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Sustainability Appraisal and Life Cycle Analysis of Strategic Waste Management Options

Report for the SE Wales Regional Waste Group. Part 3 – Appendices

ea/br/bl/std/vr10thanni

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Contents

Appendix 1 – The WRATE Tool

1.0 About WRATE

WRATE has been developed by Golder Associates and ERM on behalf of the Environment Agency and is used to assess the environmental aspects of waste management activities during their whole life. It allows users to track the environmental aspects from kerbside collection to advanced waste treatment facilities, such as anaerobic digestion, through to ultimate disposal. WRATE has been designed by waste managers for waste managers. The main innovation of the software is its ability to add user-defined processes and waste composition. This allows waste managers to model more realistically their own waste management systems.

The Life Cycle Assessment (LCA) tool developed in this project is expected to be fundamental in the development of more sustainable waste strategies. Waste managers and decision-makers will be able to compare the environmental impacts of alternative integrated waste management systems in developing their JMWS.

WRATE permits the comparison of a current reference system (base case scenario) with alternative or future integrated waste management systems. It identifies burdens at each stage of a process and each stage in the waste management system.

The key benefits of WRATE are:

- 840 environmental burdens
- 40 Impact Assessment methods
- 140 waste management processes
- Calculation of LCI by process stage
- All documentation available from within the software (available electronically)
- Processes and software validated and peer reviewed
- Integration of a LCA collection tool
- Error analysis tool
- Visual/interactive GUI
- System and user database
- Fully customisable
- Provision of default information.
- Integrated reporting functionality
- Sankey Diagrams
- Integrated results analysis tool
- Transparent (equations are available to the user)
- Use of smart tags explaining parameters in plain English
- Use of process pictures to illustrate technologies
- Electronic exchange of process information, scenarios and projects
- Electricity mix calculated using energy mix, marginal mix, transmission loss and generating efficiencies available for 40 countries, and forecast for up to 20 years.
- Mass balance at elemental levels for heavy metals
- 15 level 1 and 67 level 2 waste fractions and 11 municipal waste streams
- Landfill emissions modelled according to loading factor of each waste fraction over a 20,000 year period
- Unique modelling of 6 types of landfill
- Usage of regression equations to model any size of landfill
- Provision of headline indicators showing waste management system statistics
- Detailed results – advanced filtering of data
- Scenario comparison with baseline options
- Translatable with the change of a single file
- Backup/restore of the user database
- Product and reject managed separately by different processes.
- Unrestricted number of processes and number of links between processes
- Unrestricted number of scenarios

- Calculation of LCI and LCIA as absolute values, relative values, per person and normalised values.
- Different levels of reporting
- Export to XML, CSV.
- Copy and paste to Excel
- Packing functionality (to temporarily hide processes on map)
- Specific process restrictions on waste properties/composition.
- WRATE only calculates the environmental impacts and benefits (not financial or social ones).

2.0 Goal and Scope of WRATE

2.1 Goal

In developing WRATE the goal was to develop a scientifically and technically valid life cycle tool to assess, as accurately as possible, the environmental costs and benefits of integrated waste management systems for municipal solid waste (MSW). With the aim of producing a tool that can be used by non-LCA experts to compare options (scenarios) for integrated waste management systems.

The tool has been developed in conjunction with ISO standards (ISO 14041) on Life Cycle Assessment, so that studies can be performed using the tool to a high technical standard, with user confidence in the functioning of the software and the underlying data.

WRATE has been designed to inform decision-makers responsible for determining effective sustainable waste management strategies for MSW in the development of Municipal Waste Strategies.

Other potential applications of WRATE include use in regional and national waste strategy, Local Authority waste disposal and recycling contracts, informing Regional Planning Guidance, Waste Local Plans/UDPs, Strategic Environmental Assessments, Technology Assessments, Environmental Impact Assessments and the development of other waste related policies.

Intended users are local and regional public authorities, central government, environmental consultants, non-governmental organisations, and the waste management industry. Two categories of users are identified; Non-expert users (first time users with waste management knowledge) and Expert users (frequent users with LCA and modelling experience).

The intended audience for communicated results are waste decision-makers (waste stakeholders) responsible for identifying sustainable waste management strategies.

2.2 Scope

2.2.1 The function of the systems

The scope of WRATE is to provide a tool to calculate a Life Cycle Inventory and Life Cycle Impacts for alternative integrated waste management systems for the management of MSW. The function of the system analysed is the collection and management of MSW until its final disposal.

2.2.2 Functional unit

The functional unit is the collection and treatment of municipal solid waste generated by a local community, part of a local community, or a group of communities (such as sub-region) for a period of one year.

2.2.3 The systems to be studied

The systems to be studied are the main methods in integrated waste management systems used to collect, sort and treat MSW that are typical of current UK and European waste management practice and foreseen practice to 2009. These are home composting, waste collection (containers, sacks and vehicles) and transport (waste vehicles and private vehicles), waste transfer, pre-treatment and sorting (civic amenities, material recycling facilities (MRFs), mechanical biological treatment (MBT)), waste treatment and recovery (composting, incineration with energy recovery, anaerobic digestion / bioethanol, advanced thermal treatments), materials recycling and disposal (incineration without energy recovery and landfill).

2.2.4 The system boundaries

WRATE takes into account all the stages in the management and processing of waste, from the point where it is discarded at the back door to the technically controlled disposal or recovery of waste.

The tool takes into account first (e.g. operational inputs and outputs) and second level burdens (e.g. infrastructure) of the waste management facilities and avoided burdens due to materials and energy displacement.

The upstream limit of the system is the “resource” represented by the municipal waste produced. The model does not account for the energy and material costs of producing the waste materials that make up the resource (“zero waste burdens” approach). The model covers MSW comprising household collected waste and the main civic amenity / bring system wastes. The elementary flows provided for by the background database depend on the nature of the background data and have been obtained from recognised data sources. Cut off rules are applied as appropriate and are documented.

2.3 Allocation procedures

Allocation procedures follow the procedure recommended in ISO14041; system expansion is implicitly built into the model.

For inputs to waste management processes and co-inputs (MSW and commercial wastes/fuels) allocation is product-related (i.e. the basis of materials in the waste treated and their chemical composition) for all outputs (energy, heat and emissions).

- for thermal treatment and organic processes this is on the basis of biodegradable carbon content and calorific value.
- for co-products from sorting processes (e.g. MRF, MBT) allocation is on a product-related basis by mass.
- landfill gas emission factors are calculated using the GasSim model based on the chemical composition of the waste. Landfill leachate emissions are calculated using the LandSim model, also based on waste chemical composition.

Where relationships are known, the tool uses process-related emission factors based on known operational behaviour. For example, for thermal technologies, regulatory limits such as hydrogen chloride abatement of emissions from incinerators will be included.

2.4 Data requirements

“Foreground” waste management process data is representative of current and future UK waste management systems.

The tool provides default data on the specifications of waste treatment facilities but, in a sitespecific context where specific information is available, permits users to alter this default data through the modification of a default process scale or through the creation of a user defined process. Users may be advised to validate certain key sensitive parameters (as determined through technical testing) of the default data used in external studies.

Data obtained for the Background database on energy and material production is representative of the UK economy, but can be sourced internationally when national data is not available. These databases are integrated in calculation models that provide scientifically and technically valid results.

2.5 Assumptions

Electricity generation avoided is offset against an inventory of marginal national grid energy mixes. Heat energy is offset against a gas combustion inventory with a thermal efficiency of 85%. Assumptions concerning the efficiency of heat recovery and electricity generation are applied to each energy recovery process.

Avoided materials (i.e. recycling process products) are offset against virgin materials production.

Where recycled materials are substituted to provide the same function as a virgin material (e.g. shredded paper as a packaging material over polystyrene), materials are offset against the inventory for virgin material production for the typical material on the basis of functional equivalence. If the performance of the recycled material is different to that of the standard market material (e.g. more weight of paper is required to pack an item than the standard material) then a factor is used in the model to account for the difference.

Apart from ensuring functional equivalence, the tool does not account for the environmental impacts of the functions of materials once recovered or recycled and incorporated into new products.

Other modelling issues, such as the treatment of MSW-derived fertiliser displacement over inorganic fertilisers, will be stated in the best practice guidance.

2.6 Limitations of WRATE

WRATE has been designed for the modelling of LCA for municipal waste management. It is not intended for the study of product life cycle assessment. Nor is WRATE intended for the study of wastes that are not municipal.

The software and underlying data is limited to the best scientific knowledge of the subject, data availability and commercial confidentiality considerations/requests.

The software is limited to the chemical analysis provided for waste categories defined in the Environment Agency's waste analysis research program. The tool can be used for commercial and industrial waste streams if they are similar in composition to the municipal waste streams.

WRATE does not model financial or social cost. It does not take into account the wear and tear of processes (i.e. decrease in performance with time is not modelled).

2.7 Data quality requirements

2.7.1 Foreground processes database

Time-related coverage. Data is representative of UK waste management practice for the period 2002 to 2009. The majority of the data for the tool is provided by the Environment Agency's existing foreground database. This will be updated to take account of legislative and technology changes, and where this is required, the most recent, scientifically and technically valid data will be used. A sensitivity analysis of the existing data has been undertaken to inform this process.

