1996
2006

Asiantaeth yr Amgylchedd Cymru
Environment Agency Wales

enhancing... improving... cleaning... restoring...
changing... tackling... protecting... reducing...
creating a better place... influencing...
inspiring... advising... managing... adapting...

Sustainability Appraisal and Life Cycle Analysis of Strategic Waste Management Options

Report for the SW Wales Regional Group. Part 1
Issue 2 – January 2008

ea/br/bl/std/vr10thanni

We are the Environment Agency. It's our job to look after your environment and make it **a better place** - for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.

Published by:

Environment Agency Wales
Ty Cambria
29 Newport Road
Cardiff, CF24 0TP
Tel: 0870 8506506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

Executive Summary

The Welsh Assembly Government has appointed Environment Agency Wales to complete a life cycle analysis, best practicable environmental option assessment and sustainable waste management options appraisal to assist with the revision of the Regional Waste Plans for the three Welsh regions. The first plans were published in 2004 to comply with TAN 21 and to ensure that land use planning in Wales accounts for the needs of waste management. There is a requirement for revision of the plans to take place every three years, reflecting changes in the waste streams arising within the regions, changes in land use and developments in the treatment methods that may be adopted. The work described within this report provides quantitative environmental data for the considered waste management options, enabling direct comparison between each option.

The nineteen waste management options were developed and agreed by local authority members in work undertaken over the last 18 months. All options have high levels of recycling and composting, followed by a variety of treatment technologies to deal with the residual waste.

A life cycle assessment approach has been applied, using the Environment Agency WRATE software to provide an assessment of the environmental performance of the 19 options in accordance with waste quantities and compositions forecast for 2013.

A number of other criteria were also considered within the Sustainability Appraisal. There were 22 indicators in total, and they can be broadly grouped as environmental and health, socio-economic, waste management service delivery and public framework objectives. Generic data was used to score some of the indicators, WRATE outputs for others, and for some of the indicators a group of waste management professionals were asked to provide scores based on professional judgement. The Regional Waste Groups were asked to weight the indicators; that is to place an importance value on each of the criteria being scored. The totals for the weighted scores provide the final results, with the options with the higher scores being the more favoured options.

The results for South West Wales Regional Waste Groups shows that waste management systems incorporating high levels of thermal treatment, or MBT pre-treatment followed by thermal treatment make up the top six options.

As a number of options scored well in the appraisal, the conclusion from this sustainability assessment is that the highest scoring options should form a technical basis for further development of the Regional Waste Plan for South West Wales.

The results of these studies will be used to inform the South West Regional Waste Planning Group when they choose their preferred option for the Waste Plan Reviews, but will not be used in isolation. It should be noted that a number of other studies are also to be carried out, including Health Impact Assessment and Strategic Environmental Assessment, and a full public consultation process will be undertaken before a preferred option can be incorporated into the plan.

Contents

Contents	**3**
1 Introduction	**4**
Outline Options Description	**6**
2 Strategic Waste Management Options for 2013	**7**
Option 0 – 'Do Nothing' strategy	**9**
Option 1 – A landfill-led strategy for residual waste	**9**
Option 2 – Energy from Waste-led strategy for residual waste	**11**
Option 3 – MBT/BMT-led strategy for residual waste	**13**
Option 4 – An autoclave/Mechanical Heat Treatment -led strategy for residual waste	**16**
3 Infrastructure Requirements	**18**
4 Sustainability Appraisal Methodology	**20**
5 Sustainability Objectives and Indicators Information	**21**
Environmental & Health Objectives	**21**
Socio-Economic Objectives	**23**
Waste Management Service Delivery Objectives	**23**
Public Framework Objectives	**24**
6 Performance of Options	**25**
Environmental & Health Objectives	**25**
Socio-Economic Objectives	**30**
Waste Management Service Delivery Objectives	**32**
Public Framework Objectives	**33**
7 Weighting of Sustainability Indicators	**34**
8 Sensitivity Analysis	**35**
9 Summary	**36**
Diversion of Biodegradable Municipal Waste from landfill	**37**
Preferred options for BPEO/SWMO criteria	**37**

Version control

02/01/08 – The report has been updated from the version used during the "Our Waste Our Challenge" consultation to include a footnote on page 10 explaining the heat capture assumption in WRATE for the Coventry EfW plant.

Introduction

The drive towards more sustainable waste management methods due, in part, to European waste legislation. This requires a shift from the disposal of wastes at landfill to a range of alternative treatment and disposal methods. European legislation also requires member states to develop an adequate network of waste facilities and to prepare waste management plans.

To implement this requirement Technical Advice Note (TAN) 21, published by the Welsh Assembly Government (WAG) in November 2001, set out the framework for regional waste planning in Wales. TAN 21 required that Regional Waste Plans (RWP) were published for each of three regions of Wales within two years. The first plans were published in 2003-4.

The creation of the plans involved the development and appraisal of a range of waste management options. In line with guidance in TAN 21 and Office of the Deputy Prime Minister (ODPM) guidance[1] on Planning for Sustainable Waste Management, these were subjected to Life Cycle Analysis (LCA) as part of a sustainability appraisal to determine the Best Practicable Environmental Option (BPEO) and the preferred Strategic Waste Management Option (SWMO).

BPEO assessments focus primarily on environmental indicators and impacts. In accord with the published guidance, the inclusion of additional sustainability indicators such as employment and public involvement enables the options to be considered on environmental and practicability grounds to determine BPEO but also to incorporate socio-economic issues in the determination of SWMO[2].

Using the Environment Agency's WISARD software, a life cycle analysis was conducted by SLR Consultants to determine the BPEO for the publication of the Regional Waste Plans in 2003. The analysis appraised six different waste management options and was used to generate a number of indicators to determine the BPEO. These indicators were then supplemented by additional sustainability indicators to complete the SWMO assessment.

TAN 21 requires the RWPs be reviewed every three years. As part of this review process, the range of waste management options for assessment has been expanded to include new and emerging waste technologies and refined to account for more current data on composition and arisings of waste.

The Environment Agency (EA) has completed the LCA for each of the new range of options for the RWP review. The LCA was conducted using a new tool designed to replace WISARD. The "Waste Resources Assessment Tool for the Environment" (WRATE) was developed by the EA, ERM and Golders Associates.

The appraisal of 19 waste management options has taken account of environmental, socio-economic and implementation issues through the use of 22 weighted indicators. The goal of the LCA study is to calculate 10 of the 22 indicators contributing towards the calculation of BPEO and SWMO from the options appraised. The indicators to be considered in the sustainability assessment, their derivation and whether their scores will contribute to determination of BPEO and SWMO or SWMO only are highlighted in table 45. The indicators incorporate weightings determined through consultation with the Regional Waste Group members.

The LCA and Sustainability Assessment will contribute directly to the RWP review. The assessment year is 2013 to which all waste streams have been forecast. The EA Waste Strategy team in Cardiff has conducted the study on behalf of the three regional waste planning groups.

Options Development

---

[1] 'Strategic Planning for Sustainable Waste Management: Guidance on Option Development and Appraisal' (ODPM, 2002)

[2] The concepts of BPEO and SWMO are discussed in Annex H of TAN 21, WAG (2002) and chapter 3 of Wise About Waste: A National Waste Strategy fo Wales (WAG) 2002

The original LCA, incorporated into the RWPs, assessed six waste management options and used approximation modelling for a technology not included in WISARD. In light of the emergence of a range of new waste technologies and the enhanced capability of WRATE, a wider range of options have been assessed for the RWP review.

Waste stream arising has been projected to 2013 by the regional waste planning co-ordinators based on current understanding of waste growth and trends. These figures were agreed by each of the Regional Waste Groups for the following waste streams. The forecast for each stream can be found in Appendix 2.

- Municipal Waste
- Construction and Demolition Waste
- Industrial and Commercial Waste
- Agricultural Waste

The options were discussed and developed at meetings of the three Regional Waste Group co-ordinators, EA, WAG and WLGA. It was agreed that, for each option apart from option 0, the 2020 landfill directive target (below) would be met in the study year.

"to reduce the amount of biodegradable municipal waste landfilled to 35% of that produced in 1995"

Substantial levels of recycling/composting of municipal waste will be required through source segregation to satisfy WAG targets set for each Local. These rates are defined within the option detail.

The source segregation recycling/composting rates relate primarily to the performance of local authorities in the management of municipal solid waste (MSW). WAG targets will need to be met for other waste streams i.e. recycling targets for construction and demolition (C&D) waste, landfill diversion for industrial and commercial (I&C) waste. The major impact on these streams will be the method of management of residuals and it is assumed, where appropriate, all waste streams will use the facilities described in each option.

The Sustainability Assessment process of the Strategic Waste Management Options (SWMO) follows the guidance provided by OPDM (2002) 'Strategic Planning for Sustainable Waste Management: Guidance on Option Development and Appraisal' as recommended in 'Wise about Waste; The National Waste Strategy for Wales' (2002). The seven steps generally accepted as fulfilling the requirements of the SWMO process are as follows:

- Step 1 – Identify and agree objectives and indicators against which all SWMO will be measured. Objectives address environmental, socio-economic, operational issues and conformity with waste policy targets.
- Step 2 – Develop all viable SWMOs and should cover all stages in waste management from collection through to treatment/disposal and to meet key objectives.
- Step 3 – Assess the performance of these options against the criteria identified within Step 1
- Step 4 – Value the performance scores for each option
- Step 5 – Apply weights to the sustainability indicators. This is because decision makers are likely to attach more importance to some indicators than others.
- Step 6 – Identify the preferred option, by multiplying the performance scores by the weights assigned in step 6 to the indicators.
- Step 7 – Sensitivity analysis & Option Refinement - analyse how sensitive the results are to variations in the assumptions made or the data used

The comparison of the options will be used to assess the relative impacts of each of the options and will be used to determine the BPEO and SWMO in each RWG area. A summary of the options devised by the Regional Waste Planning Groups is presented below. Chapter 2 outlines in more detail the modelling approach applied in the Life Cycle Assessment.

This report is divided into three sections. The main body of text can be found in part 1, results tables, graphs and figures are contained in part 2 with appendices in part 3.

Outline Options Description[3]

Option 0

'Do Nothing' strategy[4]

(This option is included for assessment purposes only – as a baseline to compare the other Options against). Front end levels of recycling and composting from the other options with no further treatment, projected on to waste tonnages arising in 2013

Option 1

A landfill-led strategy for residual waste

High recycling and composting levels followed by *low* levels of thermal treatment of residual waste using either:

- Pyrolysis (Option 1A), or
- Gasification (Option 1B), or
- Incineration with energy recovery (Option 1C)

All remaining residual waste would then be sent to landfill.

(Recycling / treatment levels are those required to achieve the 2020 (Biodegradable Municipal Waste (BMW) Landfill Directive target in 2013) where possible.

Option 2

An Energy from Waste-led strategy for residual waste

High recycling and composting levels with all remaining residual wastes, where possible, being treated by *high* levels of thermal treatment using either:

- Pyrolysis (Option 2A), or
- Gasification (Option 2B), or
- Incineration with energy recovery (Option 2C)
- Anaerobic digestion (Option 2D)

Any remaining residual waste would then be sent to landfill.

(Recycling/treatment levels are those required to achieve the 2020 BMW Landfill Directive target in 2013. Energy from Waste levels aim to minimise waste to landfill).

Option 3

An MBT/BMT-led strategy for residual waste

High recycling and composting levels, all remaining residual wastes being sent to MBT/BMT with the output recovered / disposed of using either:

- Pyrolysis (Option 3A), or
- Gasification (Option 3B), or
- Incineration with energy recovery (Option 3C), or
- Fuel to off-site energy use (Option 3D), or
- On-site Anaerobic digestion (Option 3E), or
- Landfill (Option 3F)

For Options 3A–3E, any remaining residual waste would then be sent to landfill.

