of non-UK emissions, however, as a significant proportion of additional recycling tonnages were assumed to be of the category 'mixed general waste (non-combustible)', for which the offset, displaced production of primary material (assumed to be aggregate production) is relatively lower.

5.2.3 *C&I Scenario 3 – Increased EfW*

Figure 5.24 C&I Scenario 3 Greenhouse Gas Emissions (Direct UK and Indirect)

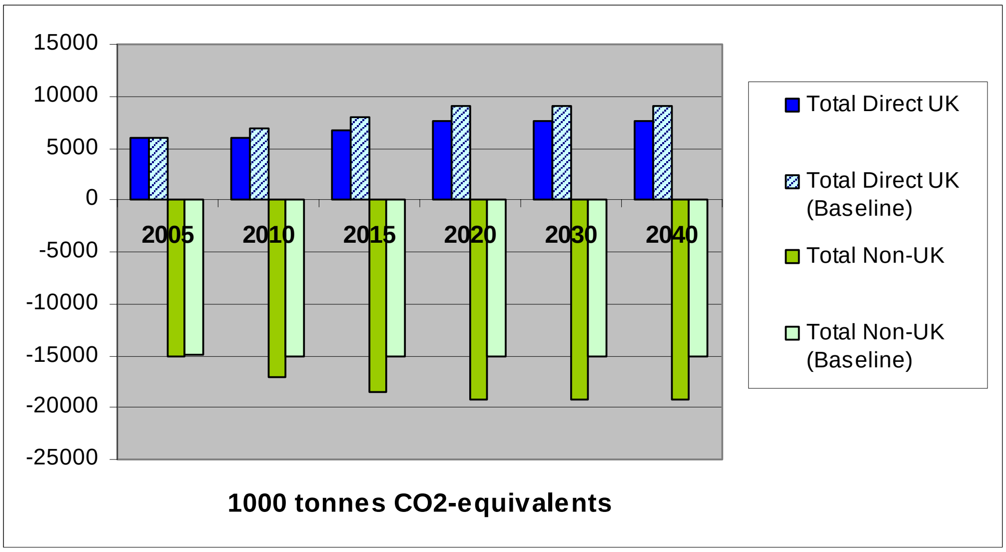


Figure 5.25 C&I Scenario 3 Greenhouse Gas Emissions (Total)

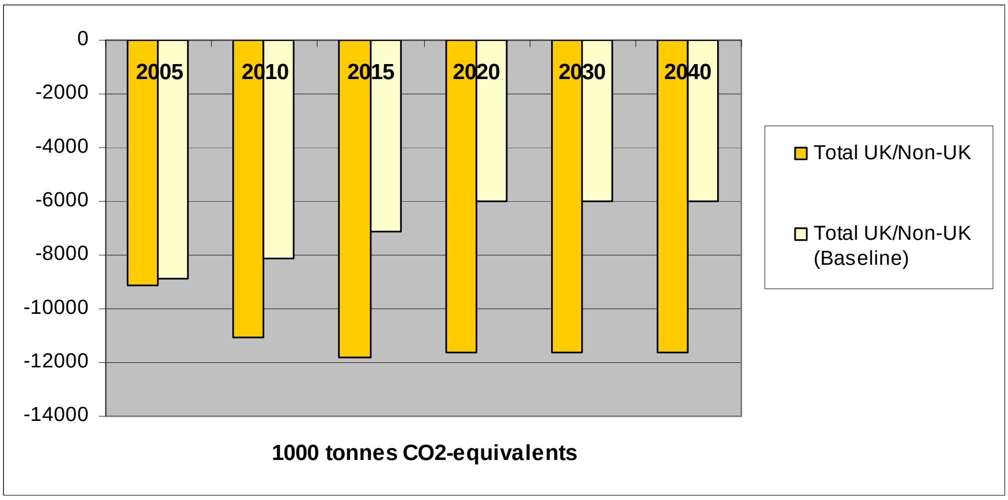


Table 5.34 C&I Scenario 3 Direct UK Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	**2005**	**2010**	**2015**	**2020**	**2030**	**2040**
Transport to and from transfer station	188	218	252	290	290	290
Transfer station	112	125	149	171	171	171
Transport to and from MRF	297	297	297	297	297	297
MRF including recycling	423	395	456	414	414	414
EfW with recovery of metals (incl transport to reprocessor)	474	1838	1954	1733	1733	1733
In-vessel composting	47	46	48	47	47	47
Landfill (direct CH_4 emissions and energy recovery)	4396	3108	3513	4614	4614	4614
Total	**5937**	**6026**	**6627**	**7565**	**7565**	**7565**

Table 5.35 C&I Scenario 3 Indirect (Non-UK) Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

Waste Management Process	2005	2010	2015	2020	2030	2040
Transport to and from transfer station	82	95	110	127	127	127
Transfer station	14	15	17	18	18	18
Transport to and from MRF	132	132	132	132	132	132
MRF including recycling	-14989	-14994	-14997	-15002	-15002	-15002
EfW with recovery of metals (incl transport to reprocessor)	-330	-2361	-3725	-4458	-4458	-4458
In-vessel composting	-16	-16	-17	-17	-17	-17
Landfill (direct CH_4 emissions and energy recovery)	18	12	14	18	18	18
Total	**-15089**	**-17116**	**-18465**	**-19183**	**-19183**	**-19183**

Table 5.36 C&I Scenario 3 Total Greenhouse Gas Emissions (1000 tonnes CO_2 Equivalents)

	2005	2010	2015	2020	2030	2040
Direct UK	5937	6026	6627	7565	7565	7565
Non-UK	-15089	-17116	-18465	-19183	-19183	-19183
Total UK / Non-UK	-9152	-11090	-11839	-11617	-11617	-11617

C&I scenario 3 shows reduced direct UK greenhouse gas emissions over the baseline scenario, predominantly associated with reduced tonnages of waste sent for landfill and the additional benefits of increased energy recovery through EfW.

The increased EfW scenario further shows increased offset benefits occurring outside of the UK system. This results from energy recovery and additional metals recycling from the EfW process.

5.2.4 Summary Results

Figure 5.26 shows total (direct and indirect) greenhouse gas emissions for each of the C&I scenarios assessed.

As with MSW scenarios, results of modelling show that overall scenario greenhouse emission profiles are dominated by the offset benefits attributed to materials recycling and energy recovery. As a result, net greenhouse gas emissions are negative for all scenarios and both the increased recycling and EfW scenario show significant benefit over the baseline.

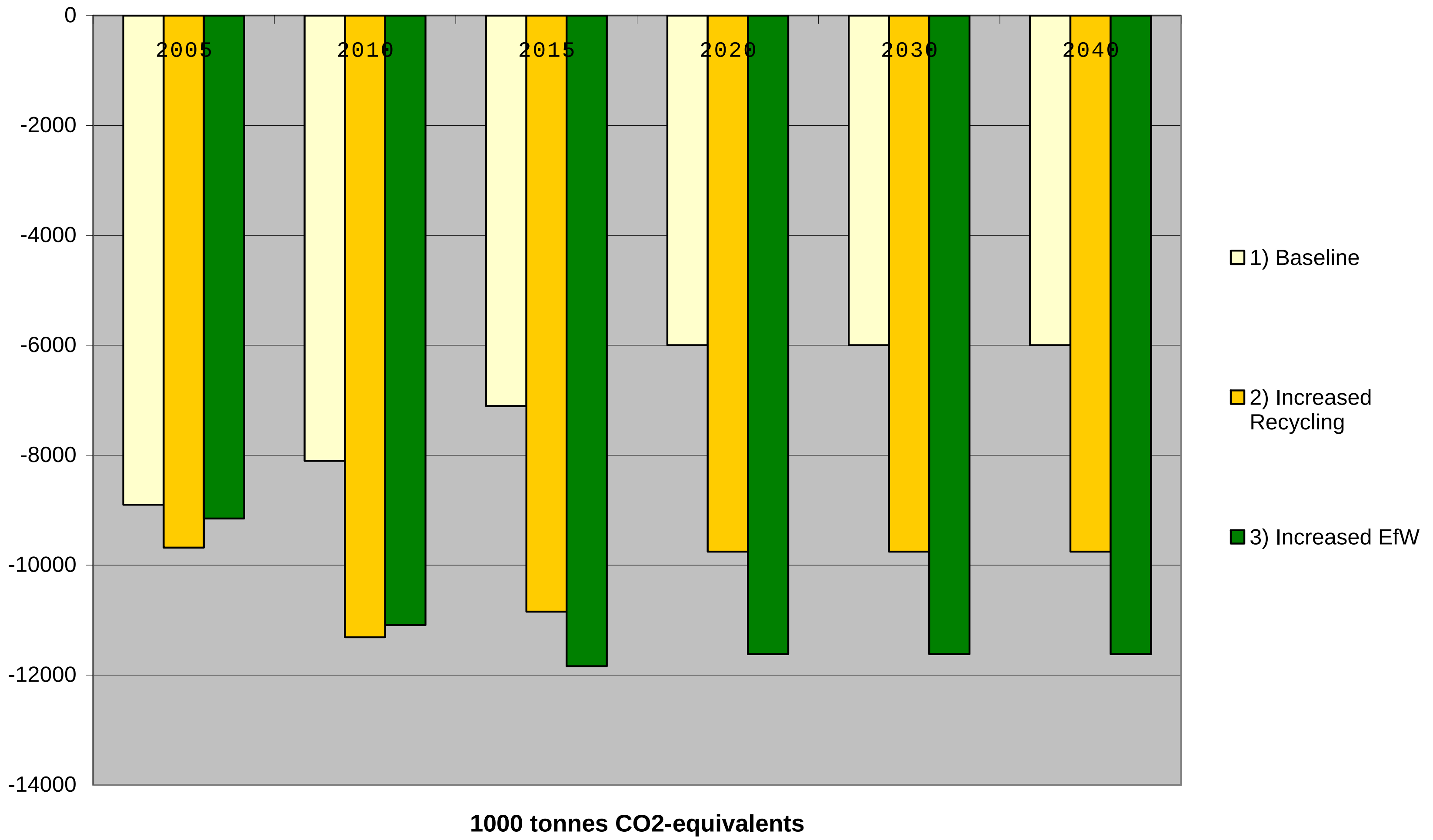
The relative balance in performance between recycling and EfW scenarios shows a shift over time, favouring recycling in the short term and EfW in the long term. This occurs, in part, due to the impact of changing waste composition on EfW performance and, in part, to due assumptions regarding materials separated for recycling.

Scenario 3 shows increasing greenhouse gas benefits over time. With increasing waste arisings but no additional separation of combustible wastes, such as paper, the relative calorific value of residual waste will increase, such that EfW plant can recover more energy and so are awarded a greater offset greenhouse gas benefit.

Scenario 2 shows decreasing greenhouse gas benefits over time. This scenario assumes increasing quantities of materials separated for recycling to reach a diversion rate of 10% per annum. Where fractional arisings were insufficient to meet this recycling need (for example, insufficient paper, ferrous and non-ferrous metals arising in the waste stream to reach increased recycling rates), it was assumed that additional recycling would be apportioned from the category, mixed general waste (non-combustible). For this category the offset displaced production of primary material (assumed to be aggregate production) is relatively lower and so net greenhouse gas benefits appear reduced in later years.

This balance is heavily influenced by assumptions regarding waste composition, for which only relatively poor data exist, and so should its interpretation should be treated with caution.

Figure 5.26 *C&I Scenarios - Comparative Greenhouse Gas Emissions (Total Direct and Indirect)*



6 *SENSITIVITY ANALYSIS*

Sensitivity analysis is a process involving investigation of key input parameters about which there may be uncertainty or for which a range of values may exist. Key areas that have been identified for discussion with regard to results sensitivity include waste growth and composition, marginal electricity mix and UK/non-UK system boundary positions.

6.1 *WASTE GROWTH AND COMPOSITION*

A number of assumptions were made regarding waste growth across the UK for both MSW and C&I waste management scenarios. *Figure 3.1* and *Error! Reference source not found.* showed the significant variation between tonnages arising through different forecasts of waste growth. As such, it is reasonable to consider that the development of scenarios with an alternative growth rate will have a significant impact on resulting greenhouse gas emissions.

Baseline compositional data for MSW and C&I waste are relatively poor, particularly with regard to C&I waste. This has implications for resulting emissions estimates, as a number of the EFs for treatment processes modelled are material dependent (*Table 4.6*).

An area of particular concern regarding influence on results is the assumed biodegradable content of C&I wastes. *Table 3.2* shows that an overall 47% biodegradable content was used to model C&I scenario greenhouse gas emissions. *Figure 6.1* and *Figure 6.2* show that this assumption has a significant affect on resulting greenhouse gas emissions. Alternatively increasing, or decreasing, the proportion of biodegradable material in the waste stream by 25% results in a significant increase, or decrease, in greenhouse gas emissions respectively.

Figure 6.1 *Baseline C&I Scenario Greenhouse Gas Emissions (Total): 25% Increase in Biodegradable Content of Waste Stream*

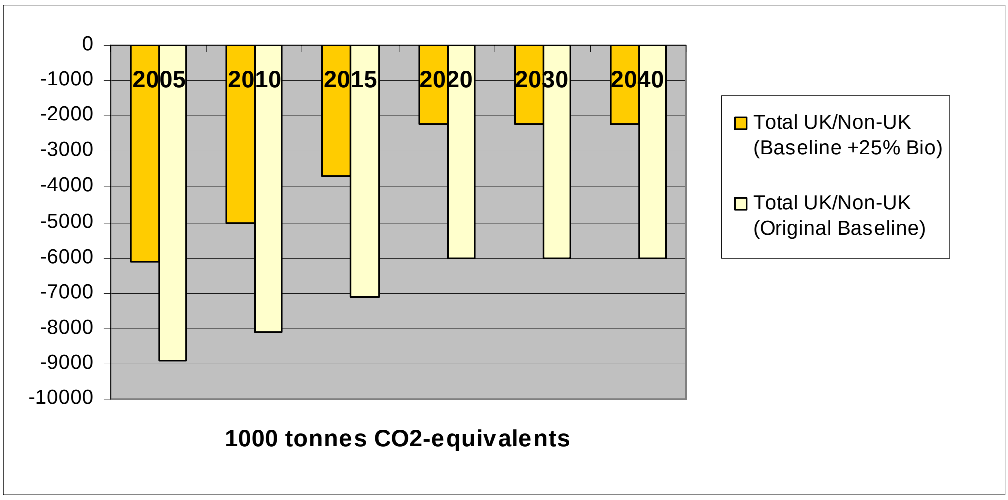
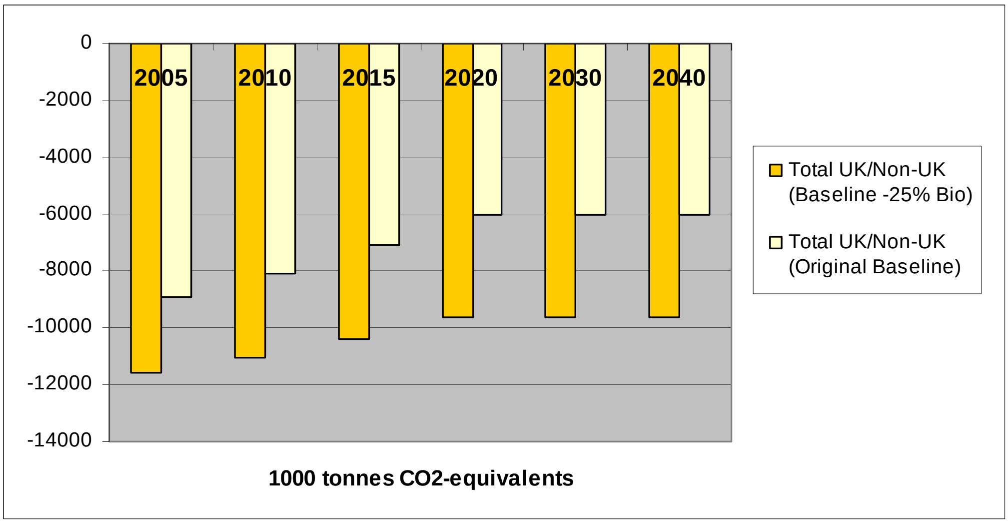


Figure 6.2 *Baseline C&I Scenario Greenhouse Gas Emissions (Total): 25% Decrease in Biodegradable Content of Waste Stream*



6.2 *ELECTRICITY MIX*

Predicted changes in UK grid electricity mix and marginal electricity mix over time were taken from the updates to the Environment Agency's WISARD tool (1) and are based upon DTI's latest energy projection data (2005). Projections are made for electricity mixes from 2005 to 2020. With no further data available, it was assumed that UK grid electricity would remain of the same mix from 2020 onwards (2).