Geographical coverage. The data is sourced from the UK operating and pilot plants or from European or other international plants where UK data is not available.

Technology coverage. The data is representative of best available technology and complies with existing UK regulatory requirements and foreseen regulatory requirements such as the Waste Incineration Directive, Landfill Directive and Animal By-products Regulations.

The data (as accurately as possible) represents operational performance for waste management facilities. Data was collected and averaged from existing facilities wherever possible. For some data (e.g. pilot facilities and future facilities), some modelling was undertaken. For these facilities, emission limit values and other regulatory requirements are accounted for in the modelling, together with a factor representative of anticipated environmental compliance to the requirements. These factors are based on expert judgement.

Data comprises a mixture of averaged site-specific data and data from published sources; a mixture of measured, calculated and estimated data has been used. Data has been collected consistently using a data collection template in accordance with the Environment Agency's Data Collection Guidelines concerning issues of data precision, completeness, representativeness, consistency and reproducibility.

The data collection template considers the requirements of the standard on Life Cycle Inventory data format, ISO14048. Text descriptions of the individual processes are available in WRATE through the use of html information sheets. The data collected is public data, although in some circumstances data confidentiality (such as commercial confidentiality) has been respected and parts of the data may have been withheld.

For prioritising the collection of new data, key sensitive parameters have been identified to establish which aspects of the existing foreground data are environmentally most significant.

2.7.2 Background processes database

Time-related coverage. Data is representative of the current UK economy but accommodates anticipated future energy production mix changes.

Geographical coverage. The data is sourced from the UK or European practices in the first instance, and elsewhere provided it is considered relevant.

Technology coverage. The data is representative of best available technology in the UK or Europe in the first instance, and elsewhere provided it is considered relevant. Data comprises a mixture of averaged site-specific data and data from published sources; a mixture of measured, calculated and estimated data has been used.

For both the foreground and background database, metadata about data quality has been compiled and is accessible to the user for each process. A quick overview of the data quality is available through a visual Data Quality Indicator.

3.0 Software and Data Peer Review

WRATE has followed a peer review process undertaken by an external independent reviewer to assess the relevance of the data, the methods used, the software functionality and included data, the modelling, the software and report transparency and the completeness against the goal and scope terms of the project. The review has been undertaken to ensure user confidence in the functioning of the tool and the underlying data.

4.0 Compliance With ISO 14040

WRATE has been developed following the International Standard ISO 14040 series. The general methodological structure of WRATE includes compliance with the following standards:

- ISO 14040:1997 – Principles and framework
- ISO 14041:1998 – Goal and scope definition and inventory analysis
- ISO 14042: 2000 – Life cycle impact assessment
- ISO 14043: 2000 – Life cycle interpretation
- ISO 14048: 2002 – Data documentation format
- ISO 14049: 2000 – Examples of application of ISO 14041 to goal and scope definition and inventory analysis

All the data collection has been undertaken following the ISO 14048 standardised format for the collection and reporting of LCA data. ISO 14048 supports transparent reporting, interpretation and review of data collection, data calculation and data quality. This has been developed mainly to facilitate the exchange of LCA data in a consistent manner. ISO/TS 14048 enables fully transparent, and hence fully reviewable and verifiable data documentation for life cycle inventories, individual waste management processes, Life Cycle Impact Assessments (LCIA) and energy mixes.

For ease of understanding, specific metadata information (information about the data) has been allocated in the process information forms provided for each waste management process. These html forms have been prepared following a strict and consistent procedure for the collection of this type of information, and contain information about the process, the modelling, validation and administrative information.

5.0 The Conceptual Model of a Process

A waste management process is defined by its inputs and outputs. In WRATE all the materials, energy and emissions associated with each waste management process are defined using this model, which applies equally to processes ranging from a simple bin liner to a much more complex incinerator or a landfill. The main categories of a generic waste management process include construction, the operational inputs (material and energy), the production of process products or wastes and finally the environmental aspects of a process.

6.0 Structure of WRATE

WRATE manages information from different databases. The energy mix database comprises all the information related to the electricity generation mix, the country under study, generation efficiency, electricity losses during electricity transport and marginal electricity production.

The waste composition database contains the information relating to the type and quantity of waste. It includes a pre-defined elemental waste composition for each waste fraction, the default waste composition, the calorific value and the moisture content of the waste. A distinction has been made between the foreground system, defined as the set of processes directly affected by the study, and the background database which includes all the materials and energy sources needed for the calculation of the project LCI. (Clift et al, 1998).

Life Cycle Impact Assessment methodologies are defined in a separate database, and finally the project information is stored in a project database. It should be Noted that the database structure has been designed to keep system default data separate from user defined data to optimise the integrity of peer reviewed data and ensure the consistent quality of the software.

7.0 Updates

Through continued involvement in the international research area, the Environment Agency will aim to keep the tool scientifically valid. Foreground and Background data **will be updated annually** to ensure the continued relevance of the software and data. Data on new waste management technologies and technology upgrades will be provided to all users, following a strict validation process by the Environment Agency and a peer review process by independent third parties. Updates can be provided by accessing the WRATE website on www.wrate-LCA.co.uk

Appendix 2 – LCA Data Limitations, Sources and Assumptions

Data Limitations

As explained in appendix 1, WRATE is specifically designed to model the environmental burdens (or avoided burdens) associated with the management of municipal waste and also elements of industrial, commercial, agricultural and construction and demolition wastes that are similar in nature to municipal wastes.

A range of waste types have been excluded from the life cycle assessment of waste management options for the regional waste plan review (these include specific industrial process wastes, hazardous wastes). The excluded wastes are detailed in table 3 of part 2 of this report. A small amount of residual hazardous waste remains in the municipal, industrial and commercial streams and has been modelled along the same route as the mixed residual.

As with any modelling exercise, there is uncertainty in the future forecasting of waste arising. The tonnage of waste forecasted to 2013 in each stream has been provided by each of the RWGs based on current arisings and trends.

The composition of waste streams has been derived from the best available data. The standard waste composition for MSW held within WRATE is based upon a WAG analysis and the fractions contained within this stream will be applied to all other waste streams for the LCA. The nature of each of the waste fractions and sub-fractions contained within WRATE are based on the municipal stream. As the non-municipal waste compositions will be translated to best fit these MSW waste fractions, the environmental costs and benefits will carry with them a degree of uncertainty.

Energy use is a key parameter in determining relative environmental impacts of the management options. The energy mix has been forecast to the study year from data held within WRATE[1] for Wales. Substantial changes in the energy mix may have a significant bearing on the relative impact of options with high-energy usage. Sensitivity analyses will be required to determine the effect such changes may have.

The collection systems for waste will not be included in the LCA. The aims of the study are to assess the impacts of different waste recovery, treatment and disposal options. As the front-end performance for each option will be constant, collection impacts will not be modelled, as they will not vary between options.

High levels of source segregation will be required to meet recycling/composting targets for all options and this will be the principal driver in determining collection methodology. The impacts of collection transport will be estimated through the addition of a fixed collection round distance (dependent on the waste stream) to the trip distance in the initial movement of waste from production to the first facility. The environmental burdens of collection containers have not been considered within the scope of the study.

Any increase in home composting, and thus the subsequent diversion of material from the main waste stream as well as the reduction in transport impacts will not be estimated within the modelling process.

[1] Data derived from WRATE Electricity Database Manual, Environment Agency, DRAFT REPORT, June 2005

WRATE does not have the specific capability to model hazardous waste. This study includes industrial and commercial, construction and demolition and agricultural wastes as well as municipal wastes. A proportion of these wastes will be hazardous.

The life cycle impacts of hazardous wastes will not be modelled within the study. During the analysis of the composition of each of the streams, the hazardous element will be removed and recorded in the final report but not modelled through the facilities in WRATE. It will be possible to account for the capacity of facilities required to manage and dispose of each of these waste streams, but their relative impacts won't be included within the study.

General assumptions

To meet the required composting levels in each of the options, a considerable amount of source segregated food and other organic waste will need to be collected. Due to the restrictions of the animal by-products regulations, specifically the requirement to kill any potential pathogens arising from food wastes, it is assumed that composting facilities will be developed with 80% of capacity in-vessel and 20% as open windrow sites. This will also account for the high proportion of food waste relative to green waste within the commercial stream. Open windrow sites will only receive garden waste fractions.

The amount of waste passing through transfer sites will be in the equivalent proportion relative to total site returns made against waste management licences as detailed in the 2004/5 site return data for Wales.

The proportion of municipal waste arisings delivered to CA sites will be in accordance with the detailed data collected in the WAG 2004/5 Municipal Waste Management Survey.

Transport distances to other waste facilities will presume an even distribution across the region and transport using the mix of roads within that region. It is assumed that for recyclates being transported out of the region, the mix of roads used will be 80% motorway, 10% urban, 10% rural.

Transport distances to transfer / treatment facilities are calculated from the area of the sub-region (in km^2) and the number of facilities required, and assumed a uniform distribution of facilities across the sub-region. The following relationship was found to generate an estimate of the average straight-line distance to a facility.

$$d = \sqrt{A} / ((4/3)+(2/3*n)$$

Where d is the required one way trip distance in km, A is the area of the region in km and n is the forecast number of facilities that are equally distributed across the region. Figure A1 illustrates typical distances based on the land area[2] for each region and the number of facilities based on the equation above.