(Recycling/treatment levels are the maximum possible – may exceed those required to achieve the 2020 BMW Landfill Directive target in 2013).

Option 4

An autoclave-led strategy for residual waste

High recycling and composting levels, all remaining residual wastes being sent to autoclave with the output recovered / disposed of using either:

- Pyrolysis (Option 4A), or
- Gasification (Option 4B), or
- Incineration with energy recovery (Option 4C), or
- Fuel to off-site energy use (Option 4D), or
- Landfill (Option 4E)

For Options 4A to 4E, any remaining residual waste would then be sent to landfill.

---

3 In all cases, the recycling/composting rate for municipal waste will exceed 50%. For option 1, the aspiration for the treatment of residual waste is to achieve the 2020 (Biodegradable Municipal Waste (BMW) Landfill Directive target in 2013. For options 2-4 all resiudal waste will be treated using the chosen technology type.

4 This option has been amended for the life cycle analysis to represent a scenario whereby no alternative disposal or treatment options are developed and all residual waste is sent to landfill. Source separated recycling and composting rates are the same as in all other options

1 Strategic Waste Management Options for 2013

The principal aim of the sustainability appraisal and life cycle analysis was to determine the Best Practicable Environmental Option (BPEO) and Sustainable Waste Management Option (SWMO) for the management of mixed residual waste in SW Wales. As discussed in chapter 1, 19 options were proposed for the South West Wales Regional Waste Planning Group however, during the assessment process, options 4A and 4B were ruled out due to technical feasibility issues following guidance by LCA Policy Advisors at the Environment Agency. The assessment was completed through the consideration of 22 environmental and sustainability indicators, which are detailed in table 45.

The waste management facilities considered were those that would receive household waste or similar fractions of industrial, commercial and agricultural wastes. The study also considered the management of construction and demolition wastes but these were managed through dedicated facilities and did not alter between options.

It was acknowledged at the outset that a number of waste types would normally be managed through specific waste facilities other than those that have been considered for this assessment. It was essential then, to determine the likely composition of each of the considered waste streams and then make a set of assumptions regarding their likely management route.

The fractions of each waste stream that would require an alternative management route (e.g. hazardous chemical wastes or oils) were excluded from the life cycle analysis and sustainability appraisal and no detailed assessment of their management routes was considered. It is suggested that the determination of the preferred option for the treatment of mixed wastes is unlikely to influence or affect the choice of management route for waste oils for example. Table 4 lists all of the waste fractions that were excluded from the modelling exercise.

All Municipal Solid Waste (MSW) was assumed to be managed through the facilities considered for this report. It was not possible to model the treatment of hazardous wastes collected separately at Civic Amenity sites. The type and arising of these wastes are shown in the first column of table 4. The modelled composition of MSW is shown in table 5 and figure 4.

As shown in table 4 and figure 3, much of the unmodelled waste is non-hazardous combustion waste from the steel industry. In accordance with the EA Industrial and Commercial Waste Survey (2003), this waste is currently managed with a fairly equal split between re-use, recycling and landfill (roughly 33% each). Chemical sludges, industrial sludges and septic tank sludges are likely to be landspread or treated. The modelled compositions of industrial and commercial wastes are shown in table 6 and 7 and figures 5 and 6.

The assumed composition of agricultural waste, shown in table 8 and figure 7 excludes the vast majority of organic agricultural wastes (manures, crop residues etc.) as it is expected that these will have an exempt or licensed management route on-farm or through other facilities not considered for this assessment. The modelled composition considers the inorganic fractions, such as plastic film and metals, which will require an external management route.

The composition of construction and demolition (C&D) waste was estimated to represent the non-inert fractions within the stream as well as the inert fractions that are often crushed and recycled as aggregate. This creates a requirement for significant levels of off-site recycling of plastic, metal and wood from C&D wastes. It was assumed that the data used for the SmithsGore survey (the baseline for forecasting the arising of construction and demolition wastes) did not account fully for the management of contaminated soils and other hazardous C&D wastes. The modelled composition for construction and demolition waste is shown in table 9 and figure 8.

The key outcome of the sustainability appraisal process is to determine the preferred options for the treatment of residual waste. The diversion from landfill is modelled in two ways; firstly an assumption has been made regarding the rate of front-end separation of wastes for recycling and composting and secondly the method use to treat the residual fraction. As the rate of front-end separation is common to each option, in describing the aspiration of each option, it is only necessary to detail the method for residual treatment as the variable factor.

For all options, the diversion of MSW at the front end for recycling/composting is 50%. This reflects the proposed 2020 target in the current review of the English waste strategy[5]. To derive the required performance the composition of the waste was examined and potentially recyclable fractions were identified[6]. Once identified, the recycling rate of each fraction was adjusted until the required overall rate was reached.

An 80.75% recycling rate was required for each of the recyclable fractions to create the desired overall rate of 50% for MSW. Inert municipal waste (waste fraction “Bricks, Blocks and Plaster”) collected at CA sites is recycled at 80.75% creating on overall recycling rate of 71.9% for that fraction. For the inert element of C&D wastes, a recycling rate of 95% has been modelled.

This recycling rate was then applied to the deemed recyclable fractions from each of the non-municipal streams. This generated a recycling rate of 74.1% for modelled industrial waste, 58.8% for modelled commercial waste, 61.8% for modelled agricultural waste and 83.5% for modelled construction and demolition waste[7].

The maintenance of an identical front-end performance across all options has ensured the study identifies the differences between the residual treatment methods. The waste management systems modelled for each option are illustrated in figures 9-25. These show the tonnage of each waste stream delivered to each facility and the transport distance assumed for each step. For detailed modelling assumptions, see appendix 2.

---

[5] Review of England’s Waste Strategy - A Consultation Document, February 2006. DEFRA

[6] The fractions that were recycled or composted from each waste stream at an overall capture rate of 80.75% are highlighted in green in tables 5-9

[7] The aggregate type materials within the C&D stream (Bricks, blocks and plaster) make up 69% of the C&D arising. This element has been recycled at a rate of 95% with all other recyclable elements recycled at 80.75%.

Option 0 – 'Do Nothing' strategy

This option is included for assessment purposes only – as a baseline to compare the other Options against. The original idea was to maintain the current levels of recycling, composting, energy from waste and landfill, however, high recycling front end levels have been applied as in all the other options, but with no further treatment. This comparison shows the effect of the residual waste management technology options. For all non-hazardous and hazardous landfills, the modelled technology in WRATE is landfill with High Density Poly Ethylene (HDPE) liner and HDPE cap. For inert landfill the assumption is for a clay liner and clay cap.

The waste flows and transport distances for option 0 are shown in figure 9, the subregional breakdown of option performance is in table 11 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 28.

Option 1 – A landfill-led strategy for residual waste

The generic aspiration for options 1a-c is for high levels of source segregated recycling followed by low levels of thermal treatment of residual waste using pyrolysis, gasification or incineration with energy recovery. A "low" level of thermal treatment is interpreted to mean the amount of additional material required to be treated to increase the level of Biodegradable Municipal Waste (BMW) landfill diversion to meet 2020 landfill directive targets. Any additional municipal and all residual commercial, industrial and agricultural wastes will be disposed of to landfill.

1a – Pyrolysis

The management of residual waste for this option is through low level thermal treatment using the following pyrolysis technology from WRATE:

- 21252[8] Pyrolysis (MSW and RDF) WASTEGEN process

This is based on plant currently operating in Germany, which treats municipal and industrial waste, bulky waste and sewage sludge. The residual MSW in the model requires no pre-treatment for this technology. All non-hazardous bottom ash/char from thermal treatments is assumed to be recycled as aggregate substitute. All Air Pollution Control (APC) residues require disposal at hazardous landfill. Electricity production will offset against the marginal project energy mix[9] (see Appendix 2).

The waste flows and transport distances for this option are shown in figure 10, the subregional breakdown of option performance is in table 12 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 29.

1b – Gasification

The management of residual waste for this option is through low level thermal treatment using the following pyrolysis technology from WRATE:

- 11268 Gasification (RDF only) ENERGOS process

The gasification process requires pre-treatment of the residual waste using a "dirty" materials recovery facility (MRF) to produce a Refuse Derived Fuel (RDF). For modelling purposes, the mechanical treatment element from a generic mechanical biological treatment (MBT) process in

[8] These process ID numbers correspond with the reference numbers associated with each technology fact sheet in appendix 3 of part 3. More detailed information on the WRATE technology can be found there

[9] The marginal mix represents the mix of power sources used to account for fluctuations in demand. It is this mix that is offset when a facility in the model is used to produce electricity (such as electricity produced from the incineration of waste)

WRATE has been used to represent a dirty MRF. Information on generic MBT processes in WRATE can be found in Appendix 3. Technology from WRATE data set to be applied:

- 11085 MBT pre-treatment GENERIC process

It is assumed the MRF is built on the same site as the gasification plant so no transport element will be required.

The MRF pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling as well as producing a light RDF fraction for gasification and a residual stream, which requires a disposal route. It is assumed that all non-hazardous bottom ash/char from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The residual fraction from the MRF is disposed of to landfill. Electricity production will offset against the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 11, the subregional breakdown of option performance is in table 13 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 30.

1c – Landfill and incineration with energy recovery

The management of residual waste for this option is through low level thermal treatment. The following two incineration technologies from WRATE have been modelled:

- 13041, Incinerator large, heat and power (COVENTRY[10]) – for urban arisings
- 11262, Incinerator medium, heat and power (GRIMSBY) – for rural arisings

These two incineration technologies were selected as they both utilise heat as well as generating electricity and are the most representative technologies available in the model. The differing scales account for the different waste densities and throughputs in both urban and rural areas.

No pre-treatment is required for incineration with energy recovery technology. It is assumed that all non-hazardous bottom ash from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill.

The waste flows and transport distances for this option are shown in figure 12, the subregional breakdown of option performance is in table 14 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 31.

[10] It should be noted that the heat capture assumption in WRATE is greater than the measured performance at the Coventry plant. The figure used reflects the average efficiency of CHP plants stated in the BREF guidance for incineration to ensure the performance of the plant is comparable with CHP plants across Europe. *IPPC Reference Document on the Best Available Techniques for Waste Incineration, EU. (2006).*

Option 2 – Energy from Waste-led strategy for residual waste

For options 2 a-d, the generic aspiration is for high levels of recycling/composting followed by high levels of thermal or microbial treatment. A “high” level of thermal treatment is interpreted to mean that all residual waste, where feasible, will be treated using the treatment technology in that option.

2a – Pyrolysis

The management of residual waste for this option is through high level thermal treatment using the following pyrolysis technology from WRATE:

- 21252 Pyrolysis (MSW and RDF) WASTEGEN process

This is based on plant currently operating in Germany, which treats municipal and industrial waste, bulky waste and sewage sludge. The residual waste in the model requires no pre-treatment for this technology. All non-hazardous bottom ash/char from thermal treatments is assumed to be recycled as aggregate substitute. All Air Pollution Control (APC) residues require disposal at hazardous landfill. Electricity production will offset against the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 13, the subregional breakdown of option performance is in table 15 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 32.

2b – Gasification

The management of residual waste for this option is through high level thermal treatment using the following pyrolysis technology from WRATE:

- 11268 Gasification (RDF only) ENERGOS process

The gasification process requires pre-treatment of the residual waste using a dirty MRF to produce a Refuse Derived Fuel (RDF). For modelling purposes, the mechanical treatment element from a generic MBT process in WRATE has been used to represent a dirty MRF. Information on generic MBT processes in WRATE can be found in Appendix 3. Technology from WRATE data set to be applied:

- 11085 MBT pre-treatment GENERIC process

It is assumed the MRF is built on the same site as the gasification plant so no transport element will be required.

