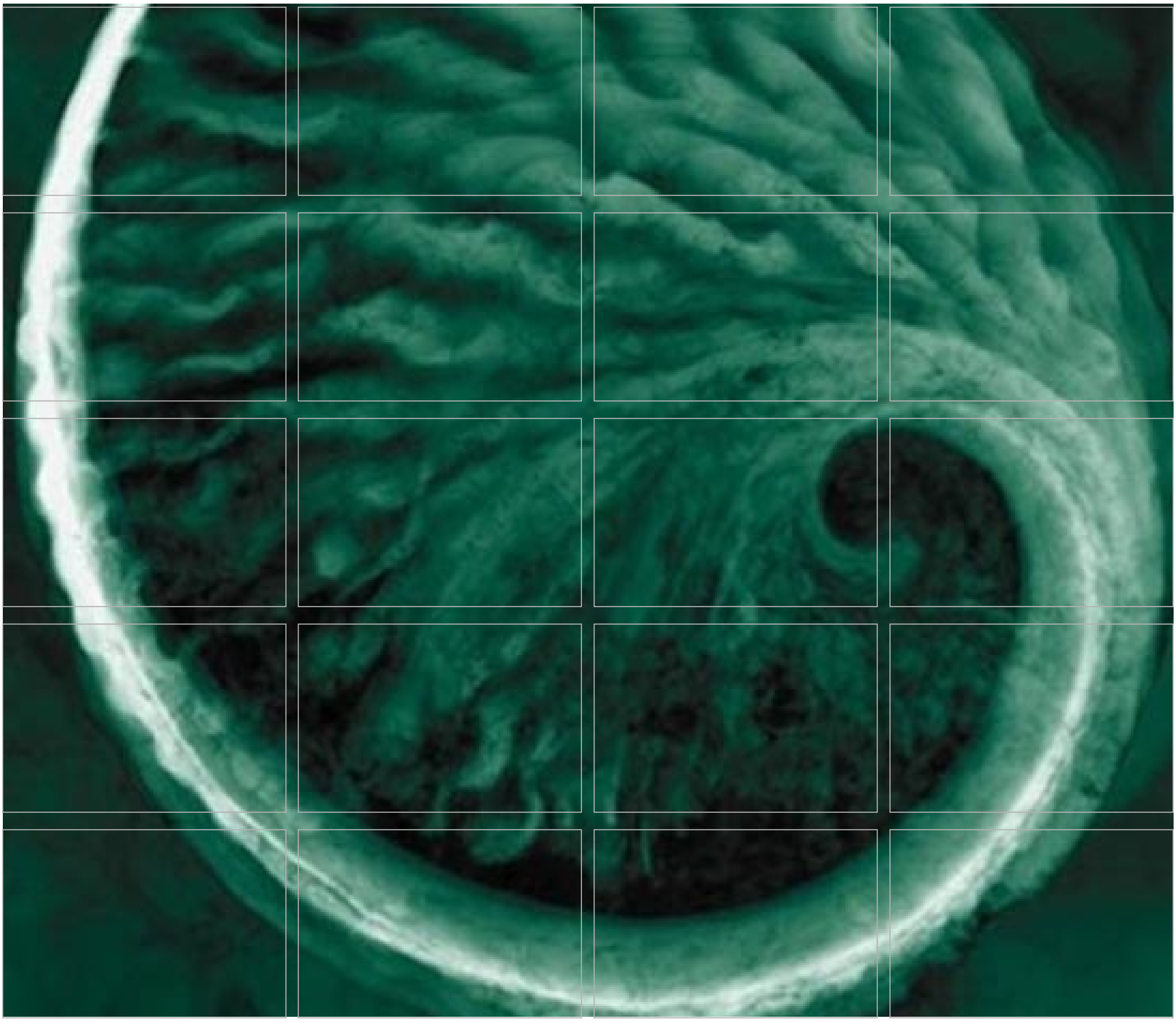

Residual Options Appraisal

Annex 5

Report

March 2006

Delivering sustainable solutions in a more competitive world

ERM

Kent Waste Forum

Residual Options Appraisal

Annex 5

Report

March 2006

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For and on behalf of Environmental Resources Management
Approved by: Simon Aumônier
Signed:
Position: Partner
Date: 31st March 2006

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1 RESIDUAL TREATMENT OPTIONS

1.1 INTRODUCTION

The Waste and Emissions Trading Act (2003) introduced the Landfill Allowance and Trading Scheme (LATS), under which challenging targets for the diversion of biodegradable municipal waste from landfill have been introduced for each Waste Disposal Authority (WDA) in England. In the event of a WDA failing to meet its targets directly, they may purchase allowances from other WDAs or borrow against future excess capacity.

As targets get harder to reach, it is envisioned that the market price of allowances will increase. If a WDA cannot cover its shortfall by purchasing allowances or borrowing, Government has made provision for them to be fined £150 per tonne of excess biodegradable municipal waste landfilled. This represents almost three times the cost of landfill.

The challenge of meeting these targets becomes more severe when the effect of economic growth is taken in to account. No allowance is made within the targets for per capita growth in waste production, or for the effects of demographic growth. Despite declining birth rates in England, Kent is predicting significant population growth which will have the effect of increasing waste arisings.

In response to this challenge, a series of options for the introduction of treatment facilities across the county have been developed. They are not intended in any way to be prescriptive, and they present only indicative routes for meeting LATS. This report will inform the Kent Authorities' decisions as to how to develop their treatment facilities and where resources and effort are best placed.

Having identified strategic options, methods were developed to appraise them objectively against a number of environmental, social and economic criteria. The purpose of this rigorous approach to options appraisal is to assist Kent's Authorities with the strategic decision-making process by identifying the potential environmental, social and financial costs of each option.

1.2 CRITERIA SELECTION

A technical options appraisal requires that the performance of alternative options be assessed against key objectives, reflected through a range of criteria, in order to identify the option (or options) that perform best overall.

The criteria will not only be used to indicate the environmental impacts of the options, but also to demonstrate how they perform in relation to deliverability and cost.

As a basis for criteria selection, the Sustainability Appraisal (SA) Objectives produced in relation to the development of the Waste Development Framework (WDF) were reviewed. Some of these concerned more site-specific issues, and thus were not appropriate for a strategic-level municipal waste management strategy (MWMS).

Workshops were held with each of the Districts and Kent County Council (KCC) to identify the assessment criteria appropriate for Kent. These were then put forward to the Kent Waste Forum for final agreement.

The assessment criteria selected are shown in *Table 1.1* below. It should be noted that energy consumption is not independent of some other appraisal criteria, for example air pollution, greenhouse gas emissions and transport distance. In reaching decisions as to the preferred options for adoption in the Strategy, the potential for impacts to have been 'double-counted' should be recognised.

Table 1.1 ***Options Appraisal Criteria***

SA Objectives	**Assessment Criteria**		**Comments**
To ensure that everyone has the opportunity to live in a decent, sustainably constructed home	N/A		Not applicable to a strategic level MSWS
To reduce the risk of flooding and the resulting detriment to public well being, the economy and the environment.	N/A		This objective is only relevant when dealing with site specific issues and is largely dependant on location. This will therefore not be applied at a strategic level
To improve the health and well being of the population and reduce inequalities in health	**Health Impact - emissions injurious to human health**	✓	
To reduce crime and the fear of crime	N/A		Not applicable to a strategic level MSWS
To improve accessibility to all services and facilities	N/A		Not applicable to a strategic level MSWS
To improve efficiency in land use	**Landuse Impacts**	✓	
To reduce air pollution and ensure air quality continues to improve; and to address the causes of climate change through reducing emissions of greenhouse gasses and ensure Kent is prepared for its impacts	**Air Pollution** **Emissions of Greenhouse Gases**	✓ ✓	
To conserve and enhance Kent's biodiversity	N/A		This objective is only relevant when dealing with site specific issues and is largely dependant on location. This will therefore not be applied at a strategic level
To protect, enhance and make accessible for enjoyment, Kent's countryside and coast, and its historic environment	N/A		This objective is only relevant when dealing with site specific issues and is largely dependant on location. This will therefore not be applied at a strategic level

SA Objectives	Assessment Criteria		Comments
To reduce road traffic and its impacts, promote sustainable modes of transport and reduce the need for travel by car or lorry	**Impacts of Road Transportation**	✓	
To reduce the global, social and environmental impact of consumption of resources by using sustainably produced and local products and services	**Impact of Resource use (Resource Depletion)**	✓	
To reduce waste generation and disposal and achieve sustainable waste management	**Compatibility with the Waste Hierarchy**	✓	
	Reliability of Delivery	✓	
	Liability of End Product	✓	
To maintain and improve the water quality of Kent's rivers, coasts and groundwater	**Impact on Water Pollution**	✓	
To increase energy efficiency and the proportion of energy generated from renewable sources in Kent	**Energy generation and consumption**	✓	
To build a strong and stable economy which provides prosperity and opportunities for all	**Number of jobs created**	✓	
	Financial Cost	✓	

1.3 *OPTION DEVELOPMENT*

Baseline Assumptions

The options selected for examination provide an illustrative guide to waste management in Kent. All options, except for option 8, are based on achieving a household recycling and composting rate of 40% by 2015 and providing for all annual LATS targets are met. Option 8 incorporates additional composting of kitchen waste, resulting in a recycling and composting rate of 49%.

The Allington Energy from Waste (EfW) plant is currently under construction, but is due to open in summer 2006. KCC has a contract for the combustion of 349,000 tonnes of waste per annum (tpa) at this facility. It has been assumed that the plant will process 174,500 tonnes in 2006/07, increasing to full capacity in future years. All of the bottom ash from all thermal treatments is assumed to be used in some form of construction. The ash is processed on site for this purpose.

Green waste is collected and composted at six sites in Kent using open windrows. Further criteria-related assumptions are detailed in the annexes.

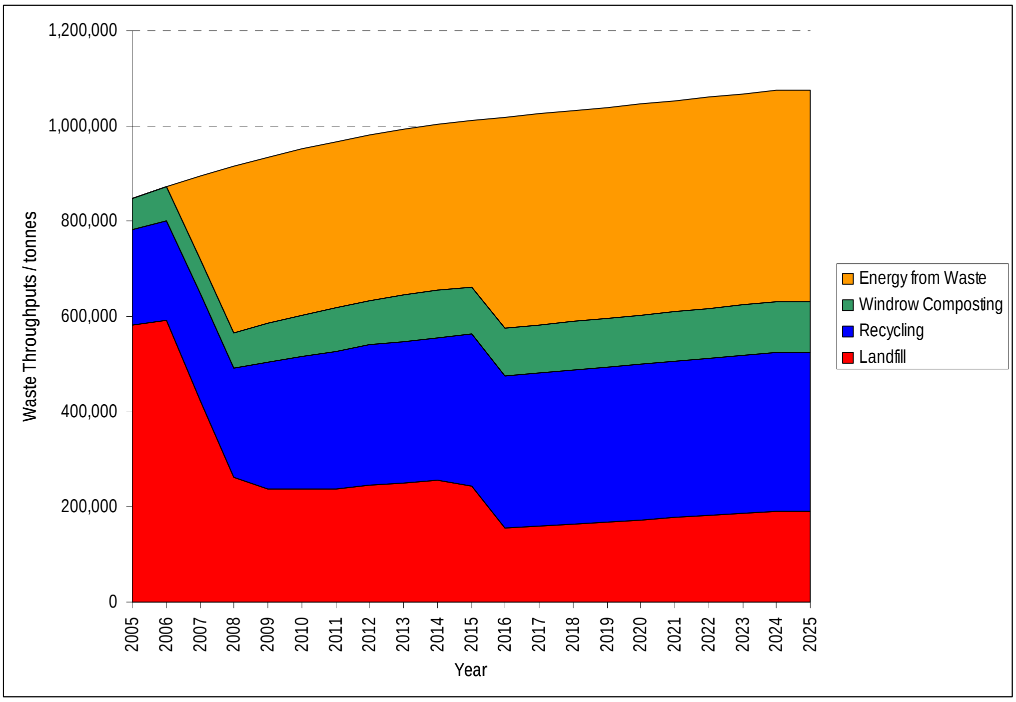
Table 1.2 *Residual Options*

Option	Description
1	New Energy from Waste facility in East Kent
2	Expand current contracted capacity at Allington EfW
3	Mechanical Biological Treatment (MBT) plant in East Kent providing Refuse Derived Fuel (RDF) to Allington EfW
4	MBT plant in East Kent stabilising material to be sent to landfill
5	Autoclave in East Kent with 'fluff' to Allington EfW
6	Gasification plant in East Kent
7	Anaerobic Digestion facility in East Kent
8	In-vessel composting facilities across Kent for Garden and Kitchen Waste

Option 1

Option 1 involves the construction of a second EfW plant, in East Kent, in 2016. The contracted capacity of the plant is set at approximately 94,000 tpa in order to meet the 2025 LATS target.

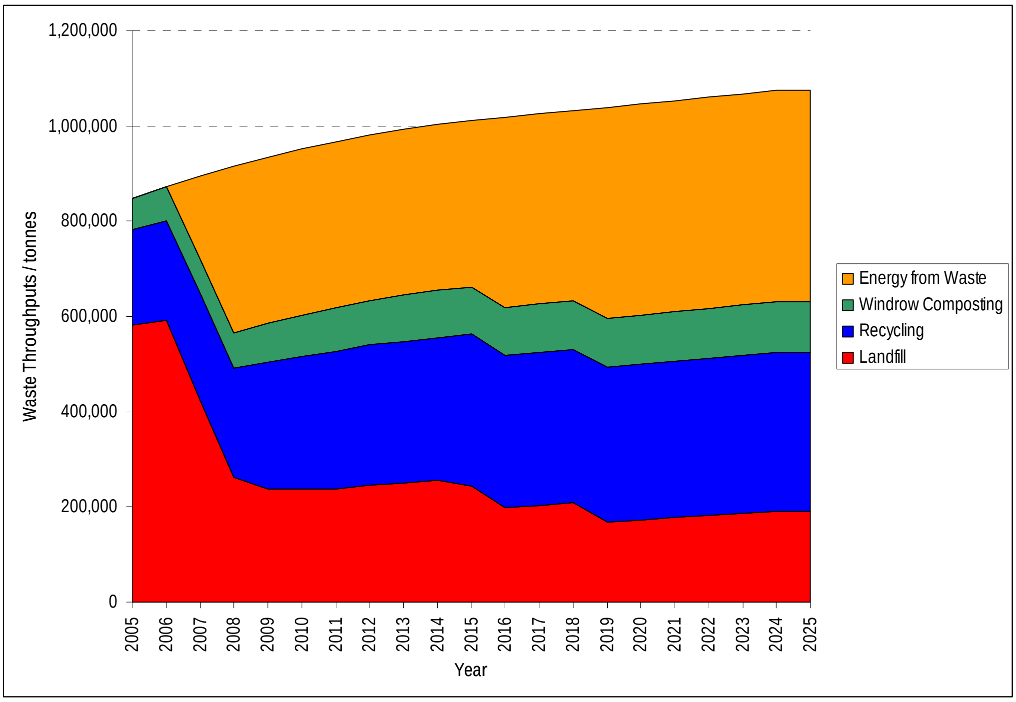
Figure 1.1 ***Option 1 - Waste Throughput***



Option 2

KCC's current contracted capacity at Allington EfW plant is 349,000 tonnes. This option envisages rises of 50,000 and 43,000 tonnes in 2016 and 2019 respectively. Allington has a total capacity of 500,000 tonnes, with the operator currently seeking to obtain the remaining throughput from other contracted sources. It has been assumed that the additional capacity required by KCC does not involve any extension of the plant.