[2] Derived from ordnance survey data and GIS polygons, Environment Agency

Figure A1 Mean trip distances for each region dependent on the number of facilities required and land area

Number of Facilties	South West Land area (km²)	Mean Trip distance South West - km	North Land area (km²)	Mean Trip distance North - km	South East Land area (km²)	Mean Trip distance South East – km
1	7023.3	41.9	8702.8	46.6	5498.7	37.1
2	7023.3	31.4	8702.8	34.9	5498.7	27.8
3	7023.3	25.2	8702.8	28.0	5498.7	22.3
4	7023.3	21.0	8702.8	23.3	5498.7	18.5
5	7023.3	17.9	8702.8	20.0	5498.7	15.9
6	7023.3	15.7	8702.8	17.5	5498.7	13.9
7	7023.3	14.0	8702.8	15.5	5498.7	12.4
8	7023.3	12.6	8702.8	14.0	5498.7	11.1
9	7023.3	11.4	8702.8	12.7	5498.7	10.1
10	7023.3	10.5	8702.8	11.7	5498.7	9.3

The split of road types to be applied to the model will be in accord with the data in figures A2, A3 and A4[3].

Figure A2 Road types and distances for SE Wales

Local Authority	Motorway km	Rural km	Urban km	All Roads	Motorway %	Rural %	Urban %
Blaenau Gwent	0.0	107.7	292.7	**400.4**	0.0	26.9	73.1
Caerphilly	0.0	470.2	523.9	**994.1**	0.0	47.3	52.7
Cardiff	17.0	133.6	909.5	**1060.1**	1.6	12.6	85.8
Merthyr Tydfil	0.0	135.5	202.5	**338.0**	0.0	40.1	59.9
Monmouthshire	22.7	1423.8	153.8	**1600.3**	1.4	89.0	9.6
Newport	26.7	271.6	428.6	**726.9**	3.7	37.4	59.0
Powys	0.0	2822.8	25.0	**2847.8**	0.0	99.1	0.9
Rhondda Cynon Taff	9.8	444.9	707.3	**1162.0**	0.8	38.3	60.9
Vale of Glamorgan	3.7	559.6	347.2	**910.5**	0.4	61.5	38.1
Torfaen	0.0	145.4	326.5	**471.9**	0.0	30.8	69.2
Total	**79.9**	**6515.1**	**3917.0**	**10512.1**	**0.8**	**62.0**	**37.2**

Figure A3 Road types and distances for SW Wales

Local Authority	Motorway km	Rural km	Urban km	All Roads	Motorway %	Rural %	Urban %
Bridgend	17.7	386.61	347.18	**751.5**	2.4	51.4	46.2
Carmarthenshire	5.1	3242.1	342.4	**3589.6**	0.1	90.3	9.5
Ceredigion	0	2203.5	49.6	**2253.1**	0.0	97.8	2.2
Swansea	15.4	429.9	726.8	**1172.1**	1.3	36.7	62.0
Neath Port Talbot	23.2	435.01	409.9	**868.1**	2.7	50.1	47.2
Pembrokeshire	0	2462.8	112	**2574.8**	0.0	95.7	4.3
Total	**61.4**	**9159.92**	**1987.9**	**11209.2**	**0.5**	**81.7**	**17.7**

[3] This information has been modified from: www.dft.gov.uk/stellent/groups/dft_transstats/documents/page/dft_transstats_032735.xls

Figure A4 Road types and distances for N Wales

Local Authority	Motorway km	Rural km	Urban km	All Roads	Motorway %	Rural %	Urban %
Conwy	0.0	1339.0	279.6	**1618.6**	0.0	82.7	17.3
Denbighshire	0.0	1231.0	182.7	**1413.7**	0.0	87.1	12.9
Flintshire	0.0	817.6	437.2	**1254.8**	0.0	65.2	34.8
Gwynedd	0.0	2377.6	64.6	**2442.2**	0.0	97.4	2.6
Isle of Anglesey	0.0	1137.6	68.7	**1206.3**	0.0	94.3	5.7
Powys	0.0	2309.6	20.5	**2330.1**	0.0	99.1	0.9
Wrexham	0.0	855.2	337.3	**1192.5**	0.0	71.7	28.3
Total	**0.0**	**10067.6**	**1390.6**	**11458.2**	**0.0**	**87.9**	**12.1**

For each region the total proportional split for motorway, rural and urban roads have been applied to the WRATE model.

Vehicle capacity will be based upon standard data held in WRATE and the number of trips required will be based upon vehicles operating at full capacity.

It will be modelled that segregated waste streams that are sent for recycling will be sent to existing facilities and these will be at a pre-determined distance from the central point of each region. Materials recycling plants already operate, often on a UK-wide basis, and so it is assumed that the location of materials re-processors will not be influenced by the development of residual treatment facilities.

All relevant ‘Wise About Waste’ recovery and diversion targets for the waste streams modelled will be met or exceeded.

- by 2009/10 and beyond achieve at least 40% recycling/composting with a minimum of 15% composting (with only compost derived from source segregated materials counting) and 15% recycling.
- by 2010, to reduce the amount of industrial and commercial waste going to landfill to less than 80% of that landfilled in 1998.
- by 2010, to reduce the amount of biodegradable industrial and commercial waste going to landfill to less than 80% of that landfilled in 1998.
- by 2010, to re-use or recycle at least 85% of C&D waste produced.

The recovery of packaging waste, as a UK target, cannot be accurately modelled within this analysis due to the nature of the registration system. Obligated companies register once (generally from a head office location) and provide evidence to cover all of their operations. This may include locations across the UK.

The re-processors who provide the evidence of recovery could be based anywhere in the UK or may be a company who export the waste for recovery. The issue of Packaging Export Recovery Notes (PERNs) also provides data of packaging recovery under the regulations. This capacity would be delivered outside of the study area.

All data used to model waste processes will be the standard data held within WRATE, wherever possible generic data will be used. More mature technology types have broader datasets concerning plant performance; this is amalgamated into a generic format in WRATE to generate impacts and performance data that is representative of the technology type. Where this is not possible, the model will apply individual case study data held within WRATE.

The capacity of required sites will be in part determined by the arising requiring management in each of the three areas. As a planning exercise, the size of the facility would be in relation to the forecast arising requiring that specific management route. The capacity data used in the original LCA and amended for publication in the RWPs are listed in fig A6.

Figure A6 Capacity data used in WISARD modelling and with amendments that took place for publication of the Wales Regional Waste Plans. All figures are tonnes per annum.

Facility Type	Capacity Used for WISARD	Capacities as used in final RWP
MRF	15,000	15,000
Open Windrow	7,500	5,000
In Vessel	10,000	10,000
Inert Recycling	30,000	30,000
EfW	60,000	60,000
Landfill	75,000	100,000
MBT	60,000	60,000
CA	20,000	5,000
Transfer	40,000	60,000
AD	50,000	50,000

Figures within WRATE for the generation of electricity are based on the draft WRATE Electricity Database manual. The figures forecast the future energy mix for Wales based on the current mix of generation. The energy mix assumed for 2013 is shown in figure A7.

Figure A7 2013 Wales' electricity generation mix assumed for the study

Energy Source	Baseline Fuel Mix (%)	Generating Efficiencies (%)	Marginal Fuel Mix (%)
Total	100.00		100.00
Coal	16.62	36.31	49.30
Oil	0.04	27.83	0.00
Gas	3.16	34.90	3.19
Gas CCGT	45.39	46.61	47.51
Nuclear	17.73	37.25	0.00
Waste	0.01	25.35	0.00
Thermal other	0.36	36.31	0.00
Renewables thermal	2.31	18.11	0.00
Solar PV	0.00	15.52	0.00
Wind	13.23	25.00	0.00
Tidal	0.00	82.00	0.00
Wave	0.00	82.00	0.00
Hydro	1.14	82.00	0.00
Geothermal	0.00	82.00	0.00
Renewable other	0.00	82.00	0.00

Figure A8 below shows the 2020 electricity mix for Wales which was used to run a sensitivity test on the options (see chapter 8)

Figure A8 2020 Wales' electricity generation mix used for sensitivity test

Energy Source	Baseline Fuel Mix (%)	Generating Efficiencies (%)	Marginal Fuel Mix (%)
Total	100.00		100.00
Coal	10.46	36.31	33.81
Oil	0.03	27.83	0.00
Gas	3.75	34.90	4.17
Gas CCGT	54.34	46.61	62.02
Nuclear	9.03	37.25	0.00
Waste	0.01	25.35	0.00
Thermal other	0.33	36.31	0.00
Renewables thermal	3.07	18.11	0.00
Solar PV	0.00	15.52	0.00
Wind	17.91	25.00	0.00
Tidal	0.00	82.00	0.00
Wave	0.00	82.00	0.00
Hydro	1.06	82.00	0.00
Geothermal	0.00	82.00	0.00
Renewable other	0.00	82.00	0.00

Municipal Waste

The composition of MSW has been derived from the standard held within WRATE[4]. The composition has beeen applied to each of the three RWG areas and is shown in table 5 and figure 4.