The MRF pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling as well as producing a light RDF fraction for gasification and a residual stream, which requires a disposal route. It is assumed that all non-hazardous bottom ash/char from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The residual fraction from the MRF is disposed of to landfill. Electricity production will offset against the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 14, the subregional breakdown of option performance is in table 16 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 33.

2c – Incineration with energy recovery

The management of residual waste for this option is through high level thermal treatment. The following two incineration technologies from WRATE have been modelled:

- 13041, Incinerator large, heat and power (COVENTRY) – for urban arisings
- 11262, Incinerator medium, heat and power (GRIMSBY) – for rural arisings

These two incineration technologies were selected as they both utilise heat as well as generating electricity and are the most representative technologies available in the model. The differing scales account for the different waste densities and throughputs in both urban and rural areas.

In determination of required capacity, the urban and rural capacitates for incineration as detailed in table 1 are still assumed.

No pre-treatment is required for incineration with energy recovery technology. It is assumed that all non-hazardous bottom ash from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. Electricity production will offset against the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 15, the subregional breakdown of option performance is in table 17 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 34.

2d – Anaerobic digestion

The management of residual waste for this option is through high levels of biological treatment of residual waste using Anaerobic Digestion (AD). AD facilities alone only treat source separated wastes. The anaerobic digestion of mixed waste is modelled as part of an MBT process. The following technology is applied in the model:

- 20216 MBT AD & low grade compost GLOBAL RENEWABLES process

This Is based on the Global Renewables UR-3R MBT plant which is detailed in appendix 3. It is assumed that the MBT/AD bio-stabilised outputs of the organic element of mixed waste would be disposed of to landfill[11]. The MBT pre-treatment will move the recycling performance beyond the 50% achieved through source segregation. Biogas production from the AD process will offset against electricity production in accord with the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 16, the subregional breakdown of option performance is in table 18 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 35.

[11] Current Agency guidance (http://www.environment-agency.gov.uk/commondata/acrobat/mbt_output_guidance_1149762.pdf) on the regulation of outputs of MBT where the feedstock is mixed MSW (or similar) is that the organic outputs would not be suitable for agricultural use. For modelling purposes, as all MBT options will receive mixed MSW, the impacts of landfilling this fraction will be included based on this guidance, as it would be unrealistic to include the offset benefits of compost production where this is unlikely to be the case.

Option 3 – MBT/BMT-led strategy for residual waste

For options 3 a-f, the generic aspiration is for high recycling/composting followed by high levels of MBT (Mechanical and Biological Treatment). A "high" level of MBT is interpreted to mean that all residual waste, where feasible, will be treated using the treatment technology in that option.

3a – MBT followed by pyrolysis

The management of residual waste for this option is using MBT with the resultant RDF treated at a pyrolysis plant. The MBT process is based on the following two Generic processes from WRATE Information on generic MBT processes in WRATE can be found in Appendix 3:

- 11089 MBT crushing and metals GENERIC process
- 11088 MBT dry stabilisation & RDF GENERIC process

These processes when combined represent a generic MBT facility that receives mixed waste and, using a two phase MBT process, mechanically crushes and sorts the waste and biologically treats the waste to bio-stabilise the residual fraction and create a high calorific RDF for thermal treatment. The RDF feedstock is then thermally treated using pyrolysis.

- 21252 Pyrolysis (MSW and RDF) WASTEGEN process

It is assumed the MBT plant is built on the same site as the pyrolysis plant so no transport element will be required.

The MBT pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling. The second stage of the process produces a light RDF fraction for pyrolysis and a bio-stabilised residual stream, which requires a disposal route. It is assumed that all non-hazardous bottom ash/char from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The stabilised residual fraction from MBT is disposed of to landfill.

The waste flows and transport distances for this option are shown in figure 17, the subregional breakdown of option performance is in table 19 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 36.

3b – MBT followed by gasification

As with option 3a, the same two generic MBT processes are used. The RDF created is then treated using the following gasification technology from WRATE Information on generic MBT processes in WRATE can be found in Appendix 3:

- 11268 Gasification (RDF only) ENERGOS process

It is assumed the MBT plant is co-located with the gasification plant so no transport element is required.

The MBT pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling. The second stage of the process produces a light RDF fraction for gasification and a bio-stabilised residual stream, which requires a disposal route. It is assumed that all non-hazardous bottom ash/char from thermal treatments will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The stabilised residual fraction from MBT is disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 18, the subregional breakdown of option performance is in table 20 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 37.

3c – MBT followed by incineration with energy recovery

As with option 3a, the same two generic MBT processes are used. Information on generic MBT processes in WRATE can be found in Appendix 3. The RDF created is thermally treated using the following incineration technologies from WRATE:

- 13041, Incinerator large, heat and power (COVENTRY) – for urban arisings
- 11262, Incinerator medium, heat and power (GRIMSBY) – for rural arisings

These two incineration technologies were selected as they both utilise heat as well as generating electricity and are the most representative technologies available in the model. The differing scales account for the different waste densities and throughputs in both urban and rural areas.

As agreed capacity of the incineration facility for urban locations is large relative to the expected output from MBT, one MBT plant is assumed to be co-located at the incineration plant with the remaining MBT facilities evenly distributed throughout the area at a ratio of 1 co-located to 3 satellite.

The MBT pre-treatment extracts additional metals (ferrous and non-ferrous) from the residual waste for recycling. The second stage of the process produces a light RDF fraction for incineration and a bio-stabilised residual stream, which requires a disposal route. It is assumed that all non-hazardous bottom ash from incineration will be recycled as an aggregate substitute. All APC residues require disposal at hazardous landfill. The stabilised residual fraction from MBT is disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 19, the subregional breakdown of option performance is in table 21 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 38.

3d – MBT followed by fuel to offsite energy use

As with option 3a, the same two generic MBT processes are used. Information on generic MBT processes in WRATE can be found in Appendix 3. The RDF is then transported off-site for co-firing in a cement kiln:

- 21274 RDF combustion in cement kiln

To determine trip distances for modelling purposes, the waste will be modelled as being transported to an existing cement kiln in South Wales. The offset is the burning of coal as a fuel in the cement kiln. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 20, the subregional breakdown of option performance is in table 22 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 39.

3e – MBT followed by anaerobic digestion

The management of residual waste for this option is through MBT including anaerobic digestion. The process is based on the following two stage generic MBT process from WRATE Information on generic MBT processes in WRATE can be found in Appendix 3:

- 11085 MBT Pre-treatment GENERIC process
- 12087 MBT AD for stabilite GENERIC process

This two stage MBT process represents firstly a mechanical pre-treatment which separates ferrous and non-ferrous metal for recycling, a light fraction which could be used as RDF and an organic rich fraction which requires biological treatment. In this scenario the light RDF fraction is landfilled as no thermal technology was proposed for the option, the metals are sent for recycling and the organic rich fraction is then sent to the second stage for anaerobic digestion.

Following AD, it is assumed that the bio-stabilised digestate along with any rejects from the process are disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled Biogas production from the AD process is offset against electricity production in accord with the marginal project energy mix.

The waste flows and transport distances for this option are shown in figure 21, the subregional breakdown of option performance is in table 23 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 40.

3f – MBT followed by Landfill

The management of residual waste for this option is through MBT including aerobic composting. The process is based on the following two stage generic MBT process from WRATE Information on generic MBT processes in WRATE can be found in Appendix 3:

- 11085 MBT Pre-treatment GENERIC process
- 12086 MBT composting for stabilite GENERIC process

This two stage MBT process represents firstly a mechanical pre-treatment which separates ferrous and non-ferrous metal for recycling, a light fraction which could be used as RDF and an organic rich fraction which requires biological treatment. In this scenario the light RDF fraction is landfilled as no thermal technology was proposed for the option, the metals are sent for recycling and the bio fraction is then sent to the second stage for composting. This process stabilises the organic rich fraction and reduces its biodegradability prior to disposal.

It is assumed that the composted waste along with any rejects from the process are disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 22, the subregional breakdown of option performance is in table 24 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 41.

Option 4 – An autoclave/Mechanical Heat Treatment -led strategy for residual waste

For options 4 a-e, the generic aspiration is for high recycling/composting followed by high levels of treatment using an autoclave (or mechanical heat treatment – MHT). A “high” level of MHT is interpreted to mean that all residual waste, where feasible, will be treated using the treatment technology in that option.

The autoclave treatment technology available in the WRATE model is based upon data supplied by Estech, who were the only technology provider able to supply data in the autoclave process. The technology is not currently used in the UK at commercial scale for the treatment of MSW. The reference facility, and the associated data held in WRATE, is a pilot plant and the performance has been scaled up to represent a full scale facility. As the technology is in development, a full set of operational data is not currently available. This is an emerging technology and a number of providers are developing plant to treat MSW, it may be that future releases of WRATE will include a more complete picture of the technology’s performance.

In the opinion of the LCA policy advisors at EA head office, there is insufficient evidence that autoclave fibre can be used as an RDF for pyrolysis or gasification and thus options 4a and 4b have been excluded from the assessment.

The viability of the output fibre as an RDF to be used as a feedstock for incineration with energy recovery or cement kiln is uncertain as are the markets for the recovered recyclate for a technology that is unproven on a commercial scale. A precautionary approach has thus been adopted to both the plastic recyclate extracted and the fibre produced. 50% of the fibre produced will be thermally treated in options 4c and 4d with the remainder disposed of to landfill and in each autoclave option, 50% of the recovered plastic recyclate will be landfilled. The recovered glass will only be used as an aggregate substitute as it is expected levels of grit and treated glass will preclude it from being recycled into glass packaging.

This approach will have altered the performance of this option. When a commercial scale operational plant is able to provide evidence that the outputs are of sufficient quality to secure their expected market, this option could be re-evaluated.

4a – Autoclave/MHT followed by pyrolysis

Scenario excluded

4b – Autoclave/MHT followed by gasification

Scenario excluded

4c – Autoclave/MHT followed by incineration with energy recovery

The treatment technology used for residual waste in this option is autoclave. The process is based on the following process from WRATE:

- 21227 Autoclave (Mechanical Heat Treatment)

The autoclave treats the mixed waste using high pressure steam producing a clean fibrous material that may be used in the manufacture of fibreboard or, by adding a drying stage, may be suitable as a feedstock for either incineration with energy recovery or cement kiln. The process also extracts additional recyclate and a reject fraction that requires landfill disposal. 50% of the fibre has been delivered to the following two incineration waste facilities:

- 13041, Incinerator large, heat and power (COVENTRY) – for urban arisings
- 11262, Incinerator medium, heat and power (GRIMSBY) – for rural arisings

These two incineration technologies were selected as they both utilise heat as well as generating electricity and are the most representative technologies available in the model. The differing scales account for the different waste densities and throughputs in both urban and rural areas.

50% of the fibre and 50% of the plastic recyclate extracted has been landfilled in accordance with the precautionary approach detailed above. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 23, the subregional breakdown of option performance is in table 25 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 42.

4d – Autoclave/MHT followed by fuel to offsite energy use

This scenario is the same as 4c except that 50% of the autoclave fibre is delivered to a cement kiln rather than an incinerator with energy recovery. The cement kiln process in WRATE is:

- 21274 RDF combustion in cement kiln

To determine trip distances for modelling purposes, the waste will be modelled as being transported to an existing cement kiln in South Wales. The offset is the burning of coal as a fuel in the cement kiln.

The remaining fibre has been sent to landfill. 50% of the plastic recyclate extracted has been recycled and the remaining material has been disposed of to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

The waste flows and transport distances for this option are shown in figure 24, the subregional breakdown of option performance is in table 26 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 43.

4e – Autoclave/MHT followed by Landfill

This option is the same as 4c except that 100% of the fibre produced is disposed of to landfill. As with the other viable autoclave options a precautionary approach has been applied with respect to the availability of markets for the recyclable material extracted by the autoclave process with 50% of the plastic being sent to landfill. A landfill with HDPE liner and HDPE cap has been modelled.