(1) ERM, (2005). WRATE Electricity Database Manual. Environmental Resources Management. Unpublished.

(2) 16% coal / thermal other / waste, 0.2% oil, 3.8% gas (non-CCGT), 55% gas (CCGT), 8.6% nuclear, 2.2% renewables thermal, 12% wind and 1.6% hydro / renewable other.

A conservative assumption, that marginal (offset) electricity is comprised 100% gas (CCGT) across the study period, was further made. This marginal / offset electricity assumption has significant implications for estimates of UK and non-UK greenhouse gas emissions, as 100% CCGT electricity has relatively lower associated CO_2 (and equivalent) emissions than, for example, coal electricity, or mixes thereof.

6.3 *UK BOUNDARY*

In order to allow independent estimation of the greenhouse gas burden in the UK, a number of assumptions were made with regard to the potential location of greenhouse gas releases. A key one of these assumptions was that, although materials are separated in UK-based MRFs, the displacement of primary material extraction and manufacture associated with materials recycling would occur outside of the UK. Accordingly, average European production data were used to model the offset benefit of displaced virgin materials, with globally sourced raw materials.

Although this is considered a reasonable assumption, as virgin materials tend to be imported, in practice it is unlikely that 100% of virgin material displacement will be accountable outside of the UK. There are two implications for resulting greenhouse gas emission estimates:

- the direct UK greenhouse burden is potentially overestimated, as some recycling benefits may well be attributable in the UK; and
- net scenario greenhouse gas burdens may potentially be overestimated, as virgin material production in UK is likely to result in greater CO_2 emissions, through the use of relatively coal-rich UK electricity. This increased offset benefit of material displacement in the UK would act to reduce overall scenario emissions.

7 COST ASSESSMENT

7.1 ASSESSMENT OF MSW SCENARIOS

Introduction

A cost model was constructed to assess the financial impacts of the nine scenarios put forward. The first of these scenarios, referred to as the baseline scenario, assesses the financial implications for the UK of continuing waste management strategy along a 'business as usual' case. The remaining eight waste management treatment scenarios comprise different approaches to satisfying the EU Landfill Directive.

In accordance with HM Treasury Green Book all future costs have been discounted to present day prices (2005) at a discount rate of 3.5% per annum. The appraisal period specified is from 2005-2045. Results are collated into the following categories:

- up to 2010;
- up to 2020; and
- over the lifetime of the policy.

Defining Cost Parameters

The primary output from the cost model was to determine the financial implications of pursuing each waste management treatment scenario. For clarity in modelling and to reflect the likelihood of a high proportion of waste management treatment being procured through private sector contractors, a 'gate fee' approach has been adopted to do this. The 'gate fee' refers to the value charged to a local authority by a private sector contractor to dispose of waste material. It is assumed that a competitively priced gate fee will reflect the capital, operational and insurance costs the commercial operator will be subjected to, as well as accounting for revenue that may be received from recyclates.

Inevitably, gate fees will vary depending on the scale of treatment and location. Due to the strategic level of this cost model a representative gate fee for each waste management treatment technology has been adopted. The gate fees charged by private contractors are often commercially sensitive. It has been necessary, therefore, to draw indicative gate fees from a range of recent publications.

The waste management treatment scenarios have varying degrees of dry and organic waste recycling. Collection of material for recycling incurs higher costs than collection of residual household waste. The scenario modelling assumes that all recycling is collected from kerbside and is source segregated. Therefore, based on previous ERM costs modelling experience, a cost per tonne of £102.00 was applied to all waste diverted to 'recycling' (dry recyclables), 'windrow' (green garden waste) and 'in vessel' (kitchen waste) treatment to reflect the assumption that this waste has been kerbside collected and source segregated. A collection cost figure of £34.00 per tonne was applied to all other waste treatment technologies to reflect that this waste has originated from the cheaper 'black bag' kerbside collection.

7.1.2 *Financial Cost of Scenarios (Excluding Emissions)*

The financial cost of each of the scenarios, in present day (2005/06) prices, is indicated in *Table 7.1* below.

Table 7.1 *Costs (£m) of Waste Management Treatment Scenarios*

Cost Period	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Up to 2010	£15,668.93	£16,821.19	£16,824.87	£16,852.06	£16,811.57
Up to 2020	£36,984.23	£43,438.19	£43,588.72	£42,902.10	£43,287.88
Over the Lifetime of the Measures	£69,917.41	£86,052.29	£86,119.59	£83,846.26	£85,072.97

Cost Period	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Up to 2010	£16,835.96	£16,799.18	£16,794.64	£17,164.72
Up to 2020	£43,889.44	£42,754.89	£42,612.90	£44,392.24
Over the Lifetime of the Measures	£87,372.98	£84,050.38	£83,634.21	£87,999.38

Figure 7.1 below indicates the varying impacts that collection and treatment costs have on total cost. The cost of collection is higher than otherwise might be expected due to the assumption that all recycled material is household collected and source segregated.

Figure 7.1 *Net Present Cost (£m) over Lifetime of Measures, Collection and Treatment*

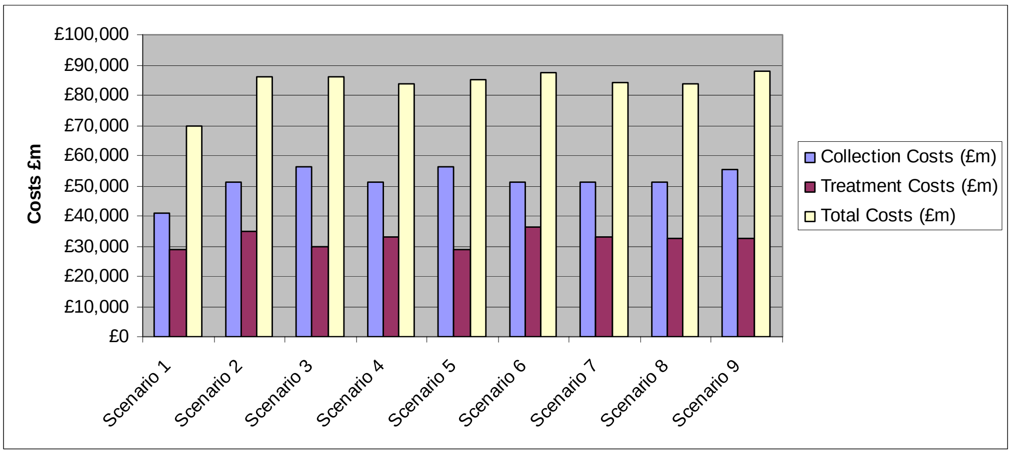


Figure 7.1 indicates that Scenarios 3, 5 and 9 all have higher levels of recycling, thus increasing collection costs. The gate fees associated with the cost of

processing recyclables are lower than for treating household residual waste. This has the additional impact of lowering costs associated with treatment.

Based on the cost model analysis, the least cost option is Scenario 1. However, landfill tax has not been included in any of the scenarios as it constitutes a transfer payment within the UK economy. Scenario 1 involves higher levels of landfill use than the other scenarios. Additionally, fines for breaching EU Landfill Directive targets have not been included in the analysis. Scenario 1 involves diverting waste to landfill above the UK's LATS allowance, thus fines would be incurred. In fact, should Scenario 1 be followed, the £150/t LATS penalty for breaching UK allowances summates to £13.4 billion in present day prices. This significantly increases the overall costs of Scenario 1.

7.1.3 *Emissions*

The scenarios developed away from the baseline case all include elements of diverting waste away from direct landfill. This can have a range of environmental benefits and impacts, notably for this study on the level of greenhouse gas emissions. Emissions of the six greenhouse gases (carbon dioxide, methane, nitrous oxide, hydroflourocarbons, perfluorocarbons and sulphur hexafluoride) associated with each of the waste treatment scenarios have been modelled. These emissions have been converted into tonnes of carbon dioxide equivalent. For clarity in modelling, analysis of costs and benefits of emissions is linked to the carbon dioxide equivalent unit.

Efforts have been made to place a monetary value on greenhouse gas emissions to reflect the Social Cost of Carbon (SCC) [(1)]. The cost model takes guidance from Defra and bases analyses on an initial value of £80.18/tonne carbon dioxide equivalent emitted rising to £96.21/tonne, in 2003/04 prices. SCC estimates are increased in real terms to reflect the increasing damage costs of greenhouse gas emissions over a BAU scenario. An inflationary index of 2.25% per annum has been applied to reflect 2005/06 prices. The SCC has not been adjusted beyond 2005/06 for future inflationary impacts, as specified by HM Treasury Green Book:

> *"The Valuation of costs or benefits should be expressed in 'real terms' or 'constant prices' (i.e. at today's general price level), as opposed to 'nominal terms' or 'current prices'. "*

Analysis of the costs of greenhouse gas emissions associated with the scenarios is presented in terms of the impact on the UK, abroad and the combined impact.

(1) As discussed in Clarkson and Deyes (2002). *Estimating the Social Cost of Carbon Emissions.* HM Treasury and GES Working Paper 140. London

Table 7.2 Cost of Greenhouse Gas Emission (Present Values £m)

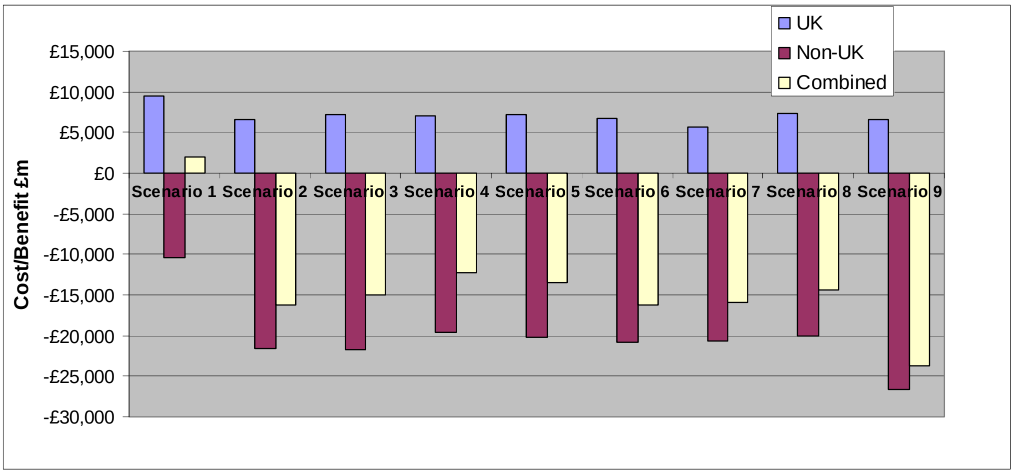
UK (£m)					
Period	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Up to 2010	£1,841.6	£1,639.1	£1,642.0	£1,638.4	£1,639.8
Up to 2020	£4,689.9	£3,595.2	£3,781.4	£3,752.8	£3,777.3
Over Lifetime	£9,462.1	£6,542.0	£7,206.7	£7,112.1	£7,196.6
Non-UK (£m)					
Period	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Up to 2010	-£2,278.7	-£3,421.0	-£3,420.8	-£3,368.7	-£3,387.1
Up to 2020	-£5,568.7	-£10,058.5	-£16,068.2	-£9,273.0	-£9,777.0
Over Lifetime	-£10,351.8	-£21,507.1	-£21,733.1	-£19,590.8	-£20,233.2
Combined (£m)					
Period	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**	**Scenario 5**
Up to 2010	-£267.2	-£1,715.5	-£1,693.6	-£1,622.2	-£1,657.9
Up to 2020	£881.1	-£7,014.9	-£6,533.4	-£5,127.9	-£6,053.9
Over Lifetime	£1,946.9	-£16,290.7	-£15,058.1	-£12,241.4	-£13,460.8

UK (£m)				
Period	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**
Up to 2010	£1,649.1	£1,613.6	£1,659.5	£1,607.5
Up to 2020	£3,687.1	£3,302.0	£3,861.1	£3,511.7
Over Lifetime	£6,805.9	£5,615.7	£7,340.6	£6,506.8
Non-UK (£m)				
Period	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**
Up to 2010	-£3,391.8	-£3,388.1	-£3,375.1	-£3,787.7
Up to 2020	-£9,915.7	-£9,931.8	-£9,634.1	-£12,265.2
Over Lifetime	-£20,741.1	-£20,705.1	-£20,067.6	-£26,563.4
Combined (£m)				
Period	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**
Up to 2010	-£1,695.5	-£1,704.7	-£1,651.9	-£2,380.1
Up to 2020	-£7,113.7	-£6,898.4	-£6,300.3	-£11,234.3
Over Lifetime	-£16,297.3	-£15,912.9	-£14,326.5	-£23,735.0

The presence of negative numbers indicates the benefits associated with avoiding greenhouse gas emissions through use of recycled materials rather than relying on primary production of resources. The analysis assumes all production of displaced materials is conducted abroad; hence non-UK values are negative in all scenarios.

Figure 7.2 illustrates the information from *Table 7.2*.