Industrial and Commercial waste

The compositions of industrial and commercial wastes were derived from the EA Industrial and Commercial Waste Survey (2003). The types of waste were assessed and a number of hazardous and non-hazardous wastes were excluded from the life cycle modelling. It is assumed these wastes will require a different management route to the municipal type facilities in the WRATE model. The estimation of the composition of modelled industrial and commercial wastes are shown in tables and figures 6 and 7.

Construction and demolition waste

The composition of construction and demolition (C&D) waste was estimated through professional judgement. This composition will be transposed onto the waste fractions defined for MSW within WRATE as listed below. C&D waste is deemed to have the same composition in each of the RWPG areas. The estimation of the composition of C&D waste can be found in table 9 and figure 9.

- Building Rubble Waste
- Non-Packaging Wood Waste
- Soil
- Other Non-Ferrous Metal
- Other Dense Plastic Packaging
- Other Packaging Film

Agricultural waste

The composition of agricultural waste was derived from 2003 agricultural census data and Marcus Hodges waste production model and transposed onto the waste fractions defined for MSW within

[4] The Composition of Municipal Solid Waste in Wales. WAG, AEA Technology (2003)

WRATE. The estimation of the composition of modelled agricultural waste is shown in table 8 and figure 8.

Waste arisings

The forecast arising of each of the waste streams for each of the Regional Waste Groups is shown in the figure A9.

Figure A9 Forecast arising per stream for each Regional Waste Planning Group

Region	Municipal Solid Waste (MSW)	Industrial Waste	Commercial Waste	Construction & Demolition Waste (C&D)	Hazardous Waste	Agricultural waste (Potentially controlled)	Total
South West	794,777	1,125,594	356,261	2,076,883	157,083	14,836	4,524,984
South East	1,153,179	593,590	542,849	3,245,301	98,243	15,115	5,648,279
North	691,090	439,124	333,226	1,460,000	79,138	23,942	3,026,520

In determination of the capacities shown in table 1 of the main report, consideration was given as to the nature of each local authority as it was agreed that more sparsely populated rural areas may require facilities with smaller capacities than densely populated urban areas. The allocations in figure A10 were agreed.

Figure A10 Split of urban and rural authorities in each Regional Waste Planning Group area

South West Wales	Urban	Rural
	Swansea Neath Port Talbot Bridgend	Ceredigion Carmarthernshire Pembrokeshire
South East Wales	**Urban**	**Rural**
	Cardiff Newport RCT Torfaen Merthyr Tydfil Caerphilly Blaenau Gwent	Monmouthshire Vale of Glamorgan Powys
North Wales	**Urban**	**Rural**
	Flintshire Wrexham	Conwy Gwynedd Powys Isle of Anglesey Denbighshire

Appendix 3 – WRATE Technology factsheets

This section contains descriptions of each of the residual waste treatment technologies in WRATE that were used for the life cycle assessment of option for the Wales' regional waste planning groups.

Pyrolysis Twin Rotary Kilns (WasteGen)

The Burgau Pyrolysis Plant

The Burgau Pyrolysis Plant processes municipal and industrial waste, bulky waste and sewage sludge.

Municipal, industrial and crushed bulky waste are delivered by waste collecting vehicles and discharged into the coarse waste storage bin. From the waste storage bin, the waste mixture is picked up by a crane, discharged onto two alternatively operated rotor cutters and cut to pieces with edge lengths of approximately 30 cm. From the rotor cutters, the material is delivered via appropriately arranged chutes into the mixed waste storage bin, where it is mixed with sewage sludge.

A crane thoroughly mixes waste and sewage sludge in order to obtain a highly homogeneous mixture. This mixture is charged by the crane via the feeding hoppers into the charging devices of the two rotary kiln. From the feeding hoppers, a speed controlled plate conveyor and a belt conveyor transport the waste to the feeding chute. At the same time, about 15 to 20 kg of quicklime per ton of waste are fed into the kiln. As soon as the maximum filling level is reached the belt and plate conveyors are switched off and the gas-tight gate above the feeding chute is closed. A feeding screw arranged downstream the feeding chute conveys the waste mixture into the pyrolysis kiln. As soon as the filling level reaches a minimum, the feeding chute gate opens and feeding via belt and plate conveyors resumes.

The two rotary kilns are heated indirectly with the flue gas from the pyrolysis gas incineration having a temperature of approximately 200C. The kilns have a heated length of 20 m and a diameter of 2.20 m. Both rotary kilns are operated slightly under pressure; about 100 Pascal (10 mm WC). The outer surface of the rotary kilns is heated to a temperature of 550°C, resulting in a pyrolysis temperature of approximately 450 to 470C and a heating gas temperature after kiln heating of 600 to 650°C.

In the front part of the kiln, small lifting blades arranged in reverse order provide greatest possible surface contact between waste and kiln wall surface without increasing dust formation by agitating the waste. A shutter blade arranged at the rear part of the kiln makes sure that it is filled with waste material to about 15 %. The speed of the rotary kiln and thus residence time of the material within the kiln can be set to periods from 30 minutes to two hours. A residence time of one hour is usually sufficient for carbonisation of the waste, i.e. production of an inert residue free of organic compounds.

Approximately half of the acid gaseous pollutants formed during the pyrolysis process, such as hydrogen chloride, hydrofluoric acid and sulphur compounds react within the rotary kiln with the quicklime added during feeding. Thus, the flue gas resulting from pyrolysis gas incineration needs only a minimum of cleaning. The main portion of the quicklime added is discharged with the solid residues.

In the first part of the rotary kiln, the waste is simply dried, in the second, it is heated to the process temperature. This is where degasification and decomposition of organic matter take place. Residues of the pyrolysis process are discharged via a wet slag remover with the pyrolysis gas being sealed from the atmosphere by the water level in the deslagger. The residues, having a residual humidity of 30 to 50 % and a temperature of 40 to 50C, are transported to the residue container by means of a conveyor belt, which may be connected alternatively to each of the two kilns.

Directly in front of the low temperature coke silo, coarse ferrous components are removed by an overhead magnetic separator and discharged into a container for recycling. These components make up to 10% of the total pyrolysis residues. From the top end of the discharge housing, the pyrolysis gas is led to hot gas cyclones from which, at intervals of four hours, accumulating fine dust is removed by injection of 1kg of sand per ton of waste by means of nitrogen. The cyclones remove approximately 80 to 100 kg of dust per hour. Their efficiency is about 70%. The cyclone dust, having a temperature of about 450°C, is discharged through double pendulum flaps and added to the pyrolysis coke via cooling screw-type conveyors. The containers filled with pyrolysis coke and cyclone dust are then transported to the county's pyrolysis coke dump, adjacent to the pyrolysis plant. All gas containing components, including the cyclones, are electrically heated to a temperature slightly exceeding that of the pyrolysis gas.

After dust removal, pyrolysis gas from the two rotary kilns is collected and fed to the combustion chamber where it is incinerated with an excess air (approximately 5 to 8 %) at a temperature of approximately 200°C. Optimum combustion conditions are created by the homogeneous fuel pyrolysis gas generated in the rotary kiln during pyrolysis of the waste mixture, and combustion chamber temperatures considerably higher than in conventional grate incinerators (~200°C).

Therefore, the flue gas contains only small quantities of carbon monoxide, dioxins, furans and hydrocarbons, and no additional treatment for reduction of these pollutants is necessary. One part of the flue gas generated in the combustion chamber is fed back for heating the rotary kiln; the remaining flue gas as well as the recirculated heating gas - cooled down to approximately 600 to 650°C - are fed into a waste heat boiler.In this boiler, steam at 30 bar and 400°C is generated from the heat of the flue gas and subsequently fed to a turbine-generator for power generation.

After cooling of the flue gas to approximately 250°C and conditioning with air, the remaining dust is removed in a bag house filter. At the same time, the remaining gaseous pollutants and mercury are absorbed and adsorbed by adding a mixture of sodium bicarbonate and activated carbon upstream the bag house filter. These simple techniques guarantee that the limits set for these compounds are kept. The bags of the baghouse filter are cleaned by air pressure pulses and the dust removed is collected in a silo. After conditioning, this dust is taken to an underground deposit. To reduce the quantity of combustion air and thus the NOx emission, approximately 5,000 m3 of treated flue gas are returned to the combustion chamber. After treatment, the flue gas is compressed by a thyristor-controlled induced draught and taken to the stack. This induced draught controls the pressure profile of the plant, activated by pressure measurements within the kiln.

Gasification of Refuse Derived Fuel (RDF) (Energos)

Waste Receipt, Fuel Production and Fuel Storage

A standard plant is equipped with two silos, one for waste from external contractors and one for fuel (pre-treated waste).Waste is delivered to the energy plant by trucks in closed containers and unloaded in the waste silo. The silo hall is equipped with an automatic odour control system to avoid smell in the vicinity of the plant. Air from the ventilation system is used in the thermal conversion process. Fuel is unloaded from the fuel silo by use of an overhead crane and delivered to the thermal conversion unit

Thermal Conversion

The thermal conversion unit consists of a primary and a secondary chamber.Drying, pyrolysis and gasification of the fuel is carried out in the primary chamber under sub-stochiometric conditions, while high temperature oxidation of syn-gas delivered from the primary chamber takes place in the secondary chamber.The primary chamber is equipped with a fixed horizontal oil-cooled grate that is divided into several separate sections, each with a separate primary air supply. A water-cooled guillotine is installed at the inlet of the primary chamber to control the thickness of the fuel bed.