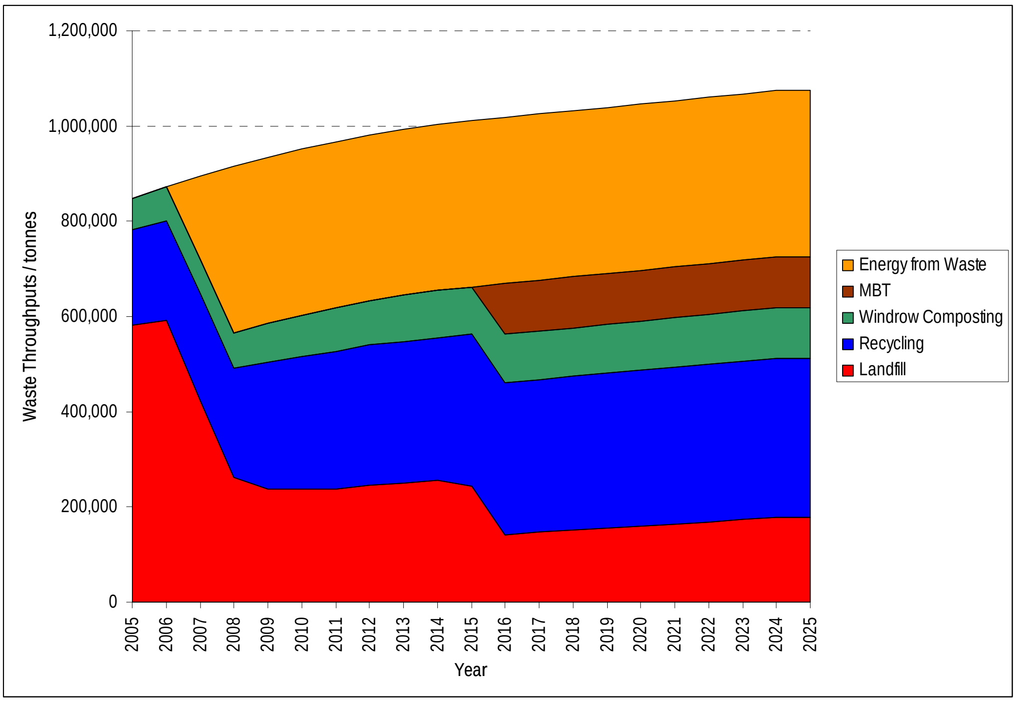
Figure 1.2 *Option 2 - Waste Throughput*



Option 3

It has been assumed in this option that a 107,000 tpa MBT plant is built, in East Kent, in 2016. The high calorific fraction from the MBT plant is sent to Allington EfW and the other residues go to landfill. The additional material is sent to Allington EfW without the need for an extension of the plant.

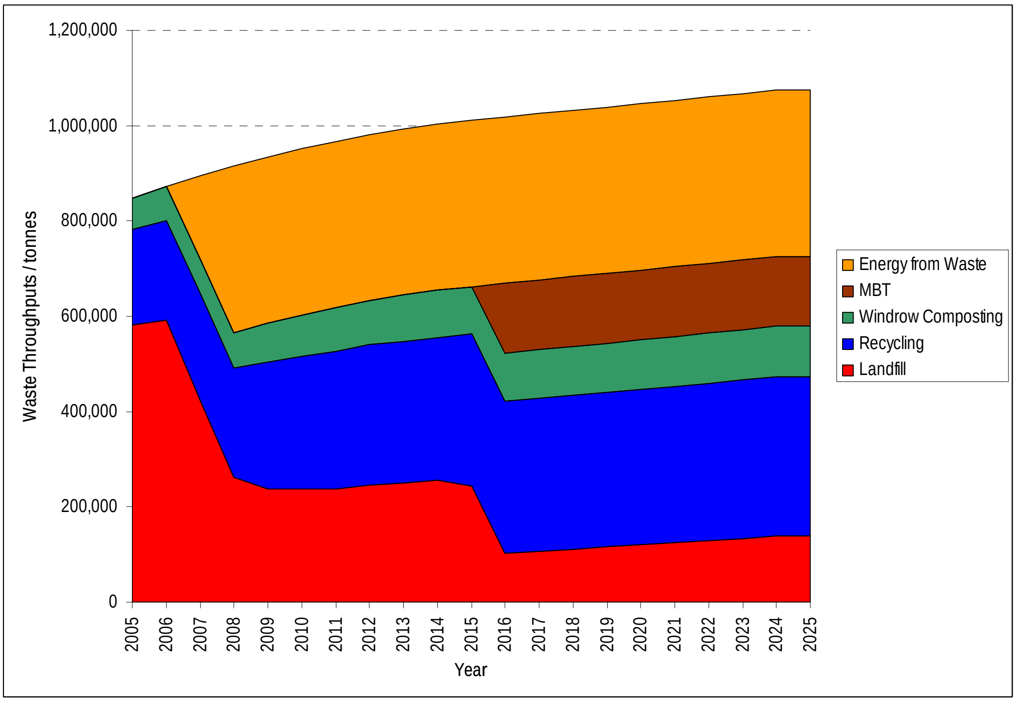
Figure 1.3 ***Option 3 - Waste Throughput***



Option 4

It is assumed in option 4 that an MBT plant is built in East Kent, in 2016, that stabilises material prior to it being sent to landfill. The capacity of the plant is approximately 146,500 tpa.

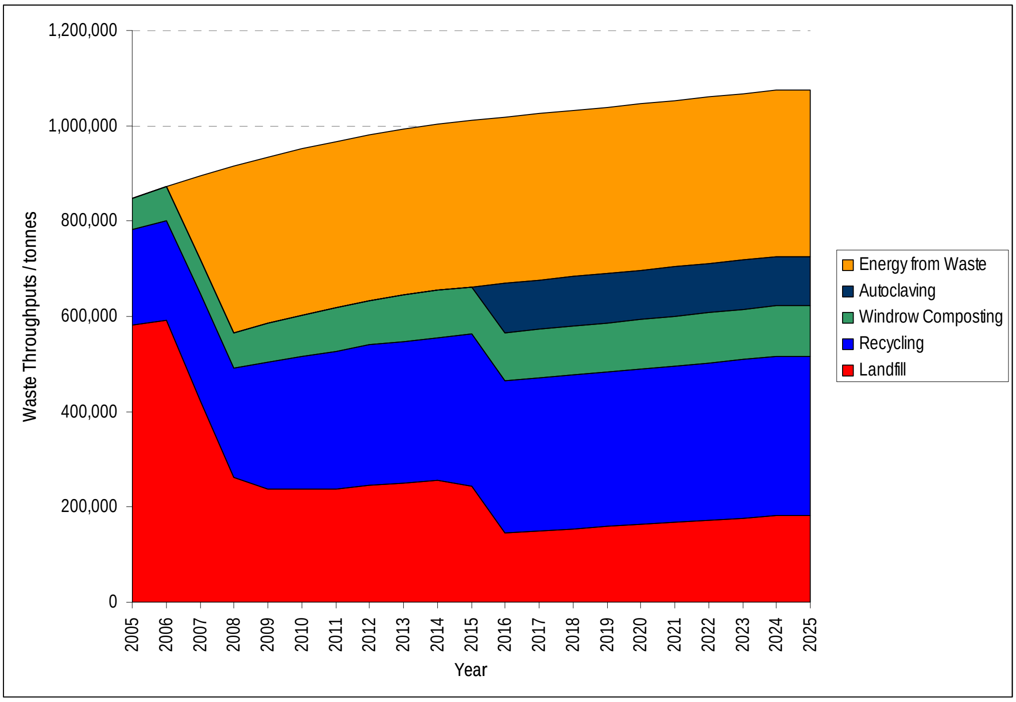
Figure 1.4 ***Option 4 - Waste Throughput***



Option 5

An autoclave facility with a capacity of 103,620 tpa is built in East Kent in 2016 to process waste in option 5. The 'fluff' or 'fibre' generated in the process is sent to Allington EfW. After removing recyclates, any other residues are sent to landfill. The additional material is sent to Allington EfW without the need for an extension of the plant.

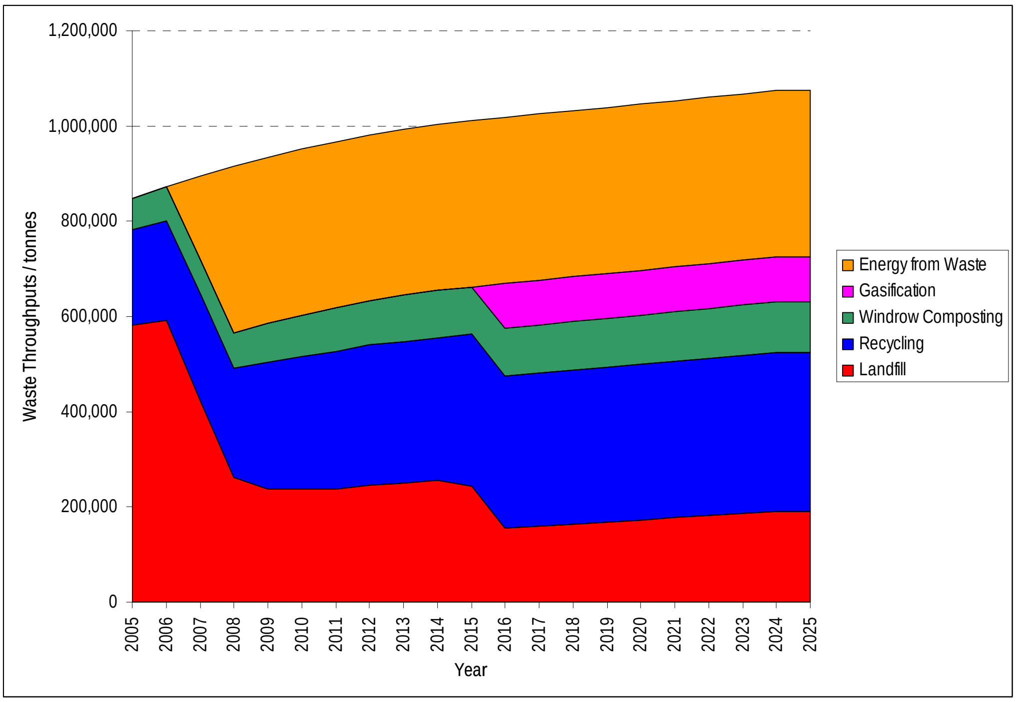
Figure 1.5 ***Option 5 - Waste Throughput***



Option 6

This option sees the construction of a gasification plant in East Kent in 2016. The plant has a capacity of 94,000 tpa.

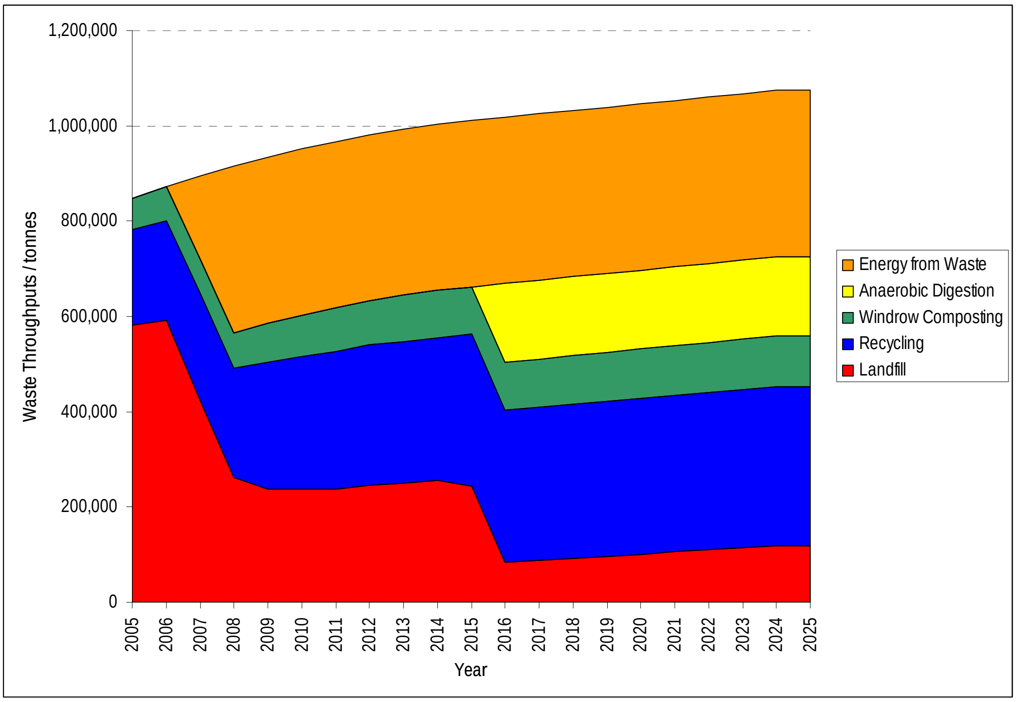
Figure 1.6 *Option 6 - Waste Throughput*



Option 7

It is assumed in this option that mixed refuse is sent to an anaerobic digestion plant in East Kent. The capacity of the plant is approximately 165,500 tpa and is built in 2016. Prior to digesting the material, the refuse is processed to remove any plastic material for recycling. The biogas produced is used to generate electricity. Any residues produced from the plant are sent to landfill.

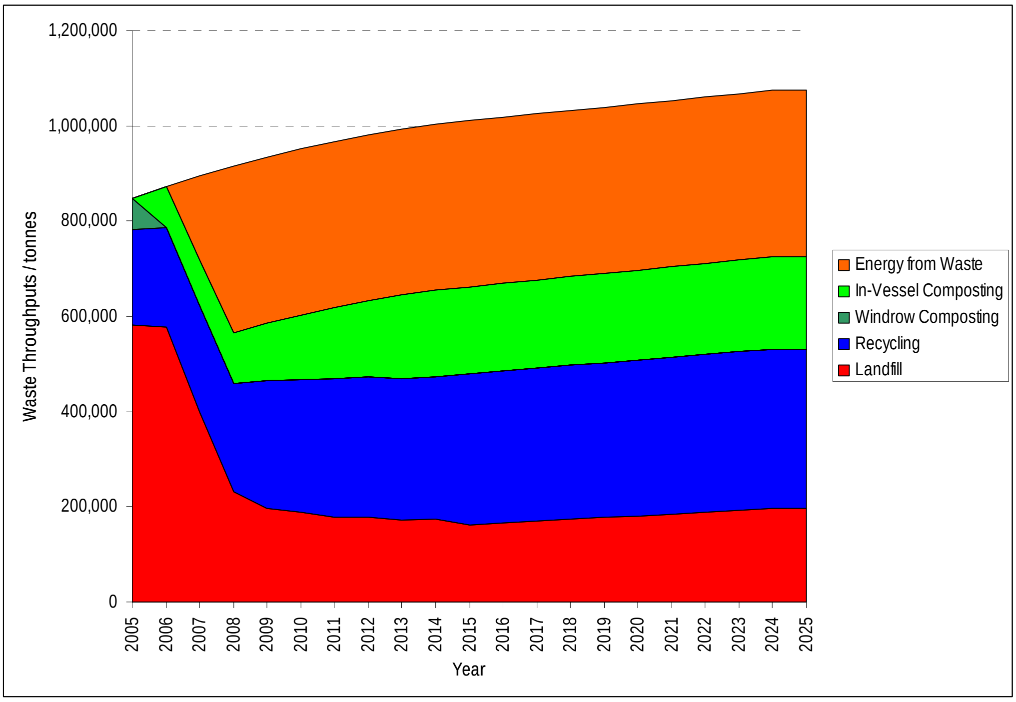
Figure 1.7 *Option 7 - Waste Throughput*



Option 8

It is assumed in this option that the collection of compostable kitchen waste is phased in between 2006 and 2013. Coverage of 90% and a participation and capture rate of 80% are achieved by 2013. The material is collected commingled with garden waste and composted in nine in-vessel compost facilities throughout Kent, each of approximately 20,000 tpa capacity.

Figure 1.8 ***Option 8 - Waste Throughput***



1.4 *Appraising the Options Against Performance Criteria*

1.4.1 *Environmental Criteria – Scope of Assessment*

A life cycle approach was used to assess the performance of options against the performance criteria. For an overview of this method please refer to *Section 1.5.1* of the Recycling and Composting report.