- 21227 Autoclave (Mechanical Heat Treatment)

The waste flows and transport distances for this option are shown in figure 25, the subregional breakdown of option performance is in table 27 and the required throughput and infrastructure to deliver the modelled elements of waste are shown in table 44.

2 Infrastructure Requirements

Existing waste management facilities

Table 2 illustrates the current licensed non-landfill waste management infrastructure in SW Wales. The data in the first part of the table summarises the maximum licensed capacity of facilities that held either a PPC permit or Waste Management Licence at the 31st March 2006. The capacity is the legislative maximum throughput allowed under the terms of the license or permit. In reality there may be other limiting factors that restrict the site from operating up to it's licensed maximum.

It can be seen that the existing capacity of residual waste treatment technologies as proposed in the options is very limited. There is an urgent need to commission new infrastructure in order to meet 2013 targets for landfill diversion whichever waste management option is chosen. There is no merchant capacity for hazardous landfill in the South West Wales region or in Wales as a whole.

It should be noted that the range of facility types listed in table 2 is beyond those that have been considered for modelled waste in the life cycle assessment. Facilities such as chemical treatment plants are specialist and are likely to deal with either hazardous wastes or other process wastes that are outside the scope of the modelling and appraisal process.

Table 3 and figure 52 show the current landfill void available in SW Wales. The data presented is the best case scenario from data collected in 2006 by the Environment Agency. The available void data assumes that all sites that are currently going through the PPC permitting process receive their permit. There is also an estimation of how much void will be used between now and 2012/13 and beyond to 2019/20.

The rate of fill is based on the continuation of current landfilling rates from the present until 2010/2011, then on a linear reduction/increase of landfill from then to the expected tonnage landfilled to deliver each option. Also included in the future tonnage is any waste from outside of Wales that was disposed of into SW landfills in 2005[12].

It should be noted that the current rates of landfill have been derived from 2005 waste site returns and include:

- Waste that is disposed of to landfill in Wales where the origin of the waste is recorded as a local authority area in South West Wales;
- Waste disposed of in landfill sites in South West Wales where the origin is outside Wales, uncodeable or just recorded as Wales;

The current rate of landfill excludes:

- Any waste that may have been produced in the area and disposed of into landfill sites outside of Wales

The fill rate is based on an assumed density of 1t/m^3 for all wastes. It is estimated that some void will still be available in 2012/13 for all options based on this set of assumptions, but the rate at which landfill is depleted beyond the study year varies significantly between the options. Option 2A preserves the most landfill void with an estimated 2,678,653m^3 remaining in 2012/13 and a subsequent annual requirement of 366,595 tonnes. Option 1C (which landfills the maximum possible MSW to still meet the 2020 Landfill Allowance target for BMW in 2013) leaves only 2,133,112m^3 with a further annual requirement of 730,289 tonnes input per annum.

[12] This figure is 37 tonnes deposited into SW landfills from outside of Wales according to 2005 site returns data

Required Infrastructure

Tables 28 to 44 show the potentially required waste management capacity for each of the options. The tables show this required infrastructure by capacity for annual tonnage throughput and number of facilities that would be required based on the agreed capacities indicated in table 1. This is broken down to local authority level and split by municipal, commercial, industrial, construction and demolition and agricultural waste streams. The required facility types for all options are assumed to be:

- Civic Amenity sites
- Household, Industrial and Commercial (HIC) waste transfer stations
- Construction and Demolition (C&D) waste transfer stations
- In-vessel composting sites
- Open windrow composting sites
- C&D exempt sites
- C&D recycling sites
- Non-hazardous landfill
- Hazardous landfill
- Inert landfill

For each option there will also be the relevant waste treatment technology such as pyrolysis plant, gasification plant, incineration plant, anaerobic digestion plant, MBT, MRF and autoclave plant.

Unmodelled Waste

It is important to note that tables 28 to 44 show the required infrastructure for the modelled wastes only. The amount of modelled and unmodelled wastes is represented in figures 1 and 2. The estimated composition of unmodelled waste is shown in Table 4 and Figure 3.

Unmodelled Hazardous Waste

Hazardous waste has not been specifically modelled within the WRATE assessment as the life cycle assessment applies to non-hazardous waste only. The South West Wales Regional Waste Planning Group has forecast an arising of 157,023 tonnes of hazardous waste for 2013. A substantial part of this has been identified from the data used to create table 4 from the compositions of each of the waste streams. It is assumed that most of the hazardous waste was actually double counted in the forecasting exercise. Hazardous industrial wastes for example are included in the baseline data used to forecast the arising of industrial waste but also appear in the forecast arising of hazardous waste.

As mentioned in chapter 2, it is assumed that the baseline used to forecast the C&D arisings did not account for hazardous C&D arisings. Therefore the amount of the hazardous waste that cannot be attributed to the specific hazardous wastes in table 4 can be assumed to arise from the C&D sector.

This will require additional treatment or landfill capacity to that shown in tables 28-44. There is expected to be a large amount of hazardous chemical wastes and hazardous oils and solvents from both the industrial and commercial wastes streams which are likely to be treated. The main arising of unmodelled hazardous waste from the Municipal waste stream are batteries and Waste Electrical and Electronic Equipment (WEEE).

Unmodelled Non-hazardous waste

As seen in Table 4 and Figure 3, much of the unmodelled waste is non-hazardous combustion wastes from the industrial waste stream, which is currently be managed with a fairly equal split between re-use, recycling and landfill[13] (roughly 33% each). Chemical sludges, industrial sludges and septic tank sludges are likely to be landspread or treated.

These unmodelled wastes, hazardous and non-hazardous, will need to be planned for in addition to the modelled wastes from the life cycle analysis and sustainability appraisal.

[13] Environment Agency Industrial and Commercial Waste Survey 2003.

3 Sustainability Appraisal Methodology

The Sustainability Appraisal of the options, as previously mentioned, follows the guidance provided by ODPM (2002) ‘Strategic Planning for Sustainable Waste Management: Guidance on Option Development and Appraisal’. The guidance sets out a methodology to appraise strategic waste management options (SWMO) that takes account of environmental, socio-economic and implementation issues. The Guidance recommends:

Identifying and agreeing Objectives and Indicators – In this assessment we have used the 22 indicators used in the preparation of the first regional waste plan (see list and description in Table 45). The Members Steering Group reviewed these and it was agreed that the indicators were relevant for the Regional Waste Plan review. The suite of indicators includes the additional indicator (added by the South East regional waste group) for dioxin emissions.

Identifying performance scores for the Sustainability Indicators - The performance scores for each of the indicators for the different options are generated using three methods:

- Quantitative Assessment Tool – WRATE Life Cycle Assessment (LCA) software tool (see Appendix 1 for detail about the software and appendix 6 for a summary of the indicators used in this report)
- Generic Data – scores are generated based on data available such as land take, number of jobs created etc.
- Professional Judgement (see Appendix 6 for more detail)

Table 45 details which method is used to generate performance scores for the different sustainability indicators. Each indicator is numbered in the format 1(i) where the number corresponds to the overall sustainability objective and roman numerals represent the specific indicator. This notation is used where the indicator results are tabulated in tables 63-64 and 66-67.

4 Sustainability Objectives and Indicators Information

This section gives information on the Sustainability Objectives that have been used in the Sustainability Appraisal.

Environmental & Health Objectives

1. To Ensure Prudent Use of Land and Other Resources

A key sustainable development objective is to use finite natural resources (such as fossil fuels and land) more efficiently. The rate of consumption of resources should not reduce their availability for future generations. For example, reusing or recycling waste reduces the environmental pollution and degradation caused by extraction, use and disposal of natural resources.

The choice of waste management option can have a significant influence on the consumption of finite natural resources. For example, an option involving reuse and recovery of materials should result in a reduction in the consumption of primary raw materials. An option involving recovery of energy from waste should result in a reduction in the use of fossil fuels. Land is also a finite resource, and some waste management options are more ‘land hungry’ than others.

2. To Reduce Greenhouse Gas Emissions

Global climate change is widely recognised as one of the greatest environmental challenges facing the world today. The clear message from the scientific community is that climate change is due, at least in part, to the increasing concentrations of greenhouse gases in the atmosphere.

A number of waste management operations give rise directly or indirectly to emissions of greenhouse gases. The main sources of CO2 emissions include: vehicles used to collect and transport waste, energy used to power waste facilities, composting operations, combustion of waste, and flaring of landfill gas. The decomposition of waste in landfill sites also gives rise to methane (CH4), which is around 20 times more potent a greenhouse gas than CO2.

3. To Minimise Adverse Impacts on Air Quality and Public Health

A key objective is to control air pollution in order to reduce the risks to human health, natural environment and quality of life. Pollutants of most concern to the Assembly Government are Nitrogen Dioxide, Sulphur Dioxide, Carbon Monoxide, particles (PM10) and Ozone.

Man-made emissions of substances containing chlorine and bromine can have consequential effects on both environment and health. In respect of Waste Management, probably the main generator of ozone depleting substances is landfill.

Small particles of dust (PM10) are injurious to public health. However, it is the soiling of property that is the most common cause of complaint. Waste management processes potentially give rise to dust, particularly where mechanical operations and storage of waste takes place in the open. Vehicle movements can also generate significant dust.

Odour is a common cause of public concern in relation to waste management and like dust, odours can be particularly acute where mechanical operations and storage of waste take place in the open.

Dioxin emissions are a matter of public concern in relation to certain waste management technologies. These substances are very tightly controlled through regulation but the indicator is included because there is public concern about this particular aspect.

4. To Conserve Landscapes and Townscapes

Landscapes and townscapes result from the interactions between the physical, biological and social components of our environment and have strong economic, social and community value. The Assembly Government is keen to improve the quality of both countryside as a whole and of urban environments and increased attention is also being placed on the importance of perceptual characteristics such as tranquillity, wildness and dark night skies.

All waste management options involve development components such as buildings, processing plant, access roads, lighting/signage, storage mounds and perimeter bunds. These can have landscape impacts and visual impacts. Concern is likely to be greatest where options involve emissions stacks, large enclosed facilities or significant storage/disposal of waste above ground level.

5. To Protect Local Amenity

Living and working environments make an important contribution to 'quality of life'. In addition to attractive settings, access to green spaces, and community safety, low levels of noise and litter are important considerations. Noise and the existence of litter can cause annoyance and stress, and the number of noise complaints is increasing. Vermin is a subject that is commonly associated to waste storage in the open, and in fact can be attracted also to street litter.

All waste management options generate noise and potentially litter, as they involve the storage, treatment and transport of waste. Litter and vermin are most likely to be of concern where the waste is stored or processed/deposited in the open. Noise is most likely to be of concern in relation to sites that operate outside standard working hours, or use particularly noisy machinery.

6. To Minimise Adverse Effects on Water Quality

Water is essential for life, provides important habitats for plants and animals, and plays an important role in the economy. A key sustainable development objective is to sustain and improve surface and groundwater quality and the aquatic environment. Eutrophication is caused by excess nutrients (nitrate and phosphate) getting into the aquatic environment causing increased algal growth and potentially toxic algal blooms.

All waste management options have potential impacts on water as they involve the storage of waste, transport of waste, and the operation of plant and vehicles. However, some waste management activities present a greater risk e.g.

The storage of waste (e.g. run off from rain and dust suppression sprays, leaching of contaminants)
The transport of waste (e.g. run off from the delivery and tipping of materials, wheel washing)
The operation of plant and vehicles (e.g. potential pollution from oil and solvents including the risk of accidental spillage).
Some waste management methods present a greater risk to water quality than others, for example:

- Composting: Water is generated as part of the process and the compost has to be turned and wetted; The liquor generated from this process may contain heavy metals and other contaminants.
- Anaerobic digestion: The process results in a digestate liquor, which may contain high levels of metals and other contaminants.
- Incineration: Cooling and cleaning water may contain high levels of contaminants, whilst the storage and disposal of ash and air pollution control residues poses a further threat to water quality.
- Landfill/landraising: The risk of pollution depends on the characteristics of the wastes, the standard of site engineering, the underlying geology and the proximity of water courses and

abstraction points. The Environment Agency's advice is that, however well engineered a landfill site, there is a risk of leachate release to the water environment.