Hydraulically operated water-cooled scrapers take care of transport of fuel along the grate. This transport mechanism is designed in such a manner that in addition to the longitudinal transport there is good local mixing of the moving fuel bed, again in order to promote the local homogeneity.

The fuel is waste that is pre-treated to ensure a sufficiently high surface-to-volume ratio and a low content of metals. A proprietary software programme controls the fuel feeding rate into the primary chamber as well as transportation along the grate. The slag is discharged from the primary chamber at the end of the grate. The discharged slag (3% TOC) is cooled in a water-basin and transported to an outdoor slag container. The container with slag is transported to a suitable dumpsite by truck at regular intervals. After the syn-gas has left the primary chamber, secondary air and re-circulated flue gas is added at several additional points, in order to achieve the right temperature trajectory and final high temperature oxidation.

Heat Recovery Steam Generator (HRSG) and the Energy Utilisation System

A Heat Recovery Steam Generator (HRSG) that recovers the energy from the flue gas is connected downstream of the thermal conversion unit. The HRSG is a combined smoke-tube-and water-tube-boiler equipped with an economiser. The HRSG is operated to control the outlet flue gas temperature. The flue gas boiler is equipped with a feed-water tank, feed-water pumps and facilities for cleaning (shot cleaning) of the heat transfer surfaces during operation.

A standard Energos plant is delivered with standardised boilers. Energos offer two standardised boilers; one for saturated steam (16 bara, saturated) and one for superheated steam (22 bara, 380 degrees centigrade). Boilers with other steam parameters are delivered upon request to meet the customer's requirements. The energy utilisation system is plant specific. It is not included in a standard turnkey contract and will be adjusted to satisfy the requirements of the energy customer.

Flue Gas Cleaning System

The flue gas enters the flue gas cleaning system downstream of the flue gas boiler. The plant is equipped with a dry flue gas cleaning system. The flue gas cleaning system is equipped with a bag-house filter, a storage silo for lime, a storage unit for active carbon and a filter dust silo. Lime and active carbon are injected at the inlet of the bag house filter. Lime, active carbon and fly ash in the flue gas build up a filter cake on the filter bags. The lime absorbs acid components in the flue gas, while active carbon absorbs dioxin, TOC and heavy metals. Spent filter-cake is released from the filter bags by use of pressure pulses and transported to the filter dust silo. The filter dust is transported to designated depositories at regular intervals. The flue gas fan is located downstream from the bag house filter. The flue gas fan maintains the required draft in the thermal conversion unit and discharges flue gas to the atmosphere via the flue gas stack. The re-circulated flue gas fan that re-circulates a portion of the flue gas to the thermal conversion unit is located downstream the flue gas fan.

Control and Monitoring System.

All Energos plants are equipped with a separate proprietary control-and-monitoring-system. The system performs automatic control of the process during normal operating conditions and gives the opportunity to monitor the different process sections through the man-machine interface. All information is available for the operator via the screen. The system is designed for remote control and monitoring of the plant. Safety and security is paramount in all aspects of the design. Logging of process parameters, including emissions monitoring parameters, is controlled in a separate data logging system. Safety is taken care of in a separate and independent emergency shutdown system. The emissions to air such as dust, CO, HCl, Hg, TOC, SO_2, NO_x, O_2, H_2O and CO_2 are continuously being monitored and displayed.

MBT Generic Process

Mechanical Biological Treatment (or whole waste composting) is a generic term for an integration of several process (Enviros, 2004). The purposes of MBT are to recover materials, for instance as refuse derived fuel for thermal treatment, to stabilise and reduce the volume of the organic fraction of the residual waste sent to landfill, or to produce a compost digestate. A variety of MBT systems are available - most include a shredding and screening stage, followed by drying and or composting, anerobic digestion and landfill, with subsequent screening. Plant vary in size and process configuration.

Generally, only mixed unsorted waste enters the plant (dry recyclables may, or may not have been removed at the kerbside). There are no restrictions in terms of moisture content. The process may involve bag splitting, separation of metals by magnetic and eddy current separators for ferrous and non-ferrous metals respectively, air separation for segregation of materials suitable for further material recovery, sieving and homogenisation of organic materials for biological treatment. The output of the biological treatment will be a stabilised residue which, after possible further screening, may be used as landfill cover, soil conditioning applications, or RDF.

The data presented are from German research and are divided into three generic processes; to MBT aerobic, MBT anaerobic digestion, MBT aerobic dry stabilisation.

MBT aerobic

The first process step is a mechanical stage, with shredding screening and separation. The waste is shredded and put through a screen (80 - 100 mm). Metals will be separated for recycling from both fractions. The coarse fraction (screen overflow) has got a high caloric value and will be used as RDF (further processing steps might be required dependent on the requirements of the RDF utilisation plant). The fines fraction, with a high content of biodegradable matter, is is send to the biological stage. In this case it is a composting step, where the organic matter of the waste is degraded and stabilised in order to minimise the environmental burdens of the this waste if landfilled. All exhaust air gases are captured and cleaned using a combination of acidious scrubber and biofilter. Typically the energy used for mechanical treatment ranges 30 - 60 %, for biological treatment - aerob 40 - 70 %. The exhaust air purification system is typically 2 - 25 % of biolog. treatment. Wallmann & Fricke 2002

MBT anaerobic digestion

The mechanical part of this model is equivalent to MBT aerobic. In the biological stage the fines material is send to a anaerobic treatment unit first to produce biogas for energy recovery. The digestate are dewatered and sent to a composting phase for at least one week to drive off anaerobic gases especially ammonia and methane and moisture. This also ensures a reduction of odour of the material. It might furthermore be necessary to achieve a higher degree of stabilisation (if required or desired). The biogas is utilised in a CHP and all off gases are captured and cleaned.

MBT aerobic dry stabilisation

The first step of the process is a mechanical stage with crushing and removing of ferrous metals. No other separation takes place at the front-end mechanical preparation. All material is then dried biologically using heat produced from composting. The waste is dried to a moisture content of less than 15 % to ease efficient mechanical separation. A combination of various screens, shredders, air classifier and density separation are used to separate the RDF from the waste. Dependent on the degree of mechanical preparation the residues might be suitable for recycling or landfilling in an inert landfill.

Air emissions are calculated for an air purification system efficiency varying between 23 and 90% by individual species.

Number of employees are for a 100k plant. It is assumed the mechanical pre-treatment for biological processes requires 2 persons and the metals pre-treatment requires 1 person

For biological processes, the composition of the residual low calorific fraction is calculated for a treatment of a typical UK residual household waste, an analysis for Coarse RDF and an assumed degradation rate for the carbon in the paper and card of 50% and the organic fraction 90%. For biodrying, the final composition of the stabilised waste requires 97.36% of moisture to be removed in the process.

Publication References

Various references from Germany as documented in accompanying assumptions spreadsheet.

The Royal Society (2004), Royal Society's peer review of DEFRA's report on the environmental and health effects of waste management. March 2004. Royal Society, London.
Enviros (2004) Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes. Enviros, University of Birmingham, Defra.

Mechanical-biological-treatment-A guide for decision-makers: Processes, Policies and Markets. Juniper consultancy services Ltd. March 2005. www.sitaenvtrust.org.uk.

Incinerator Medium Scale Rotary Kiln (Combined Heat and Power)

The Rotary Kiln facility burns Municipal Solid Waste to recover energy. The installation includes the site and the entire incineration plant including the incineration line, waste reception, storage, waste-fuel and air supply systems, boiler, facilities for the treatment of exhaust gases, on-site facilities for handling and storage of residues and waste water, stack, systems for controlling incineration operations and the recording and monitoring devices.

The plant has a design capacity of 7 tonnes per hour, which equates to 56,000 tonnes per annum including an allowance for plant shutdown. There is one waste incineration stream. The heat produced is used to generate electricity for export to the national grid and hot water for export to the adjacent chemical plant. The process generates approximately 3MW of electricity. The site currently exports hot water for use in an adjacent industrial process.

Waste is delivered to the plant in covered vehicles. These are weighed before proceeding to the tipping hall. This is a fully enclosed building, maintained under slight negative pressure to ensure that no odours, dust or litter can escape the building. The vehicles tip into a waste storage pit from where a 1.5 m3 grab transfers waste to the feed hopper of the combustion plant. The grab is also used to homogenise the waste and to identify and remove any large bulky items, whether combustible (e.g. sofas) or non-combustible (e.g. bicycles). The combustor is a conical oscillating kiln. As the waste enters the incinerator it passes through a drying zone, a combustion zone and a burnout zone. Primary combustion air is extracted from within the tipping hall and fed in below the waste to promote good combustion. Secondary combustion air is injected above the waste where it provides for good mixing and combustion control. NOx reduction is by SNCR using urea, which is injected into the combustion chamber to react with the oxides of nitrogen, chemically reducing them to nitrogen and water. Auxiliary low NOx gas burners are fitted for start-up and to ensure that a temperature above 8500C for 2 seconds can always be maintained. The oxygen concentration and temperature are carefully controlled to minimise dioxin emissions.