Figure 7.2 *PV Cost of Greenhouse Gas Emissions (£m) – Over Lifetime of Measures*



The baseline scenario (scenario 1) is the only option resulting in a positive net volume of carbon emissions when UK and non-UK emissions are combined, therefore incurring an overall societal cost of carbon. Scenarios 2 – 9 all emit greenhouse gases, with subsequent social cost, in the UK. When greenhouse gas emissions are considered across both the UK and non-UK geographies, a net reduction in emissions is apparent due to high levels of greenhouse gas emissions avoided.

7.1.4 Impact on Costs

To consider the full economic, environmental and social cost of pursuing the waste treatment options detailed in Scenarios 1 – 9 the impact of the social cost of carbon emitted / saved must be included to the financial cost of collection and disposal.

Table 7.3 illustrates the total cost of collection and treatment to the UK for each option, with the full impact of greenhouse gas emissions. *Table 7.4* indicates the cost of waste treatment scenarios, incorporating the positive and negative effects of changes in greenhouse gas volumes (both UK and non-UK of greenhouse gas emissions).

Table 7.3 Full Cost of Waste Treatment Scenarios to the UK (Present Value £m)

Period	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Up to 2010	£17,510.5	£18,460.3	£18,466.9	£18,490.4	£18,451.3
Up to 2020	£41,674.1	£47,033.4	£47,370.1	£46,654.9	£47,065.2
Over Lifetime	£79,379.5	£92,594.3	£93,326.3	£90,958.3	£92,269.5

Period	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Up to 2010	£18,485.0	£18,412.8	£18,454.2	£18,772.2
Up to 2020	£47,576.6	£46,056.9	£46,474.0	£47,903.9
Over Lifetime	£94,178.9	£89,666.1	£90,974.8	£94,506.2

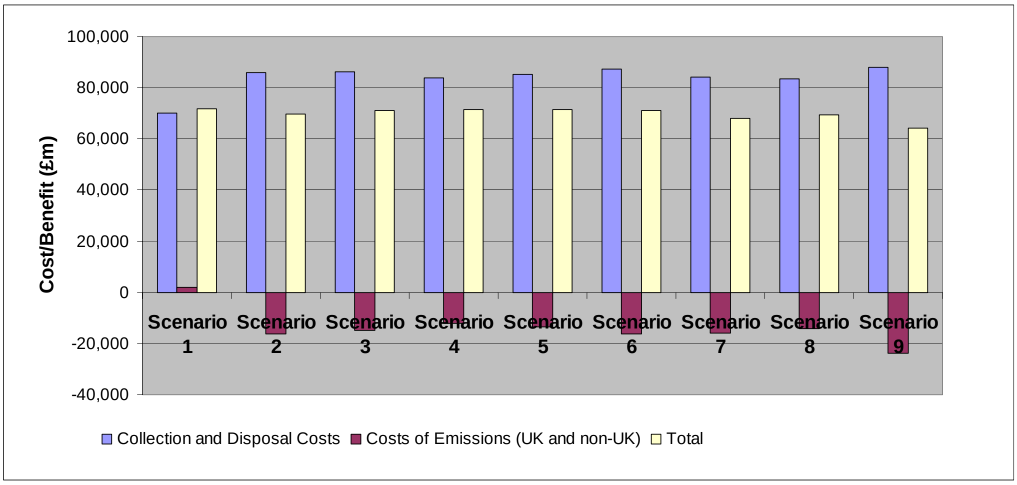
Table 7.4 Full Cost of Waste Treatment Scenarios, UK and non-UK (Present Value £m)

Period	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Up to 2010	£15,401.8	£15,105.7	£15,131.3	£15,229.9	£15,153.7
Up to 2020	£37,865.3	£36,423.3	£37,055.3	£37,774.2	£37,234.0
Over Lifetime	£71,864.3	£69,761.6	£71,061.5	£71,604.9	£71,612.2

Period	Scenario 6	Scenario 7	Scenario 8	Scenario 9
Up to 2010	£15,140.4	£15,094.5	£15,142.8	£14,784.6
Up to 2020	£36,775.8	£35,856.5	£36,312.6	£33,158.0
Over Lifetime	£71,075.7	£68,137.5	£69,307.7	£64,264.4

The treatment, emission and net costs of each waste management scenario over the lifetime of the measures and capturing both UK and non-UK impacts, is illustrated in *Figure 7.3.*

Figure 7.3 Net Present Value of Scenarios, UK and non-UK Impacts (£m)



7.1.5 *Incremental Cost per Tonne of Carbon Avoided*

Adopting a strategy to meet the targets of the EU Landfill Directive will have a subsequent impact on levels of greenhouse gas emissions. *Table 7.5* below indicates the additional waste treatment spending above the reference case per tonne of greenhouse gas (carbon dioxide or equivalent) not emitted.

The values are presented for the lifetime of the measures for the UK (greenhouse gases not emitted) and for the UK and non-UK impacts (capturing the saving of greenhouse gas emission through diverted production).

Table 7.5 Additional Waste Management Cost above Reference Case (Scenario 1) per Tonne GHG Avoided

	Scenario 2	**Scenario 3**	**Scenario 4**	**Scenario 5**	**Scenario 6**	**Scenario 7**	**Scenario 8**	**Scenario 9**
UK	£258	£339	£279	£316	£307	£170	£305	£289
Non UK	£69	£68	£71	£74	£81	£66	£68	£54
Combined	£43	£47	£48	£49	£48	£39	£42	£36

7.1.6 *Cost of Landfill Avoided*

Scenarios 2 through to 9 all involve elements of waste management that assist in diverting material away from landfill sites and thus helping the UK to meet the obligations of the EU Landfill Directive. It is interesting to compare the effectiveness with which these scenarios contribute to landfill diversion. *Table 7.6* indicates the additional cost above the reference case per tonne of waste material not sent to landfill.

Table 7.6 Cost above Baseline per Tonne of Waste Material Diverted from Landfill

Scenarios	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Cost above baseline per tonne landfill diversion	£20.18	£22.29	£21.45	£20.86	£21.83	£17.52	£17.16	£24.20

7.2 *Assessment of C&I Waste Scenarios*

7.2.1 *Introduction*

The format used to assess the impacts of scenarios associated with C&I waste treatment was similar to modelling municipal solid waste. The key difference is in relation to gate fees charged. Generally, contracts with private sector waste contractors for household waste are on a fixed bulk basis. In contrast, private contractors accept C&I waste on a more *ad hoc* basis, thus gate fees associated with C&I waste tend to be higher than those associated with household waste. C&I gate fees have been assumed based on ERM experience. Flexibility is built into the cost model so that any modifications to gate fees can be readily incorporated.

7.2.2 Costs of Collection and Treatment

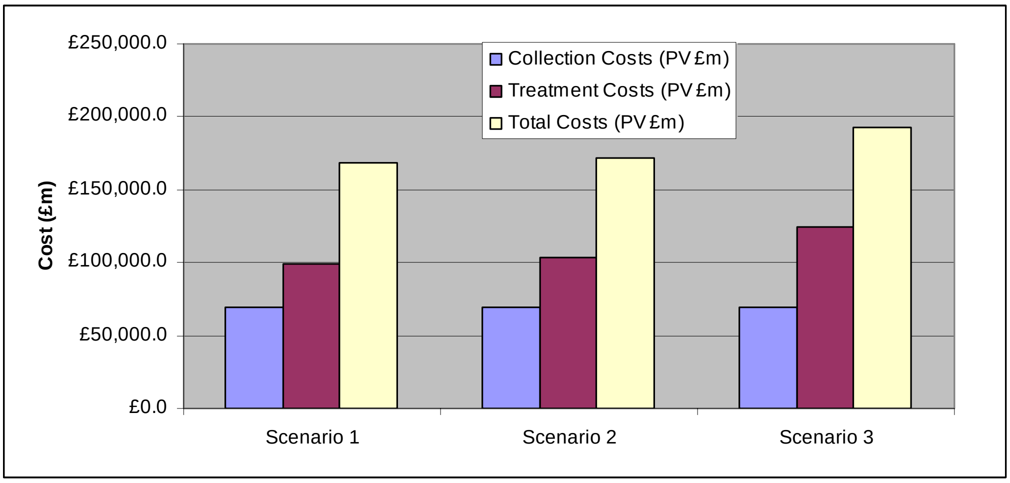
The costs incurred with following the three C&I scenarios are detailed in *Table* 7.7.

Table 7.7 Present Value Costs Associated with C&I Scenarios (£m)

Period	Scenario 1	Scenario 2	Scenario 3
Collection			
up to 2010	£14,344.0	£14,344.0	£14,344.0
up to 2020	£35,737.8	£35,737.8	£35,737.8
Over Lifetime	£68,845.0	£68,845.0	£68,845.0
Treatment			
up to 2010	£20,961.4	£21,471.5	£23,963.0
up to 2020	£51,819.9	£53,866.7	£63,852.3
Over Lifetime	£99,242.3	£103,449.8	£123,976.4
Subtotal (treatment + collection)			
up to 2010	£35,305.4	£35,815.5	£38,306.9
up to 2020	£87,557.7	£89,604.5	£99,590.1
Over Lifetime	£168,087.4	£172,294.8	£192,821.4

Scenario 3, incorporating high levels of EfW, was found to be the most expensive option. This figure is inevitably heavily influenced by the EfW gate fee. The least cost option was found to be the baseline case. *Figure 7.4* below illustrates this cost information.

Figure 7.4 Present Value Costs Associated with C&I Scenarios (£m)



7.2.3 *Costs of Greenhouse Gas Emissions*

As with the modelling of household waste, analyses were conducted to determine the social cost of greenhouse gases associated with the three C&I scenarios. The costs of greenhouse gas emissions associated with the scenarios is presented in terms of the impact on the UK, non-UK and as a combined impact.

Table 7.8 *PV Costs/Benefits of Emissions - C&I Scenarios (£m)*

Period	Scenario 1	Scenario 2	Scenario 3
UK			
up to 2010	£3,076.2	£2,577.0	£2,853.4
up to 2020	£8,448.3	£6,492.8	£6,492.8
Over Lifetime	£17,604.7	£13,341.4	£14,847.1
Non-UK			
up to 2010	-£7,137.3	-£7,574.7	-£7,670.4
up to 2020	-£17,185.6	-£18,588.3	-£19,924.5
Over Lifetime	-£32,176.1	-£34,995.1	-£38,906.8
Combined			
up to 2010	-£4,061.1	-£4,997.7	-£4,817.0
up to 2020	-£8,737.3	-£8,886.7	-£12,563.7
Over Lifetime	-£14,571.3	-£21,698.2	-£24,295.4

The presence of negative numbers indicates the benefits associated with avoiding greenhouse gas emissions through use of recycled materials rather than relying on primary production of resources. The analysis assumes all displacement of materials is attributable abroad; hence non-UK values are negative in all scenarios.

7.2.4 Impact on Costs

To consider the full economic, environmental and social cost of pursuing the waste treatment options detailed in Scenarios 1 – 3 the social cost of carbon saved emitted / saved must be captured by the model. *Table 7.9* below takes into account the social cost of greenhouse gas emissions on the cost of the three C&I scenarios for the UK only.

Table 7.9 *Present Value Total Cost of C&I Scenarios, including Cost of GHG Emissions - UK only (£m)*

Period	Scenario 1	Scenario 2	Scenario 3
up to 2010	£38,381.6	£38,392.5	£41,160.3
up to 2020	£96,006.0	£96,097.3	£106,082.9
Over Lifetime	£185,692.1	£185,636.2	£207,668.5

The impact of savings in carbon emissions through diverted production resources due to recycling can be seen by including the non-UK greenhouse gas 'savings' in *Table 7.10*.

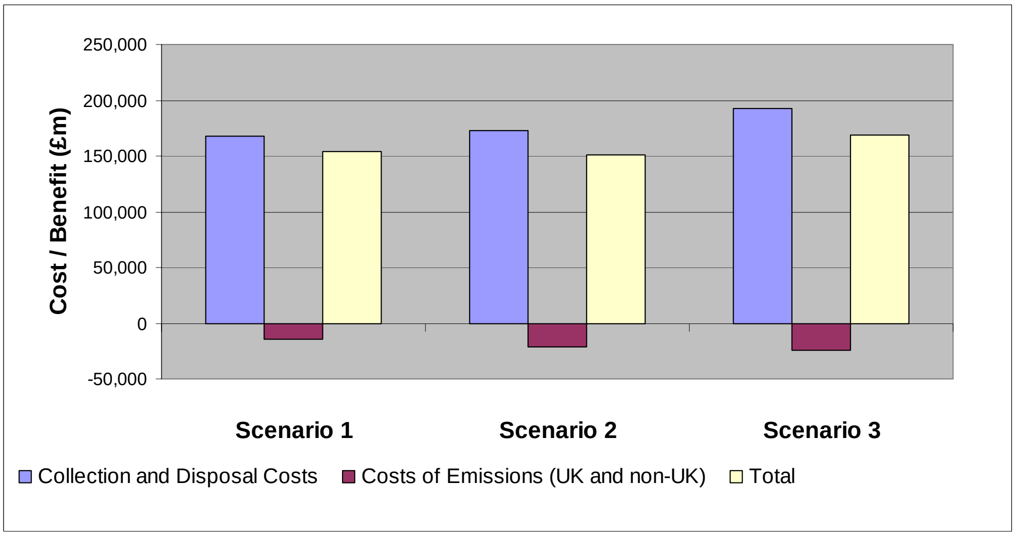
Table 7.10 *Present Value Total Costs of C&I Scenarios, including Costs/Benefits of GHG Emissions – UK and non-UK sources (£m)*

Period	Scenario 1	Scenario 2	Scenario 3
up to 2010	£31,244.4	£30,817.8	£33,489.9
up to 2020	£78,820.4	£80,717.8	£87,026.4
Over Lifetime	£153,516.0	£150,596.7	£168,526.0

The impact of the offsetting of greenhouse gas emissions through non-UK sources considerably reduces the costs associated with the C&I scenarios.

The total cost of each of the C&I scenarios over the appraisal lifetime is split between collection and disposal costs and emission costs as indicated in *Table 7.5*.

Figure 7.5 *C & I Costs over Lifetime of Appraisal*



7.2.5 *Incremental Cost per Tonne of Greenhouse Gas Avoided*

Adopting a C&I strategy to meet the targets of the EU Landfill Directive will have a subsequent impact on levels of greenhouse gas emissions. *Table 7.11* indicates the additional waste treatment spending above the reference case per tonne of greenhouse gas (carbon dioxide or equivalent) avoided.

The values are presented for the lifetime of the measures for the UK (greenhouse gases not emitted) and for the UK and non-UK impacts (capturing the saving of greenhouse gas emission through diverted production).