1.4.2 *Impacts of Resource Use (Resource Depletion)*

Fossil fuel and mineral resources are limited, and current rates of consumption are considered to be unsustainable. Waste management can play a significant role improving the efficiency of resource use through waste recycling and recovery.

Methods and Assumptions Used

WISARD (1) determines non-renewable resource depletion as the 'Abiotic Depletion Factor' (ADF) for the extraction of individual minerals and fossil fuels. This is based on concentration reserves and rate of de-accumulation, and expresses the results in 'kg antimony equivalents/kg extraction'.

For this study, we have simplified the process by assessing the depletion of coal, natural gas and crude oil as proxies for the ADF. Since these are the major resources affected by the options assessed, it is assumed that this represents a valid means of performing the analysis.

Calculation of the Impact Scores

ERM calculated the resource requirements (tonnes of diesel, kWh of electricity, tonne-kilometres waste transported, etc.) of the various facilities and processes involved in each option. It was then a case of applying the emission factors (which provide emissions per tonne of diesel, etc.), in order to determine the emissions associated with the activities. These emission factors are presented in *Annex A*.

Figures for the three depleted materials (coal, crude oil and natural gas) were then combined. *CML 2000* (2) provides resource depletion figures for the three species, in terms of kilograms of antimony. These can be compared, as shown in *Table 1.3*, to generate a single figure representing the resource depletion of each of the options, in terms of '*tonnes of crude oil equivalents*'.

Table 1.3 ***Resource Depletion Equivalents*** (†)

Resource	1 kg antimony	1 kg crude oil	Units
Antimony	1	0.020	kg
Coal	74.627	1.500	kg
Natural gas	53.476	1.075	m^3
Crude oil	49.751	1	kg

(†) Data from CML 2000

Results

Resource depletion results are presented in *Table 1.4*, expressed as a cumulative depletion of crude oil equivalents over the assessment period, 2005/6 to 2024/25.

Note that all of the total scores for each option are negative values. This is because the combination of activities involved in each option results in a net *reduction* in resource depletion. All the options therefore offer a net benefit in relation to this criterion.

(1) ***WISARD*** is the Environment Agency's life cycle assessment software for waste management. Details of the ***WISARD*** software can be found in *Annex F*.
(2) CML 2000 - Centre of Environmental Science - Leiden University (CML), Leiden, The Netherlands.

Options 7 and 5 perform best under this criterion. For the Anaerobic Digestion (AD) and autoclaving options, it is assumed that both plastics and metals are separated for recovery before processing and, as a result, there are high resource recovery benefits through the displacement of the production of virgin materials. In addition, both processes also recover energy – AD through combustion of biogas (methane) and autoclaving through the combustion of a cellulose fibrous material commonly referred to as 'fluff' or 'fibre'.

Table 1.4 *Resource Depletion Scores (Tonnes of Crude Oil Equivalents)*

Option	**Total**	**Rank (1 = best performing)**
1	-3,411,017	**4**
2	-3,393,398	**6**
3	-3,394,507	**5**
4	-3,311,400	**7**
5	-3,461,535	**2**
6	-3,428,183	**3**
7	-3,565,545	**1**
8	-3,309,702	**8**

It was assumed for option 7 that the residues from the AD plant would not be suitable for use as a soil conditioner and so would be landfilled. In order to meet LATS requirements in later years, a large AD plant, of approximately 165,000 tpa is required. The autoclave plant is assumed to be smaller, at 103,000 tpa, because it diverts more waste from landfill by producing fluff for combustion at Allington EfW. The greater throughput of the AD plant results in more material being separated for recycling and energy recovery. A similar size autoclave may perform better, as more energy is generated from fluff combustion than is generated through the production and consumption of bio-gas, on a like-for-like basis.

Option 6, the construction of a gasification plant to achieve LATS targets, performs better than options 1 and 2. Although these options rely on EfW, figures from the Waste Technology Data Centre (*Annex A*) afford gasification a higher energy generation efficiency than EfW.

Option 1 relies on the construction of a second 93,000 tpa EfW plant in East Kent. Option 2 sees the expansion of the current contract with the EfW plant at Allington by 50,000 tpa in 2016, and by a further 44,000 tpa in 2019. The additional waste consumed by the second EfW plant in option 1 between 2016 and 2019 results in a higher ranking for option 1 over option 2. Option 3, use of an MBT plant to produce RDF, scores higher than option 2 for a similar reason. Options 4 and 8 perform the worst, as the additional treatment technologies do not involve any energy recovery.

1.4.3 *Air Acidification*

Extensive experience by ERM and others in assessing the acidification impact of integrated waste management processes has found SO_2 emissions to be the greatest contributor to the acidification impact, with NO_x emissions the second largest contributor (1). Both NO_x and SO_2 emissions are the result of combustion processes and the emission of one is considered an indicator for the presence of the other (2). The contribution to acidification impact of 1kg of SO_2 is greater than the impact of 1kg of NO_x (3).

Hence for this study, we have focused solely on SO_2 emissions as a proxy for all the acidifying gases. It is assumed that SO_2 emissions alone are satisfactorily indicative of the overall acidification potential of the options.

Calculation of the Impact Scores

In the resource depletion section, it was mentioned that ERM calculated the resource requirements (tonnes of diesel, kWh of electricity, tonne-kilometres waste transported, etc.) of the various facilities and processes. The same activities, the generation and use of diesel, the generation of electricity (eg using coal-fired power stations) and the transport of waste, also result in emissions of acidifying gases, including SO_2. As with the resource depletion calculations, it was then a case of applying the emission factors. These can be found in *Annex A*.

Results

Air pollution (acidification) results are presented in *Table 1.5*, expressed as cumulative emissions of SO_2 over the assessment period, 2005/6 to 2024/25.

Table 1.5 Air Pollution (Acidification) Scores (Tonnes of SO_2)

Option	**Total**	**Rank (1 = best performing)**
1	-31,939	**5**
2	-31,831	**6**
3	-32,027	**4**
4	-31,572	**7**
5	-32,243	**2**
6	-32,058	**3**
7	-32,784	**1**
8	-31,309	**8**

(1) Enviros Aspinwall (January 2002) arc21 - Consultation Waste Management Plan
(2) http://www.aeat.co.uk/netcen/airqual/naei/annreport/annrep99/index.htm [05Jan05 @ 11:44]
(3) CML 2 Baseline 2000, Institute of Environmental Sciences (CML), University of Leiden, the Netherlands, 2000.

As with resource depletion, we see that all scores result in net *reductions* in acidification, as the activities offset the generation of SO_2 by other processes, such as the extraction of raw materials or the generation of power by alternative means.

Options 7 and 5 perform best due to the recovery of greater amounts of plastics and metals than other options allied to energy generation from biogas and the combustion of fluff at Allington EfW. The greater energy generation efficiency of gasification (*Annex A*) sees this option perform better than options 1 and 2 which also rely on thermal treatment.

Option 3 performs better than options 1 and 2 where waste goes direct to EfW facilities. Option 3 separates a greater quantity of metals for recycling than options 1 and 2. In contrast, less energy is generated in option 3 as not all residues are combusted. The greater degree of recycling in option 3 compensates for the reduced energy production to produce a higher ranking in this criterion. Options 4 and 8 perform worst due to a lack of energy production in both options.

1.4.4 Greenhouse Gas Emissions

Increasing anthropogenic emissions of greenhouse gases has altered the composition of the atmosphere. These gases increase the heat-trapping potential of the Earth's atmosphere and have the potential to significantly alter the climate.

Method and Assumptions Used

Gases contributing to the greenhouse effect are aggregated according to their impact on radiative warming, compared to CO_2 as the reference gas. Characterisation factors as developed by the Intergovernmental Panel on Climate Change (IPCC) were selected, the figures being shown in *Table 1.6*.

Table 1.6 Greenhouse Gas Characterisation Factors (†)

Gas	Formula	Characterisation factor	Units
Carbon dioxide	CO_2	1	CO_2 equivalent
Methane	CH_4	21	CO_2 equivalent

(†) Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide/kg emission.

For the CO_2 emissions, a firm distinction was made between 'renewable' and 'non-renewable' sources of CO_2, with only the latter (from the combustion of fuels and plastics) taken as making a contribution to the greenhouse gas figures. Clearly, CO_2 is CO_2: however, it is assumed that the effect of releasing carbon from renewable sources is neutral because these releases are balanced by uptakes in the short-term, mainly in agro-forestry systems. By contrast, releases from non-renewable sources are only balanced out over geologic time periods.

Calculation of the Impact Scores

The calculation of the impact scores followed the same pattern as for resource depletion and acidification. The emissions factors for the two gases were scaled according to the total amount of resource consumption, and then converted into CO_2 equivalents using the figures in *Table 1.6*.

Results

Greenhouse gas emission results are presented in *Table 1.7*, expressed as cumulative emissions of CO_2 equivalents over the assessment period, 2005/6 to 2024/25.

Table 1.7 ***Greenhouse Gas Emission Scores (Tonnes of CO_2 Equivalents)***

Option	Total	Rank (1 = best performing)
1	-5,361,810	5
2	-5,351,544	7
3	-5,351,831	6
4	-5,364,684	4
5	-5,602,111	2
6	-5,408,378	3
7	-5,768,375	1
8	-5,088,642	8

The trend set by resource depletion and acidification is continued with greenhouse gas emissions. The figures are all negative, as the management options reduce greenhouse gas emissions through recycling materials and displacing energy production.

Options 7 and 5 perform best in relation to this criterion, as they did with the previous criteria. Once more, the higher recovery of materials for recycling, together with the recovery of energy from the combustion of biogas and RDF, leads to a greater displacement of CO_2 equivalent emissions.

Options 4 and 5, involving the use of MBT, perform well against this criterion. The large amount of secondary recycling performed at the MBT stage counterbalances the additional energy produced by the EfW plants in options 1 and 2. Option 2 performs worse than option 1, as it does not displace the same quantity of electricity from the national grid. Option 2 may perform better under this criterion if a greater quantity of waste was treated at Allington EfW. Again, the assumed greater energy efficiency of gasification sees this option outperform both options 1 and 2.

1.4.5 *Energy Consumption*

Energy consumption is a central indicator of sustainability, affecting all aspects of development: social, economic and environmental. In February 2003, the Government's Energy White Paper set energy efficiency at the heart of UK energy policy, identifying improved energy efficiency as the most cost-effective way to meet all of our energy policy goals. By using less energy we can reduce carbon emissions, enhance the security of our energy supplies, improve the competitiveness of UK businesses and reduce fuel poverty [1].

Methods and Assumptions Used

All waste treatment and disposal activities consume energy, predominantly in the form of either electricity or diesel for machinery operation. In contrast, some activities lead to the direct generation of energy (eg landfill, through the capture and utilisation of landfill gas) or indirect energy savings (eg through materials recycling/composting and the displacement of virgin material production).

The calculation of energy consumption impact scores followed a similar pattern as for the quantification of resource depletion, based on relative consumption of coal, natural gas and crude oil. Since these are the major energy carriers affected by the options assessed, it is assumed that this represents a valid means of performing the assessment.

Coal, natural gas and crude oil depletion factors for alternative waste management activities (presented in *Annex A*) were used to calculate the consumption of these resources associated with each option. Figures for the three fuel sources (coal, crude oil and natural gas) were then converted into a common energy equivalent, based on calorific value. Calorific values for coal, natural gas and crude oil are shown in *Table 1.8*.

Table 1.8 Resource Calorific Values

Resource	**Calorific Value**	**Source**
Coal	30.3 MJ/kg	BUWAL life cycle database
Natural Gas	60.2 MJ/m^3	Engineering Toolbox (http://www.engineeringtoolbox.com/)
Crude Oil	42.3 MJ/kg	BUWAL life cycle database

Results

Energy consumption results are presented in *Table 1.9*, expressed as a cumulative consumption/generation of energy (TJ) over the assessment period, 2005/6 to 2024/25.

(1) http://www.defra.gov.uk/environment/energy/review/

Table 1.9 *Energy Consumption Scores (TJ)*

Option	Total	Rank (1 = best performing)
1	-169,297	4
2	-168,404	5
3	-168,344	6
4	-164,013	8
5	-173,052	2
6	-170,173	3
7	-177,576	1
8	-164,353	7

There is a net energy saving associated with all of the options in this assessment. Energy is saved through reduced demands on virgin materials, and the use of EfW facilities recovers energy, offsetting national grid production.

As with the previous criteria, the greater material recycling in addition to some energy production results in options 7 and 5 ranking highest. Options 8 and 4 rank lowest, as these options do not involve energy recovery. However, both still represent total energy savings, and are therefore still in line with the Government's Energy White Paper, 2003.

1.4.6 *Impacts on Human Health*

The construction of new waste management facilities is often controversial, with their perceived public health impacts central to the debate. There are numerous conflicting reports and opinions about the relative impacts of different facilities available to fuel this debate.

In an attempt to clarify the situation, Defra recently published a health effects report [(1)] that aimed to bring together, in one place, information from all the studies conducted to date. Although there are a number of data gaps (notably on composting and emerging technologies such as autoclaving), this is the best reference information that is available, and ERM has used it as the basis for assessment in this study.

Method and Assumptions Used

The specific starting point was Table 4.5 of the Defra report, on page 206, which is reproduced in *Table 1.11* below. This quantifies, to the degree possible from the data sources, the various health impacts that might be expected to occur as a result of waste management operations.

(1) *Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes*, Enviros Consulting Ltd and University of Birmingham with Risk and Policy Analysts Ltd, Open University and Maggie Thurgood, 2004, available at http://www.defra.gov.uk/environment/waste/health-effects/index.htm [01Jun04 @ 15:13]

As can be seen, the table presents impacts for six classes of process: composting; MBT; anaerobic digestion; pyrolysis/gasification; energy from waste; and landfill. Autoclaving is missing, and there are actually no impacts for composting. To cover all the technologies used in this assessment, it was necessary to extrapolate data from these processes, and the associated approximations are presented in *Box 1.1*. These assumptions are used to generate the data in *Table 1.12*.

Box 1.1 Health Impact Technology Assumptions

Autoclaving:	Autoclaving is a sterilisation process, neither biological (MBT) nor combustion (energy from waste). It has been assumed that the health effects of autoclaving are similar to those of anaerobic digestion, and those figures have been used.
Composting:	Given that the release of bioaerosols from composting plants can be an issue, it has been decided to assign to composting the higher of the impacts in each category from the most similar processes, MBT and anaerobic digestion.
Landfill:	Data is given on six different landfill types, using flares or engines at small, medium and large sites. A typical value has been deduced by averaging the impacts from medium-sized flare and medium-sized engine landfill sites.

The figures in *Table 1.12* apply to health impacts as waste is treated by the different technologies, so impacts from multiple stage processes must be added together. If, for example, residual waste from an MBT plant is sent to a cement kiln, then the health impacts from both processes are taken into account in the calculations. However, the offset health impacts of energy production during combustion processes are not taken into account in this assessment. Similarly, the benefits of recycling are not taken into account, in terms of an offset health impact of material (paper, glass etc.) production.

Comparing the Impacts

Clearly, a 'death brought forward' is more serious than a 'respiratory admission' and therefore the columns in *Table 1.12* cannot be totalled. Moreover, some processes do not have estimated impacts for all four categories, and therefore an aggregate health impact is difficult to ascertain. The World Health Organisation (WHO), as part of its Global Burden of Disease project, has developed a table of Disability Weights associated with various conditions (1). Illnesses, referred to in general as *sequelae*, are rated on a scale from 0.0 (perfect health) to 1.0 (death). ERM used this dataset to determine scores for the four health effects listed, as explained in *Table 1.10*. These figures are used in *Table 1.13* to calculate the final scores for each waste management technology.