Bottom ash from the end of the kiln is discharged into a water filled quench pit. A conveyor then transports the wet ash through a magnetic separator to remove some of the ferrous metals, which are stored in the ferrous metals bunker. A vibrating grid then removes larger material, which is collected in the oversize bunker. The remaining bottom ash is stored in the bottom ash bunker for reuse or disposal. Bottom ash may also then be moved to the external ash weathering area. Both the bottom ash and ferrous metal bunkers have been designed for a capacity of at least four days. Liquids collected from the bunkers are collected in the industrial water lagoon. Bottom ash and APC residues are sent for disposal or recovery off site by licensed contractors subject to waste licensing legislation.

Ferrous metals are sent for recovery off site by licensed contractors subject to waste licensing legislation. Sampling of the ash is carried out to ensure effective burn out is being achieved by testing for the total organic carbon (TOC) or the loss on ignition (LOI) of the residual ash. All other solid waste residues arising from the operation of the process are removed from site for disposal by suitable contractors.

Hot gases from the waste combustion pass through the boiler plant. The design of the boiler plant, following a computerised fluid dynamics assessment, is such that the flue gas temperature is quickly reduced through the critical temperature range to minimise the risk of dioxin reformation. The steam raised in the boiler plant is fed to a steam turbine, which generates electricity. The steam is condensed and recycled to the boiler. The water make-up is taken from the mains supply and is treated in the demineralisation plant prior to use in the boiler. Hot water is also extracted and its energy content exported by means of a closed loop to the adjacent chemical plant. There is no need for cooling water because the steam is condensed by an air-cooled condenser, which is capable of taking the full load from the boiler to ensure continuous operation of the incinerator. The plant has been designed for zero process water discharge during normal operation. All process waste waters pass to the industrial water lagoon which is designed for, as near as practicable, closed loop recycling of waters used by the process. Excess wastewater is tested and is tankered off site for disposal at an appropriate licensed facility. Water from the industrial water lagoon is used for direct cooling of the bottom ash.

Flue gases pass from the boiler to the gas cleaning equipment. The gas enters a reaction chamber where powdered lime and activated carbon are injected to neutralise acid gases and absorb (primarily) dioxins, furans, dioxin like PCBs, volatile organic compounds (VOCs) and mercury. There is a continuous recirculation of lime and ash in the reaction chamber in order to improve the efficiency of the neutralisation reaction. Bag filters remove the fine ash, excess lime and carbon as the gases pass across the bag fabric. Reverse pulses of compressed air are used to remove the accumulated particulate (“APC residues”) from the bags. The APC residues fall into a collection hopper and are then conveyed to a storage silo. The cleaned gas then discharges to atmosphere via one 55-metre stack.

Incinerator Large Scale Moving Grate with Electricity Generation & District Heating

The Municipal Waste Incinerator (MWI) at Coventry and Solihull Waste disposal Company Limited (CSWDC), Bar Road, Coventry, has been operational since 1975. It currently operates at approximately 225,000 tones throughput per annum. It consists of three individual incineration streams, known as Units 1, 2 and 3. Each stream has a maximum throughput of 12 tonnes per hour, depending on the calorific value of the waste. The plant processes predominantly municipal waste.

The waste consists of domestic municipal waste, collected and delivered to the site on behalf of Coventry City Council and Solihull Metropolitan Borough Council, and other Councils’ waste, commercial and industrial waste from private traders (mixed municipal waste, MMW), and small quantities of special waste.

Refuse and trade vehicles tip waste directly into one of ten fully enclosed tipping positions in the waste bunker, located within an enclosed reception hall. This hall is ventilated by drawing primary combustion air from above the bunker through the tipping hall. Odour suppression systems, or ‘deodorant’ sprays, are located above the waste bunker, and are utilised when necessary.
Two overhead cranes, mounted on rails, are used to deploy grabs, which redistribute waste within the bunker, if necessary remove oversize waste or inappropriate items (e.g. wheelie bins) and transfer waste from the bunker to the feed hoppers of the incinerator units. The cranes are operated from a control room on the south face of the bunker. Operation is assisted by CCTV viewing the furnace feed chutes, refuse bunker and vehicle manoeuvring apron. The grabs are equipped with load-cells, which help to indicate the rate of charging of each incineration stream. The cranes are operated from stations within the control room.

The feed hoppers are equipped with foam fire-fighting systems. These can suppress hopper fires for a limited period.

The three incineration units are labelled 1, 2 and 3. All three units use a Martin reverse action grate, and each furnace is water-walled. All units are fitted with the Ecotube air system. Waste is discharged from the feed hopper onto the furnace feed table using a feed ram, which is adjustable for both push speed and stroke length. This is an operator-controlled adjustment, to account for the observed waste properties. Operators are trained to optimise combustion conditions depending on the homogeneity of the waste feed (which is itself maximised by careful mixing and removal of bulky or inappropriate items in the waste hall).

Primary air is fed to the underneath of the grates in 5 zones down the grate, and 2 across. The primary air circuit was also historically used for the transportation of riddlings to the ash quench hopper and collection pit. The Improvement Programme details planned upgrading to this system, allowing for improved combustion control. Secondary air, which is 100% flue gas recirculation (FGR), is introduced via the secondary air manifolds.

Each furnace is fitted with two Stordy Fire-Mix auxiliary burners, each on dual fuel. These were originally rated at 7.5MW each on gas-oil, assuming 8,750Nm3/hr combustion air (at 20% excess air). These are capable of pre-heating the incinerator units to the required temperature (8500C) prior to waste feed introduction, preventing waste combustion at temperatures below this. Thereafter waste feed is used for maintaining this temperature. An interlock and software upgrade will automate this improvement.

Energy is recovered from flue gases leaving the furnaces using a water-tube boiler and finned tube economiser (which cools hot gases to 1400C. This is achieved by controlling the feed water inlet temperature to the economiser by balancing the temperature of the feed water input with re-circulated water from the boiler drum to maintain a 1300C economiser inlet temperature). The metal interface between flue gas and cooling water is maintained at less than 1700C, to prevent de novo dioxin formation (expected at 4500C down to approximately 2000C, with a tailing off probability below this temperature).

This system allows gases to be cooled sufficiently to enable the use of bag filtration plant for particulate removal. Prior to the baghouse, flue gases pass from the economiser to a Venturi scrubber, where injection of dry slaked lime and lignite takes place. This removes acid gases, VOCs and dioxins and furans and heavy metals respectively (dry scrubbing). Subsequent fabric filtration in the baghouse removes particulates and conjoined dioxins and furans and heavy metals. The dry scrubber and baghouse constitute the flue gas treatment (FGT) plant.

Reagents and fly ash are recirculated within the FGT system, to allow for minimisation of reagent use, and to ensure the maintenance of the active filtration cake on the filter medium surface. Reagents and ash are periodically removed from the system for disposal, and reagents are replaced accordingly. Typically pressure drop indicators alarm at 200 mmHg, which is a level 50mmHg below the maximum desirable pressure differential. The bag filter is cleaned using reverse air jet pulsing. Newly cleaned and fresh bags are coated with lime prior to operational use, to ensure an active cake on the fabric is filtering incident flue gas.

The Continuous Emissions Monitoring System (CEMS) is located between the outlet of the bag filter and the inlet side of each induced draft (ID) fan of each incinerator unit. This currently consists of an extractive sampling system, connected to a multi-gas analyser based on infra red (IR) absorption, with FID being used for VOC monitoring on unit 1.

Bottom ash is routed from the ash quench hopper to the ash pit on a common conveyor via a magnetic overband separator, which removes ferrous materials (namely cans), which are collected in a 300m3 capacity sub-surface pit for recycling. Bottom ash is collected from the clinker in a separate but adjacent 300m3 capacity sub surface pit. It is sampled regularly for total organic carbon (TOC), the maximum limit for this being 3%, or 5% loss upon ignition (LOI), and removed from site for re-use as landfill capping material.

Fly ash from the FGT plant together with the spent reagents are removed from the enclosed dry scrubbing system and stored in three 55 tonne capacity silos one dedicated to each incinerator unit. It is then removed from site and is currently re-used as a chemical waste neutralisation agent. This residue is sampled regularly for various parameters including TOC by LOI.

Energy recovered from the cooling system is routed to two steam turbine generators, sized at 12.9MWe (G1) and 4.8MWe (G2). G1 is fitted with a water-cooled condenser and evaporative cooling tower, and has more efficient cooling than G2, which is equipped with an air-cooled condenser. This difference in efficiencies is due to the lower condenser pressure in G1 High-pressure hot water (HPHW) is generated from steam and fed to Peugeot, Stoke facility in the heating season. Steam is also used for office heating, and to provide heat to the hot-well. Steam also keeps the HP condensers (used for emergency heat dump in the event of plant failure) warm at all times.

Coventry NOx Abatement

The abatement system at Coventry EfW plant consists of an Ecotube System, an advanced combustion improvement and CO and NOx reduction technology solution developed and patented by the Swedish environmental equipment and research firm, Ecomb AB. The System utilises a hybrid of two proven technologies: over-fired air and SNCR and consists of retractable, self cleaning lance tubes penetrating the furnace, a fan system, a water-cooling system, a reliability data management system, and an electrical power and control system. A “reagent” injection system and/or small-scale post combustion catalytic reduction system may be included for additional emissions reductions, although this hasn’t been used at the Coventry site. The system delivers air at high pressure to the upper furnace chamber, via the lance tube injection system, changing the airflow from a laminar flow to a turbulent flow and increasing residence time for the furnace air/fuel mixture- improving combustion process efficiency.