Table 7.11 Additional Waste Management Cost above Reference Case (Scenario 1) per Tonne GHG Avoided

	Scenario 2	**Scenario 3**
UK	£48	£415
Non UK	£76	£176
Combined	£29	£118

7.2.6 Cost of Landfill Avoided

Scenarios 2 and 3 both involve elements of waste management that assist in diverting material away from landfill sites and thus helping the UK to meet the obligations of the EU Landfill Directive. It is interesting to compare the effectiveness with which these scenarios contribute to landfill diversion. *Table 7.12* indicates the additional cost above the reference case per tonne of waste material diverted from landfill.

Table 7.12 Net Present Cost above Baseline (Scenario 1) per Tonne of Waste Material Diverted from Landfill

Scenarios	**2**	**3**
Cost above baseline per tonne landfill diversion	£3.52	£20.82

8 CONCLUSIONS

The results of the modelling undertaken show that overall scenario greenhouse emission profiles are dominated by the offset benefits attributed to materials recycling and, to a lesser extent, energy recovery. As a result, net greenhouse gas emissions are negative over the study period for the majority of scenarios assessed.

MSW scenarios comprising elevated levels of both recycling and energy recovery (mixed technology scenario, high EfW scenario, high paper and card recycling scenario, high MBT with RDF combustion scenario) show greater net greenhouse gas benefits.

The relative balance in performance between recycling and EfW for C&I waste scenarios shows a shift over time, with recycling favoured in the short term and EfW in the long term. This balance is heavily influenced by assumptions regarding commercial and industrial waste composition, however, for which only relatively poor data exist.

The MSW baseline scenario was the only option resulting in a positive net volume of greenhouse gas emissions over the study period; and accordingly incurred an overall societal cost of carbon. The benefit of offsetting greenhouse gas emissions through energy recovery and materials recycling considerably reduced the external costs of all other scenarios.

Key areas that were identified with regard to results sensitivity include:

- waste growth and compositional assumptions;
- choices made as to modelled marginal electricity mix; and
- the position of recycling offset benefits within UK/non-UK system boundaries.

Annex A

Waste Treatment Process Modelling Assumptions

A1 *INTRODUCTION*

Alternative waste management scenarios were quantitatively assessed using a series of linked spreadsheets, combining the quantities and composition of arising waste streams, the management routes they are assumed to follow, and greenhouse gas emission factors for the activities involved in their management.

This A*nnex* details the data and sources used to calculate and model emission factors for waste treatment processes, energy production and use, recycling operations and transport.

Greenhouse gas emission factors have been derived and applied for each activity in a waste management route life cycle and, where appropriate, according to waste fraction, eg paper / plastic / textiles. This enables account to be taken of changes in residual waste composition as materials are separated from the waste stream for recycling and composting. Similarly, compositional changes following pre-treatment processes, such as MBT were accounted for.

Emission factors describe not only greenhouse gas impacts, but also the offset benefits of energy recovery and materials recycling. For every kWh of electricity generated through waste treatment, an emission factor (EF) for generating each kWh of electricity from gas was used to quantify the greenhouse gas savings. Similarly, for every tonne of material sent to recycling, EFs describing the production of a tonne of that material from virgin material was used to calculate the potential savings in greenhouse gas emissions from recycling.

EFs for waste management activities were calculated using a series of steps:

1. Resource EFs (greenhouse gas emissions per tonne of diesel produced, per kWh of electricity generated, per tonne of virgin material displaced through recycling, per tonne-kilometre of waste transported, etc) were sourced from published life cycle inventory databases. Data sources for these EFs are presented in *Section A2*.
2. The resource inputs (tonnes of diesel, kWh of electricity, tonne-kilometres of residues transported, etc), useful outputs (tonnes of material separated for recycling, kWh electricity recovered, etc) and direct greenhouse gas emissions associated with the management of one tonne of waste were determined for each treatment process (MRF, composting, EfW, MBT, etc). Data and sources for these inputs and outputs are presented in *Section A3*.
3. Direct process emissions and those associated with resource consumption / material recycling / energy recovery were combined to give a total greenhouse gas EF for each treatment process. These factors are presented in *Error! Reference source not found.* of the main report.

The main sources of data for greenhouse gas EFs were the Environment Agency (EA) work on updating their life cycle assessment tool (WISARD) and life cycle inventories for material production and energy generation systems produced by Ecoinvent [1]. Ecoinvent is a state-of-the art, peer-reviewed database, containing life cycle inventory data for over 2500 processes in the energy, transport, building materials, chemicals, paper/board, agriculture and waste management sectors. Data relate predominantly to Western European process technologies.

The following sources were drawn upon for guidance and data in support of the work;

- *Impact of EU Landfill Directive and National Strategies on UK Greenhouse Gas Emissions*, Defra/ERM, March 2004;
- *Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes*, Defra/Enviros, May 2004;
- the Environment Agency (EA) work on updating their Life Cycle Assessment tool (WISARD);
- WRAP executive summaries from LCA review work (the work was incomplete at time of writing and of limited use in summary form);
- work currently underway for Defra by Golder Associates on methane emissions from landfill;
- the common basis for appraisal of future policies in the context of the CCPR, in line with HMT Green Book methodology; and
- other relevant work on greenhouse gas emissions including the energy projections developed by the Department of Trade and Industry (DTI) and the UK Greenhouse Gas Inventory (produced annually under contract to Defra by AEAT to meet legal reporting requirements to the EU and the United Nations Framework Convention on Climate Change).

(1) http://ecoinvent.ch/

A2 RESOURCE EMISSION FACTORS

A2.1 ELECTRICITY AND FUEL PRODUCTION AND USE

A2.1.1 Diesel

Data relating to diesel production were sourced from SimaPro: *"Diesel, low-sulphur, at regional storage/RER S"*. Data relating to diesel combustion were sourced from the UK Greenhouse Gas Inventory (1990-2003).

A2.1.2 Electricity

EFs for electricity generation have been generated by ERM and take into account DTI's latest projected electricity mix for UK 2005-2020. The projected electricity mix for 2020 has been used to generate estimates for 2025-2045.

Data for fuel production and electricity generation were sourced from Ecoinvent, version 1.1.

A2.1.3 Marginal electricity

The UK marginal electricity mix for 2005-2045 is assumed to consist of 100 % gas (CCGT).

Data for the electricity fuel production and electricity generation were sourced from Ecoinvent, version 1.1.

A2.2 RECYCLING OPERATIONS

A greenhouse gas benefit has been attributed to the displacement of materials through recycling.

A2.2.1 Paper and card

Collected paper and card is assumed to replace the input of mechanical pulp to paper production when recycled (assuming a process input of 75% collected paper, and 25% virgin fibre). The offset was calculated using data for pulp production from Ecoinvent, version 1.1 (*"Thermo-mechanical pulp, at plant/RER).*

A2.2.2 Textiles

Collected textiles are assumed to consist of both natural and synthetic fibres, and both data for the production of cotton and polyester have been used to calculate the offset, assuming a 50/50 split.

Data for the production of cotton were sourced from Aumônier and Collins (2005) [1], and data for production of polyester were sourced from Ecoinvent, version 1.1 *("Polyethylene terephthalate, granulate, amorphous, at plant/RER S").*

A2.2.3 Ferrous Metals

Data for the recycling of ferrous metals, including offsets, were sourced from Ecoinvent, version 1.1 (*"Recycling steel and iron/RER U"*).

A2.2.4 Non-ferrous Metals

Data for the recycling of non-ferrous metals, including offsets, were sourced from Ecoinvent, version 1.1 (*"Recycling aluminium/RER S"*).

A2.2.5 Glass

Data for the recycling of glass, including offsets, were sourced from Ecoinvent, version 1.1 (*Recycling glass/RER S"*).

A2.2.6 Plastic, dense

Data for the recycling of dense plastic, including offsets, were sourced from Ecoinvent, version 1.1 (*"Recycling PET/RER S"*).

A2.2.7 Plastic, film

Data for the recycling of plastic film, including offsets, were sourced from Ecoinvent, version 1.1 (*"Recycling PE/RER S"*).

A2.2.8 Miscellaneous Non-Combustible

Miscellaneous non-combustible material was assumed to replace the mining of gravel. Data were sourced from Ecoinvent, version 1.1 (*"Gravel, unspecified, at mine/CH S"*).

A2.2.9 Compost

Compost production is assumed to replace the mining of peat. Data for peat production were sourced from Ecoinvent, version 1.1 (*"Peat, at mine/NORDEL U"*).

A2.3 TRANSPORT

A2.3.1 Refuse Collection Vehicle (RCV)

Data used for the operation of refuse collection vehicles, used to transport waste from households to transfer station / MRF were sourced from Ecoinvent, version 1.1.

(1) Aumônier S, and Collins M W, May 2005, Life Cycle Assessment of Disposable and Reusable Nappies in the UK, Environment Agency, ISBN: 1-84-432427-3

A2.3.2 Bulk transport

Data used for the operation of bulk transport vehicles, used to transport recyclables from MRF to reprocessor and residual waste to treatment facilities, were sourced from Ecoinvent, version 1.1 (*40-tonne truck*).

A3 WASTE TREATMENT PROCESSES

A3.1 TRANSFER STATION

Data for the fuel and electricity requirements to process waste via transfer stations were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of their development of a waste management life cycle assessment tool (currently referred to as WRATE). Inputs and outputs per tonne of waste processed are presented in *Table 3.1*.

Table 3.1 Input/Output for Transfer Station (per tonne of waste treated)

Flow	Quantity	Unit	Direct UK impact	Non-UK impact
Inputs				
Diesel	0.32	kg	Combustion	Production
Electricity	1.94	kWh	Generation and distribution	Fuel production

Source: ERM & Environment Agency Data (2003-2005) - *Transfer Station (road) - with compaction*

A3.2 MATERIAL RECOVERY FACILITY (MRF)

Data for the fuel and electricity requirements to process waste via MRFs were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of the development of WRATE. Inputs and outputs per tonne of waste processed are presented in *Table 3.2*.

Table 3.2 Input/Output for MRF (per tonne of waste treated)

Flow	Quantity	Unit	Direct UK impact	Non-UK impact
Inputs				
Diesel	0.931	kg	Combustion	Production
Electricity	22.8	kWh	Generation and distribution	Fuel production

Source: ERM & Environment Agency Data (2003-2005) - *Mechanical Semi-Automated MRF*

A3.3 ENERGY FROM WASTE

Data for the inputs and outputs associated with the combustion of waste via EfW were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of the development of WRATE. Inputs and outputs per tonne of waste processed are presented in

Table 3.3. Process emissions of carbon dioxide are based on the fossil carbon content of the waste stream (*Annex D*). The electricity generation is related to the calorific value of the waste stream (*Annex D*).

Table 3.3 Input/Output for EfW (per tonne of waste treated)

Flow	**Quantity**	**Unit**	**Direct UK impact**	**Non-UK impact**
Inputs				
Diesel	0.118	kg	Combustion	Production
Electricity	3.91	kWh	Generation and distribution	Fuel production
Process emissions				
$CO_{2,\ fossil}$ (Textiles)	731	kg	Process emission	-
$CO_{2,\ fossil}$ (Fines)	252	kg	Process emission	-
$CO_{2,\ fossil}$ (Misc combustibles)	704	kg	Process emission	-
$CO_{2,\ fossil}$ (Misc non-combustibles)	128	kg	Process emission	-
$CO_{2,\ fossil}$ (Plastic, dense)	2010	kg	Process emission	-
$CO_{2,\ fossil}$ (Plastic film)	1753	kg	Process emission	-
Outputs				
Bottom ash	290	kg	-	-
Fly ash	32.3	kg	-	-
Electricity (Paper and card)	857	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Kitchen waste)	280	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Garden waste)	280	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Textiles)	1117	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Fines)	271	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. Combustible)	1096	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. Non-combustibles)	200	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Ferrous)	0	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Non ferrous)	0	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Glass)	111	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Plastic, dense)	1938	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Plastic film)	1658	kWh	Offset marginal generation	Offset marginal fuel production

Source: ERM & Environment Agency Data (2003-2005) - *Mass Burn - New Moving Grate*

A3.4 GASIFICATION

Data for the inputs and outputs associated with the treatment of waste via gasification were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of the development of WRATE. Inputs and outputs per tonne of waste processed are presented in *Table 3.4*. Process emissions of carbon dioxide are based on the fossil carbon content of the waste stream (*Annex D*). The electricity generation is related to the calorific value of the waste stream (*Annex D*).

Table 3.4 Input/Output for Gasification (per tonne of waste treated).

Flow	**Quantity**	**Unit**	**Direct UK impact**	**Non-UK impact**
Inputs				
Diesel	2.41	kg	Combustion	Production
Electricity	97.5	kWh	Generation and distribution	Fuel production
Process emissions				
$CO_{2, fossil}$ (Textiles)	731	kg	Process emission	-
$CO_{2, fossil}$ (Fines)	252	kg	Process emission	-
$CO_{2, fossil}$ (Misc combustibles)	704	kg	Process emission	-
$CO_{2, fossil}$ (Misc non-combustibles)	128	kg	Process emission	-
$CO_{2, fossil}$ (Plastic, dense)	2010	kg	Process emission	-
$CO_{2, fossil}$ (Plastic film)	1753	kg	Process emission	-
Outputs				
Bottom ash	156	kg	-	-
Fly ash	34.3	kg	-	-
Electricity (Paper and card)	908	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Kitchen waste)	296	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Garden waste)	296	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Textiles)	1183	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Fines)	287	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. Combustible)	1161	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. Non-combustibles)	212	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Ferrous)	0	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Non ferrous)	0	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Glass)	117	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Plastic, dense)	2053	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Plastic film)	1756	kWh	Offset marginal generation	Offset marginal fuel production

Source: ERM & Environment Agency Data (2003-2005) - *Gasification*

A3.5 *ANAEROBIC DIGESTION*

Data for the inputs and outputs associated with the treatment of waste via anaerobic digestion were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of the development of WRATE. Inputs and outputs per tonne of waste processed are presented in *Table 3.5*. Data for mining of peat have been used to calculate the greenhouse gas offset from the generated compost.

Table 3.5 Input/Output for Anaerobic Digestion (per tonne of waste treated).

Flow	Quantity	Unit	Direct UK impact	Non-UK impact
Inputs				
Diesel	1.30	kg	Combustion	Production
Electricity	20.6	kWh	Generation and distribution	Fuel production
Process emissions				
CH_4	0.0213	kg	Process emission	-
N_2O	0.0115	kg	Process emission	-
Outputs				
Electricity	26.7	kWh	Offset marginal generation	Offset marginal fuel production
Compost	241	kg	-	Offset peat production

Source: ERM & Environment Agency Data (2003-2005) - *High solids system*

A3.6 *WINDROW COMPOSTING*

Data for the inputs and outputs associated with the treatment of waste via windrow composting were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of the development of WRATE. Inputs and outputs per tonne of waste processed are presented in *Table 3.6*. Data for mining of peat have been used to calculate the greenhouse gas offset from the generated compost.

Table 3.6 Input/Output for Windrow Composting (per tonne of waste treated).