(1) http://www3.who.int/whosis/burden/manual/other/GBD90 Disability Weights.zip [08Jun04 @ 19:11]

Table 1.10 Health Impact Disability Weighting Assumptions

Health Impact	Discussion	Disability Weighting
Deaths brought forward:	There is no analogous category in the WHO disability weights to 'deaths brought forward', so ERM selected *terminal cancers* as an equivalent malady.	0.809
Respiratory admissions:	Respiratory diseases are divided between lower and upper respiratory diseases, but since the Defra report mentions both types, an average has been taken of the three non-zero sequelae (*upper respiratory episodes*, *pharyngitis* and *chronic lower respiratory sequelae*).	0.149
Cardiovascular admissions:	The Defra report cites a large number of cardiovascular sequelae, and disability weightings for these, where available, have been averaged for this impact. The sequelae included are: *congestive heart failure, acute myocardial infarction, angina pectoris, first-ever stroke, myocarditis, pericarditis, endocarditis* and *cardiomyopathy.*	0.260
Additional cancer cases:	Similarly, the Defra report was scanned to determine which cancers were included in this category, resulting in the inclusion of "*cancers of the stomach, colon, rectum, liver, pancreas, trachea, bronchus, lung, melanoma and other skin, breast, cervix uteri, corpus uteri, ovary, prostate gland and bladder, leukaemia, lymphomas and multiple myeloma* in the estimation".	0.165

Table 1.11 Estimated Health Impacts due to Emissions to Air (per Million (10^6) Tonnes of Waste Processed) (†)

Health Effects	Composting	MBT	Anaerobic Digestion	Pyrolysis / Gasification	Incineration / Cement Kiln	Landfill – Medium + Flare (‡)	Landfill – Medium + Engine (‡)
Deaths brought forward	No Data	0.018	0.0015	0.031	0.064	0.015	0.012
Respiratory admissions	No Data	0.050	0.072	0.293	1.5	0.024	0.11
Cardiovascular admissions	No Data	No Data	No Data	0.0055	0.0004	0.0013	0.001
Additional cancer cases	No Data	No Data	0.0000011	0.000019	0.00002	0.000048	0.00005
Data quality	n/a	Poor (3)	Moderate (5)	Moderate (6)	Moderate (6)	Poor (4)	Poor (4)

(†) Figures multiplied by 10^6 versus the report, to show their relative values more clearly.

(‡) Data is given in the report for small, medium and large landfill in these two categories – six in all.

Table 1.12 Estimates of Health Impacts due to Emissions to Air (per Million (10^6) Tonnes of Waste Processed), as Modified by ERM (†)

Health Effects	Composting	MBT	Anaerobic Digestion	Autoclaving	Incineration / Cement Kiln	Active Landfill – Medium
Deaths brought forward	0.018	0.018	0.0015	0.0015	0.064	0.014
Respiratory admissions	0.072	0.050	0.072	0.072	1.5	0.067
Cardiovascular admissions	No Data	No Data	No Data	No Data	0.0004	0.0012
Additional cancer cases	0.0000011	No Data	0.0000011	0.0000011	0.00002	0.000049

(†) Figures multiplied by 10^6 versus the report, to show their relative values more clearly.

Table 1.13 Health Impact Scores with Disability Weightings Factored into the Calculations

Health Effects	Deaths brought forward	Respiratory admissions	Cardiovascular admissions	Additional cancer cases	Final 'score' (†)
Composting	0.018	0.072	No Data	0.0000011	0.0085
MBT (‡)	0.018	0.050	No Data	No Data	0.011
Anaerobic digestion	0.0015	0.072	No Data	0.0000011	0.0040
Pyrolysis/gasification	0.031	0.29	0.0055	0.00019	0.017
Incineration/ cement kiln	0.064	1.5	0.0004	0.00002	0.069
Autoclaving (‡)	0.0015	0.072	No Data	0.0000011	0.0040
Landfill	0.014	0.067	1.15	0.00049	0.0053
Disability weighting	*0.809*	*0.149*	*0.260*	*0.165*	

(†) The final 'score' is calculated by summing the products of each of the impacts and their disability weighting, and represents a relative value that combines the number and severity of incidents resulting from the handling of a common unit weight of waste by the stated waste management technique. Put simply, the final 'score' is the number of 'death equivalents' per million tonnes of waste throughput.

(‡) The impacts for MBT and Autoclaving only reflect the plants themselves, and not the possible treatment of the RDF or Fibre residues.

Applying the Impact Scores to the Options

In order to apply the calculated impact scores to the options, it is necessary to multiply the final health effect scores by the amount of waste being handled by that technique, and sum for each option.

Results

The results of applying the impact factors to the throughputs of each facility type within each option are presented in *Table 1.14*.

Table 1.14 Health Impacts Score

	1	2	3	4	5	6	7	8
Recycling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Composting	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.028
Energy from Waste	0.509	0.500	0.480	0.444	0.495	0.444	0.444	0.444
MBT	-	-	0.012	0.016	-	-	-	-
Autoclave	-	-	-	-	0.004	-	-	-
Gasification	-	-	-	-	-	0.016	-	-
Anaerobic Digestion	-	-	-	-	-	-	0.007	-
Landfill	0.028	0.029	0.029	0.029	0.028	0.028	0.028	0.026
Hazardous Landfill	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Total	0.555	0.546	0.538	0.507	0.545	0.507	0.496	0.499
Rank (1 = best performing)	8	7	5	4	6	3	1	2

The greatest impact on health is associated with mass burn energy from waste in this assessment. Therefore, options 1 and 2 perform worst in this assessment. Options 3 and 5 perform poorly, despite low impacts from MBT and autoclaving, as the end products of these processes are assumed to be combusted in Allington EfW.

The relatively benign impact of AD combined with the landfilling of the end product from the process results in option 7 being ranked highest.

1.4.7 Landtake

Land is a finite resource. The emphasis of Government policy is to 'recycle' the use of land and buildings through brownfield site development and re-use of buildings. However, many of the brownfield sites available for development are in the industrial heartland of the UK away from the areas of highest demand – the south and south east. It is, therefore, vital that land and its efficient use in Kent are given full consideration.

This criterion considers the amount of land that would be required to be given up on a long-term basis. The assessment estimates the average annual landtake requirements, of each option, over the study period. Landtake was measured using professional judgment based on the typical size of different facilities.

Method and Assumptions Used

The assessment estimates the landtake requirements of waste treatment and disposal facilities for each option.

Landtake requirements for autoclaving, anaerobic digestion and MBT facilities where they form part of the management option have been assessed. However, the landtake requirements of disposal/treatment facilities for the outputs from these technologies have not been included in the assessment.

Assumptions used to underpin this assessment, including an estimate of landtake (in hectares) for each facility type, are given in *Annex B*. These figures have been used to determine the total landtake that each management option will require. The landtake requirements of proposed facilities for each option have been summed and then averaged, to provide an average landtake figure for each option for each year.

The option with the lowest landtake requirement has been awarded the highest rank of 1, the option with the highest landtake requirement has been given the lowest performance ranking of 8, and all other options have been ranked according to their position within this range.

Results

A summary of the potential 'total landtake' for all options is given in *Table 1.15*. The quantity of waste landfilled has the greatest bearing on land use. The area taken up by non-landfill facilities is relatively constant.

Table 1.15 Average Annual Landtake over Period for Kent Options (ha)

Technology	**Option**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Non – Landfill	65.1	64.2	65.2	65.4	64.8	65.1	65.3	64.3
Landfill	41.7	42.8	41.7	44.4	41.7	41.7	41.7	37.5
Total	**106.8**	**107.0**	**107.0**	**109.7**	**106.6**	**106.8**	**107.0**	**101.8**
Rank (1 = best performing)	3	6	5	8	2	4	7	1

Although the number of sites increases in option 8, the use of in-vessel compost facilities reduces the quantity of land required negating the increase in composting tonnages. The increased recycling and composting rate in this option also results in less waste going to landfill, reducing the landtake of this option. Option 5 performs second best due to the relatively small size of an autoclave facility.

The landtake of non-landfill facilities is lowest in option 2. This option does not require the construction of any new facilities. The waste contract with the existing facility is increased first in 2016 by 50,000 tpa and then by a further 43,000 tpa in 2019. In the other options, completed facilities are brought online in 2016 with the objective of meeting the 2025 LATS target. This results in a greater landfill landtake for option 2 than for other thermal treatment options.

Option 4 performs the worst against this criterion due to the disposal to landfill of the end product. In order to meet future LATS targets, an AD plant with a capacity of 165,489 tpa is constructed in 2016 as part of option 7. The greater throughput after the plant's construction compared to the throughput in option 4 results in far less waste going direct to landfill, improving the landtake figures. In addition, the annual output to landfill from the MBT plant in option 4 is approximately 76,000 tpa, compared to 66,000 tpa from the AD plant. The AD process reduces the volume of waste to a much greater extent than the MBT process, thereby improving its landtake score for landfill.

Although land required for landfill may be unsuitable for construction after closure, there are many examples of former landfills being put to good use for leisure facilities.

1.4.8 Extent of Water Pollution

Pressure on water resources in the south-east from increased consumption and lower than average rainfall amplifies the need to protect what resources are available. Lower river flows have a reduced assimilative capacity for wastewater discharges and pollution incidents so the importance of protecting these resources has increased.

Methods and Assumptions Used

For assessing the environmental risk to water (bodies) for the proposed options, ERM used the Environment Agency's OPRA (Operator & Pollution Risk Appraisal) for Waste scoring methodology.

The OPRA model is based on the consideration of the likelihood of problems arising and a measure of their consequences. Evaluation of risk involves: firstly the probability of an occurrence of an undesirable event; and, secondly, the consequence of such an event.

To assess the options, assumptions had to be taken in order to proceed. For the environmental appraisal in OPRA, there are 24 possible facility types. ERM matched up the technologies used in the options with types of facility in OPRA, shown the table below.

Table 1.16 ***Type of Facility***

Facility	**OPRA Description**	**Score**
Recycling	Materials Recycling Facility (A15)	15
Windrow	Composting Facility (A22)	15
In-vessel composting	Biological Treatment (A23)	15
AD	Biological Treatment (A23)	15
MBT	Biological Treatment (A23)	15
Autoclave	Physical Treatment (A16)	20
Incineration	Incinerators (A18)	20
Gasification	Incinerators (A18)	20
Landfill	HCI and/or Household Waste Landfill (A4)	40
Hazardous Landfill	A1/A2 Special Waste &/or co-disposal Landfill	60

Calculation of the Impact Scores

In order to score the type of facility, one needs to know the quantity of facilities that will be applied for each option. In order to assess the variations in tonnes landfilled, it has been assumed that every 100,000 tonnes of landfill space is equivalent to a single facility.

All these scores were worked out for each year, as in each option further facilities are added in certain years. However, in order to facilitate comparison, the total score for source and target were averaged for all the years assessed.

Results

Table 1.17 shows the result of the water assessment for Kent.

Table 1.17 ***Water Assessment Results***

Option	**Source Score**	**Target Score**	**Total Environmental Score**	**Rank**	**Value**
1	685	520	**1204**	5	0.35
2	670	507	**1177**	1	1.00
3	677	518	**1195**	4	0.57
4	688	527	**1216**	7	0.08
5	672	518	**1190**	2	0.68
6	691	518	**1190**	2	0.68
7	694	527	**1215**	6	0.10
8	680	539	**1219**	8	0.00

Option 2 performs best against this criterion, as no new facilities are built under this option. Under option 2, the current disposal contract at the Allington EfW is altered to take more waste in 2016 and 2019. The expansion of the contract does not involve any further risk to water than that already in place under the current contract.

Options 5 and 6 also perform well against this criterion. The high recovery of plastics and metals in the autoclave, in option 5, reduces the quantity of waste combusted and therefore the amount of hazardous and non-hazardous waste sent to landfill. Option 6 involves constructing a new gasification plant and the process produces limited outputs or residues that require further treatment.

The number of facilities for processing compost in option 8 significantly increase the risk associated with this option, even though the facilities are small and individually pose less of a risk than the other proposed plants.

1.4.9 Total Road Kilometres

The total expected road distance travelled in each option has been calculated. These figures can give an indication of the local transport impacts associated with each option, for example, road traffic congestion and accidents.

Method and Assumptions Used

To estimate the total road distance travelled for each indicative option, a number of assumptions have been made. Although this assessment is not a site-specific assessment, assumptions on indicative reprocessing, treatment and disposal locations have had to be made in order to allow transport distances to be calculated. These assumptions are listed in *Annex C*.

Distances to and from facilities have been measured using route mapping software. The shortest road route on major roads was selected. Preferences were given to Motorways and A Roads, with B Roads and minor roads being used close to the ends of each journey.

The tonnages of waste travelling to each facility have been identified. To establish the number of lorry movements to each facility, the tonnages been divided by 22. This reflects the assumption that bulker lorries will be used to transport the waste, with an average load of 22 tonnes. To establish the total road transport distance for each option, the estimated distances have multiplied the number of lorry movements.

Results

The total transport results, in kilometres, are shown in *Table 1.18*.

Table 1.18 Total Road Transport Distance for each Option (te-km)

	Option							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Total distance	52,073,274	51,653,330	53,301,919	52,065,179	56,790,470	52,156,058	55,993,597	52,113,145
Rank (1 = best performing)	3	1	6	2	8	5	7	4

There is not a significant difference in transport distances between options 1, 4, 6 and 8. The assessment is not site-specific, and any small alteration to the locations of the facility in East Kent may quite easily affect the order of these options.

Option 3 involves the use of an MBT plant in East Kent with the resulting RDF being transported across Kent to be treated in the Allington EfW plant. If it could be guaranteed that any RDF produced would be accepted at Allington, it may be economically and environmentally prudent to site the MBT facility in the same vicinity. However, this could significantly alter the collection and transfer distances for those districts in the east of the county.

Option 5 has high levels of secondary plastic recycling. This option performs worst as the nearest plastics reprocessor is in St Helens, near Liverpool, over 430 kms away. The development of a local market for this material would have a noteworthy effect in reducing this distance.

1.4.10 Financial Costs

A problem commonly associated with data on the financial costs of waste management activities is the acquisition of detailed, reliable and up-to-date information, and the necessity of relying on small and dated data sets in forecasting future costs. In addition, some technologies are not as well established as others, resulting in additional difficulties in making accurate cost predictions. Assumptions underpinning the estimation of financial costs in this assessment can be found in *Annex D*.

Method and Assumptions Used

The principal cost elements appraised in this assessment relate to waste treatment/disposal. Professional judgement based on experience of waste management costs has been made in appraising this criterion. Costs are based on current costs as at 2005 and are stated in 2005 prices. The exception to this is the landfill tax, which has been assumed to increase to £35/t by 2012 and to stay at this level until 2025.

Costs associated with each option have been assessed principally on an operational and capital cost basis. These costs have been collected from a variety of sources in the waste industry. Landfill costs have been assessed on a gate fee basis of £55 per tonne [1].

There are considerable uncertainties associated with the market value of products from the autoclaving process. This has meant that is difficult to attribute a gate fee to autoclaving. For the purposes of this assessment, the costs associated for this technology have been based on likely gate fees for new technologies.

The total costs per tonne for each option over the period have been estimated. This total includes consideration of both operating and capital expenditure, but not of revenues. Revenues from different treatment options were not considered in this assessment. The market price of recyclate can vary widely and the revenue associated with MBT and autoclave processes are not well established in the UK. Although there are many energy from waste facilities selling electricity to the national grid, it has been assumed that the gate fee of £60 used in this assessment incorporates this revenue.

The option that provides the least expensive waste management option has been awarded the highest ranking of 1, the most costly option has been given the lowest ranking of 8 and the remaining options have been ranked accordingly within the range.

Results

Table 1.19 presents an estimate of the costs for each option from 2005 to 2025 on a total gross cost and cost per tonne basis. These costs include both operating and capital costs.

Option 8, in-vessel composting of garden and kitchen waste, performs best. Although the investment in in-vessel composting is higher than other investments in different treatment technologies, the additional level of composting associated with this option significantly reduces landfill costs. However, those authorities that do not currently collect garden waste would have to make a large investment in collection infrastructure as discussed in the Recycling and Composting section of this report.