Socio-Economic Objectives

7. To Minimise Local Transport Impacts

An efficient transport system is needed to support a strong and prosperous economy and to maintain and improve people's quality of life. Congestion and unreliability of journeys add to the costs of business, and undermines competitiveness. Major roads can cause 'severance' when people become separated from parts of the community and other people. Heavy levels of traffic also damages towns and cities and harms the countryside.

All waste management options have transport impacts as they involve some degree of off-site movement of waste. The scale of impacts will be influenced by factors such as vehicle size, frequency of vehicle movements, road/pavement width, and traffic speeds. The proportion of motorway and non-motorway transport will be region specific according to the available transport network.

8. To Provide Employment Opportunities

A high employment rate is one of the key objectives of sustainable development. Development of new waste management facilities will create temporary construction employment, which may be available to local people, and their long-term operation will create jobs, the nature of which will depend on the facility.

9. To Provide Opportunities for Public Involvement and Education

Public participation is at the heart of sustainable development. Recent surveys in the North West of England suggest that the public is keen to participate in more sustainable waste management practices. In this context it is important for the Assembly Government, nationally and regionally to 'send the right signals' to the public in order to encourage changes in behaviour and lifestyles.

Waste Management Service Delivery Objectives

10. To Minimise the Costs of Waste Management

Although not strictly a sustainability objective, costs are clearly a key concern of local authorities and waste contractors. There are widely varying estimates of waste collection and waste treatment/disposal costs, of which the ETSU/DTI publication 'An Introduction to Household Waste Management' (1998), gives useful cost information for a range of facilities. Also information is available from the waste technologies database managed by the Environment Agency[14] and available through our website.

11. To Ensure Reliability of Delivery

Although a waste management option may perform well against a range of indicators, it may not be possible to implement the option due to practical constraints. Such constraints may include:

- Availability of financial resources
- Technological issues, related to the availability of the appropriate plant and machinery
- Difficulties in obtaining planning consents

[14] www.environment-agency.gov.uk/wtd

Public Framework Objectives

12. To Conform with Waste Policy

The Welsh Assembly Government actively promotes the waste hierarchy, including (in the following order of preference) waste reduction, re-use, recycling and composting, energy recovery, with disposal as a last resort. The Government also wishes to see waste managed in line with the proximity principle which states that waste should generally be disposed of as near to its source as possible. This is in part to ensure that waste problems are not simply exported to other regions or countries, and also recognises that the transportation of wastes can have significant environmental impacts. The principal aim of this waste strategy process is to conform with local, national and European waste policy.

5 Performance of Options

This section presents and discusses the performance of the waste management options against each of the indicators. For a full description of the indicators see chapter 5, table 45 and appendix 6. The indicator number (in the format **1(i)**) corresponds throughput to the numbers in tables 45, 63-64 and 66-67. A summary of the overall performance of all options by stream is shown in table 10, a further breakdown by option is presented at local authority level in tables 11-27.

Environmental & Health Objectives

Objective 1: To ensure prudent use of land and other resources

Indicator 1(i): **Abiotic Resource Depletion of resources such as water, fuels and ores**
Method of measurement: WRATE output – a lower or more negative score is desirable

This indicator examines the amount of abiotic resources used to deliver each waste management option. It is part of the suite of standard life cycle indicators produced by WRATE and is presented using the unit "kg of antinomy equivalent". This means that the depletion of "non-living" mineral and metallic resources are characterised such that their depletion may be presented as an equivalent mass of antimony (see appendix 6 for details of WRATE impact assessments). A positive value from the WRATE model indicates that the option has resulted in the depletion of abiotic resources, a negative value represents an avoided burden.

- Best Option: 3D – MBT followed by fuel to offsite energy use
- Worst Option: 4E – Autoclave/MHT followed by Landfill

All options demonstrate a significant environmental saving however, this is predominantly due to the high levels of recycling. Recycling accounted for an avoided burden of -9,921,455 kg antimony equivalent for option 3D of which 60% was due to the recycling of Aluminium. The differences between the options can be attributed to differences in the method of residual treatment.

3D Scores well on this indicator as the off site energy plant used to treat the RDF following MBT has not been built specifically for the purpose of treating waste, therefore, the resource impacts associated with the construction of a residual waste treatment plant are significantly reduced.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 26.

Indicator 1(ii): Land take
Method of measurement: Generic Data – A lower score is preferable

This indicator provides an estimation of the land required to deliver each of the waste management options. The indicator is calculated by multiplying the number of each facility type required (see tables 28-44) by an assumed land take per facility[15] (see table 51 – column 6)

- Best Option: 2A Pyrolysis
- Worst Option: 3F MBT followed by landfill

Options 2A and 2C require the least amount of land for waste facilities as only one type of residual treatment facility is required. Option 2B requires a Dirty MRF prior to thermal treatment adding to the land take at the residual treatment plant and further land is required to provide the landfill to dispose of the rejects from the MRF. There are no significant outputs from the pyrolysis plant that require disposal.

Option 3F is the worst scoring option and this reflects the fact that an MBT treatment facility is required and also considerable landfill space to receive the MBT rejects, the RDF fuel produced and the bio stabilised organic fraction.

[15] This data is taken from the data collected in the WRATE model for each facility type

The land take impacts of re-processors or exempt facilities for C&D waste have not been considered in this indicator.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 27.

Objective 2: To reduce greenhouse gas emissions

Indicator 2(i): Greenhouse gases emitted
Method of measurement: WRATE output – a lower or more negative score is preferable

This indicator quantifies the amount of gaseous emissions generated or avoided by the waste management system that are known to contribute to climate change. The indicator is part of the suite of standard life cycle indicators produced by WRATE and is presented using the unit "kg of carbon dioxide equivalent". This means that the total releases (or avoided releases) of all greenhouse gases are normalised such that their global warming potential is presented as an equivalent mass of CO_2. A positive value from the WRATE model indicates that the option has resulted in the production of gases contributing to global warming, a negative value indicates that there has been a saving.

- Best Option: 3B MBT followed by Gasification
- Worst Option: 0 All residual waste to landfill

As with the resource depletion indicator, there is a large overall avoided burden in the generation of greenhouse gases but again, much of this is due to the recycling processes. The difference in performance between the options can be attributed to the residual waste treatment processes. Options 3a-c outperformed options 2a-c for this indicator suggesting that treating waste using MBT prior to thermal treatment results in lower overall emissions of greenhouse gases.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 28.

Objective 3: To minimise adverse impacts on air quality and public health

Indicator 3(i): Emissions which are injurious to public health
Method of measurement: WRATE output – a lower or more negative score is preferable

This indicator quantifies the amount of gaseous emissions that are detrimental to human health and are either produced or avoided for each waste management option. It is part of the suite of standard life cycle indicators produced by WRATE and is presented using the unit "kg of 1,4-dichlorobenzene". This means that the total releases (or avoided releases) of gases deemed to be detrimental to human health are characterised such that their toxicity is presented as an equivalent mass of 1,4-dichlorobenzene. A positive value from the WRATE model indicates that the option has resulted in the production of gases, a negative value indicates that the production of emissions injurious to human health has been avoided by the waste management system.

- Best Option: 4E Autoclave/MHT followed by Landfill
- Worst Option: 2C Incineration with energy recovery

This indicator score derives from a range of gaseous emissions normalised to the toxic equivalence of 1.4 dichlorobenzene produced or avoided as a result of waste management activities. Option 2C overall emits more (or avoids the emission of least) but potential impacts on human health have a locational aspect and therefore this indicator can't determine actual exposure to these emissions. Health impact assessments on specific sites or choices of sites would be required to determine the actual impacts. It should be noted that although there is slight variation between the types of thermal treatment and their performance for this indicator, all the facilities comply with the requirements of the WID Directive. The relative differences between all options are small and each demonstrates an avoided burden due to the high levels of recycling assumed.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 29.

Indicator 3(ii): Emissions contributing to air acidification
Method of measurement: WRATE output – a lower or more negative score is preferable

This indicator quantifies the amount of emissions of acidifying compounds. These emissions are either produced or avoided by waste management operations within the model. The indicator is part of the suite of standard life cycle indicators produced by WRATE and is presented using the unit "kg of sulphur dioxide". This means that the total releases (or avoided releases) of gases contributing towards air acidification are characterised such that their acidifying potential is presented as an equivalent mass of SO_2. A positive value from the WRATE model indicates that the option has resulted in the production of gases causing air acidification, a negative value indicates that the process has avoided the emission of acidifying gases.

- Best Option: 4D Autoclave/MHT followed by fuel to off-site energy use
- Worst Option: 2C Incineration with energy recovery

There is some variance between the options for this indicator. Option 4D, where the residual waste is treated using an autoclave plant and the fibre is then sent to off site energy use, has the most negative value for this indicator. All of the autoclave options perform reasonably well. No burning takes place at the plant and thus gaseous emissions are avoided here. Also, metals are extracted for recycling which has an environmental benefit through the avoidance of energy used for metal production.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 30.

Indicator 3(iii): Emissions contributing to depletion of the ozone layer
Method of measurement: WRATE output – a lower or more negative score is preferable

This indicator is calculated in WRATE's life cycle inventory and quantifies the amount of ozone depleting substances as "kg CFC-11 equivalent" produced or avoided as a result of the waste management system. This means that the total releases (or avoided releases) of gases contributing towards ozone depletion are characterised such that their depleting potential is presented as an equivalent mass of CFC-11.

- Best Option: 2C Incineration with energy recovery
- Worst Option: 0 All residual waste to landfill

Incinerator plants generally have very high tech flue gas cleaning systems where as landfills are quite poor at cleaning gases before they are released to the atmosphere. The incinerators are more efficient at removing chlorinated substances.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 31.

Indicator 3(iv): Extent of odour problems

Method of measurement: Professional Judgement – a lower score is preferable

For this indicator each facility type was considered by the professional judgement panel and the odour scores in table 47 were derived (see appendix 6 for the derivation). Each score was then multiplied by the modelled number of facilities in each option (see tables 28-44 for infrastructure requirements).

- Best Option: 2A Pyrolysis
- Worst Option: 2D Anaerobic digestion

Option 2D performed badly as a significant amount of waste is delivered to an anaerobic digestion plant, a poor scoring facility type for odour, relative to most other options. Option 2D results in a high percentage of waste being sent to landfill, which also contributes to the odour score.

All residual waste in option 2A is delivered to the pyrolysis plant, which has a relatively low facility score for odour and the only outputs contribute little to odour problems. Bottom ash is sent for recycling and a small amount of Air Pollution Control Residue (fly ash) is sent to landfill. In general the options which included a two stage residual treatment technology (i.e. MBT followed by incineration) performed less well than those options where only a single stage technology was modelled (i.e. all waste direct to incineration).

The performance of all options for this indicator is shown in tables 52 and 63 and figure 32.

Indicator 3(v): Extent of dust problems
Method of measurement: Professional Judgement – a lower score is preferable

For this indicator each facility type was considered by the professional judgement panel and the dust scores in table 48 were derived (see appendix 6 for the derivation). Each score was then multiplied by the modelled number of facilities in each option (see tables 28-44 for infrastructure requirements).

- Best Option: 2C Incineration with energy recovery
- Worst Option: 2B Gasification

One component of the odour and dust indicators for each facility was vehicle movements. The double handling of waste in option 2B as first an input to the dirty MRF and then as a reject requiring landfill disposal increased the expected number of vehicle movements contributes towards the poor score for options where the same waste is handled at two different facilities.