At the Coventry plant the Ecotube System will reduce aerial emissions of NOx from 350 mg/m-3 to 200 mg/m-3 (x1.75 reduction) and will also reduce carbon monoxide from 50-60 mg/m-3 to 30 mg/m-3 (~x2 reduction). Furthermore, due to the air introduced into the furnace, which creates a blanket of air in the upper regions of the furnace, there is an increase in combustion within the furnace, and an expected reduction in fly ash from the facility. However, this fly ash reduction has to be offset against the subsequent increase in bottom ash. Due to the novelty of the system at the Coventry plant the latter points haven’t been fully quantified to date and are not reflected in the current data set.

The key drawback from the application of the Ecotube System is the increased energy consumption, due to electrical energy required to pump air into the furnace, however this has yet to be quantified at the Coventry EfW plant.

Mechanical Biological Treatment with ISKA Percolation AD and SCT Composting (Global Renewables)

The UR-3R Facility receives and processes municipal solid waste (MSW), which includes collected household, commercial and green waste. The facility integrates unit process technologies in: waste stream separation; ISKA® Percolation; SCT Composting and refining; and, energy recovery. Each unit process is proven and currently in commercial operation around the world. The Eastern Creek UR-3R Facility in Sydney is the first to fully integrate these leading technologies to provide a total solution for waste management. There are 11 stages in the process:

The Receival Area

employs fast acting doors and air curtains as a means of reducing the potential for fugitive emissions. Depending on local requirements the receival systems are either designed for flow through of traffic, where the doors are open only long enough for trucks to pass through, with airlocks that the trucks can reverse into, or traffic light controlled. Whilst the buildings are under negative pressure, and the doors are open only for short durations, as an additional precaution against the escape of odour or litter, air curtains are installed on all doors with vehicular traffic, operating whenever the doors are open. The waste is then inspected to ensure compliance with material classified as catering waste that the plant is licensed to treat for ABPR purposes. Wheels of trucks are washed before they leave site to comply with ABPR requirements.

The Pre-sort Station

consists of a feed system (comprising feed hopper and belt feeder) which regulates the flow of material, and a “sorting” conveyor. Waste is fed by front-end loader into the pre-sort feeder and bulky materials are removed. Both the feeder and the sorting conveyor are variable speed to allow control of feed rate in order that a shallow bed depth of material is achieved on the sorting belt, to allow hand-sorting personnel to visually identify and remove hazardous and incompatible material. The Separation and Sorting stages start with a ‘Bag Opener’ which mechanically opens plastic bags, in order that the contents may be discharged in subsequent processing stages.

A Scalping Trommel undertakes the first stage of separation and separates the material into two size fractionated streams, oversize and undersize.

The Organic Removal Trommel treats the undersize fraction from the scalping trommel and fractionates the material into two sizes. The screens are enclosed and have an air extraction point for connection to the plant extraction system.

Windsifters are located at selected conveyor transfers where the falling material stream is opposed by an air stream. An air curtain, generated by a combination of the windsifter blower and suction fans, removes the suspended light materials such as plastic film and dry loose paper from the falling waste stream. A sorting cabin is utilised for manual sorting of the recyclable materials from the material discharged as oversize from the Scalping Trommel and Organic Recovery Trommel. The sorting belt operates at slow speed and is fitted with a variable speed drive to allow selection of the most appropriate operating speed and hence bed depth.

Ferrous metals are separated from the waste by overband electromagnets and are often contaminated by adhering organic matter. In addition, many of the steel cans retain part of their original contents, whilst others will be contained inside plastic bags (which were too small to be opened in the bag opener at the head of the circuit). The metals cleaning circuit opens these bags and removes the plastic, residual contents and as many other non-metallic contaminants as possible, to give a relatively clean product suitable for sale.

The system is a dry process and consists of a trommel screen followed by electromagnets to recover the metal. The trommels have sufficient residence time so that the tumbling action of the sharp metal objects will degrade the plastic bags and dislodge any adhering organic material. Whilst the metals are retained within the trommel, the liberated fine organic material is discharged through the screen to minimise the potential for recontamination of the metals. Electro-magnets are utilised on the trommel undersize and oversize streams to collect the ferrous metals, whilst rejecting the organic matter and other non-magnetic contaminants. Non-ferrous metals are separated from the waste by the use of eddy current non-ferrous separators. Compaction presses and transport containers are installed for waste materials of low density, in order to allow trucks to be loaded to their rated capacity.

The unrecovered materials from sorting are then fed to Residuals Shredders which consist of slow-running, high torque, single or dual shaft roll crushers. The Organic Scavenging Trommel treats the residual oversize from the scalping trommel after recyclables have been recovered and following shredding. The trommel splits material between two size fractions with the fines going to composting and the oversize going to landfill. A Baling Press is utilised for the compaction of the separated recyclable materials. The press includes buffer storage for the incoming material and for the bales produced. The unit incorporates a wire-tying system to ensure the integrity of the completed bales during transport. The produced bales are removed from the load-out table by forklift for transport and stacking in the storage area.

The undersize from the trommel screen is fed into one end of an ISKA® Percolator where it is irrigated and aerated. It is also intermittently agitated to move it through the Percolator over a two-day period. The temperature within the Percolators is maintained by preheating the irrigation water. Bacterial hydrolysis reactions assist with washing out soluble organics and odour causing species, so that the immediate odour production potential of the material is greatly reduced by the time it leaves the Percolator. Excess water is drained from the bottom of the Percolators through a grate system carrying with it some of the sand and fine glass. The solids and entrained liquid are fed to a filter press after Percolation, to recover semi-dry solids that can be screened to further upgrade the organics. The liquid from the filter press along with the water recovered directly from the Percolators provide the feed to liquid phase anaerobic digestion.

The Anaerobic Digestion of Liquid Percolate Stream comprises of three stages:

- Anaerobic digestion of volatile matter in the liquid stream from the ISKA® Percolators;
- Recovery and treatment of biogas from the Digester to produce electricity; and
- Recovery and utilisation of treated water from the Digester.

The screened percolate is pumped from the digester feed tank to the digesters. Digester feed is metered into each digester on a frequent basis. Each digester is equipped with a dedicated circulating pump to constantly recirculate the digester contents through an individual digester heat exchanger. During normal operation, the percolation water is constantly mixed into the digester feed stream prior to passing through the heat exchangers, and the digester feed liquid is heated before re-distribution back to the digester. The proportions of circulation fluid and the added percolate can be adjusted or changed in response to the material composition via a variable speed controller. A separate pump is also installed on each digester to transfer the digester liquor back to the percolators. Using the circulating water suction manifold, the transfer pump on each digester will pump liquor back to the percolator distribution manifolds. This pump is also used to pump digester outlet liquor into the water denitrifiers. Prior to distribution to the percolator manifold, digested liquor will be heated. Excess water from digestion is used for compost moisture maintenance.

Each digester vessel includes an inert biological support for retention of biomass. The biomass support or filter bed is filled with polypropylene packing VPP-VSD. Biomass adheres to the surface of the packing, or forms bridging flocs providing a relatively high biological loading in minimal volume. The fixed nature of the biomass allows greater variations in feed capacity when compared with alternative digester configurations, by virtue of a stabilised biomass population. The digesting liquor is circulated through the media and organic degradation occurs with the biomass supported on the media. The COD is converted to biogas that is collected at the apex of the digester and passed on to the biogas processing section.

The digester is also equipped with a bottom rake and screw conveyor for desludging desanding the digester floor. The sludge discharge takes place as required and is manually operated (normally once a week for a maximum of 60 minutes). The sludge is pumped into a tanker for disposal onto the compost or to landfill. The discharge of the sludge is monitored by an operator and is terminated manually when the solids loading is reduced.

Prior to Electricity and Heat Recovery from Gas Engine Combustion of the Biogas, the gas will be scrubbed to H2S levels, at which the biogas can be burnt safely in gas engines with minimal operational problems. The biogas is passed through a dedicated oxidative desulphurisation column before being used as gas engine fuel. The H2S is removed in a single stage vertical counter flow, packed bed, fibreglass scrubber column through which ethylene diamine tetra-acetic acid (EDTA) solution is circulated. The spent solution is pumped through a stand-alone catalytic reactor to enhance absorption efficiency by liquid phase oxidation of pollutants. Desulphurised biogas is stored in an inflatable, double-skinned, membrane storage vessel. A gas flare is provided to allow the biogas to be burnt during emergency shutdowns or maintenance periods. During normal operation of the power general facility, biogas is withdrawn from the storage vessel and compressed in individual blowers to supply the packaged gas-fired process water heater, the bio filter air heater and the generator engines. Two biogas engines with integral transformers are installed to generate over two thirds of the electricity requirements of the MBT facilities. Waste heat is also recovered from the engines for process heating to increase the energy utilisation efficiency. The biogas engines are standard spark-induced diesel engine generator sets adapted to biogas operation.