The expansion of the current contract at Allington in Option 2 assumes that the original gate fee of £60 per tonne is maintained. This option is ranked second as there is no additional capital expenditure driving up costs.

(1) http://www.wasteonline.org.uk/resources/WasteWatch/BeyondTheBin_files/page1.html

Table 1.19 Breakdown of Treatment and Disposal Costs for Kent Options 2005 - 2025

Technology	**Option**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Recycling (£'000'000)	46	46	46	46	46	46	46	46
Composting (£'000'000)	37	37	37	37	37	37	37	93
Energy from Waste (£'000'000)	387	363	366	335	379	335	335	335
MBT (£'000'000)			30	39				
Autoclave (£'000'000)					18			
Gasification (£'000'000)						59		
Anaerobic Digestion (£'000'000)							42	
Landfill (£'000'000)	348	356	359	389	357	348	369	316
Total Gross Cost (£'000'000)	817	801	837	846	837	824	828	789
Total (£/tonne)	39.19	38.40	40.12	40.54	40.10	39.49	39.70	37.84
Rank (1 = best performing)	3	2	7	8	6	4	5	1

1.4.11 *Reliability of Delivery*

Reliability of delivery is a criterion that encompasses a number of subsidiary factors. The key issues are the probability of securing planning permission for new facilities and the prospects for technologies that are not entirely proven.

Method and Assumptions Used

A simple method has been derived to encompass the main elements relating to reliability of delivery identified above.

Probability of Securing Planning Permission

To assess the probability of securing planning permission against each option, the number of sites required for treatment technologies have been reviewed. Options requiring larger number of treatment facilities have been given a lower score. This takes into account the logistics, time and cost involved in obtaining planning permissions.

The energy from waste plant at Allington is already under construction and due to open during the summer of 2006. This plant is, therefore, counted as an existing facility.

Table 1.20 ***Scores Attributed to Number of Treatment Facilities***

Number of treatment facilities required	**Score**
0	4
1 or 2	3
3 or 4	2
5 >	1

Proven Technologies

There is a long history of waste management technologies being presented in the market as a new and advantageous solution to the waste problem, only for obstacles to their successful implementation and operation to emerge at a later date. Such technologies should not be disregarded. However, it is prudent to account for risks associated with delivery in practice, albeit that this is difficult to assess in advance.

In addition, it is often harder to secure financial backing for facilities that have not been proven in the UK, or that have not been shown to work at large scale or on feedstock with the same characteristics as the intended waste stream. The scores identified in *Table 1.21* below have been attributed to each option.

Table 1.21 ***Points Attributed to Proven Technologies***

Development state	**Score**
Proven on a large scale in the UK	4
Proven on a large scale in Europe	3
Proven on a small scale in the UK	2
Proven on a small scale in Europe	1

Results

The scores of both elements have then been weighted equally and added together to give a final score (highest rank = best performance for this criterion).

Table 1.22 Reliability of Delivery Results for MSW Options

	Option							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Securing Planning Permission	3	4	3	3	3	3	3	1
Proven Technologies	4	4	3	3	1	1	3	4
Total option score	7	8	6	6	4	4	6	5
Rank (1 = best performing)	2	1	3	3	7	7	3	6

Option 2, the expansion of the Allington EfW contract, performs best as no new facilities are required and the EfW technology is well proven. There are a number of in-vessel composting facilities throughout the UK, so it has been considered a proven technology. However, the availability of suitable sites and the probability of securing planning permission hamper this option.

The score attributed to securing planning permission for a second EfW in option 1 is the same as that attributed to the other technologies under this method. The development of any major waste facility, be it an EfW or MBT plant, can arouse significant public opposition. Public acceptance of waste facilities in the UK is low, and the track record of the facility at Allington may affect the probability of securing planning permission for a second facility.

1.4.12 *Compliance with Waste Policy*

This criterion assesses the ability of each of the options to manage waste in accordance with UK waste policy. Nevertheless, key constraints were established during the initial development of options to ensure that each of the options complies with the statutory LATS targets and that a minimum of 40% recycling and recovery is achieved by 2015 in all options. As such, these requirements have been excluded from the assessment of this criterion.

Government policy seeks to drive the management of waste up the waste hierarchy. The waste hierarchy represents a sliding scale starting with reduction of waste through re-use, recycling and composting, recovery and disposal. Where waste is produced it should be viewed as a resource to be put to good use; disposal should be the last option for dealing with it.

Figure 1.9 Waste Hierarchy, Waste Strategy 2000 (1)

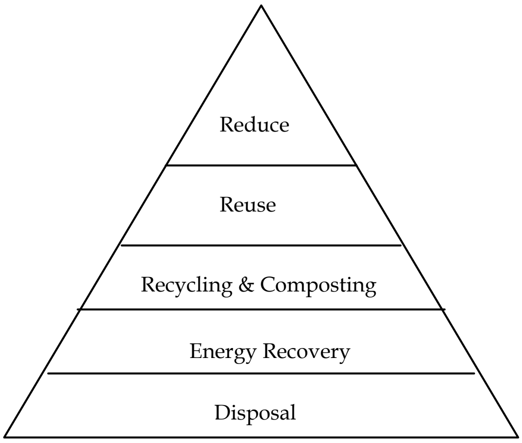


Table 1.23 presents the 'score' that has been awarded to each technology according to its position in the hierarchy. The most preferred is the removal of the problem through waste reduction and minimisation. These scores have been used to determine the performance of each option.

Table 1.23 Ranking System for Waste Policy Criterion

Waste treatment/disposal facility	Waste Hierarchy Factor
Waste reduction & minimisation	4
Recycling & composting	3
Anaerobic Digestion	1
Energy from waste/gasification	1
Landfill	0

Method and Assumptions Used

MBT and autoclaving have been excluded from the ranking, as it does not provide an end treatment, but an interim treatment process. Where options have included the use of these technologies to manage waste, the final recovery or disposal of the outputs from MBT and autoclaving has been evaluated.

All of the bottom ash associated with EfW is assumed to be diverted from landfill. However, it is assumed that the hazardous fly ash is landfilled. The waste hierarchy score associated with landfill is applied to this material.

(1) Department of the Environment, Transport and the Regions, (2004). Changes to Decision Making Principles for Waste Strategy 2000.

Anaerobic digestion has been assessed on the tonnages of waste recycled, converted to biogas and landfilled. The tonnage recycled was scored with a three and the tonnes landfilled scored zero. The tonnage of waste converted to biogas was given a score of one as this was considered to be on the same level as EfW and below composting.

For each option, the score given to each technology has been multiplied by the amount of waste treated by that technology (expressed as a percentage total waste managed by that option) over the whole period. These figures have been summed to provide a total score for each option.

The highest scoring option employed treatment facilities that manage waste at the top of the waste hierarchy, and, as a result, has been awarded the highest overall rank (1). The option that scored least well relies on managing waste lower down the waste hierarchy and was allocated the lowest rank (8). Again, all other options were ranked according to their position within this range.

Results

Table 1.24 presents the total quantities of waste as a percentage being managed under each level of the waste hierarchy. These percentages were multiplied by the waste hierarchy score for each technology over the whole period. These figures have been summed to provide a total score for each option.

Table 1.24 Percentage of Material at each level of Waste Hierarchy*

	Option							
Waste Technology	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Waste Minimisation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Recycling and Composting	39.58	39.57	39.62	39.67	40.19	39.58	40.62	46.13
Energy from Waste / Gasification	35.46	34.82	33.43	30.95	34.49	35.46	30.95	30.95
Landfill	26.57	27.18	26.85	27.58	26.84	26.61	26.14	24.27

*The total percentage of waste is greater than 100% as a proportion of the material landfilled and recycled has also been processed by the Energy from Waste / Gasification facility.

Table 1.25 presents the performance scores for each option.

Table 1.25 ***Compliance with Waste Policy to Determine Performance Score for MSW Options***

	Option							
Waste Technology	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Recycling/composting	1.19	1.19	1.19	1.19	1.21	1.19	1.22	1.37
Anaerobic digestion							0.06	
Energy from waste / Gasification	0.35	0.35	0.33	0.31	0.34	0.35	0.31	0.31
Landfill	0	0	0	0	0	0	0	0
Total	1.54	1.54	1.52	1.50	1.55	1.54	1.59	1.68
Rank (1 = best performing)	4	6	7	8	3	4	2	1

Option 8 performs best, as compostable kitchen waste is also collected as part of this option, thereby significantly increasing the tonnes of waste composted while simultaneously reducing dependence on landfill. Options 5 and 7 perform strongly against this criterion due to an increased level of recycling associated with both processes and some additional energy recovery.

Option 2 performs worse than options 1 and 6, as less waste is thermally treated, resulting in more waste being landfilled and reduced levels of ferrous metal recycling. Option 2 sees the introduction of additional thermal treatment in stages. The quantity of waste landfilled is greater between 2016 and 2019 than in options 1 and 6 and this results in a lower rank against this criterion for option 2.

1.4.13 *End Product Liability*

This criterion considers the risks associated with finding a market willing to accept the end products arising from the technologies employed by each option. Some waste management technologies have greater risks associated with the management of end products because the markets for these materials are unproven or under-developed. The methodology used to assess the likely risks associated with the markets for end products has been outlined below.

Method and Assumptions Used

The end product(s) from each technology have been awarded a score based on the current risk associated with markets willing to accept it. These risks have been estimated using professional judgement.

Table 1.26 presents the 'score' that has been awarded to end product markets. A high score (0.10) indicates a higher risk of finding a market willing to accept an end product. A low score (0.01) indicates that markets for end products are stable and well established. These scores have been used to determine the performance of each option.

Table 1.26 End Product Liability Score

End Product & Destination	Risk of Finding a Market	End Product Liability Score
RDF combusted at Allington	HIGH	**0.07**
Hazardous material to landfill	MED	**0.05**
Markets for composting and landspreading – generic	MED	**0.05**
Markets for dry recyclables	MED	**0.04**
Non-hazardous material to landfill	LOW	**0.02**

A high liability score has been attached to RDF produced by treatment technologies for combustion at Allington EfW because there is, as yet, no guarantee that this material will be accepted at a reasonable gate fee.

The recent ban on co-disposal of hazardous and non-hazardous waste in the UK has severely reduced the number of landfill sites licensed to accept hazardous waste. However, there is a landfill site capable of accepting hazardous material being planned for the Isle of Sheppey in Kent. The disposal of hazardous waste to landfill has been ranked as medium risk as any problems at this landfill would require significant extra transport outside the region to the next nearest hazardous landfill site.

For each option, the tonnages of each end product (as a percentage of total waste managed) have been multiplied by the end product liability score. These figures have been summed for each end product over the period to provide a total score for each option.

The option with the lowest risk score employs treatment facilities that have established markets willing to accept end products and, as a result, has been awarded the highest overall rank (1). The option with the highest risk score relies on managing waste by technologies that have less established markets willing to accept end products and was allocated the lowest rank (8). Again, all other options were ranked according to their position within this range.

Results

Table 1.27 presents the total quantities of each end product as a percentage of the total waste managed by each option. The percentages were multiplied by the end product liability score and these figures summed to provide a total score for each option.

Table 1.27 ***End Products from each Technology for Kent (Expressed as a % of Total Waste Managed)***

End Products	Option							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
All Recyclates	30	30	30	30	31	30	31	30
Compost/landspread	9	9	9	9	9	9	9	16
Additional RDF	25	26	26	27	26	25	25	23
Hazardous residues	1	1	1	1	1	1	1	1
Non-Hazardous residues	25	26	26	27	26	25	25	23

Table 1.28 presents the performance scores for each option.

Table 1.28 ***End Product Liability Ranking to Determine Performance Score for Kent Options***

End Products	Option							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Recyclate	1.20	1.20	1.21	1.21	1.23	1.20	1.25	1.20
Compost / Landspread	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.80
RDF	0.00	0.00	0.17	0.00	0.25	0.00	0.00	0.00
Hazardous Residues	0.06	0.05	0.05	0.05	0.05	0.06	0.05	0.05
Non-Hazardous Residues	0.51	0.52	0.52	0.53	0.51	0.51	0.50	0.47
Total Score	**2.24**	**2.25**	**2.42**	**2.26**	**2.52**	**2.24**	**2.27**	**2.52**
Rank (1 = best performing)	1	3	6	4	8	2	5	7

Options 5 and 7 perform worst due to the large quantities of recyclate and RDF produced by the autoclave and the extra material collected for composting respectively. As recycling rates increase and more is collected, recycling markets will stabilise and the liability associated with this material should reduce. Conversely, as more green waste and food scraps are collected nationwide, there is the potential for markets to be flooded. The liability of this material may increase without further national and local efforts to develop markets so that it can compete directly with other commercially available composts.

The thermal treatment of further waste in options 1, 2 and 6 does not significantly increase the liability associated with hazardous waste. The low scores associated with the hazardous residues reflect the relatively small quantities of residues produced in each option.

1.4.14 *Employment Opportunities*

The increase in long and short-term employment opportunities in the county created by the operations phase of new waste management facilities is an important criterion in terms of benefits for the local community and the local economy. The number of jobs generated by a particular facility depends primarily on two factors:

- type of facility (ie type of waste treatment/disposal technology); and
- size of facility (ie annual waste treatment/disposal capacity).

Methods and Assumptions Used

Limited research has been carried out in this area until now, hence the data used here was taken from another BPEO report, the South West Regional Assembly (SWRA) BPEO Report from June 2003,(1) which was part of 'Developing a Regional Waste Strategy for the South West'.

This report included baseline information on employment opportunities created by large (ranging from 15,000 to 100,000 tonnes per annum) and small (ranging from 2,500 to 5,000 tonnes per annum) waste management facilities including MRF, windrow composting, in-vessel composting, AD, MBT, autoclave, EfW and landfill. The employment data for gasification facilities was provided by Thermoselect SA(2). These are only indicative numbers as employment might be expected to vary between facilities using the same technology.

The baseline information included data on the total number of jobs generated, shift work and working time per month by type of facility at a specific annual capacity. The total jobs generated were split into four categories:

- skilled workers (consisting of site managers, assistant managers and foremen),
- unskilled workers (consisting of operatives).
- ancillary workers (consisting of workers associated with waste management supporting industries but not directly involved)
- construction workers

For each type of facility, the number of skilled and unskilled workers was scaled according to facility capacity. The number of workers employed at larger facilities was assumed to be less than proportionally greater than the number employed at a smaller facility due to economy of scale (*Annex E*).

(1) SLR Consulting Limited (June 2003) SWRA BPEO Report, Appendixes 4 & 7. http://www.southwest-ra.gov.uk/swra/downloads/ourwork/waste/downloads/BPEO/Phase4.pdf [09/11/04 @ 14:30]
(2) Thermoselect SA is a Swiss technology provider for a high temperature gasification process named THERMOSELECT, who was the source for indicative employment opportunities data for gasification.

Calculation of the Impact Scores

The impact score for the employment opportunities criterion consists of an annual average of total jobs for each of the eight options. An option's score was based on the total number of workers associated with an option.

Results

The employment opportunities results are presented in *Table 1.29* in terms of the average number of jobs over the total period across different sectors.

Table 1.29 ***Employment Opportunity Scores (in Total Jobs for the Period) for each Option***

	Option							
Employment Type	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Skilled	53.6	52.3	55.2	54.3	55.2	53.6	53.6	62.0
Unskilled	186.2	181.2	187.2	190.5	188.2	187.6	183.8	178.0
Ancillary	147.2	147.2	152.2	154.1	152.2	147.2	147.2	147.3
Construction	42.9	28.6	35.2	33.3	35.2	42.9	33.3	45.7
Total	429.8	409.2	429.9	432.3	430.8	431.2	417.9	433.0
Rank (1 = best performing)	6	8	5	2	4	3	7	1

The additional in-vessel composting sites require greater construction manpower. The greater level of automation associated with in-vessel composting, as opposed to windrow composting, results in a drop in unskilled operational staff, but an increase in skilled staff in comparison to the other options.