Flow	**Quantity**	**Unit**	**Direct UK impact**	**Non-UK impact**
Inputs				
Diesel	3.07	kg	Combustion	Production
Electricity	0.509	kWh	Generation and distribution	Fuel production
Process emissions				
CH_4	0.0303	kg	Process emission	-
N_2O	0.0165	kg	Process emission	-
Outputs				
Compost	294	kg	-	Offset peat production

Source: ERM & Environment Agency Data (2003-2005) - *Open - Air Windrow Composting*

A3.7 *In-Vessel Composting*

Data for the inputs and outputs associated with the treatment of waste via in-vessel composting were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of the development of WRATE. Inputs and outputs per tonne of waste processed are presented in *Table 3.7*. Data for mining of peat have been used to calculate the greenhouse gas offset from the generated compost.

Table 3.7 Input/Output for In-Vessel Composting (per tonne of waste treated).

Flow	**Quantity**	**Unit**	**Direct UK impact**	**Non-UK impact**
Inputs				
Diesel	2.99	kg	Process emission	-
Electricity	9.00	kWh	Process emission	-
Process emissions				
CH_4	0.0178	kg	-	Offset peat production
N_2O	0.00989	kg	Process emission	-
Outputs			Process emission	-
Compost	500	kg		

Source: ERM & Environment Agency Data (2003-2005) - *In-Vessel Batch Mobile with Enclosed Windrow Composting*

A3.8 *MBT with RDF combustion*

Data for the inputs and outputs associated with the treatment of waste via MBT with RDF combustion were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of the development of WRATE. Inputs and outputs per tonne of waste processed are presented in *Table 3.8*. RDF combustion emission data were adjusted to reflect split the between stabilised waste and RDF.

Process emissions of carbon dioxide are based on the fossil carbon content of the waste stream (*Annex D*). Emissions of methane include emissions through combustion and emissions from landfilling of stabilised waste (see *Annex B* for calculations and *Annex D* for carbon content assumptions).

Table 3.8 Input/Output for MBT with RDF combustion (per tonne of waste treated).

Flow	Quantity	Unit	Direct UK impact	Non-UK impact
Inputs				
Diesel	0.80	kg	Combustion	Production
Electricity	80	kWh	Generation and distribution	Fuel production
Process emissions				
$CO_{2,\ fossil}$ (Textiles)	560	kg	Process emission	-
$CO_{2,\ fossil}$ (Fines)	193	kg	Process emission	-
$CO_{2,\ fossil}$ (Misc. combustibles)	539	kg	Process emission	-
$CO_{2,\ fossil}$ (Misc. non-combustibles)	98	kg	Process emission	-
$CO_{2,\ fossil}$ (Plastic, dense)	1539	kg	Process emission	-
$CO_{2,\ fossil}$ (Plastic film)	1328	kg	Process emission	-
CH_4 (Paper and card)	1.03	kg	Process emission	-
CH_4 (Kitchen waste)	0.467	kg	Process emission	-
CH_4 (Garden waste)	0.467	kg	Process emission	-
CH_4 (Textiles)	0.653	kg	Process emission	-
CH_4 (Fines)	0.237	kg	Process emission	-
CH_4 (Misc combustibles)	0.630	kg	Process emission	-
CH_4 (Misc. Non-combustibles)	0.129	kg	Process emission	-
CH_4 (Ferrous)	0.0178	kg	Process emission	-
CH_4 (Non ferrous)	0.0178	kg	Process emission	-
CH_4 (Glass)	0.0267	kg	Process emission	-
CH_4 (Plastic, dense)	0.0178	kg	Process emission	-
CH_4 (Plastic film)	0.0178	kg	Process emission	-
N_2O (Paper and card)	0.0135	kg	Process emission	-
N_2O (Kitchen waste)	0.0135	kg	Process emission	-
N_2O (Garden waste)	0.0135	kg	Process emission	-
N_2O (Textiles)	0.0135	kg	Process emission	-
N_2O (Fines)	0.0135	kg	Process emission	-
N_2O (Misc combustibles)	0.0135	kg	Process emission	-
N_2O (Misc. Non-combustibles)	0.0135	kg	Process emission	-

Flow	Quantity	Unit	Direct UK impact	Non-UK impact
N_2O (Ferrous)	0.00989	kg	Process emission	-
N_2O (Non ferrous)	0.00989	kg	Process emission	-
N_2O (Glass)	0.0135	kg	Process emission	-
N_2O (Plastic, dense)	0.0135	kg	Process emission	-
N_2O (Plastic film)	0.0135	kg	Process emission	-
Outputs				
Stabilised waste	153	kg	Landfill emissions	
Electricity (Paper and card)	884	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Kitchen waste)	290	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Garden waste)	290	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Textiles)	1143	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Fines)	278	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. Combustible)	1122	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. Non-combustibles)	205	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Ferrous)	0	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Non ferrous)	0	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Glass)	113	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Plastic, dense)	1970	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Plastic film)	1686	kWh	Offset marginal generation	Offset marginal fuel production

Source: ERM & Environment Agency Data (2003-2005) - *MBT Dry Stabilisation*

A3.9 MBT with Stabilisation

Data for the inputs and outputs associated with the treatment of waste via MBT with stabilisation for landfill were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of the development of WRATE. Inputs and outputs per tonne of waste processed are presented in *Table 3.9*.

Process emissions of methane are based on the biogenic carbon content of the waste stream, assuming 75 % stabilisation rate (see *Annex B* for calculations and *Annex D* for carbon content assumptions). Electricity generation from the process arises through the degradation of stabilised waste on landfill (75% is assumed to be inert and the remaining 25% biodegradable, generating methane, of which 37.5% is captured).

Table 3.9 Input/Output for MBT with Stabilisation (per tonne of waste treated).

Flow	Quantity	Unit	Direct UK impact	Non-UK impact
Inputs				
Diesel	0.80	kg	Combustion	Production
Electricity	80	kWh	Generation and distribution	Fuel production
Process emissions				
N_2O	0.00989	kg	Process emission	-
CH_4 (Paper and card)	4.36	kg	Process emission	-
CH_4 (Kitchen waste)	1.93	kg	Process emission	-
CH_4 (Garden waste)	1.93	kg	Process emission	-
CH_4 (Textiles)	2.73	kg	Process emission	-
CH_4 (Fines)	0.954	kg	Process emission	-
CH_4 (Misc. combustibles)	2.63	kg	Process emission	-
CH_4 (Misc. Non-combustibles)	0.494	kg	Process emission	-
CH_4 (Ferrous)	0.0178	kg	Process emission	-
CH_4 (Non ferrous)	0.0178	kg	Process emission	-
CH_4 (Glass)	0.0491	kg	Process emission	-
CH_4 (Plastic, dense)	0.0178	kg	Process emission	-
CH_4 (Plastic film)	0.0178	kg	Process emission	-
Outputs				
Stabilised waste	653	kg	Landfill emissions	
Electricity (Paper and card)	52.3	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Kitchen waste)	23.1	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Garden waste)	23.1	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Textiles)	32.7	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Fines)	11.3	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Glass)	0.46	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. Non-combustible)	5.7	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. Combustible)	31.5	kWh	Offset marginal generation	Offset marginal fuel production

Source: ERM & Environment Agency Data (2003-2005) - *MBT Dry Stabilisation*

A3.10 *LANDFILL*

Data for the inputs and outputs associated with the landfilling of waste were generated using data the Environment Agency have collected (2003-2005) for waste management processes in support of the development of WRATE. Inputs and outputs per tonne of waste processed are presented in *Table 3.10*.

Process emissions of methane and energy outputs are based on the biogenic carbon content of the waste stream (see *Annex B* for calculations and *Annex D* for carbon content assumptions). Emissions of nitrous oxide from flaring of the landfill gas are sourced from UK Greenhouse Gas Inventory (1990-2003).

Table 3.10 Input/Output for Landfill (per tonne of waste treated).

Flow	**Quantity**	**Unit**	**Direct UK impact**	**Non-UK impact**
Inputs				
Diesel	0.904	kg	Combustion	Production
Process emissions		kg		
N_2O	0.000189	kg	Process emission	-
CH_4 (Paper and card)	17.4	kg	Process emission	-
CH_4 (Kitchen waste)	7.68	kg	Process emission	-
CH_4 (Garden waste)	7.68	kg	Process emission	-
CH_4 (Textiles)	10.9	kg	Process emission	-
CH_4 (Fines)	3.75	kg	Process emission	-
CH_4 (Glass)	0.18	kg	Process emission	-
CH_4 (Misc non-combustibles)	1.9	kg	Process emission	-
CH_4 (Misc combustibles)	10.5	kg	Process emission	-
Outputs				
Electricity (Paper)	209	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Kitchen waste)	92.5	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Garden waste)	92.5	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Textiles)	131	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Fines)	45.2	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Glass)	1.5	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. non-combustible)	23	kWh	Offset marginal generation	Offset marginal fuel production
Electricity (Misc. combustibles)	126	kWh	Offset marginal generation	Offset marginal fuel production

Source: ERM & Environment Agency Data (2003-2005) - *Transfer Station (road) - with compaction*

Annex B

Methane Emissions from Landfill: Calculations

Methane emissions from landfill:			Reference:
	145	m3 landfill gas / tonne MSW	Golder (2005)
	50%	methane in landfill gas	Golder (2005)
	72.5	m3 methane / tonne MSW	Golder (2005)
Density methane:	0.71	kg / m3	Technical data
	51.5	kg methane / tonne MSW	Calculated
	214.6	kg C / tonne MSW	ERM & Environment Agency Data (2003-2005)
	66%	biogenic C / tonne MSW	ERM & Environment Agency Data (2003-2005)
	141.6	kg biogenic C / tonne MSW	ERM & Environment Agency Data (2003-2005)
	0.36	kg methane / kg biogenic C	Calculated
Heat value CH4:	35.2	MJ / m3	Technical data

Methane emissions and generated electricity per waste fraction:		Biogenic Carbon (%) (Annex C)	kg methane produced / kg waste	Lost to atmosphere (15%) (kg / kg)	Lost to atmosphere (15%) (kg CH4 / tonne waste)	Burnt in power plant (37.5%) (kg / kg)	Generated electricity (MJ / kg waste) (Efficiency power plant: 0.35)	Generated electricity (kWh / kg waste)	Generated electricity (kWh / tonne waste)
	Paper / Card	32%	0.116	0.017	17.4	0.043	0.75	0.21	209
	Kitchen Waste	14%	0.051	0.008	7.68	0.019	0.33	0.09	92.5
	Garden Waste	14%	0.051	0.008	7.68	0.019	0.33	0.09	92.5
	Textiles	19.9%	0.072	0.011	10.9	0.027	0.47	0.13	131
	Fines	6.88%	0.025	0.004	3.75	0.009	0.16	0.05	45.2
	Misc. Combustible	19.2%	0.070	0.010	10.5	0.026	0.45	0.13	126
	Misc. Non-Combustible	3.5%	0.013	0.002	1.9	0.005	0.08	0.02	23.0
	Ferrous Metals	0%							0
	Non-Ferrous Metals	0%							0
	Glass	0.28%	0.001	0.0002	0.15	0.0004	0.007	0.002	1.8
	Plastic Dense	0%							0
	Plastic Film	0%							0
	Stabilised waste	3.6%	0.013	0.002	2.0	0.005	0.085	0.024	23.6

Methane emissions from stabilised waste:

	kg methane produced/kg stabilised waste (75% stabilisation)	Lost to atmosphere (15%) (kg/kg)	Lost to atmosphere (15%) (kg CH4/tonne waste)	Burnt in power plant (37.5%) (kg/kg)	Generated electricity (MJ/kg waste) (Efficiency power plant: 0.35)	Generated electricity (kWh/kg waste)	Generated electricity (kWh/tonne waste)
Paper/Card	0.029	0.004	4.34	0.011	0.188	0.0523	52.3
Kitchen Waste	0.013	0.002	1.92	0.005	0.083	0.0231	23.1
Garden Waste	0.013	0.002	1.92	0.005	0.083	0.0231	23.1
Textiles	0.018	0.003	2.72	0.007	0.118	0.0327	32.7
Fines	0.006	0.001	0.94	0.002	0.041	0.0113	11.3
Misc. Combustible	0.017	0.003	2.62	0.007	0.114	0.0315	31.5
Misc. Non-Combustible	0.0032	0.0005	0.48	0.001	0.021	0.0057	5.7
Ferrous Metals							
Non-Ferrous Metals							
Glass	0.0003	0.00004	0.04	0.0001	0.002	0.0005	0.46
Plastic Dense							
Plastic Film							
Stabilised waste	0.003	0.0005	0.49	0.001	0.021	0.0059	5.91

Annex C

Scenario Results: 'Basket of Six' Greenhouse Gas Emissions

C1 SCENARIO RESULTS: 'BASKET OF SIX' GREENHOUSE GAS EMISSIONS

This *Annex* presents scenario greenhouse gas emissions, quantified for each of the 'basket of six' greenhouse gases serving as an indicator of climate change:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- hydrofluorocarbons (HFCs);
- perfluorocarbons (PFCs); and
- sulphur hexafluoride (SF_6).