For the best performing option, all residual waste in option 2C is delivered to an incinerator, which has a relatively low facility score for dust and no reject requiring subsequent management. It should be noted that there is actually little variation between the options, as many of the facilities are common to each option and thus the impacts are equal for these facilities.

The performance of all options for this indicator is shown in tables 52 and 63 and figure 33.

3(vi) Indicator: Dioxin emissions

Method of measurement: WRATE output – a lower score is preferable

This indicator is calculated in WRATE's life cycle inventory and quantifies the amount of dioxins and furans produced or avoided as a result of the waste management system

- Best Option: 2D Anaerobic digestion
- Worst Option: 2C Incineration with energy recovery

All options resulted in the slight avoidance of dioxin emissions. The results do not differ significantly between options as is shown in figure 34. The difference between the best and worst performing options is just 0.00039 kg.

The performance of all options for this indicator is shown in tables 52 and 63 and figure 34.

Objective 4: To conserve landscapes and townscapes

Indicator 4(i): Extent of visual and landscape impacts

Method of measurement: Professional Judgement – a lower score is preferable

For this indicator each facility type was considered by the professional judgement panel and the visual and landscape scores in table 51 were derived (see appendix 6 for the derivation). Each score was then multiplied by the modelled number of facilities in each option (see tables 28-44 for infrastructure requirements).

- Best Option: 2A Pyrolysis
- Worst Option: 3F MBT followed by Landfill

The residual treatment method for option 2A is a one-stage process with no requirement for waste pre-treatment, no substantial process rejects and few outputs requiring disposal. As there is little double handling of waste, the land take and combined visual and landscape impacts are low.

Options 3E, 3F and 0 score poorly for this indicator primarily due to the amount of landfill disposal required. Option 3E has less landfill requirement than option 0, however, once more there is a cumulative effect of double handling the waste at a treatment facility and then a significant reject fraction also requires disposal. The visual and landscape impacts of building an in-building facility to enable the MBT treatment to take place are added to the need to landfill a significant proportion of the outputs.

The performance of all options for this indicator is shown in tables 51, 54 and 63 and figure 35.

Objective 5: To protect local amenity

5(i) Indicator: Extent of noise, litter and vermin problems
Method of measurement: Professional Judgement – a lower score is preferable

For this indicator each facility type was considered by the professional judgement panel and the noise, litter and vermin scores in tables 49 and 50 were derived (see appendix 6 for the derivation). Each score was then multiplied by the modelled number of facilities in each option (see tables 28 - 44 for infrastructure requirements).

- Best Option: 2A Pyrolysis
- Worst Option: 2B Gasification

The clear dividing factor in how each option has scored for this indicator is whether the process includes a pre-treatment. For example, option 2B performs poorly as there is a cumulative effect of first handling the waste at dirty MRF, which contributes towards the indicator. A sizeable reject fraction is also sent to landfill adding further to the poor score. The single stage treatments in options 2A and 2C perform well for this indicator as the waste is delivered directly to one facility, the process is contained within building and no physical processing of the waste takes place which could have contributed to noise issues.

The performance of all options for this indicator is shown in tables 49, 50, 53 and 63 and figure 36

Objective 6: To minimise adverse effects on water quality

6(i) Indicator: Emissions contributing to eutrophication
Method of measurement: WRATE output – a lower score is preferable

This indicator is calculated in WRATE's life cycle inventory and is presnted using the units “kg PO_4 equivalent” produced or avoided as a result of the waste management system. This means that the total releases (or avoided releases) contributing towards eutrophication are characterised such that their eutrophication potential is presented as an equivalent mass of phosphate.

- Best Option: 4E MHT/Autoclave and landfill
- Worst Option: 3D MBT followed by fuel to offsite energy use

The MHT/Autoclave options performed well for this indicator although 4D where the fibre is sent for offsite energy use performed least well of the three. Option 3D performed worst overall and the link between the two options is the offsite energy process.

Further analysis of the potential impact for eutrophication of watercourses from cement kilns revealed that NOx emissions direct to air from the incinerator stack were dominant (circa 90%) (i.e through assumed deposition to water and subsequent nitrification in susceptible watercourses), followed by ammonia emissions to water (circa 10%).

For compilation of the cement kiln dataset in WRATE, NOx emissions were estimated from the pollution inventory for an operational cement kiln in 2004 and these were allocated to the RDF.

These data are representative of a cement kiln with intermediate emissions abatement. Improved abatement systems such as selective non-catalytic reduction-DeNOx systems are likely to reduce such emission in future.

The performance of all options for this indicator is shown in tables 46, 63 and figure 37

6(ii) Indicator: Extent of water pollution
Method of measurement: WRATE output (aquatic ecotoxicity) – a lower score is preferable

This indicator is calculated in WRATE's life cycle inventory and quantifies the amount of releases contributing to aquatic ecotoxicity using the units "kg 1,4-dichloro-benzene equivalent". This means that the total releases (or avoided releases) contributing towards aquatic ecotoxicity are characterised such that their polluting potential is presented as an equivalent mass of 1,4-dichloro-benzene.

- Best Option: 4C MHT/Autoclave and incineration with energy recovery
- Worst Option: 0 All residual waste to landfill

Option 0 scores badly as leachate is produced at a landfill site and has the potential to contribute significantly to water pollution. Those technologies that include a waste pre-treatment and stabilisation perform better for this indicator than options where a single treatment takes place.

The performance of all options for this indicator is shown in tables 46 and 63 and figure 38

Socio-Economic Objectives

Objective 7: To minimise local transport impacts

7(i) Indicator: Total waste kilometres
Method of measurement: Generic Data – a lower score is preferable

This indicator provides an estimation of the total waste kilometres travelled in order to deliver each of the waste management options. The indicator quantifies the cumulative distance travelled by all waste from the point of production to the first waste facility (either as a bulk collection or by car to CA site) including an account of the distance of the collection round. It also includes the distance travelled during all subsequent phases including long distance haulage to waste re-processors which may be outside the region.

- Best Option: 1B Low level of gasification
- Worst Option: 2D Anaerobic digestion

The anaerobic digestion process in option 2D is a component part of an MBT plant, which extracts a significant additional tonnage of paper for recycling from the residual waste in comparison to the other options. The assumption is that this material would be transported to an existing paper mill in the SE of England and this has a bearing on the relatively high total waste km for option 2D.

The assumed capacity of the residual treatment methodology influences the total waste km. Option 2C – incineration with energy recovery – incorporates capacities of 56ktpa for rural facilities and 216ktpa for urban facilities. The number of sites required is lower than the number of pyrolysis plants required for option 2A (30ktpa and 90ktpa).

It is also noted that, in each scenario, householders deliver 176,310 tonnes of waste to CA sites. Based on an assumed one way trip distance of 4.56km and an average load of 43.64kg per trip, this part of the system alone contributes 36,858,532km to the total waste km in each option.

The performance of all options for this indicator can be found in tables 55 and 63 and figure 39

7(ii) Indicator: Transport along roads other than motorways
Method of measurement: Generic Data – a lower score is preferable

This indicator provides an estimation of the waste kilometres travelled along non-motorway roads in order to deliver each of the waste management options.

- Best Option: 1B Low level of gasification
- Worst Option: 3D MBT followed by fuel to offsite energy use

In option 3D the waste travels from an MBT plant to an offsite energy use plant (e.g. cement kiln) within the region, The distances to the cement kiln is fairly long as there is assumed to be one plant in the region rather than a few. As this plant is assumed to be within the South West Wales region the distance covered by motorway is less than leaving the region, therefore high km on non-motorway roads. The impact of the paper extracted by the MBT in option 2D is less significant as it is assumed that 80% of the transport for long distance haulage is on motorways.

The performance of all options for this indicator can be found in tables 56 and 63 and figure 40

Objective 8: To provide employment opportunities

8(i) Indicator: Number of jobs likely to be created[16]
Method of measurement: Generic data - higher score preferable

Much of Wales has lower than average levels of employment due to structural changes that have happened to the industrial base over recent decades. The economic opportunities offered by waste processing can be viewed as beneficial.

This indicator provides an estimate of jobs required to directly staff each of the residual waste treatment facilities. For example this includes in option 2C the number of staff required to operate the incinerators, the hazardous landfill which receives the air pollution control residues and the inert and non-hazardous landfills receiving residual construction and demolition wastes. The number of jobs per facility was estimated using site specific information from reference plants in the Environment Agency's Waste Technology Data Centre.

- Best Option: 2B Gasification
- Worst Option: 0 All residual waste to landfill

Landfill sites require less direct manpower in comparison to waste treatment plants, therefore option 0 scores poorly on this indicator as it has the most tonnage being sent to landfill and no residual waste treatment plant. Option 2B is a gasification plant, which also requires a front-end materials recovery facility. Both of these plants are relatively labour intensive and therefore the option creates the most employment opportunities.

The performance of all options for this indicator can be found in tables 57 and 63 and figure 41.

Objective 9: To provide opportunities for public involvement and education

9(i) Indicator: Extent of opportunities for public involvement and education (concerning sustainable waste management practices)
Method of measurement: Professional Judgement - lower score preferable

Education on sustainable waste management is desirable, we all produce waste and we all need to understand what happens to the materials we discard and how those materials can contribute to the economy through recovery of materials or energy.

The professional judgement panel discussed a scoring system for this indicator and an amendment to the approach was proposed. There wasn't an obvious way of scoring one technology choice against the others to determine the possible extent of public involvement and education. As a proxy for this indicator, it was agreed that a single score on a scale of 1 to 10 would represent how the technology choice was perceived by the general public to have a potential for energy recovery.

[16] The typical number of employees per facility are taken from case studies on the Environment Agency Waste Technology Data Centre http://www.environment-agency.gov.uk/wtd

- Best Option: 3D MBT followed by fuel to offsite energy use
- Worst Option: 0 All residual waste to landfill

This indicator reflects the waste hierarchy, which scores landfill as the worst option.

The performance of all options for this indicator can be found in tables 58 and 63 and figure 42.

Waste Management Service Delivery Objectives

Objective 10: To minimise costs of waste management

10(i) Indicator: Costs of management and disposal, including material and energy revenues
Method of measurement: Generic Data – a lower score is preferable

Management of waste is a cost to society as a whole and needs to be kept to the minimum necessary to achieve environmentally acceptable outcomes.

The only facilities that were considered in the costing indicator were the residual treatment and disposal facilities. Following the methodology described in appendix 6, a "per tonne" cost for each residual treatment facility was derived. This included a combination of capital and operational costs and for new technologies is based on data provided for the Waste Technology Data Centre.

- Best Option: 0 All residual waste to landfill
- Worst Option: 3F MBT followed by Landfill

The landfill option scores well for this indicator reflecting the historical reliance on landfill as a cheap disposal option. As current treatment costs have been included for all other facilities, the current rate of landfill tax[17] has been included for waste landfilled. It is expected that landfill tax will have risen to £35 per tonne for active waste in 2013. Also not considered for this indicator is that for every tonne of MSW that a local authority disposes to landfill beyond the amount permitted under the Landfill Allowance Scheme Regulations (Wales) a fine of £200 would be levied by the Welsh Assembly Government.

In general, two stage processes carry a greater cost than single stage processes as, for example, in option 3C there is cost to build and operate the MBT facility and a further cost to build and operate the incinerator that receives the RDF.

The performance of all options for this indicator can be found in tables 59 and 63 and figure 43.

Objective 11: To ensure reliability of delivery

11(i) Indicator: Likelihood of implementation within required timescale, taking account of maturity of technology, necessary level of public participation, and the need for planning permission (taking account of scale of development and likely perceived adverse impacts)
Method of measurement: Professional Judgement - lower score preferable

The changes to the way we manage our waste from landfill of the majority of municipal waste and a high proportion of other waste streams to a higher degree of recovery both of resources and energy are urgently needed. Options that are more likely to be delivered are therefore more desirable.