The large quantity of waste passing through the relatively man-power intensive MBT plant in option 4 results in this option producing the next highest level of employment. The complexity of the new facilities in options 1 and 6 requires a high level of construction staff.

Option 2 does not require the construction of any new facilities, relying on one EfW plant. As the waste flow is concentrated through one existing facility, the number of operatives and construction staff is reduced.

Although this criterion is ranked so that it favours those options that create employment, it may also be examined from an alternative angle. Employment in the southeast of England is high and many jobs in the waste industry, especially unskilled positions, are not considered very desirable. Those options that require higher numbers of staff outside of construction may struggle to attract the required number of people to fill these positions. A high rate of employment may, therefore, be considered a negative impact.

1.4.15 *Summary of Option Results*

A summary table of options is provided below. The performance of the alternative waste management options against the criteria is summarised on the pullout sheet. The performance matrix is a valuable aid to decision-making in itself in indicating the relative advantages and disadvantages of the options. However, direct use of the results it contains is difficult because of the matrix's complexity and the use of different units. The performance of each option for each criterion is also ranked, with the rank shown in brackets.

Results show that the environmental benefits of materials recycling and recovery outweigh the impact of the processes and associated transport. Option 7 performs best against the environmental criteria due to the presence of a plastics separation process prior to digestion. However, such a process might be 'bolted on' to any of the options to increase recycling rates. The recycling of plastics has a large positive impact on these criteria due to the relatively large environmental impact associated with virgin plastic production.

Option 8 relies on in-vessel composting to achieve its targets. Although there are considerable environmental benefits from this option, the lack of additional energy production results in this option ranking lowest against the environmental criteria. This option does score well in terms of compatibility with the waste hierarchy, job creation, land use and cost. However, the production of large quantities of compost may hamstring this option. The risk to water pollution is greatest in this option due to the large number of composting sites.

Option 2 performs well under the deliverability criterion as the option relies on a well established technology and does not require the construction of any further facilities. However, the greater level of mixed refuse treated at EfW plants in options 1 and 2 is responsible for the greater health impacts of these options. The options involving thermal treatment have the lowest liability associated with their end products.

There is not a significant difference in transport distances between options 1, 4, 6, 7 or 8. This assessment is not site-specific and any small alteration to the locations of the facility in East Kent may quite easily affect the order of these options. The location of a plastics reprocessor in St Helens combines with transporting autoclave fluff across the county to Allington from East Kent to increase the total transport distance associated with option 5 over the other options.

The costs associated with option 8 are lowest; however, those authorities that do not currently collect garden waste would have to make a large investment in collection infrastructure as discussed in the Recycling and Composting section of this report.

The selection of any of the above treatment options should only be undertaken with a full understanding of the impact of that option on the collection infrastructure of the associated districts.

Summary of Residual Waste Options Results

Criterion	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Depletion of resources (tonnes of crude oil equivalents)								
Score	-3,411,017	-3,393,398	-3,394,507	-3,311,400	-3,461,535	-3,428,183	-3,565,545	-3,309,702
Rank	(4)	(6)	(5)	(7)	(2)	(3)	(1)	(8)
Value	0.40	0.33	0.33	0.01	0.59	0.46	1.00	0.00
Air acidification (tonnes of sulphur dioxide)								
Score	-31,939	-31,831	-32,027	-31,572	-32,243	-32,058	-32,784	-31,309
Rank	(5)	(6)	(4)	(7)	(2)	(3)	(1)	(8)
Value	0.43	0.35	0.49	0.18	0.63	0.51	1.00	0.00
Greenhouse gas emissions (tonnes of carbon dioxide equivalents)								
Score	-5,361,810	-5,351,544	-5,351,831	-5,364,684	-5,602,111	-5,408,378	-5,768,375	-5,088,642
Rank	(5)	(7)	(6)	(4)	(2)	(3)	(1)	(8)
Value	0.40	0.39	0.39	0.41	0.76	0.47	1.00	0.00
Health impacts (health impacts score)								
Score	0.5548	0.5464	0.5379	0.5075	0.5454	0.5066	0.4963	0.4993
Rank	(8)	(7)	(5)	(4)	(6)	(3)	(1)	(2)
Value	0.00	0.14	0.29	0.81	0.16	0.82	1.00	0.95
Energy consumption (GJ)								
Score	-169,297,001	-168,404,221	-168,343,617	-164,012,945	-173,051,689	-170,173,353	-177,576,344	-164,352,797
Rank	(4)	(5)	(6)	(8)	(2)	(3)	(1)	(7)
Value	0.39	0.32	0.32	0.00	0.67	0.45	1.00	0.03
Total road kilometres (te-km)								
Score	52,073,274	51,653,330	53,301,919	52,065,179	56,790,470	52,156,058	55,993,597	52,113,145
Rank	(3)	(1)	(6)	(2)	(8)	(5)	(7)	(4)
Value	0.92	1.00	0.68	0.92	0.00	0.90	0.16	0.91
Employment opportunities (annual average no. of total jobs)								
Score	429.8	408.5	429.9	432.3	430.8	431.2	417.9	433.0
Rank	(6)	(8)	(5)	(2)	(4)	(3)	(7)	(1)
Value	0.87	0.00	0.87	0.97	0.91	0.93	0.38	1.00
Compliance with policy (tonnes recycled/composted)								
Score	1.54	1.54	1.52	1.50	1.55	1.54	1.59	1.68
Rank	(4)	(6)	(7)	(8)	(3)	(4)	(2)	(1)
Value	0.23	0.20	0.13	0.00	0.28	0.23	0.48	1.00
Liability of end product (tonnes recycled/composted)								
Score	2.24	2.25	2.42	2.26	2.52	2.24	2.27	2.52
Rank	(1)	(3)	(6)	(4)	(8)	(2)	(5)	(7)
Value	1.00	0.96	0.35	0.93	0.00	0.99	0.90	0.00
Deliverability & Risk								
Score	7.00	8.00	6.00	6.00	4.00	4.00	6.00	5.00
Rank	(2)	(1)	(3)	(3)	(7)	(7)	(3)	(6)
Value	0.75	1.00	0.50	0.50	0.00	0.00	0.50	0.25
Water Pollution								
Score	1204	1177	1195	1216	1190	1190	1215	1219
Rank	(5)	(1)	(4)	(7)	(2)	(2)	(6)	(8)
Value	0.35	1.00	0.57	0.08	0.68	0.68	0.10	0.00
Land Use								
Score	106.8	107.0	107.0	109.7	106.6	106.8	107.0	101.8
Rank	(3)	(6)	(5)	(8)	(2)	(4)	(7)	(1)
Value	0.37	0.35	0.35	0.00	0.40	0.37	0.34	1.00
Cost								
Score	39.19	38.40	40.12	40.54	40.10	39.49	39.70	37.84
Rank	(3)	(2)	(7)	(8)	(6)	(4)	(5)	(1)
Value	0.50	0.79	0.15	0.00	0.16	0.39	0.31	1.00

Option	Description
Option 1	New Energy for Waste facility in East Kent
Option 2	Expand current contracted capacity at Allington EfW
Option 3	Mechnical Biological Treatment (MBT) plant in East Kent providing Refuse Derived Fuel (RDF) to Allington EfW
Option 4	MBT plant in East Kent stabilising material to landfill
Option 5	Autoclave in East Kent with 'fluff' to Allington EfW
Option 6	Gasification plant in East Kent
Option 7	Anaerobic Digestion facility in East Kent
Option 8	In-vessel composting facilities across Kent for Garden and Kitchen Waste

Key

- Best Performing Option
- Second Best Performing Option
- Next to Worst Performing Option
- Worst Performing Option

2 SENSITIVITY ANALYSIS

2.1 THE NEED FOR SENSITIVITY ANALYSIS

The results of the options appraisal showed that option 7, the commissioning of an anaerobic digestion (AD) plant to serve East Kent, performed favourably against a number of criteria, specifically those dealing with environmental performance. In the subsequent weighting step, significant weight was allocated to these environmental criteria and, as such, option 7 was found to out-perform other residual treatment options overall.

Investigation into the reasons behind the strong performance of option 7 and it was showed that a significant proportion of environmental benefit resorted from upfront plastics recycling associated with the process.

Plastic recycling has a significant beneficial impact on performance against environmental criteria due to the significant environmental impacts associated with virgin plastic production.

The AD technology option assessed was a process that only accepts residual MSW for treatment, rather than separated organic waste. Very little published data exists for a process of this kind. The Oaktech AD process presented in the Environment Agency's Waste Technology Data Centre was used as a reference for data and assumptions employed in modelling. The main stages in the process include: MSW separation, bag splitting, wet separation of clean recyclables; hydrocrushing to separate fibres in the biodegradable material; followed by a two-stage anaerobic digestion.

A Key issue is the separation of 95% of incoming plastics for recycling prior to digestion.

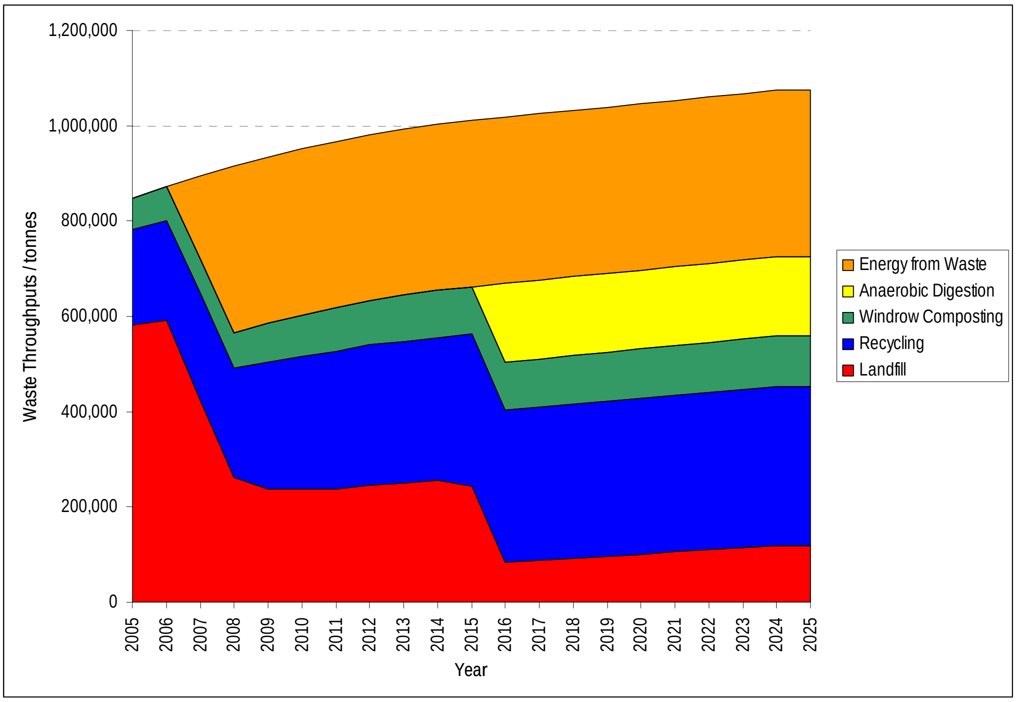
However, upfront pre-sorting of plastics from a mixed residual waste stream such as this would be technologically feasible with a number of the alternative technologies assessed, not only AD. Further, little is known of the quality of materials recovered and their useful potential for reprocessing into secondary products. In light of these uncertainties, there is a need to assess the sensitivity of results to this assumption, to determine the extent to which the outcomes might be biased because of the plastic recycling associated with the AD reference data.

2.2 CARRYING OUT THE SENSITIVITY ANALYSIS

2.2.1 *Developing the Alternative Option*

An alternative option, 7a, was developed to characterise an identical anaerobic digestion plant to that modelled as option 7 in the original assessment. Again the plant separates plastics and other materials for recycling prior to digestion. However, in this case it is assumed that the separated plastics will be of poor quality, unsuitable for recycling and instead will be sent to landfill. The capacity of the plant and the timing of construction are the same as for option 7 (approximately 165,500 tpa, built in 2016). Waste throughputs for option 7a are shown in *Figure 2.1* and are the same as for option 7.

Figure 2.1 ***Option 7a - Waste Throughput***



2.2.2 *Appraising the Sensitivity Option*

Option 7a was appraised against the same set of performance criteria as used in the original assessment. The methods used to assess the option against criteria are identical to those described in *Section 1.4* of the *Residual Treatment Options* report.

2.3 SENSITIVITY RESULTS SUMMARY

Performance scores for option 7a scores are presented in the table below within the context of the other waste management options considered in the assessment. The performance of each option against each criterion is ranked, with the rank shown in brackets. Valued performance results are also presented, presenting the results for each option against each criterion in terms of the common index of 'value'.

The results show that, where option 7 out-performed all the other options against the environmental criteria (depletion of resources, air acidification, greenhouse gas emissions, energy consumption), option 7a performs less well.

Instead, autoclaving, option 5, is the higher-performing technology. This is evident in particular for resource depletion and energy consumption. This is an expected outcome as the plastics recycling previously allocated to the AD option is rewarded with a considerable resource depletion and energy benefit, to account for high consumption during virgin material production. The removal of this recycling benefit has a significant effect on the overall benefits offered by anaerobic digestion.

We can conclude that the results for AD are highly sensitive to the inclusion of a pre-sorting process for plastics. When the results of the residual options appraisal are employed, account should be taken of the less favourable performance of AD against the environmental criteria should pre-sorted plastics be unusable or unsuitable for recycling.

Summary of Sensitivity Residual Waste Options Results including Option 7a

Criterion	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7a	Option 8
Depletion of resources (tonnes of crude oil equivalents)								
Score	-3,411,017	-3,393,398	-3,394,507	-3,311,400	-3,461,535	-3,428,183	-3,396,496	-3,309,702
Rank	(3)	(6)	(5)	(7)	(1)	(2)	(4)	(8)
Value	0.67	0.55	0.56	0.01	1.00	0.78	0.57	0.00
Air acidification (tonnes of sulphur dioxide)								
Score	-31,939	-31,831	-32,027	-31,572	-32,243	-32,058	-32,187	-31,309
Rank	(5)	(6)	(4)	(7)	(1)	(3)	(2)	(8)
Value	0.67	0.56	0.77	0.28	1.00	0.80	0.94	0.00
Greenhouse gas emissions (tonnes of carbon dioxide equivalents)								
Score	-5,361,810	-5,351,544	-5,351,831	-5,364,684	-5,602,111	-5,408,378	-5,596,651	-5,088,642
Rank	(5)	(7)	(6)	(4)	(1)	(3)	(2)	(8)
Value	0.53	0.51	0.51	0.54	1.00	0.62	0.99	0.00
Health impacts (health impacts score)								
Score	0.5548	0.5464	0.5379	0.5075	0.5454	0.5066	0.4973	0.4993
Rank	(8)	(7)	(5)	(4)	(6)	(3)	(1)	(2)
Value	0.00	0.15	0.29	0.82	0.16	0.84	1.00	0.96
Energy consumption (GJ)								
Score	-169,297,001	-168,404,221	-168,343,617	-164,012,945	-173,051,689	-170,173,353	-168,331,533	-164,352,797
Rank	(3)	(4)	(5)	(8)	(1)	(2)	(6)	(7)
Value	0.58	0.49	0.48	0.00	1.00	0.68	0.48	0.04
Total road kilometres (te-km)								
Score	52,073,274	51,653,330	53,301,919	52,065,179	56,790,470	52,156,058	52,432,685	52,113,145
Rank	(3)	(1)	(7)	(2)	(8)	(5)	(6)	(4)
Value	0.92	1.00	0.68	0.92	0.00	0.90	0.85	0.91
Employment opportunities (annual average no. of total jobs)								
Score	429.8	408.5	429.9	432.3	430.8	431.2	417.9	433.0
Rank	(6)	(8)	(5)	(2)	(4)	(3)	(7)	(1)
Value	0.87	0.00	0.87	0.97	0.91	0.93	0.38	1.00
Compliance with policy (tonnes recycled/composted)								
Score	1.54	1.54	1.52	1.50	1.55	1.54	1.53	1.68
Rank	(3)	(5)	(7)	(8)	(2)	(3)	(6)	(1)
Value	0.23	0.20	0.13	0.00	0.28	0.23	0.17	1.00
Liability of end product (tonnes recycled/composted)								
Score	2.24	2.25	2.42	2.26	2.52	2.24	2.25	2.52
Rank	(1)	(4)	(6)	(5)	(8)	(2)	(3)	(7)
Value	1.00	0.96	0.35	0.93	0.00	0.99	0.97	0.00
Deliverability & Risk								
Score	7.00	8.00	6.00	6.00	4.00	4.00	6.00	5.00
Rank	(2)	(1)	(3)	(3)	(7)	(7)	(3)	(6)
Value	0.75	1.00	0.50	0.50	0.00	0.00	0.50	0.25
Water Pollution								
Score	1204	1177	1195	1216	1190	1190	1233	1219
Rank	(5)	(1)	(4)	(6)	(2)	(2)	(8)	(7)
Value	0.51	1.00	0.68	0.31	0.76	0.76	0.00	0.25
Land Use								
Score	106.8	107.0	107.0	109.7	106.6	106.8	107.0	101.8
Rank	(3)	(6)	(5)	(8)	(2)	(4)	(7)	(1)
Value	0.37	0.35	0.35	0.00	0.40	0.37	0.34	1.00
Cost								
Score	39.19	38.40	40.12	40.54	40.10	39.49	40.54	37.82
Rank	(3)	(2)	(6)	(7)	(5)	(4)	(8)	(1)
Value	0.50	0.78	0.15	0.00	0.16	0.39	0.00	1.00