C1.1 MSW SCENARIO GREENHOUSE GAS EMISSIONS

C1.1.1 Scenario 1 – Baseline (2003/-04) Recycling and EfW Capacity

Table 1.1 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-691	'000 tonnes
Methane	211	'000 tonnes
Nitrous Oxide	-0.000184	'000 tonnes
PFCs	0.382	'000 tonnes CO_2 eq
HFCs & CFC	-0.00649	'000 tonnes CO_2 eq
SF_6	-0.000799	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-3971	'000 tonnes
Methane	-7.14	'000 tonnes
Nitrous Oxide	-0.144	'000 tonnes
PFCs	-0.0569	'000 tonnes CO_2 eq
HFCs & CFC	-290	'000 tonnes CO_2 eq
SF_6	-0.0120	'000 tonnes

Table 1.2 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-779	'000 tonnes
Methane	229	'000 tonnes
Nitrous Oxide	-0.00241	'000 tonnes
PFCs	0.399	'000 tonnes CO_2 eq
HFCs & CFC	-0.00677	'000 tonnes CO_2 eq
SF_6	-0.000837	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-3973	'000 tonnes
Methane	-7.18	'000 tonnes
Nitrous Oxide	-0.144	'000 tonnes
PFCs	-0.0563	'000 tonnes CO_2 eq
HFCs & CFC	-291	'000 tonnes CO_2 eq
SF_6	-0.0122	'000 tonnes

Table 1.3 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-851	'000 tonnes
Methane	245	'000 tonnes
Nitrous Oxide	-0.00410	'000 tonnes
PFCs	0.416	'000 tonnes CO_2 eq
HFCs & CFC	0.00823	'000 tonnes CO_2 eq
SF_6	-0.000871	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-3974	'000 tonnes
Methane	-7.20	'000 tonnes
Nitrous Oxide	-0.144	'000 tonnes
PFCs	-0.0558	'000 tonnes CO_2 eq
HFCs & CFC	-292	'000 tonnes CO_2 eq
SF_6	-0.0124	'000 tonnes

Table 1.4 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-915	‘000 tonnes
Methane	259	‘000 tonnes
Nitrous Oxide	-0.00596	‘000 tonnes
PFCs	0.431	‘000 tonnes CO_2 eq
HFCs & CFC	0.00776	‘000 tonnes CO_2 eq
SF_6	-0.000902	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-3975	‘000 tonnes
Methane	-7.24	‘000 tonnes
Nitrous Oxide	-0.144	‘000 tonnes
PFCs	-0.0555	‘000 tonnes CO_2 eq
HFCs & CFC	-293	‘000 tonnes CO_2 eq
SF_6	-0.0125	‘000 tonnes

Table 1.5 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-1013	‘000 tonnes
Methane	280	‘000 tonnes
Nitrous Oxide	-0.00832	‘000 tonnes
PFCs	0.453	‘000 tonnes CO_2 eq
HFCs & CFC	0.00779	‘000 tonnes CO_2 eq
SF_6	-0.000949	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-3976	‘000 tonnes
Methane	-7.22	‘000 tonnes
Nitrous Oxide	-0.144	‘000 tonnes
PFCs	-0.0548	‘000 tonnes CO_2 eq
HFCs & CFC	-294	‘000 tonnes CO_2 eq
SF_6	-0.0127	‘000 tonnes

Table 1.6 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-1063	'000 tonnes
Methane	291	'000 tonnes
Nitrous Oxide	-0.00953	'000 tonnes
PFCs	0.464	'000 tonnes CO_2 eq
HFCs & CFC	0.00781	'000 tonnes CO_2 eq
SF_6	-0.000973	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-3975	'000 tonnes
Methane	-7.21	'000 tonnes
Nitrous Oxide	-0.144	'000 tonnes
PFCs	-0.0545	'000 tonnes CO_2 eq
HFCs & CFC	-294	'000 tonnes CO_2 eq
SF_6	-0.0128	'000 tonnes

C1.1.2 Scenario 2 – High EfW

Table 1.7 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-510	'000 tonnes
Methane	192	'000 tonnes
Nitrous Oxide	0.0161	'000 tonnes
PFCs	0.411	'000 tonnes CO_2 eq
HFCs & CFC	-0.00616	'000 tonnes CO_2 eq
SF_6	-0.000762	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-5328	'000 tonnes
Methane	-9.66	'000 tonnes
Nitrous Oxide	-0.194	'000 tonnes
PFCs	-0.0787	'000 tonnes CO_2 eq
HFCs & CFC	-378	'000 tonnes CO_2 eq
SF_6	-0.0107	'000 tonnes

Table 1.8 2010

Emission	**Value**	**Unit**
Direct UK		
Carbon Dioxide Fossil	-176	‘000 tonnes
Methane	169	‘000 tonnes
Nitrous Oxide	0.0217	‘000 tonnes
PFCs	0.467	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00863	‘000 tonnes CO_2 eq
SF_6	-0.00106	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-6814	‘000 tonnes
Methane	-12.5	‘000 tonnes
Nitrous Oxide	-0.248	‘000 tonnes
PFCs	-0.101	‘000 tonnes CO_2 eq
HFCs & CFC	-481	‘000 tonnes CO_2 eq
SF_6	-0.0177	‘000 tonnes

Table 1.9 2015

Emission	**Value**	**Unit**
Direct UK		
Carbon Dioxide Fossil	761	‘000 tonnes
Methane	102	‘000 tonnes
Nitrous Oxide	0.010	‘000 tonnes
PFCs	0.533	‘000 tonnes CO_2 eq
HFCs & CFC	0.0103	‘000 tonnes CO_2 eq
SF_6	-0.00204	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8019	‘000 tonnes
Methane	-15.0	‘000 tonnes
Nitrous Oxide	-0.290	‘000 tonnes
PFCs	-0.114	‘000 tonnes CO_2 eq
HFCs & CFC	-568	‘000 tonnes CO_2 eq
SF_6	-0.0394	‘000 tonnes

Table 1.10 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1161	'000 tonnes
Methane	77.4	'000 tonnes
Nitrous Oxide	0.00200	'000 tonnes
PFCs	0.567	'000 tonnes CO_2 eq
HFCs & CFC	0.00755	'000 tonnes CO_2 eq
SF_6	-0.00254	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8461	'000 tonnes
Methane	-16.0	'000 tonnes
Nitrous Oxide	-0.305	'000 tonnes
PFCs	-0.119	'000 tonnes CO_2 eq
HFCs & CFC	-604	'000 tonnes CO_2 eq
SF_6	-0.0510	'000 tonnes

Table 1.11 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1116	'000 tonnes
Methane	92.2	'000 tonnes
Nitrous Oxide	0.00485	'000 tonnes
PFCs	0.601	'000 tonnes CO_2 eq
HFCs & CFC	0.00882	'000 tonnes CO_2 eq
SF_6	-0.00257	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8985	'000 tonnes
Methane	-17.0	'000 tonnes
Nitrous Oxide	-0.324	'000 tonnes
PFCs	-0.127	'000 tonnes CO_2 eq
HFCs & CFC	-640	'000 tonnes CO_2 eq
SF_6	-0.0511	'000 tonnes

Table 1.12 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1093	‘000 tonnes
Methane	99.8	‘000 tonnes
Nitrous Oxide	0.00630	‘000 tonnes
PFCs	0.618	‘000 tonnes CO_2 eq
HFCs & CFC	0.00946	‘000 tonnes CO_2 eq
SF_6	-0.00259	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9253	‘000 tonnes
Methane	-17.4	‘000 tonnes
Nitrous Oxide	-0.334	‘000 tonnes
PFCs	-0.131	‘000 tonnes CO_2 eq
HFCs & CFC	-658	‘000 tonnes CO_2 eq
SF_6	-0.0511	‘000 tonnes

C1.1.3 Scenario 3 – High Paper and Card Recycling

Table 1.13 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-510	‘000 tonnes
Methane	192	‘000 tonnes
Nitrous Oxide	0.0161	‘000 tonnes
PFCs	0.411	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00616	‘000 tonnes CO_2 eq
SF_6	-0.000762	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-5328	‘000 tonnes
Methane	-9.66	‘000 tonnes
Nitrous Oxide	-0.194	‘000 tonnes
PFCs	-0.0787	‘000 tonnes CO_2 eq
HFCs & CFC	-378	‘000 tonnes CO_2 eq
SF_6	-0.0107	‘000 tonnes

Table 1.14 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-193	'000 tonnes
Methane	170	'000 tonnes
Nitrous Oxide	0.0305	'000 tonnes
PFCs	0.469	'000 tonnes CO_2 eq
HFCs & CFC	-0.00751	'000 tonnes CO_2 eq
SF_6	-0.000930	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-6896	'000 tonnes
Methane	-12.7	'000 tonnes
Nitrous Oxide	-0.254	'000 tonnes
PFCs	-0.120	'000 tonnes CO_2 eq
HFCs & CFC	-477	'000 tonnes CO_2 eq
SF_6	-0.0148	'000 tonnes

Table 1.15 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	907	'000 tonnes
Methane	105	'000 tonnes
Nitrous Oxide	0.0424	'000 tonnes
PFCs	0.542	'000 tonnes CO_2 eq
HFCs & CFC	0.0165	'000 tonnes CO_2 eq
SF_6	-0.00155	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8468	'000 tonnes
Methane	-16.0	'000 tonnes
Nitrous Oxide	-0.320	'000 tonnes
PFCs	-0.205	'000 tonnes CO_2 eq
HFCs & CFC	-561	'000 tonnes CO_2 eq
SF_6	-0.0317	'000 tonnes

Table 1.16 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1559	‘000 tonnes
Methane	82.8	‘000 tonnes
Nitrous Oxide	0.0658	‘000 tonnes
PFCs	0.588	‘000 tonnes CO_2 eq
HFCs & CFC	0.0198	‘000 tonnes CO_2 eq
SF_6	-0.00156	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9430	‘000 tonnes
Methane	-18.3	‘000 tonnes
Nitrous Oxide	-0.368	‘000 tonnes
PFCs	-0.311	‘000 tonnes CO_2 eq
HFCs & CFC	-589	‘000 tonnes CO_2 eq
SF_6	-0.0366	‘000 tonnes

Table 1.17 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1311	‘000 tonnes
Methane	103	‘000 tonnes
Nitrous Oxide	0.0659	‘000 tonnes
PFCs	0.611	‘000 tonnes CO_2 eq
HFCs & CFC	0.0201	‘000 tonnes CO_2 eq
SF_6	-0.00157	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9494	‘000 tonnes
Methane	-18.4	‘000 tonnes
Nitrous Oxide	-0.370	‘000 tonnes
PFCs	-0.313	‘000 tonnes CO_2 eq
HFCs & CFC	-602	‘000 tonnes CO_2 eq
SF_6	-0.0385	‘000 tonnes

Table 1.18 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1197	'000 tonnes
Methane	114	'000 tonnes
Nitrous Oxide	0.0658	'000 tonnes
PFCs	0.623	'000 tonnes CO_2 eq
HFCs & CFC	0.0203	'000 tonnes CO_2 eq
SF_6	-0.00158	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9521	'000 tonnes
Methane	-18.4	'000 tonnes
Nitrous Oxide	-0.371	'000 tonnes
PFCs	-0.31	'000 tonnes CO_2 eq
HFCs & CFC	-608	'000 tonnes CO_2 eq
SF_6	-0.0393	'000 tonnes

C1.1.4 Scenario 4 – High Anaerobic Digestion

Table 1.19 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-510	'000 tonnes
Methane	192	'000 tonnes
Nitrous Oxide	0.0161	'000 tonnes
PFCs	0.411	'000 tonnes CO_2 eq
HFCs & CFC	-0.00616	'000 tonnes CO_2 eq
SF_6	-0.000762	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-5328	'000 tonnes
Methane	-9.66	'000 tonnes
Nitrous Oxide	-0.194	'000 tonnes
PFCs	-0.0787	'000 tonnes CO_2 eq
HFCs & CFC	-378	'000 tonnes CO_2 eq
SF_6	-0.0107	'000 tonnes

Table 1.20 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-204	‘000 tonnes
Methane	170	‘000 tonnes
Nitrous Oxide	0.0362	‘000 tonnes
PFCs	0.463	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00725	‘000 tonnes CO_2 eq
SF_6	-0.000899	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-6778	‘000 tonnes
Methane	-12.46	‘000 tonnes
Nitrous Oxide	-0.247	‘000 tonnes
PFCs	-0.1007	‘000 tonnes CO_2 eq
HFCs & CFC	-476	‘000 tonnes CO_2 eq
SF_6	-0.0141	‘000 tonnes

Table 1.21 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	887	‘000 tonnes
Methane	105	‘000 tonnes
Nitrous Oxide	0.0590	‘000 tonnes
PFCs	0.521	‘000 tonnes CO_2 eq
HFCs & CFC	0.0186	‘000 tonnes CO_2 eq
SF_6	-0.00153	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-7958	‘000 tonnes
Methane	-14.9	‘000 tonnes
Nitrous Oxide	-0.288	‘000 tonnes
PFCs	-0.115	‘000 tonnes CO_2 eq
HFCs & CFC	-560	‘000 tonnes CO_2 eq
SF_6	-0.0313	‘000 tonnes

Table 1.22 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1507	'000 tonnes
Methane	82	'000 tonnes
Nitrous Oxide	0.0965	'000 tonnes
PFCs	0.544	'000 tonnes CO_2 eq
HFCs & CFC	0.0235	'000 tonnes CO_2 eq
SF_6	-0.00157	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8351	'000 tonnes
Methane	-15.9	'000 tonnes
Nitrous Oxide	-0.302	'000 tonnes
PFCs	-0.120	'000 tonnes CO_2 eq
HFCs & CFC	-589	'000 tonnes CO_2 eq
SF_6	-0.0364	'000 tonnes

Table 1.23 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1401	'000 tonnes
Methane	95.7	'000 tonnes
Nitrous Oxide	0.100	'000 tonnes
PFCs	0.577	'000 tonnes CO_2 eq
HFCs & CFC	0.0248	'000 tonnes CO_2 eq
SF_6	-0.00159	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8870	'000 tonnes
Methane	-16.9	'000 tonnes
Nitrous Oxide	-0.321	'000 tonnes
PFCs	-0.128	'000 tonnes CO_2 eq
HFCs & CFC	-624	'000 tonnes CO_2 eq
SF_6	-0.0358	'000 tonnes

Table 1.24 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1350	'000 tonnes
Methane	103	'000 tonnes
Nitrous Oxide	0.102	'000 tonnes
PFCs	0.594	'000 tonnes CO_2 eq
HFCs & CFC	0.0255	'000 tonnes CO_2 eq
SF_6	-0.00160	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9136	'000 tonnes
Methane	-17.3	'000 tonnes
Nitrous Oxide	-0.331	'000 tonnes
PFCs	-0.132	'000 tonnes CO_2 eq
HFCs & CFC	-642	'000 tonnes CO_2 eq
SF_6	-0.0355	'000 tonnes

C1.1.5 Scenario 5 – High Green/ Kitchen Composting + Increased Paper Composting

Table 1.25 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-510	'000 tonnes
Methane	192	'000 tonnes
Nitrous Oxide	0.0161	'000 tonnes
PFCs	0.411	'000 tonnes CO_2 eq
HFCs & CFC	-0.00616	'000 tonnes CO_2 eq
SF_6	-0.000762	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-5328	'000 tonnes
Methane	-9.66	'000 tonnes
Nitrous Oxide	-0.194	'000 tonnes
PFCs	-0.0787	'000 tonnes CO_2 eq
HFCs & CFC	-378	'000 tonnes CO_2 eq
SF_6	-0.0107	'000 tonnes

Table 1.26 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-189	‘000 tonnes
Methane	170	‘000 tonnes
Nitrous Oxide	0.0347	‘000 tonnes
PFCs	0.463	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00721	‘000 tonnes CO_2 eq
SF_6	-0.000895	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-6780	‘000 tonnes
Methane	-12.5	‘000 tonnes
Nitrous Oxide	-0.247	‘000 tonnes
PFCs	-0.1007	‘000 tonnes CO_2 eq
HFCs & CFC	-476	‘000 tonnes CO_2 eq
SF_6	-0.0141	‘000 tonnes

Table 1.27 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	910	‘000 tonnes
Methane	105	‘000 tonnes
Nitrous Oxide	0.0539	‘000 tonnes
PFCs	0.520	‘000 tonnes CO_2 eq
HFCs & CFC	0.0156	‘000 tonnes CO_2 eq
SF_6	-0.00153	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-7965	‘000 tonnes
Methane	-15.1	‘000 tonnes
Nitrous Oxide	-0.289	‘000 tonnes
PFCs	-0.115	‘000 tonnes CO_2 eq
HFCs & CFC	-560	‘000 tonnes CO_2 eq
SF_6	-0.0313	‘000 tonnes