- Best Option: 0 All residual waste to landfill
- Worst Option: 4C Autoclave/MHT followed by incineration with energy recovery

Option 0 scores well on this indicator as there is not much change from today's situation for the management of residual waste. The option therefore has the most likelihood of implementation by

[17] £21 per tonne for active waste and £2 per tonne for inert

2013. Option 4C includes an autoclave, which is not a commercially proven technology in this country. It also includes incinerators, which are likely to face public opposition at the planning stage due to current adverse perception of the technology amongst the public.

The performance of all options for this indicator can be found in tables 60 and 63 and figure 44.

Public Framework Objectives

Objective 12: **To conform with waste policy**

12(i) Indicator: Percentage composted
Method of measurement: Generic Data - higher score preferable

The Wales Waste Strategy places a high emphasis on composting, this is a mechanism whereby material that would otherwise generate methane in landfill sites can be turned into a resource.

- Best Option: All equal
- Worst Option: All equal

All options are the same for this indicator as all the composting is part of the front-end process.

The performance of all options for this indicator can be found in tables 61 and 63 and figure 45.

12(ii) Indicator: Percentage recycled
Method of measurement: Generic Data - higher score preferable

The Wales waste strategy places a high emphasis on recycling, this is a mechanism where resources can be retained within the economic cycle and is a major contributor to increasing sustainability overall. All resources are finite and conservation of resources is desirable, loss of resources into landfill is not a sustainable practice and should be minimised.

- Best Option: 2A Pyrolysis
- Worst Option: 0 All residual waste to landfill

Option 2A scores particularly well on this indicator is because it produces so much 'Incinerator bottom ash' which is sent direct to a recycling processor. Option 0 scores worst on this indicator as it contains the same front end recycling rates that are included in all the options as a minimum.

The performance of all options for this indicator can be found in tables 61 and 63 and figure 45.

12(iii) Indicator: Percentage landfilled
Method of measurement: Generic Data – a lower score is preferable

Policy at a Wales level is to reduce the amount of waste landfilled, this will comply with European policy and contribute to the improved sustainability of the nation through the retention of resources in the economy. The Welsh Assembly Government has a statutory driver in the Government of Wales Act 1998 to take account of sustainability.

- Best Option: 2A Pyrolysis
- Worst Option: 0 All residual waste to landfill

In options 2A and C, waste is recovered using either an incinerator or advanced thermal treatment plant without pre-treatment. This results in a minimum amount of waste requiring landfill disposal. Other options, which include some sort of mechanical or biological treatment, produce rejects generally require disposal at landfill so these perform less well than straight incineration. Option 0 performs the worst for this indicator as all waste is landfilled following source-separated recycling/composting.

The performance of all options for this indicator can be found in tables 61 and 63 and figure 45.

6 Weighting of Sustainability Indicators

The weighting of the indicators is recommended by the ODPM guidance[18]. This is because it is accepted that decision-makers are likely to attach more importance to some indicators or criteria than to others. The guidance shows that, by eliciting and applying 'weights' to the valued performance information, the relative importance of indicators can be taken into account.

All stakeholders including local authorities, government agencies and waste trade associations of the regional waste groups were given an opportunity to provide their weighting of the indicators to capture a variety of opinions and different perspectives. These included:

- Unitary Authorities and National Parks Authorities
- Welsh Assembly Government (WAG)
- Environment Agency Wales (EAW)
- Countryside Council for Wales (CCW)
- Community Recycling Network in Wales (CYLCH)
- Wales Environment Trust (WET)
- Wales Environment Services Association (WESA)
- Arena Network
- Confederation of British Industry (CBI)

Each organisation was given 22 points to divide between the 22 indicators, according to their perceived relative importance. These were used to determine the final weighting of the indicators for each of the regions.

The actual calculation of the weighting scores had to be agreed for each regional waste group. This is because it was noted, as in the creation of the first regional waste plan, that there are more Unitary Authorities compared to other organisations in the regional waste groups. This could give Unitary Authorities with a bigger proportion of the vote compared to other organisations. Therefore analysis was completed to see what effect is on the weighting scores when the Unitary Authorities are given a combined vote compared to when they are each given a vote. 'UA Equal' is where Unitary Authorities are given a combined average score and then averaged with the rest of the organisation scores. 'Average Weighting' is where Unitary Authorities are each given a score and averaged with the rest of the organisations.

The results showed that there were slight differences between the two calculation methods. With the 'UA Equal' method there was higher weighting given to the greenhouse gas emissions indicator for all regions and also in particular resource depletion in South West Wales. With the 'Average Weighting' method, costs of waste management and likelihood of implementation were weighted higher in South West and North Wales. Also, quantity of emissions injurious to human health indicator was weighted higher in South East and North Wales.

Following the analysis, It was agreed in North Wales to use the weighting scores from the 'UA Equal' method and in South East & South West Wales to use the 'Average Weighting' method of calculation. Table 65 shows the agreed weightings in the three regional waste groups in Wales. The results show that North Wales chose use the UA Equal method.

The final weightings agreed for each of the regions are applied to the performance scores generated for the indicators. These are used to review the preferred strategic waste management option for all controlled wastes for each region.

[18] 'Strategic Planning for Sustainable Waste Management: Guidance on Option Development and Appraisal' (ODPM, 2002)

7 Sensitivity Analysis

A sensitivity test was completed on the indicators weightings agreed by the South West Wales Regional Waste Group. As each indicator, in its raw form, has different units and scale, to enable comparison of the overall performance of each waste management options, the indicator scores had to be valued. This involved placing each indicator onto a scale of 0 to 1 where 0 represented the worst performing option for that specific indicator and 1 represented the best performing option.

This created a theoretical maximum valued[19] score for an option of 22 (whereby it performs the best for each of the 22 SWMO indicators). The actual outcome of valued score comparison for both BPEO and SWMO can be found in table 64 and figures 46 and 49.

Then, following the process detailed in chapter 7, each indicator had a weighting applied and the option scores were recalculated. The results of this are shown in table 66 and figures 47 and 50.

To examine the impacts of these weightings, they were reversed, re-applied to each valued indicator score and the options were re-evaluated. The reverse weighted indicator scores can be found in table 67 and figures 48 and 51.

A summary of all rankings for BPEO and SWMO using valued, weighted and reverse weighted indicators are shown in table 68

For BPEO indicators, the weighting had a strong influence on the ranking of the best performing options. In particular, option 3D scored highly for a number of environmental indicators, which also were given high weights by the SW RWG. These include abiotic resource depletion (weighted 1.89), greenhouse gases emitted (weighted 1.45) and likelihood of implementation (weighted 1.51). When the weightings were applied, option 3D moved from a close second place (figure 46) to the Best Practicable Environmental Option (figure 47). Conversely when the weights were reversed this option moved down into 6th place (figure 48).

For SWMO indicators the weighting had less impact on the overall outcome. 2A remains as the leading option for valued, weighted and reverse weighting of indicators (see figures 49-51) however by weighting the indicators there is less difference between the top performing 6 options. The weighting promotes option 3B to 2nd place from 3rd. With the weights reversed, the relative order of the top three options does not alter from the valued scores.

A further sensitivity test was carried out on the WRATE derived indicators by altering the power generation mix to reflect the expected energy mix for Wales in 2020. The energy mixes used for the main project and in the sensitivity tests are shown in appendix 2 of part 3. The mix for 2020 has a lower generation density from coal, with a greater density of renewables and gas.

Revised indicators were generated in the WRATE model and then used to recalculate the SWMO score for each option. The results of this exercise are shown in figure 53 for weighted indicators only. There was no significant change to the ranking of the results in this sensitivity test. Option 3D (MBT/Cement Kiln) moved from 4th to 3rd place. This change in rank reflects the differences in energy offsets between the cement kiln process and the other thermal technologies.

The cement kiln offsets the burning of coal and therefore the avoided burden was not influenced significantly by the alteration in electricity generation mix. The pyrolysis plant in option 3A would offset the production of electriciyt in accordance with the marginal energy mix and as the 2020 mix is from cleaner technology, the avoided burden is less for technologies that offset electricity generation.

[19] Valued score is the sum of the raw scores before any weightings are applied

8 Summary

By using the methodology described, the different options can be compared against a number of different assessment criteria. This sustainability assessment has considered 5 main options with 17 sub-options for management of waste in 2013 (assessment year), the full list of options being:

Option 0
'Do Nothing' strategy
(This option is included for assessment purposes only – as a baseline to compare the other Options against). The same front-end levels of recycling and composting as the other options with no further treatment and all residual waste sent to landfill.

Option 1
A landfill-led strategy for residual waste
High recycling and composting levels followed by *low* levels of thermal treatment of residual waste using either:

- Pyrolysis (Option 1A), or
- Gasification (Option 1B), or
- Incineration with energy recovery (Option 1C)

All remaining residual waste would then be sent to landfill.

Option 2
An Energy from Waste-led strategy for residual waste
High recycling and composting levels with all remaining residual wastes, where possible, being treated by *high* levels of thermal treatment using either:

- Pyrolysis (Option 2A), or
- Gasification (Option 2B), or
- Incineration with energy recovery (Option 2C)
- Anaerobic digestion (Option 2D)

Any remaining residual waste would then be sent to landfill.

Option 3
An MBT/BMT-led strategy for residual waste
High recycling and composting levels, all remaining residual wastes being sent to MBT/BMT with the output recovered / disposed of using either:

- Pyrolysis (Option 3A), or
- Gasification (Option 3B), or
- Incineration with energy recovery (Option 3C), or
- Fuel to off-site energy use (Option 3D), or
- On-site Anaerobic digestion (Option 3E), or
- Landfill (Option 3F)

For Options 3A–3E, any remaining residual waste would then be sent to landfill.

Option 4
An autoclave-led strategy for residual waste
High recycling and composting levels, all remaining residual wastes being sent to autoclave with the output recovered / disposed of using either:

- Pyrolysis (Option 4A), or
- Gasification (Option 4B), or
- Incineration with energy recovery (Option 4C), or
- Fuel to off-site energy use (Option 4D), or
- Landfill (Option 4E)

For Options 4C to 4D, any remaining residual waste would then sent to landfill. It was not possible to assess options 4A and 4B following guidance from the Environment agency's LCA Advisor that the fibre produced would be unsuitable for use for advanced thermal treatment (pyrolysis/gasification).

Diversion of Biodegradable Municipal Waste from landfill

A separate modelling exercise for Municipal Solid Waste (MSW) only was conducted using the WRATE tool. The aim was to assess the amount of biodegradable waste landfilled to enable comparison with the expected 2020 BMW allowances made under the Landfill Allowances scheme. WRATE calculates the amount of biodegradable waste landfilled based on assumed biodegradability of each fraction of waste that is managed.

The indications from this exercise, shown in table 62, are that all options apart from option 0, 1B, 2B, 2D, 3E, 3F and 4E deliver 2020 Landfill Allowance Scheme targets by 2013. Options 1B and 2B required the use of a Dirty MRF to produce a Refuse Derived Fuel for gasification. The rejects from the MRF process required disposal to landfill and contributed strongly to the amount of biodegradable waste landfilled. A number of MRF facilities from the model were tried and in each case the landfill allowance target was breached.

Options 2D and 3E are both MBT processes, which include Anaerobic Digestion. In option 2D, the process was based on a technology that operates from Australia where the regulatory regime allows the outputs from MBT to be applied to land as a soil improver. Environment Agency guidance restricts the usage of composts derived for mixed waste and so the low grade compost produced was modelled to landfill. A similar process operated in option 3E but this was based upon generic process data held in WRATE (see Appendix 3 of part 3 for an explanation of generic processes). The configuration was such that the MBT process also produced a Refuse Derived Fuel. As this option had no thermal treatment plant to burn the RDF, this was also landfilled.