Option	Description
Option 1	New Energy for Waste facility in East Kent
Option 2	Expand current contracted capacity at Allington EfW
Option 3	Mechnical Biological Treatment (MBT) plant in East Kent providing Refuse Derived Fuel (RDF) to Allington EfW
Option 4	MBT plant in East Kent stabilising material to landfill
Option 5	Autoclave in East Kent with 'fluff' to Allington EfW
Option 6	Gasification plant in East Kent
Option 7a	Anaerobic Digestion Sensitivity
Option 8	In-vessel composting facilities across Kent for Garden and Kitchen Waste

Key

- Best Performing Option
- Second Best Performing Option
- Next to Worst Performing Option
- Worst Performing Option

Annex A

Technology Assumptions

A1 TECHNOLOGY CALCULATION ASSUMPTIONS

A1.1 INTRODUCTION

Modelling assumptions relating to the operating requirements and process outputs for each technology options are documented in this annex.

Data relating to the utility input requirements and output emissions assumed for each technology are presented in *Table A1.1* for comparison. These inputs and outputs are assumed to be proportional to the weight of waste processed, so no economies of scale are factored into these calculations. Further information and assumptions regarding specific technology options are detailed in sections *A1.3* to *A1.8*.

The majority of technology data has been sourced from the Environment Agency's life cycle assessment software tool for waste management, WISARD. Further details of the WISARD software can be found in *Annex E*. The Environment Agency's Waste Technology Data Centre, has also been used as a key source of information. The Waste Technology Data Centre is a centre of waste treatment technology data, assessment and knowledge sited in the Environment Agency, providing impartial information on the regulation, authorisation, performance and costs of waste management technologies and their overall environmental value.

Table A1.1 Summary of General Technology Data Assumptions

Technology	Input			Output		
	Electricity Demand (kWh/tonne)	**Diesel Usage (litres/tonne)**	**Steam Usage (MJ/tonne)**	**Electricity (kWh/tonne)**	**SO_2 (g/tonne)**	**CH_4 (g/tonne)**
MRF	25.0	0	0	0	0	0
Transfer Station	9.9	0	0	0	0	0
Windrow Composter	0	7.2	0	0	11.5*	17.8*
In-vessel Composter	0.1	7.4	0	0	11.5*	17.8*
AD	0	0.5**	0	232.0†	8.1	12.4
MBT (dry stabilisation)	50**	0.5**	0	0	7.5*	17.8*
MBT (aerobic composting)	50**	0.5**	0	0	11.5*	17.8*
Autoclave (‡)	23.9	0	510.7	0	0	0
EfW	0	1.2	0	532.5†	90.5	0
Gasification	0	1.2	0	611.0†	90.5	0
Landfill	0	1	0	see text	see text	see text
Hazardous Landfill	0	1	0	0	0	0

All data from ***WISARD***, apart from:

(†) Waste Technology Data Centre

(‡) *Mercia Waste Management*

(*) German research: Wallman, 1999 (1), Schwing, 2001 (2)

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(1) Wallman (1999) Ökologische Bewertung der Mechanisch-biologischen Restabfallbehandlung und der Müllverbrennung auf Basis von Energie- und Schadgasbilanzen. Dissertation, ANS Arbeitskreis für die Nutzbarmachung von Siedlungsabfällen e.V. (Hrsg.), Herft 38, Mettmann (DE)

(2) Schwing (2001), E.: Bewertung der Emissionen der Kombination mechanisch-biologischer und thermischer Abfallbehandlungsverfahren in Südhessen, Dissertation, Verein zur Förderung des Instituts WAR (Hrsg.), Schriftenreihe WAR Bd. 111, Darmstadt (DE), ISBN 3-93

(**) German research: Wallman, 1999

A1.2 *IMPACT FACTORS*

As discussed in the main report, emission factors were used to represent the impacts and emissions associated with various activities in the waste management chain, such as electricity generation or materials recycling. Figures for material depletion (coal, crude oil and natural gas) were used to quantify resource depletion and energy generation impacts/benefits. SO_2 emissions were used to assess acidification impacts and CO_2 and CH_4 emissions were used in the calculation of potential greenhouse gas impacts from these activities.

Table A1.2 shows the emission factors used in the assessment and methods described in the main report further explain how these emission factors are utilised.

Table A1.2 Impact Factors Used in Assessment

Activity	Coal Usage (kg)	Crude Oil Usage (kg)	Natural Gas Usage (m^3)	SO_2 Generation (g)	CO_2 Generation (g)	CH_4 Generation (g)	Basis	Source
Grid Electricity Generation	0.24	0.006	0.074	1.62	590.4	2.07	per kWh generated	BUWAL 250[1]
Diesel Generation	0.019	0.92	0.0026	2.30	421.68	3.70	per litre generated	ETH[4]
Diesel Combustion	-	-	-	0.76	2640	0.16	per litre combusted	WISARD
Transportation (28 tonne truck)	0.0012	0.055	0.0040	0.18	182	0.19	per tonne-km	Ecoinvent v1.2[2]
Transportation (RCV)	0.0094	0.37	0.019	1.67	1213	0.70	per tonne-km	Ecoinvent v1.2[2]
*Material Recycling**								
Plastic	0.011	-0.78	-1.032	-6.12	-1701	-3.09	per kg recycled	Idemat (2001)[3], BUWAL 250[1]
Glass	-0.091	-0.20	-0.0022	-2.42	-465	-0.78	per kg recycled	BUWAL 250[1]
Aluminium	-2.62	-1.25	-0.20	-54.76	-9070	20.25	per kg recycled	ETH[4]
Ferrous	-1.008	-0.063	-0.0	-3.32	-1810	-8.77	per kg recycled	BUWAL 250[1]
Aggregate	-0.0011	-0.0015	-0.00059	-0.021	-8.46	-0.011	per kg recycled	Idemat (2001)[3]
Paper	-0.04	-0.083	-0.0093	-3.54	-367	-0.629	per kg recycled	BUWAL 250[1]
Textiles	-0.28	-0.75	-1.1	-16.3	-2030	-4.05	per kg recycled	Idemat (2001)[3], BUWAL 250[1]
Garden Waste (fertiliser equivalent)	-0.0019	-0.0043	-0.011	-0.082	-37.1	-0.073	per kg composted	Ecoinvent v1.2[2]
Kitchen Waste (fertiliser equivalent)	-0.0025	-0.0057	-0.014	-0.11	-49.0	-0.097	per kg composted	Ecoinvent v1.2[2]
Wood	-0.021	-0.032	-0.010	-0.51	-179.4	-0.24	per kg recycled	Ecoinvent v1.2[2]

References:

1. BUWAL 250, 2nd edition. Fully documented and licensed database. (http://www.pre.nl/download/manuals/DatabaseManualBUWAL250.pdf)
2. Frischknecht R., Jungbluth N., Althaus H.-J., Doka G., Heck T., Hellweg S., Hischier R., Nemecek T., Rebitzer G., Spielmann M. (2004) Overview and Methodology. Ecoinvent report No. 1. Swiss Centre for Life Cycle Inventories, Dübendorf, 2004 (http://www.ecoinvent.ch/download/01_OverviewAndMethodology.pdf)
3. Data collection from various sources supervised by Dr. Han Remmerswaal, Faculty of Industrial Design Engineering, Delft Technical University, The Netherlands
4. ETH-ESU. Licensed database. (http://www.pre.nl/download/manuals/DatabaseManualETH-ESU96.pdf

**Benefits* per kg of material recycled

A1.3 *ANAEROBIC DIGESTION (AD) FACILITIES*

The AD technology option under consideration for the assessment was a process that would accept residual MSW for treatment, rather than solely organic waste. The WISARD software does not feature data for a process of this kind, and very little published data exists as such. The Waste Technology Data Centre presents mass balance data for the Oaktech Anaerobic digestion process and so modelling assumptions were based on this.

Key stages in the process include: MSW separation, bag splitting, wet separation of clean recyclables, hydrocrushing to separate fibres in the biodegradable material, followed by a two-stage anaerobic digestion.

The process suppliers report the following rate of separation of materials for recycling and these have been included in modelling calculations:

- ferrous metals – 95%
- non-ferrous metals – 90%
- plastics – 95% (3)
- glass/aggregate – 66%

The remainder of materials are assumed to contribute to the residue stream from the process.

The process suppliers further estimate a 56% loss of carbon during the process. It was therefore assumed that 56% of incoming biodegradable materials would be lost during the process, and the remainder would be left in the digestate product stream.

Net electricity output is reported as 232kWh per tonne of waste input. This was assumed to be attributable to the biodegradable fractions of incoming waste only, and so was apportioned accordingly.

No data regarding fuel consumption for plant machinery, or direct process emissions, are provided, but were assumed to be the same as for an MBT anaerobic digestion plant and based on figures from German research.

A1.4 *MECHANICAL BIOLOGICAL TREATMENT (MBT) FACILITIES*

Two alternative MBT technology options were under consideration for the assessment: a process configured to produce a refuse derived fuel (RDF) for burning; and a process configured to stabilise waste for landfill. Data regarding generic MBT configurations is very difficult to compile, as a wide variety of specific processing technologies exist. WISARD does not have any data for MBT plant and mass balance information in the Waste Technology Data Centre is limited (4).

(3) This material is assumed to be of poor quality and so is awarded only half of the offset benefit presented in *Table A1.2*
(4) As accessed on 1st March 2006.

Whilst in the process of developing generic data on MBT for the forthcoming update of their WISARD tool, the Environment Agency met with various industry contacts, ORA and Juniper Consultants to collate generic datasets, based on techno-economic status and technical feasibility in the UK of various process configurations. Data from German research were identified and hail from two predominant sources:

- *Wallman (1999)* Ökologische Bewertung der Mechanisch-biologischen Restabfallbehandlung und der Müllverbrennung auf Basis von Energie- und Schadgasbilanzen. Dissertation, ANS Arbeitskreis für die Nutzbarmachung von Siedlungsabfällen e.V. (Hrsg.), Herft 38, Mettmann (DE)
- *Schwing (2001),* E.: Bewertung der Emissionen der Kombination mechanisch-biologischer und thermischer Abfallbehandlungsverfahren in Südhessen, Dissertation, Verein zur Förderung des Instituts WAR (Hrsg.), Schriftenreihe WAR Bd. 111, Darmstadt (DE), ISBN 3-93

In order to model the waste composition and material flows through both processes, some assumptions were necessarily made and are detailed below. These are based on the German research, as noted, and on discussions with the Environment Agency.

MBT configured to produce RDF

- 95% of ferrous and non-ferrous removal for recycling;
- materials extraction to the high calorific value fraction (RDF) is 5% for inert materials and 95% for all other materials. Remaining materials report to the residue product stream and are sent for landfill; and
- a biodrying process is used to reduce the mass of the high calorific value fraction to 50% of the input waste (5).

MBT configured to stabilise waste for landfill

- 95% of ferrous and non-ferrous removal for recycling;
- paper and card fractions degrade by approximately 50% and putrescible fractions (kitchen and garden waste) by 90%. Dependent on input waste composition, this is equivalent to approximately 60% loss of biodegradable content from incoming residual waste. The recent report on MBT technologies by Juniper (6) presents a range of 24-90% BMW diversion for processes stabilising output for landfill. The midpoint of this range is 57% and so the modelled degradation rate is considered reasonable.
- the remainder of materials remain in the residue product stream and will be sent to landfill.

(5) Reported in: Lechner *et al*. MBT - How can goals be reached. In: Papadimitriou, E. K.; Stentiford, E. I. (Ed.): Biodegradable and Residual Waste Management, Publisher: CalRecovery Europe Ltd., Leeds (UK) 2004, p. 31 -45, ISBN 0-9544708-1-8

(6) Juniper Consultancy Services Ltd (2005). *MBT: A Guide for Decision Makers. Processes, Policies and Markets.*

Fuel consumption and electricity requirements were assumed to be same for both plant and were based on figures from Wallman (1999). Process emissions data were further based on the German research earlier noted.

A1.5 *AUTOCLAVING FACILITIES*

Autoclaving is another new process that is not modelled in WISARD. Information is rather limited in the public domain on autoclaving, so ERM was obliged to makes key assumptions, based on information provided by Mercia Waste Management:

- autoclaving does not destroy waste; 100% of input weight (plus additional water that is added during the process) is sent to one of three fates:
    1. recycled (7) ;
    2. converted to fibre for use as a refuse-derived fuel (with an assumed calorific value of 8MJ/kg) for combustion; and
    3. sent to inert landfill.
- it was assumed that the moisture content of the fibre is 50%. This is made up of a combination of moisture in the incoming waste and steam used in the process.

A1.6 *ENERGY FROM WASTE (EFW) FACILITIES*

ERM modelled EfW plant to be new facilities, with all the state-of-the-art emission controls that that entails. Information from the Waste Technology Data Centre was used to model energy generation from EfW, based on net yields as reported from the SITA plant in Cleveden (8).

Data relating to yields of bottom ash (27%) and fly ash (3.7%) were based on estimates from a similar EfW process in WISARD. It was assumed that all bottom ash will be recycled as aggregate and fly ash will be sent to hazardous landfill.

In addition to the emissions data provided in *Table A1.1*, it was necessary to estimate the fossil CO_2 emissions from burning plastics. *SIMAPRO* was used to calculate that each tonne of plastic burnt would generate, on average, 2.283 tonnes of fossil CO_2.

A1.7 *GASIFICATION FACILITIES*

Again, gasification does not appear in WISARD and information on the technologies is rather limited. In the absence of further data, ERM assumed the same operating requirement (fuel for machinery) as EfW and the same process emissions. Data from the Waste Technology Data Centre was used to

(7) The process assumes 95% recovery of metals and plastics, and 80% recovery of glass

(8) http://www.environment-agency.gov.uk/wtd/679004/679021/679059/976243/976284/?version=1&lang=_e

model energy generation, based on net yields from the KBI plant in Arnstadt, Germany, as this was the only gasification plant for which comprehensive data were available [9]. Data relating to yields of bottom ash (22%) and fly ash (4.3%) were also based on this plant.

It was assumed that all bottom ash will be recycled as aggregate and fly ash will be sent to hazardous landfill.