Table 1.28 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1546	'000 tonnes
Methane	83	'000 tonnes
Nitrous Oxide	0.0880	'000 tonnes
PFCs	0.544	'000 tonnes CO_2 eq
HFCs & CFC	0.0175	'000 tonnes CO_2 eq
SF_6	-0.00156	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8364	'000 tonnes
Methane	-16.34	'000 tonnes
Nitrous Oxide	-0.303	'000 tonnes
PFCs	-0.1199	'000 tonnes CO_2 eq
HFCs & CFC	-589	'000 tonnes CO_2 eq
SF_6	-0.0364	'000 tonnes

Table 1.29 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1298	'000 tonnes
Methane	103	'000 tonnes
Nitrous Oxide	0.0881	'000 tonnes
PFCs	0.567	'000 tonnes CO_2 eq
HFCs & CFC	0.0179	'000 tonnes CO_2 eq
SF_6	-0.00157	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8428	'000 tonnes
Methane	-16.5	'000 tonnes
Nitrous Oxide	-0.305	'000 tonnes
PFCs	-0.122	'000 tonnes CO_2 eq
HFCs & CFC	-602	'000 tonnes CO_2 eq
SF_6	-0.0383	'000 tonnes

Table 1.30 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1183	'000 tonnes
Methane	114	'000 tonnes
Nitrous Oxide	0.0880	'000 tonnes
PFCs	0.578	'000 tonnes CO_2 eq
HFCs & CFC	0.0180	'000 tonnes CO_2 eq
SF_6	-0.00158	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8455	'000 tonnes
Methane	-16.5	'000 tonnes
Nitrous Oxide	-0.305	'000 tonnes
PFCs	-0.123	'000 tonnes CO_2 eq
HFCs & CFC	-607	'000 tonnes CO_2 eq
SF_6	-0.0391	'000 tonnes

C1.1.6 Scenario 6 – High MBT with Stabilisation for Landfill

Table 1.31 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-510	'000 tonnes
Methane	192	'000 tonnes
Nitrous Oxide	0.0161	'000 tonnes
PFCs	0.411	'000 tonnes CO_2 eq
HFCs & CFC	-0.00616	'000 tonnes CO_2 eq
SF_6	-0.000762	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-5328	'000 tonnes
Methane	-9.66	'000 tonnes
Nitrous Oxide	-0.194	'000 tonnes
PFCs	-0.0787	'000 tonnes CO_2 eq
HFCs & CFC	-378	'000 tonnes CO_2 eq
SF_6	-0.0107	'000 tonnes

Table 1.32 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-180	‘000 tonnes
Methane	170	‘000 tonnes
Nitrous Oxide	0.0702	‘000 tonnes
PFCs	0.462	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00527	‘000 tonnes CO_2 eq
SF_6	-0.000661	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-6833	‘000 tonnes
Methane	-12.28	‘000 tonnes
Nitrous Oxide	-0.248	‘000 tonnes
PFCs	-0.1005	‘000 tonnes CO_2 eq
HFCs & CFC	-485	‘000 tonnes CO_2 eq
SF_6	-0.0094	‘000 tonnes

Table 1.33 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	663	‘000 tonnes
Methane	108	‘000 tonnes
Nitrous Oxide	0.212	‘000 tonnes
PFCs	0.512	‘000 tonnes CO_2 eq
HFCs & CFC	0.114	‘000 tonnes CO_2 eq
SF_6	-0.000345	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8073	‘000 tonnes
Methane	-14.1	‘000 tonnes
Nitrous Oxide	-0.291	‘000 tonnes
PFCs	-0.1113	‘000 tonnes CO_2 eq
HFCs & CFC	-577	‘000 tonnes CO_2 eq
SF_6	-0.0086	‘000 tonnes

Table 1.34 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1030	'000 tonnes
Methane	85	'000 tonnes
Nitrous Oxide	0.278	'000 tonnes
PFCs	0.539	'000 tonnes CO_2 eq
HFCs & CFC	0.146	'000 tonnes CO_2 eq
SF_6	-0.000205	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8540	'000 tonnes
Methane	-15.2	'000 tonnes
Nitrous Oxide	-0.306	'000 tonnes
PFCs	-0.115	'000 tonnes CO_2 eq
HFCs & CFC	-615	'000 tonnes CO_2 eq
SF_6	-0.0086	'000 tonnes

Table 1.35 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	985	'000 tonnes
Methane	100	'000 tonnes
Nitrous Oxide	0.280	'000 tonnes
PFCs	0.572	'000 tonnes CO_2 eq
HFCs & CFC	0.148	'000 tonnes CO_2 eq
SF_6	-0.000235	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9064	'000 tonnes
Methane	-16.1	'000 tonnes
Nitrous Oxide	-0.325	'000 tonnes
PFCs	-0.1231	'000 tonnes CO_2 eq
HFCs & CFC	-651	'000 tonnes CO_2 eq
SF_6	-0.0087	'000 tonnes

Table 1.36 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	962	‘000 tonnes
Methane	108	‘000 tonnes
Nitrous Oxide	0.282	‘000 tonnes
PFCs	0.589	‘000 tonnes CO_2 eq
HFCs & CFC	0.148	‘000 tonnes CO_2 eq
SF_6	-0.000251	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9332	‘000 tonnes
Methane	-16.6	‘000 tonnes
Nitrous Oxide	-0.335	‘000 tonnes
PFCs	-0.1272	‘000 tonnes CO_2 eq
HFCs & CFC	-670	‘000 tonnes CO_2 eq
SF_6	-0.0087	‘000 tonnes

C1.1.7 Scenario 7 – High MBT with RDF Production

Table 1.37 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-510	‘000 tonnes
Methane	192	‘000 tonnes
Nitrous Oxide	0.0161	‘000 tonnes
PFCs	0.411	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00616	‘000 tonnes CO_2 eq
SF_6	-0.000762	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-5328	‘000 tonnes
Methane	-9.66	‘000 tonnes
Nitrous Oxide	-0.194	‘000 tonnes
PFCs	-0.0787	‘000 tonnes CO_2 eq
HFCs & CFC	-378	‘000 tonnes CO_2 eq
SF_6	-0.0107	‘000 tonnes

Table 1.38 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-321	‘000 tonnes
Methane	170	‘000 tonnes
Nitrous Oxide	0.04591	‘000 tonnes
PFCs	0.461	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00839	‘000 tonnes CO_2 eq
SF_6	-0.001033	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-6811	‘000 tonnes
Methane	-12.29	‘000 tonnes
Nitrous Oxide	-0.248	‘000 tonnes
PFCs	-0.1006	‘000 tonnes CO_2 eq
HFCs & CFC	-481	‘000 tonnes CO_2 eq
SF_6	-0.0094	‘000 tonnes

Table 1.39 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	130	‘000 tonnes
Methane	109	‘000 tonnes
Nitrous Oxide	0.110	‘000 tonnes
PFCs	0.507	‘000 tonnes CO_2 eq
HFCs & CFC	0.0799	‘000 tonnes CO_2 eq
SF_6	0.000912	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8009	‘000 tonnes
Methane	-14.1	‘000 tonnes
Nitrous Oxide	-0.289	‘000 tonnes
PFCs	-0.113	‘000 tonnes CO_2 eq
HFCs & CFC	-568	‘000 tonnes CO_2 eq
SF_6	-0.0086	‘000 tonnes

Table 1.40 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	295	'000 tonnes
Methane	86	'000 tonnes
Nitrous Oxide	0.138	'000 tonnes
PFCs	0.531	'000 tonnes CO_2 eq
HFCs & CFC	0.100	'000 tonnes CO_2 eq
SF_6	-0.00237	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8451	'000 tonnes
Methane	-15.13	'000 tonnes
Nitrous Oxide	-0.304	'000 tonnes
PFCs	-0.1173	'000 tonnes CO_2 eq
HFCs & CFC	-604	'000 tonnes CO_2 eq
SF_6	-0.0086	'000 tonnes

Table 1.41 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	250	'000 tonnes
Methane	101	'000 tonnes
Nitrous Oxide	0.141	'000 tonnes
PFCs	0.564	'000 tonnes CO_2 eq
HFCs & CFC	0.102	'000 tonnes CO_2 eq
SF_6	-0.00240	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8975	'000 tonnes
Methane	-16.10	'000 tonnes
Nitrous Oxide	-0.323	'000 tonnes
PFCs	-0.1253	'000 tonnes CO_2 eq
HFCs & CFC	-640	'000 tonnes CO_2 eq
SF_6	-0.0087	'000 tonnes

Table 1.42 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	227	'000 tonnes
Methane	108	'000 tonnes
Nitrous Oxide	0.142	'000 tonnes
PFCs	0.581	'000 tonnes CO_2 eq
HFCs & CFC	0.102	'000 tonnes CO_2 eq
SF_6	-0.00241	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9243	'000 tonnes
Methane	-16.59	'000 tonnes
Nitrous Oxide	-0.333	'000 tonnes
PFCs	-0.1294	'000 tonnes CO_2 eq
HFCs & CFC	-658	'000 tonnes CO_2 eq
SF_6	-0.0087	'000 tonnes

C1.1.8 Scenario 8 – High Gasification

Table 1.43 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-510	'000 tonnes
Methane	192	'000 tonnes
Nitrous Oxide	0.01609	'000 tonnes
PFCs	0.411	'000 tonnes CO_2 eq
HFCs & CFC	-0.00616	'000 tonnes CO_2 eq
SF_6	-0.000762	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-5328	'000 tonnes
Methane	-9.66	'000 tonnes
Nitrous Oxide	-0.194	'000 tonnes
PFCs	-0.0787	'000 tonnes CO_2 eq
HFCs & CFC	-378	'000 tonnes CO_2 eq
SF_6	-0.0107	'000 tonnes

Table 1.44 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-85	‘000 tonnes
Methane	169	‘000 tonnes
Nitrous Oxide	0.0101	‘000 tonnes
PFCs	0.465	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00842	‘000 tonnes CO_2 eq
SF_6	-0.00104	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-6808	‘000 tonnes
Methane	-12.2	‘000 tonnes
Nitrous Oxide	-0.248	‘000 tonnes
PFCs	-0.100	‘000 tonnes CO_2 eq
HFCs & CFC	-481	‘000 tonnes CO_2 eq
SF_6	-0.0094	‘000 tonnes

Table 1.45 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1143	‘000 tonnes
Methane	103	‘000 tonnes
Nitrous Oxide	-0.0378	‘000 tonnes
PFCs	0.524	‘000 tonnes CO_2 eq
HFCs & CFC	0.0955	‘000 tonnes CO_2 eq
SF_6	-0.00193	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-7996	‘000 tonnes
Methane	-13.88	‘000 tonnes
Nitrous Oxide	-0.289	‘000 tonnes
PFCs	-0.1116	‘000 tonnes CO_2 eq
HFCs & CFC	-568	‘000 tonnes CO_2 eq
SF_6	-0.0086	‘000 tonnes

Table 1.46 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1691	'000 tonnes
Methane	79	'000 tonnes
Nitrous Oxide	-0.0667	'000 tonnes
PFCs	0.555	'000 tonnes CO_2 eq
HFCs & CFC	0.121	'000 tonnes CO_2 eq
SF_6	-0.00239	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8434	'000 tonnes
Methane	-14.87	'000 tonnes
Nitrous Oxide	-0.304	'000 tonnes
PFCs	-0.1155	'000 tonnes CO_2 eq
HFCs & CFC	-604	'000 tonnes CO_2 eq
SF_6	-0.0086	'000 tonnes

Table 1.47 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1646	'000 tonnes
Methane	93	'000 tonnes
Nitrous Oxide	-0.0638	'000 tonnes
PFCs	0.588	'000 tonnes CO_2 eq
HFCs & CFC	0.122	'000 tonnes CO_2 eq
SF_6	-0.00242	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-8958	'000 tonnes
Methane	-15.84	'000 tonnes
Nitrous Oxide	-0.323	'000 tonnes
PFCs	-0.1235	'000 tonnes CO_2 eq
HFCs & CFC	-640	'000 tonnes CO_2 eq
SF_6	-0.0087	'000 tonnes

Table 1.48 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1623	'000 tonnes
Methane	101	'000 tonnes
Nitrous Oxide	-0.0624	'000 tonnes
PFCs	0.605	'000 tonnes CO_2 eq
HFCs & CFC	0.123	'000 tonnes CO_2 eq
SF_6	-0.00243	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9226	'000 tonnes
Methane	-16.33	'000 tonnes
Nitrous Oxide	-0.333	'000 tonnes
PFCs	-0.1275	'000 tonnes CO_2 eq
HFCs & CFC	-658	'000 tonnes CO_2 eq
SF_6	-0.0087	'000 tonnes

C1.1.9 Scenario 9 – Mixed Technology Scenario

Table 1.49 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-513	'000 tonnes
Methane	192	'000 tonnes
Nitrous Oxide	0.0202	'000 tonnes
PFCs	0.417	'000 tonnes CO_2 eq
HFCs & CFC	-0.00616	'000 tonnes CO_2 eq
SF_6	-0.000762	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-5629	'000 tonnes
Methane	-10.1	'000 tonnes
Nitrous Oxide	-0.205	'000 tonnes
PFCs	-0.0836	'000 tonnes CO_2 eq
HFCs & CFC	-398	'000 tonnes CO_2 eq
SF_6	-0.0101	'000 tonnes

Table 1.50 2010

Emission	**Value**	**Unit**
Direct UK		
Carbon Dioxide Fossil	-259	'000 tonnes
Methane	166	'000 tonnes
Nitrous Oxide	0.0463	'000 tonnes
PFCs	0.485	'000 tonnes CO_2 eq
HFCs & CFC	-0.00803	'000 tonnes CO_2 eq
SF_6	-0.000993	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-7902	'000 tonnes
Methane	-14.14	'000 tonnes
Nitrous Oxide	-0.288	'000 tonnes
PFCs	-0.1174	'000 tonnes CO_2 eq
HFCs & CFC	-546	'000 tonnes CO_2 eq
SF_6	-0.0074	'000 tonnes

Table 1.51 2015

Emission	**Value**	**Unit**
Direct UK		
Carbon Dioxide Fossil	577	'000 tonnes
Methane	103	'000 tonnes
Nitrous Oxide	0.0775	'000 tonnes
PFCs	0.565	'000 tonnes CO_2 eq
HFCs & CFC	0.0522	'000 tonnes CO_2 eq
SF_6	-0.00162	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-9830	'000 tonnes
Methane	-17.95	'000 tonnes
Nitrous Oxide	-0.347	'000 tonnes
PFCs	-0.1358	'000 tonnes CO_2 eq
HFCs & CFC	-542	'000 tonnes CO_2 eq
SF_6	-0.0104	'000 tonnes