Option 3F used a generic MBT process from WRATE (composting and RDF production) and, as with option 3E, the RDF produced as part of the process had no management route other than to landfill.

Option 4E used an autoclave to produce a fibre from the organic elements. The model suggests that a market needs to be found for the fibre as by using the process as a pre-treatment to landfill would be insufficient to meet 2020 landfill targets for South West Wales in 2013.

These outcomes should be viewed with caution, as a number of factors would influence whether or not an authority met its LAS targets. A number of assumptions have been made about the composition of the waste, the types of material removed for recycling/composting and the amount of waste in the study year (a growth scenario of 3% pa was applied for Municipal Waste.

The actual reduction of biodegradability caused by a process also requires extensive monitoring and would be likely to vary dependent on the input composition. The performance of the facilities in WRATE is based on actual measurement of plant performance but this will also depend on the nature of the waste inputted. To demonstrate the actual reduction in biodegradability from a waste treatment plant, Environment Agency guidance must be adhered to.

Preferred options for BPEO/SWMO criteria

Guidance on the sustainability assessment of each option through stakeholder consultation weighting exercise placed great significance on impact on climate change, waste management cost, recovery and recycling achievements and the reliability of selected options, in identifying the preferred approach. The outcome of this exercise has been applied to each of the options in the form of weighted evaluation criteria to compare the relative performance of each waste management option for 2013 (the assessment year). The weighted results are shown in Table 66.

All options have been subjected to sensitivity analysis, comprising determination of weighted performance scores using inverted criteria weightings these are shown in table 67. **The overall ranking of options for SWMO and BPEO is shown in Table 68 and Figures 46-51 as well as in the summary below.**

Option 1: (A landfill-led strategy for residual waste)
Option 1a (Do minimum pyrolysis):

Weighted performance scores:	10th for weighted SWMO performance 12th for weighted BPEO performance
Valued performance scores:	11th for SWMO valued[20] performance 12th for BPEO valued performance
Sensitivity scores (Inverted criteria):	10th for SWMO weighted sensitivity 11th for BPEO weighted sensitivity

Option 1b (Do minimum gasification):

Weighted performance scores:	14th for weighted SWMO performance 17th for weighted BPEO performance
Valued performance scores:	15th for SWMO valued performance 17th for BPEO valued performance
Sensitivity scores (Inverted criteria):	16th for SWMO weighted sensitivity 17th for BPEO weighted sensitivity

Option 1c (Do minimum incineration with energy recovery):

Weighted performance scores:	13th for weighted SWMO performance 13th for weighted BPEO performance
Valued performance scores:	13th for SWMO valued performance 14th for BPEO valued performance
Sensitivity scores (Inverted criteria):	13th for SWMO weighted sensitivity 15th for BPEO weighted sensitivity

Option 2: (An Energy from Waste-led strategy for residual waste)
Option 2a (Pyrolysis of residual waste):

Weighted performance scores:	1st for weighted SWMO performance 4th for weighted BPEO performance
Valued performance scores:	1st for SWMO valued performance 4th for BPEO valued performance
Sensitivity scores (Inverted criteria):	1st for SWMO weighted sensitivity 2nd for BPEO weighted sensitivity

Option 2b (Gasification of residual waste):

Weighted performance scores:	9th for weighted SWMO performance 11th for weighted BPEO performance
Valued performance scores:	10th for SWMO valued performance 11th for BPEO valued performance
Sensitivity scores (Inverted criteria):	12th for SWMO weighted sensitivity 12th for BPEO weighted sensitivity

Option 2c (Incineration of residual waste with energy recovery):

Weighted performance scores:	5th for weighted SWMO performance 6th for weighted BPEO performance
Valued performance scores:	4th for SWMO valued performance 7th for BPEO valued performance
Sensitivity scores (Inverted criteria):	5th for SWMO weighted sensitivity 8th for BPEO weighted sensitivity

[20] This is the sum of the raw valued scores before weightings have been applied

Option 2d (Anaerobic digestion[21] of residual waste):

Weighted performance scores:	12th for weighted SWMO performance 8th for weighted BPEO performance
Valued performance scores:	12th for SWMO valued performance 10th for BPEO valued performance
Sensitivity scores (Inverted criteria):	11th for SWMO weighted sensitivity 10th for BPEO weighted sensitivity

Option 3: (An MBT/BMT-led strategy for residual waste)
Option 3a (MBT of residual waste with RDF to pyrolysis):

Weighted performance scores:	3rd for weighted SWMO performance 3rd for weighted BPEO performance
Valued performance scores:	2nd for SWMO valued performance 1st for BPEO valued performance
Sensitivity scores (Inverted criteria):	2nd for SWMO weighted sensitivity 1st for BPEO weighted sensitivity

Option 3b (MBT of residual waste with RDF to gasification):

Weighted performance scores:	2nd for weighted SWMO performance 2nd for weighted BPEO performance
Valued performance scores:	3rd for SWMO valued performance 3rd for BPEO valued performance
Sensitivity scores (Inverted criteria):	3rd for SWMO weighted sensitivity 3rd for BPEO weighted sensitivity

Option 3c (MBT of residual waste with RDF to incineration with energy recovery):

Weighted performance scores:	6th for weighted SWMO performance 5th for weighted BPEO performance
Valued performance scores:	7th for SWMO valued performance 6th for BPEO valued performance
Sensitivity scores (Inverted criteria):	8th for SWMO weighted sensitivity 7th for BPEO weighted sensitivity

Option 3d (MBT of residual waste with RDF to off-site energy use):

Weighted performance scores:	4th for weighted SWMO performance 1st for weighted BPEO performance
Valued performance scores:	5th for SWMO valued performance 2nd for BPEO valued performance
Sensitivity scores (Inverted criteria):	6th for SWMO weighted sensitivity 6th for BPEO weighted sensitivity

Option 3e (MBT/AD of residual waste with stabilite to landfill):

Weighted performance scores:	15th for weighted SWMO performance 14th for weighted BPEO performance
Valued performance scores:	14th for SWMO valued performance 13th for BPEO valued performance
Sensitivity scores (Inverted criteria):	14th for SWMO weighted sensitivity 13th for BPEO weighted sensitivity

[21] This is modelled using an MBT process incorporating Anaerobic Digestion

Option 3f (MBT composting of residual waste with stabilite to landfill):

Weighted performance scores:	17th for weighted SWMO performance 16th for weighted BPEO performance
Valued performance scores:	16th for SWMO valued performance 15th for BPEO valued performance
Sensitivity scores (Inverted criteria):	15th for SWMO weighted sensitivity 14th for BPEO weighted sensitivity

Option 4: (An autoclave-led strategy for residual waste)

Option 4c (MHT/Autoclave of residual waste with fibre to incineration with energy recovery):

Weighted performance scores:	8th for weighted SWMO performance 9th for weighted BPEO performance
Valued performance scores:	8th for SWMO valued performance 9th for BPEO valued performance
Sensitivity scores(Inverted criteria):	9th for SWMO weighted sensitivity 9th for BPEO weighted sensitivity

Option 4d (MHT/Autoclave of residual waste with fibre to off-site fuel use):

Weighted performance scores:	7th for weighted SWMO performance 7th for weighted BPEO performance
Valued performance scores:	6th for SWMO valued performance 5th for BPEO valued performance
Sensitivity scores(Inverted criteria):	4th for SWMO weighted sensitivity 4th for BPEO weighted sensitivity

Option 4e (**MHT/Autoclave of residual waste with fibre to landfill):**

Weighted performance scores:	11th for weighted SWMO performance 10th for weighted BPEO performance
Valued performance scores:	9th for SWMO valued performance 8th for BPEO valued performance
Sensitivity scores(Inverted criteria):	7th for SWMO weighted sensitivity 5th for BPEO weighted sensitivity

The best performing six options for both BPEO and SWMO are from either option 2 or option 3 indicating that the preferred waste management method is to thermally treat the residual waste with energy recovery either directly or using a Mechanical and Biological pre-treatment. As the top six options have similar overall scores, it is difficult to conclusively say that one option significantly out performs the others.

Overall, the best performing option for BPEO using weighted criteria is option 3D. This option describes the scenario where all residual waste is treated at an MBT plant producing a Refuse Derived Fuel (RDF), material is extracted for recycling and the reject fraction is sent to landfill. The RDF is subsequently sent off-site for thermal treatment at an existing facility.

It is perhaps not surprising that an option that includes a facility that is already in existence should score well. From an environmental perspective, the burdens are much less than for building a new facility, visual and landscape indicators score well as the facility is already in existence. The burning of the waste directly offsets the burning of coal in the cement kiln at a ratio of 1 tonne of waste offsetting 900 kg of coal. This differs from the benefits of burning waste in an energy from waste plant as this offsets the marginal mix of power generation options assumed for Wales in 2013, (see part 3 appendix 2) and is subject to the conversion efficiency of the thermal treatment plant.

Caution must be exercised in relation to this technology choice, as the likely constraint in the delivery of the option is the availability of capacity. The model indicates a required capacity of over 300,000 tonnes per annum and it will be very difficult to secure this capacity either within the region or further afield.

The cement kiln option score less well when other sustainability criteria are included. For SWMO, the best performing option for valued, weighted and reverse weighted scores is option 2A. This is where all residual waste is sent to a pyrolysis plant.

The high ranking of this specific option may be due to the technology plant used in WRATE. The modelling is based upon the WasteGen Pyrolysis plant in Bergau, Germany. Efficiency and emissions standards in Germany are higher than in some other European countries so its overall performance may be better than other technologies based in UK. For example, the Coventry and Grimsby incinerators (upon which options 1C, 2C, 3C and 4Care based) may have never breached any emissions standards, but if those standards are lower than Germany's then the performance may be quite different. Pyrolysis and gasification plants do not have an established history of treating municipal waste in the UK, neither does RDF to off site energy sites such as cement kilns. Therefore, options 2C and 3C may look like more attractive and more deliverable options in this regard.

The characterisation of options and the subsequent options assessment is based on assumed generic facility capacities, shown in Table 1 of this report. Some discrimination between the size of facility appropriate to rural and urban areas has been built into the report. However, in reality, facilities are unlikely to conform to these assumed sizes, actual built capacities will depend very much on local factors. The impact of facility size on the performance of options does not form part of this assessment but it is likely that larger facilities would perform slightly better than smaller facilities in overall terms. Whilst this may be the case, it does not eliminate the need for the appropriate use of smaller community based facilities which often form a fundamental part of an integrated strategy for waste management.

Option 0 was included for comparison purposes and does not score well. This reflects the situation whereby all residual waste is landfilled. As well as the poor performance scores for the sustainability appraisal, this option would not be followed for municipal waste due to the requirement of the Landfill Directive to divert biodegradable waste from landfill.

Option 1 (do minimum thermal treatment) performs less well than option 2 (energy from waste-led strategy) indicating that it is more desirable to replace all landfill disposal with thermal treatment with energy recovery rather than a partial replacement.

Option 4 relies on a technology that is commercially unproven for municipal waste in the UK and did not perform particularly well for SW Wales. Figure 50 illustrates the relative weighted scores and rankings of each option for SWMO criteria.

Option 2B scores less well than 2A or 2C due to the high amount of reject from the dirty MRF process that is required to produce RDF prior to gasification. Options 2D, 3E and 3F are all MBT processes with no thermal treatment and therefore still have a high requirement for the landfill disposal of outputs.

Whilst it is difficult to conclusively say that one option significantly out performs the others, the results for SW Wales Regional Waste Group indicate that waste management systems incorporating high levels of thermal treatment, or Mechanical Biological Treatment (MBT) followed by thermal treatment make up the top six options. As all of these options scored well in the appraisal, and in order to provide flexibility in the waste planning process, the conclusion from this sustainability appraisal is that any of the highest scoring options could be considered when reviewing the Regional Waste Plans.