A1.8 LANDFILL

The active landfill model used was from WISARD, based on a large, wet, composite-lined landfill. A number of assumptions were made, in order to complete the modelling, based upon the rate of generation of gases and the fate of the landfill gas. Firstly, it is assumed that the gases generated are dependent on the incoming waste composition, as shown in *Table A1.3*.

Table A1.3 Landfill Gas Generation (kg Gas per tonne Waste Component)

Waste Component	Generation of CH_4	Generation of SO_2
Putrescibles	43.5	14.2
Paper/Card	97.8	31.8

Secondly, it is assumed that the landfill gas' fate is as given in *Table A1.4*.

Table A1.4 Landfill Gas Fate

Fraction	Fate
23%	Discharged
37%	Flared
40%	To Gas Engine

Finally, the gas engines are assumed to have an efficiency of 32.5%, with methane having a CV of 50.0 MJ/kg. With this information, it is possible to calculate (for example) the electricity generation, as shown in *Box A1.1*.

Box A1.1 Formula for the Calculation of Landfill Engine Electricity Generation

$$\begin{matrix}\text{Electricity}\\\text{Generation}\end{matrix} = \begin{matrix}\text{Waste}\\\text{Throughput}\end{matrix} \times \left[\left(\text{CH}_4 \text{ per te} \times \%\right)_{\text{Paper}} + \left(\text{CH}_4 \text{ per te} \times \%\right)_{\text{Putrescibles}}\right] \times \begin{matrix}\text{\% to Gas}\\\text{Engine}\end{matrix} \times \begin{matrix}\text{Engine}\\\text{Efficiency}\end{matrix} \times \begin{matrix}\text{CV of}\\\text{Methane}\end{matrix}$$

Hazardous landfills were assumed to have no direct emissions and generate no electricity as it was assumed that the wastes that they receive are inert. It was further assumed that hazardous landfills have the same operating requirements as active landfills.

(9) As accessed on 1st March 2006.

Annex B

Landtake Requirements

Table B1.1 Landtake Requirements (Hectares)

Plant Size / kte	MRF	Windrow Composting	In-Vessel Composting	MBT	EfW	Coal Displacement	Dirty MRF	Land Application / Other Treatment	Simple Combustion
10	0.44	4.51	1.02	1.44	0.83	0.83	0.44	10.72	0.83
20	0.81	9.02	2.07	1.51	0.94	0.94	0.81	10.76	0.94
30	1.18	13.54	3.11	1.58	1.05	1.05	1.18	10.79	1.05
40	1.55	18.06	4.16	1.65	1.16	1.16	1.55	10.83	1.16
50	1.92	22.57	5.21	1.72	1.27	1.27	1.92	10.86	1.27
60	2.29	27.09	6.25	1.79	1.38	1.38	2.29	10.89	1.38
70	2.66	31.60	7.30	1.86	1.50	1.50	2.66	10.93	1.50
80	3.03	36.12	8.34	1.93	1.61	1.61	3.03	10.96	1.61
90	3.39	40.63	9.39	2.00	1.72	1.72	3.39	10.99	1.72
100	3.76	45.15	10.43	2.07	1.83	1.83	3.76	11.03	1.83
110	4.13	49.66	11.48	2.14	1.94	1.94	4.13	11.06	1.94
120	4.50	54.18	12.52	2.21	2.05	2.05	4.50	11.10	2.05
130	4.87	58.70	13.57	2.28	2.16	2.16	4.87	11.13	2.16
140	5.24	63.21	14.61	2.35	2.27	2.27	5.24	11.16	2.27
150	5.61	67.73	15.66	2.42	2.38	2.38	5.61	11.20	2.38

Annex C

Transport

Table C1 *Location of & Distances (km) between Potential Transfer Facilities & HWRCs*

Facility Type & Location	Postcode	Distance to Allington EfW & MRF (ME19 5PF)	Distance to Shelford Landfill (CT2 0PR)	Proposed Facility in East Kent (CT1 3RJ)
Transfer Station & HWRC				
North Farm	TN2 3UY	24.3	80.5	71.9
Dunbrik	TN14 6EP	17.4	89.8	87.9
Church Marshes	ME10 2QD	33.5	29.6	27.7
Whitfield	CT16 3EH	87.5	28.2	23
Hawkinge	CT18 7AW	72.9	29.6	24.5
Average Distance		50.5	57.0	51.8

Table C2 *Location of & Distances (km) between Sites*

Facility Type & Location	Postcode	Distance to Allington EfW & MRF (ME19 5PF)	Proposed Facility in East Kent (CT1 3RJ)
Hazardous Waste Landfill			
Norwood Farm	ME12 3AJ	43.8	49.4
Energy from Waste Plant			
Allington EfW	ME19 5PF	-	59.5
Paper Reprocessors			
SCA Aylesford	ME20 7TW	11	-
Kensley Mill, Sittingbourne	ME10 2TD	34	-
Cardboard Reprocessors			
Kensley Mill, Sittingbourne	ME10 2TD	34	-
Smurfit, Snodland	ME6 5AX	12	-
Glass Reprocessors			
Industrial Reclamation, Faversham.	ME13 7TX	50	18.2
Berrymans, Dagenham	RM9 6QD	44	90.1
Metal Reprocessors			
EMR, Erith	DA8 2AD	34	79.3
Sims, Newport	CF24 2RX	283	353.6
Plastic Reprocessor			
Centrol, St Helens	WA9 4HY	384	430.5
Textiles			
London (LMB)	E16 4TG	43	-

Table C3 *Average Distance (km) from Composting Facilities to Assumed Transfer Stations and HWRCs*

Composting Facility	Postcode	Average Distance
Current Facilities		
Shelford	CT2 0PR	55.8
Dunbrick	TN14 6EP	57.5
Piper Farm, Conghurst	TN18 4RJ	52.9
Blaze Farm, Ashton*	ME19 6LU	49.2
Pinden Quarry	DA2 8EB	59.3
Assumed Additional Facilities**		
Ashford	TN23 4FD	50.7
Temple Ewell	CT16 3DR	57.9
Faversham	ME13 7DF	54.4

*Postcode unavailable for exact location; central Ashton postcode used.

** Postcodes represent random points near these locations.

Annex D

Financial Assumptions

D1 ERM WASTE FINANCIAL MODEL – EXPLANATORY NOTE

D1.1 INTRODUCTION

The waste financial model was developed to allow the financial comparison of a series of waste management options. The model provides the appraiser with a tool that is simple in operation and that offers a high degree of flexibility should it be required.

D1.2 ELEMENTS OF THE FINANCIAL MODEL

For explanatory purposes, the model has been broken down into several parts. These are:

- essential appraiser input;
- capital costs, operational costs and gate fees;
- collection costs; and
- revenue.

These four parts of the model are now explained one by one.

D1.2.1 *Essential Appraiser Input*

In this first section of the model, the user decides on the appraisal base year and the discount rate to be used. The discount rate places all future values, both costs and revenues, in present day prices. For Kent, a discount rate of 3.5% was used.

Secondly, the user can then input revenues per tonne that could be yielded from a variety of waste treatment approaches. It is suggested that commodity prices are taken from the Materials Recycling Week publication (www.mrw.co.uk).

Thirdly, several pieces of information relating to landfill must be entered:

- a landfill gate fee per tonne, based upon 2005/06 fees. In this case a value of £55.00 per tonne has been used;
- landfill tax per tonne: the model currently has this value at £18/te rising by £3/te/yr to a maximum of £35/te.

D1.2.2 *Capital Costs, Operational Costs and Gate Fees.*

The output from ERM's Waste Arisings Model and Mass Balance Model provides details on the tonnage of waste that will be allocated to each method of treatment. Based on this information the size of each treatment unit can be determined, as well as the year that it will come 'on line'.

The size of plant will have an impact on the cost. Treatment plant capital costs have been taken from the best available sources. Firstly, the Environment Agency's Waste Treatment Database (1) provides information on capital costs by manufacturer for a range of processes. Secondly, cost information is taken from a report by the Prime Minister's Strategy Unit (2).

Average operational costs for each type of treatment are taken from the same two sources.

The capital cost information is used to plot a graph demonstrating the correlation between the size of treatment unit and cost. An indicative cost can then be drawn from this to give a capacity based cost for any proposed treatment plants.

Some residual waste will go to landfill, either directly from household sources or after reduction at a treatment unit. The model calculates waste to landfill based on a gate fee approach, the value of which is specific to the geography being considered.

D1.2.3 Collection Costs

A separate ERM Collection Model provides information on tonnages levels collected from household sources, bring sites, civic amenity sites, etc. The ERM Financial Model links to this information and, based on the collection costs per tonne provided by the user at the essential appraiser input stage, can give a total collection cost for each waste management option.

D1.2.4 Revenue

In some cases, the potential revenue, that can be derived from a treatment process will influence whether it is incorporated into an authority's waste management strategy.

One of the outputs from ERM's Mass Balance Model is a tonnage value by waste stream and by treatment unit. The model takes this information and applies it to the information completed by the user in the essential appraiser input to calculate the revenue that would be gained from each treatment unit.

In addition to the revenues that can be gained from recyclates, a local authority may be in a position to sell excess landfill capacity at the price per tonne specified in the essential appraiser information.

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(1) Environment Agency's Waste Treatment Database
www.environment-agency.gov.uk/wtd
(2) "Delivering the Landfill Directive: the role of new and emerging technologies", SU Report, 2002.
www.strategy.gov.uk/downloads/files/af123.pdf [28 July 05 @ 2005]

It should be noted that if the authority does not want to include revenue in the appraisal, or wants to exclude some commodities for which it expects prices to fluctuate greatly, then the user simply has to set the value to zero in the introductory element stage.

Annex E

Employment Assumption

E1 EMPLOYMENT ASSUMPTIONS

Table E1.1 Skilled and Unskilled Employment by Facility Type

	Waste tonnage treated per annum	No of skilled	No of unskilled	Total number of workers
MRF/Transfer Station	25,000	3	13	16
	50,000	3	20	23
	75,000	3	24	27
	100,000	6	27	33
	125,000	6	30	36
	150,000	6	32	38
	175,000	6	34	40
	NB New shift needed per 100ktpa			
Windrow	15,000	2	4	6
	30,000	2	6	8
	45,000	2	7	9
	90,000	2	10	12
In-Vessel Composting	25,000	3	3	6
	50,000	3	5	8
	75,000	3	6	9
Anaerobic Digestion	50,000	2	5	7
	100,000	2	8	10
	150,000	4	9	13
	200,000	4	10	14
MBT	100,000	4	14	18
	150,000	4	26	30
	200,000	8	32	40
Energy from Waste	100,000	4	14	18
	200,000	8	32	40
	350,000	12	42	54
Gasification	100,000	11	50	61
	200,000	11	50	61
Landfill	100 000	3	4	7
	200 000	3	6	9

NB:
Skilled and Unskilled assume: site managers, assistant managers and foremen are skilled; and operatives/ weighbridge operators and machine operators are unskilled.
All figures above are taken from Appendix 4 SWRA BPEO Report June 2003
http://www.southwest-ra.gov.uk/swra/downloads/ourwork/waste/downloads/BEPO/Phase4.pdf

Table E1.2 Ancillary Jobs

Facility	Ancillary Industry	No. of Jobs per 10kte
Recycling	Recycling Industry	5
Windrow Composting	Agriculture	0
In-Vessel Composting	Agriculture	0
MBT	Recycling Industry	1
Autoclaving	Recycling Industry	1

Table E1.3 Construction Jobs

Facility	Number of Job Years
MRF	40
Windrow Composting	5
In-Vessel Composting	40
Anaerobic Digestion	100
MBT	100
Autoclaving	100
Incineration	300
Gasification	300
Active Landfill	10
Hazardous Landfill	10
Transfer Station	40

Annex F

WISARD Outline

F1 WISARD: AN OUTLINE

F1.1 INTRODUCTION

WISARD (Waste: Integrated Systems Analysis for Recovery and Disposal) is a waste management software tool developed for the Environment Agency of England and Wales by the Ecobilan Group (PriceWaterhouseCoopers).

The software employs a life cycle assessment (LCA) approach to forecasting the potential environmental impacts associated with user-specified integrated waste management systems. Accordingly, the software addresses potential impacts stemming from all stages in the management and processing of waste, including waste collection, transport, treatment and disposal activities, taking account of the associated infrastructure, together with the avoided impacts associated with materials and energy recovery.

F1.2 WISARD DEVELOPMENT

WISARD's development originates in 1994, when the then Wastes Technical Division of the Department of the Environment (now part of the Environment Agency) began a programme of research to quantify the environmental burdens [(1)] and related impacts, of management options for waste from cradle to grave, using a LCA framework. The initiative was aimed at providing a thorough and unbiased basis for comparing the environmental costs and benefits of waste management strategies and of options for individual waste types. The first report from the series examined how life cycle inventories for waste management could be developed (CWM 128/97 and 128A/97).

The programme's deliverables were aimed at informing two areas of policy development: national waste management policies and, in particular, the waste strategy for England and Wales; and waste management planning at the level of development planning and regional planning conferences.

WISARD's underlying software platform and interface is also used by Eco-Emballages in France, by the Scottish Environmental Protection Agency (SEPA) and by authorities in New Zealand. In each case, separate databases have been employed to reflect national circumstances, including energy sources etc.

(1) 'Burden' is a LCA term used to describe a demand made by a system on its environment, ie energy and raw material inputs, and outputs in the form of emissions, wastes and by-products.

F1.3 *WISARD DATA*

The software tool manipulates large databases, or life cycle inventories, which describe the environmental burdens associated with each of the activities of which an integrated waste management system is comprised, on a unit basis. For example, per tonne of waste collected. The inventories are multiplied according to the system defined by the user (eg 100,000 tonnes waste collected) and the burdens are then aggregated across the whole system and related to environmental impacts such as global warming and air acidification.

WISARD uses 'foreground' data on waste management activities (generally the most significant parts of the systems examined), together with 'background' data on materials and energy production (usually less important). Most of the foreground data were collected by the Agency's contractors as part of its life cycle research programme for waste management, under six separate projects [(1)]. The resulting inventories were peer reviewed by experts in the individual fields concerned, and the reports published, together with the review and project record, as PR P1/392/2 - 7. Guidelines for the collection and reporting of the data were also provided by the Agency to ensure compatibility and consistency (PR P1/392/8). ***WISARD*** provides information pages on sources and underlying assumptions for foreground data sets to aid data transparency.

Background data for ***WISARD*** were provided by the Ecobilan Group. Many of these data sources are standard life cycle references in the public domain, whilst others have been collected by the Ecobilan Group and are confidential. There is no information provided on the sources and underlying assumptions for these data. Although the background data were not peer reviewed, the software itself was subjected to a wider peer review by a panel of life cycle and waste management authorities (PR P1/392/1).

F1.4 *COVERAGE OF ENVIRONMENTAL IMPACTS*

In common with other life cycle tools, ***WISARD*** considers a set of environmental impacts which are generally global in nature because the sources of burdens considered are many and disparate. The ***WISARD*** Reference Guide [(2)] notes that the software has limitations in its assessment of environmental impact: specifically, it does not address *"human or environmental safety, legal compliance issues or nuisance issues (eg litter, dust and visual amenities)."* The Guide clearly states that *"there are other tools such as risk assessment and environmental impact assessment, which should be used for other functions such as assessing the safely of particular processes or the siting of particular waste handling or treatment plants."*

(1) Waste transport & other vehicle use, landfill, composting & anaerobic digestion, recycling and waste collection & separation.
(2) WISARD Reference Guide, Version 3.3, May 2000, Ecobilan - WM3.4r1, page 9.

The Environment Agency's Strategic Waste Management Assessments, published in November 2000, use ***WISARD*** to investigate the environmental impacts associated with future waste management scenarios for the planning regions of England and Wales. The report is restricted to four environmental impacts: air acidification, depletion of non-renewable resources; greenhouse effect and photochemical oxidant formation, which are *"…commonly associated with waste management systems."*, in order *"…to highlight the differences that result from managing the same waste in different ways"*.