Table 1.52 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1162	'000 tonnes
Methane	79	'000 tonnes
Nitrous Oxide	0.0911	'000 tonnes
PFCs	0.631	'000 tonnes CO_2 eq
HFCs & CFC	0.0570	'000 tonnes CO_2 eq
SF_6	-0.00170	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-11995	'000 tonnes
Methane	-22.15	'000 tonnes
Nitrous Oxide	-0.427	'000 tonnes
PFCs	-0.1642	'000 tonnes CO_2 eq
HFCs & CFC	-622	'000 tonnes CO_2 eq
SF_6	-0.0030	'000 tonnes

Table 1.53 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	934	'000 tonnes
Methane	101	'000 tonnes
Nitrous Oxide	0.0916	'000 tonnes
PFCs	0.655	'000 tonnes CO_2 eq
HFCs & CFC	0.0575	'000 tonnes CO_2 eq
SF_6	-0.00171	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-12101	'000 tonnes
Methane	-22.39	'000 tonnes
Nitrous Oxide	-0.430	'000 tonnes
PFCs	-0.1663	'000 tonnes CO_2 eq
HFCs & CFC	-640	'000 tonnes CO_2 eq
SF_6	-0.0062	'000 tonnes

Table 1.54 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	829	‘000 tonnes
Methane	112	‘000 tonnes
Nitrous Oxide	0.0917	‘000 tonnes
PFCs	0.667	‘000 tonnes CO_2 eq
HFCs & CFC	0.0576	‘000 tonnes CO_2 eq
SF_6	-0.00171	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-12146	‘000 tonnes
Methane	-22.49	‘000 tonnes
Nitrous Oxide	-0.431	‘000 tonnes
PFCs	-0.1671	‘000 tonnes CO_2 eq
HFCs & CFC	-648	‘000 tonnes CO_2 eq
SF_6	-0.0076	‘000 tonnes

C1.2 C&I Waste Scenario Greenhouse Gas Emissions

C1.2.1 C&I Scenario 1 – Baseline (2002/03) Recycling and EfW Capacity

Table 1.55 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-177	‘000 tonnes
Methane	296	‘000 tonnes
Nitrous Oxide	0.0162	‘000 tonnes
PFCs	1.20	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00669	‘000 tonnes CO_2 eq
SF_6	-0.000874	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-12604	‘000 tonnes
Methane	-25.6	‘000 tonnes
Nitrous Oxide	-0.482	‘000 tonnes
PFCs	-1.004	‘000 tonnes CO_2 eq
HFCs & CFC	-1507	‘000 tonnes CO_2 eq
SF_6	-0.0050	‘000 tonnes

Table 1.56 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-475	‘000 tonnes
Methane	352	‘000 tonnes
Nitrous Oxide	0.0091	‘000 tonnes
PFCs	1.28	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00758	‘000 tonnes CO_2 eq
SF_6	-0.000997	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-12632	‘000 tonnes
Methane	-25.9	‘000 tonnes
Nitrous Oxide	-0.483	‘000 tonnes
PFCs	-1.002	‘000 tonnes CO_2 eq
HFCs & CFC	-1514	‘000 tonnes CO_2 eq
SF_6	-0.0068	‘000 tonnes

Table 1.57 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-752	‘000 tonnes
Methane	416	‘000 tonnes
Nitrous Oxide	0.0029	‘000 tonnes
PFCs	1.36	‘000 tonnes CO_2 eq
HFCs & CFC	0.05699	‘000 tonnes CO_2 eq
SF_6	-0.001134	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-12650	‘000 tonnes
Methane	-25.9	‘000 tonnes
Nitrous Oxide	-0.483	‘000 tonnes
PFCs	-1.000	‘000 tonnes CO_2 eq
HFCs & CFC	-1520	‘000 tonnes CO_2 eq
SF_6	-0.0083	‘000 tonnes

Table 1.58 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-1061	'000 tonnes
Methane	486	'000 tonnes
Nitrous Oxide	-0.0056	'000 tonnes
PFCs	1.45	'000 tonnes CO_2 eq
HFCs & CFC	0.05531	'000 tonnes CO_2 eq
SF_6	-0.001289	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-12662	'000 tonnes
Methane	-26.1	'000 tonnes
Nitrous Oxide	-0.484	'000 tonnes
PFCs	-0.998	'000 tonnes CO_2 eq
HFCs & CFC	-1526	'000 tonnes CO_2 eq
SF_6	-0.0096	'000 tonnes

Table 1.59 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-1061	'000 tonnes
Methane	486	'000 tonnes
Nitrous Oxide	-0.0056	'000 tonnes
PFCs	1.45	'000 tonnes CO_2 eq
HFCs & CFC	0.05531	'000 tonnes CO_2 eq
SF_6	-0.001289	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-12662	'000 tonnes
Methane	-26.1	'000 tonnes
Nitrous Oxide	-0.484	'000 tonnes
PFCs	-0.998	'000 tonnes CO_2 eq
HFCs & CFC	-1526	'000 tonnes CO_2 eq
SF_6	-0.0096	'000 tonnes

Table 1.60 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	-1061	'000 tonnes
Methane	486	'000 tonnes
Nitrous Oxide	-0.0056	'000 tonnes
PFCs	1.45	'000 tonnes CO_2 eq
HFCs & CFC	0.05531	'000 tonnes CO_2 eq
SF_6	-0.001289	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-12742	'000 tonnes
Methane	-26.5	'000 tonnes
Nitrous Oxide	-0.469	'000 tonnes
PFCs	-0.739	'000 tonnes CO_2 eq
HFCs & CFC	-1526	'000 tonnes CO_2 eq
SF_6	-0.0096	'000 tonnes

C1.2.2 C&I Scenario 2 – Increased Recycling

Table 1.61 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	48	'000 tonnes
Methane	271	'000 tonnes
Nitrous Oxide	0.0243	'000 tonnes
PFCs	1.26	'000 tonnes CO_2 eq
HFCs & CFC	-0.00613	'000 tonnes CO_2 eq
SF_6	-0.000810	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-13066	'000 tonnes
Methane	-26.5	'000 tonnes
Nitrous Oxide	-0.510	'000 tonnes
PFCs	-1.084	'000 tonnes CO_2 eq
HFCs & CFC	-1508	'000 tonnes CO_2 eq
SF_6	-0.0053	'000 tonnes

Table 1.62 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	865	'000 tonnes
Methane	199	'000 tonnes
Nitrous Oxide	0.0662	'000 tonnes
PFCs	1.72	'000 tonnes CO_2 eq
HFCs & CFC	-0.00377	'000 tonnes CO_2 eq
SF_6	-0.000574	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-13821	'000 tonnes
Methane	-27.8	'000 tonnes
Nitrous Oxide	-0.553	'000 tonnes
PFCs	-1.192	'000 tonnes CO_2 eq
HFCs & CFC	-1529	'000 tonnes CO_2 eq
SF_6	-0.0107	'000 tonnes

Table 1.63 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	832	'000 tonnes
Methane	231	'000 tonnes
Nitrous Oxide	0.0732	'000 tonnes
PFCs	1.91	'000 tonnes CO_2 eq
HFCs & CFC	0.11250	'000 tonnes CO_2 eq
SF_6	-0.000611	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-13909	'000 tonnes
Methane	-28.0	'000 tonnes
Nitrous Oxide	-0.557	'000 tonnes
PFCs	-1.194	'000 tonnes CO_2 eq
HFCs & CFC	-1542	'000 tonnes CO_2 eq
SF_6	-0.0138	'000 tonnes

Table 1.64 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	496	'000 tonnes
Methane	301	'000 tonnes
Nitrous Oxide	0.0642	'000 tonnes
PFCs	2.00	'000 tonnes CO_2 eq
HFCs & CFC	0.10925	'000 tonnes CO_2 eq
SF_6	-0.000758	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-13914	'000 tonnes
Methane	-28.3	'000 tonnes
Nitrous Oxide	-0.558	'000 tonnes
PFCs	-1.192	'000 tonnes CO_2 eq
HFCs & CFC	-1546	'000 tonnes CO_2 eq
SF_6	-0.0147	'000 tonnes

Table 1.65 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	496	'000 tonnes
Methane	301	'000 tonnes
Nitrous Oxide	0.0642	'000 tonnes
PFCs	2.00	'000 tonnes CO_2 eq
HFCs & CFC	0.10925	'000 tonnes CO_2 eq
SF_6	-0.000758	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-13914	'000 tonnes
Methane	-28.3	'000 tonnes
Nitrous Oxide	-0.558	'000 tonnes
PFCs	-1.192	'000 tonnes CO_2 eq
HFCs & CFC	-1546	'000 tonnes CO_2 eq
SF_6	-0.0147	'000 tonnes

Table 1.66 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	496	‘000 tonnes
Methane	301	‘000 tonnes
Nitrous Oxide	0.0642	‘000 tonnes
PFCs	2.00	‘000 tonnes CO_2 eq
HFCs & CFC	0.10925	‘000 tonnes CO_2 eq
SF_6	-0.000758	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-13914	‘000 tonnes
Methane	-28.3	‘000 tonnes
Nitrous Oxide	-0.558	‘000 tonnes
PFCs	-1.192	‘000 tonnes CO_2 eq
HFCs & CFC	-1546	‘000 tonnes CO_2 eq
SF_6	-0.0147	‘000 tonnes

C1.2.3 C&I Scenario 3 – Increased EfW

Table 1.67 2005

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	185	‘000 tonnes
Methane	275	‘000 tonnes
Nitrous Oxide	0.0136	‘000 tonnes
PFCs	1.21	‘000 tonnes CO_2 eq
HFCs & CFC	-0.00928	‘000 tonnes CO_2 eq
SF_6	-0.001183	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-12832	‘000 tonnes
Methane	-26.5	‘000 tonnes
Nitrous Oxide	-0.455	‘000 tonnes
PFCs	-0.524	‘000 tonnes CO_2 eq
HFCs & CFC	-1521	‘000 tonnes CO_2 eq
SF_6	-0.0082	‘000 tonnes

Table 1.68 2010

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	2078	‘000 tonnes
Methane	192	‘000 tonnes
Nitrous Oxide	-0.0077	‘000 tonnes
PFCs	1.35	‘000 tonnes CO_2 eq
HFCs & CFC	-0.02714	‘000 tonnes CO_2 eq
SF_6	-0.003336	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-13581	‘000 tonnes
Methane	-27.8	‘000 tonnes
Nitrous Oxide	-0.508	‘000 tonnes
PFCs	-1.034	‘000 tonnes CO_2 eq
HFCs & CFC	-1680	‘000 tonnes CO_2 eq
SF_6	-0.0466	‘000 tonnes

Table 1.69 2015

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	2153	‘000 tonnes
Methane	218	‘000 tonnes
Nitrous Oxide	-0.0148	‘000 tonnes
PFCs	1.45	‘000 tonnes CO_2 eq
HFCs & CFC	0.04335	‘000 tonnes CO_2 eq
SF_6	-0.003967	‘000 tonnes
Non - UK		
Carbon Dioxide Fossil	-14175	‘000 tonnes
Methane	-29.1	‘000 tonnes
Nitrous Oxide	-0.524	‘000 tonnes
PFCs	-1.051	‘000 tonnes CO_2 eq
HFCs & CFC	-1787	‘000 tonnes CO_2 eq
SF_6	-0.0723	‘000 tonnes

Table 1.70 2020

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1648	'000 tonnes
Methane	286.6	'000 tonnes
Nitrous Oxide	-0.021	'000 tonnes
PFCs	1.547	'000 tonnes CO_2 eq
HFCs & CFC	0	'000 tonnes CO_2 eq
SF_6	-0.0041	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-14484	'000 tonnes
Methane	-30.0	'000 tonnes
Nitrous Oxide	-0.532	'000 tonnes
PFCs	-1.059	'000 tonnes CO_2 eq
HFCs & CFC	-1844	'000 tonnes CO_2 eq
SF_6	-0.0861	'000 tonnes

Table 1.71 2030

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1648	'000 tonnes
Methane	287	'000 tonnes
Nitrous Oxide	-0.0211	'000 tonnes
PFCs	1.55	'000 tonnes CO_2 eq
HFCs & CFC	0.04164	'000 tonnes CO_2 eq
SF_6	-0.004087	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-14484	'000 tonnes
Methane	-30.0	'000 tonnes
Nitrous Oxide	-0.532	'000 tonnes
PFCs	-1.059	'000 tonnes CO_2 eq
HFCs & CFC	-1844	'000 tonnes CO_2 eq
SF_6	-0.0861	'000 tonnes

Table 1.72 2040

Emission	Value	Unit
Direct UK		
Carbon Dioxide Fossil	1648	'000 tonnes
Methane	287	'000 tonnes
Nitrous Oxide	-0.0211	'000 tonnes
PFCs	1.55	'000 tonnes CO_2 eq
HFCs & CFC	0.04164	'000 tonnes CO_2 eq
SF_6	-0.004087	'000 tonnes
Non - UK		
Carbon Dioxide Fossil	-14484	'000 tonnes
Methane	-30.0	'000 tonnes
Nitrous Oxide	-0.532	'000 tonnes
PFCs	-1.059	'000 tonnes CO_2 eq
HFCs & CFC	-1844	'000 tonnes CO_2 eq
SF_6	-0.0861	'000 tonnes

Annex D

Waste Fraction Property Assumptions

Key assumptions regarding the calorific value and carbon content of the waste fractions modelled are detailed in *Table 1.1* and *Table 1.2*. These have a direct influence on emissions estimates and energy recovery values for the alternative waste treatment processes modelled.

Table 1.1 Waste Fraction Calorific Values

Waste Fraction	**Net Calorific Value (MJ/kg)**
Paper & Card	11.00
Kitchen Waste	3.59
Green Waste	3.59
Textiles	14.33
Fines	3.48
Ferrous Metal	-
Non-ferrous Metal	-
Glass	1.42
Plastic (dense)	24.86
Plastic (film)	21.28
Miscellaneous Combustibles	14.06
Miscellaneous Non-combustibles	2.57

Source: *The Composition of Municipal Waste in Wales.* National Assembly for Wales (NAW) / AEAT Technology - December 2003.

Table 1.2 Waste Fraction Carbon Content

Waste Fraction	**Biogenic Carbon Content (%)**	**Fossil Carbon Content (%)**
Paper & Card	31.87	
Kitchen Waste	13.46	
Green Waste	17.17	
Textiles[1]	19.93	19.93
Fines[1]	6.88	6.88
Ferrous Metal	-	-
Non-ferrous Metal	-	-
Glass	0.28	
Plastic (dense)	54.83	
Plastic (film)	47.81	
Miscellaneous Combustibles[1]	19.20	19.20
Miscellaneous Non-combustibles[1]	3.50	3.50

Source: *The Composition of Municipal Waste in Wales.* National Assembly for Wales (NAW) / AEAT Technology - December 2003.

Notes:

1. Assumed to comprise 50% biogenic carbon content and 50% fossil carbon content