The First ABPR Barrier Treatment of Solids From Percolation is carried out with a conveyor which transfers the solids from the filter press after percolation to the first stage of the SCT Biomax-G® automated composting system. The purpose of the first stage is to satisfy the requirements of the first barrier in a composting process to meet SVS ABPR requirements. During the week that the material spends in the first section of the SCT process the target criterion is to achieve a temperature of at least 60°C for two days. In practice once this temperature is achieved it is maintained for the rest of the time as temperature control is achieved by varying the aeration rate. While in the first stage of the SCT process the material is turned twice a day by a proprietary two auger system that mixes and transports the material across the bay in 14 passes over one week.

At the end of the stage the augers lift the material over the wall between the first and second stages to ensure mixing of the material between stages to comply with SVS ABPR requirements. This serves as the first barrier in a composting process to comply with SVS ABPR requirements.

During the Second ABPR Barrier Treatment of Solids From Percolation the target criterion is once again to achieve a temperature of at least 60°C for two days. In practice once this temperature is achieved it is maintained for the rest of the time as temperature control is achieved by varying the aeration rate. While in the second stage of the SCT process the material is turned twice a day by a proprietary two auger system that mixes and transports the material across the bay in 14 passes over one week. At the end of the stage the augers lift the material onto a conveyor belt that transports it to the third composting maturation stage. Once the material passes out of the second barrier it has completed the pasteurisation requirements for ABPR compliant composting.

At the end of the second barrier the material is sampled for Salmonella and other parameters before moving on to the composting maturation stage. (In the event of Salmonella being detected in any of the batches of material coming out of the second barrier, that batch of material and the adjacent batched before and after it will have to be removed from the composting maturation hall for reprocessing or landfill).

The intensive Extended Composting maturation process converts the crude compost from the two barrier pasteurisation process into a mature compost that exerts negligible phytoxicity. Moisture is added as required during the composting maturation process to control the moisture content to optimise biological activity during the process and leave it at the optimum level for refining at the end of the process. At the end of this stage, the augers lift the material onto a conveyor belt that transports it to the refining screening section before it moves to on site storage section of the plant. OGM Refining is where the material is screened and treated by densiometric separation to produce a quality compost product, with low physical contamination. The refined OGM compost can spend up to four weeks in OGM Storage on-site in stockpiles (during which further maturation can occur as there is provision to turn the material weekly).

Composting In Vessel Vertical Flow (TEG)

TEG Silo-Cage Composting System

The TEG Silo Cage (TSC) composting system provides for the rapid high temperature composting of organic wastes in a continuous flow plant. The insulated silos, each with a capacity of 32 m3, are suspended above a concrete base in a large steel structure. A single silo-cage bank consists of between 8 and 28 silos, depending on the annual input or output requirements. For larger operations, multiple silo-cage banks are run in parallel. A silo-cage bank has a front-end mixer and loading system. An unloading system and side conveyor remove the composted material from the silo-cage. The back end of the silo-cage can be equipped with a screen and bagging line or the composted material can be collected and taken to a maturation barn to fully mature.

Feedstock Delivery

The organic waste is mixed with selected amendments in a predetermined ratio to give a feedstock that is ideal for composting. The amendment may need to be nitrogen-rich (e.g. manure) or carbon-rich (e.g. wood shavings) depending on the chemical composition of the waste. Amendment selection is crucial to ensuring that the feedstock material is bulky with sufficient airspace to support the aerobic microbial activity in all parts of the organic material. Each silo receives an amount appropriate to operation's requirements – typically about 3 m3 per silo per day. The feedstock material is 'sprinkled' on top of the previous day's load. The material drops no more than about half a metre into the silo and so its open structure is maintained.

Composting Silos

The feedstock material sits on the hotter lower layers. It quickly warms, accelerating microbial activity and is rapidly colonised by micro-organisms from the already composting organic material below. As the silo is unloaded, the composting organic material gradually and evenly descends the silo and passes through a series of temperature bands. To monitor the progress of the process, the temperature in each silo is continuously measured by temperature probes and recorded on a pc-based data logger. The hottest layers in the silo tend to be between one and two metres from the top. As well as air in the bulky organic material, the vertical temperature gradient in the organic material creates a chimney effect and air is drawn up into the material from the open base of the silo. There is therefore no need for costly forced aeration, turning or agitation of the organic material. The feedstock characteristics and the end-product specifications determine the residence time in the silos, which can vary between 10 and 21 days.

Unloading Composting Silos

An unloading mechanism traverses beneath the silo-cage and extracts the bottom layer of composted organic material from the silos. The material is still warm (about 45°C) and side conveyors carry it to the end collection points. From here it may be dispatched straight to land or it may go to storage for maturation and further stabilisation in static piles before bagging.

Autoclaving Large Scale Processing MSW

The Fibrecycle process is based on autoclave technology to process the MSW followed by a sorting and separation stage. Unsorted MSW is received and initially unloaded into a waste reception area. From the reception area waste is then transferred by bulk loader to a feed hopper and then via a series of conveyors to a temporary storage vessel. The temporary storage vessel is used to supply the waste directly to the steam treatment process, or autoclave. Each autoclave is supported by a hinged platform to allow the feed and discharge end to be raised for loading feedstock and then lowered into the 'cooking' position. An individual autoclave is capable of treating 20 tonnes of waste per batch which is 'cooked' using steam for approximately 45 minutes. During the process, steam (approximately 5 barg and 160°C) treats the waste and breaks it down. The autoclave is designed to rotate at 12rpm and has an internal helix structure to promote mixing of the waste.

When the treatment cycle is complete, the contents of the autoclave are discharged (this takes approximately 10 minutes) via a series of conveyors to the post-treatment separation system. Here plastics, metals, glass and other inert materials are removed from the fibre produced from the organic fraction of the waste. To avoid the risk of contamination of treated material with untreated waste, separate conveyor systems are used for discharge and feed.

The output tonnage is determined by the characteristics of the unprocessed waste and the exact temperature and pressure profile that the waste is exposed to. The full effects of autoclaving the waste are still being investigated though it is known that a small proportion of the total weight of the input waste will be driven off as volatiles and water vapour within the autoclave process. In addition it is expected that the organic materials will undergo an increase in the moisture content. The balance of these two effects is not fully known and a complete understanding of the mass gain loss has still to be gained.

In addition to the simple evaporative loss and moisture gain the autoclave cycle will expose the waste to significant physical and chemical change. Primary effects will be a change in the bulk density and particle size of the waste. Furthermore, it is anticipated that there will also be significant secondary effects, mainly of a chemical nature associated with the fibrous organic fraction. The organic fraction is predominantly made up of lignocellulosic material and the temperature and pressure cycling will significantly change the chemical state of this material. Here the chemical bonds within the lignocellulosic material will be hydrolysed and a significant proportion of the cellulose will become chemically altered. Lignin, another key constituent of organic matter is unlikely to be altered by the steam treatment.

Primary benefits of the process are reported to be increased recyclate quality as the MSW has been ‘sterilised’ during the autoclave process and the ability to separate and recycle fibrous organic matter. End markets for the fibre are the manufacture of fibre and insulating board, absorbents and potentially fuel for power generation.

Estech was happy with the majority of the information required. They had a few minor queries relating to some of the terms used in the spreadsheets however all were simple relating to terminology used in the templates. Estech requested that they be updated with the progress of the WRATE project and remain happy to answer any queries should they arise.

Assumption Made

Estech have not, at present, developed a full scale commercial plant though they have developed a small scale commercial plant and a mobile plant for demonstration purposes. Without full scale operating experience the data supplied cannot be treated as fully operational data and is a therefore a mixture of calculated and estimated figures. This is reflected in the quality of the data received in the template. Due to the nature of the process certain components such as the boiler and recyclate separation equipment are standard commercially available items and performance specification data has been taken from the suppliers of this equipment by Estech. This type of data can be treated with a high level of confidence providing it is used within the manufacturers specification.

Appendix 4 – Glossary of terms

Agricultural Waste	Waste produced at agricultural premises as a result of an agricultural activity.
Anaerobic Digestion	A **resource recovery** process where **biodegradable waste** is treated by means of bacterial action in the absence of oxygen to produce **digestate** and **biogas**.
Animal By-products	The EU Animal By-Products Regulation (1774/2002) states that animal by-products are the entire bodies or parts of animals, or products of animal origin, not intended for human consumption.
Autoclave	A pressurised steam **treatment** process.
Best Practicable Environmental Option	The **BPEO** procedure establishes the waste management option, or mix of options, that provides the most benefits or the least damage to the environment as a whole, at acceptable cost, in the long-term as well as in the short-term.
Bioaerosols	Airborne micro-organisms.
Biological Mechanical Treatment	A generic term for a **resource recovery** process which integrates several processes commonly found in other waste management facilities such as **MRF**s, and **composting** facilities. **BMT/MBT** facilities can incorporate a number of different processes in a variety of combinations and can be built for a range of purposes. A common aspect of all **BMT/MBT** plant used for **MSW** management is to sort mixed waste into different fractions using mechanical means and to **recover** materials for **recycling**.
Biodegradable Waste	Waste that is capable of being broken down by plants (including fungi) and animals (including worms and micro-organisms).
Biofilter	Biofilters use moist organic materials (including compost, soil, peat, and chipped wood/wood bark) to trap the compounds in exhaust gases that then become a food source for the ecosystem living on the organic materials.
Biogas	Gas produced by **biodegradable waste** as it breaks down by biological and chemical reaction. The gas can be used as a fuel and/or in a **Combined Heat and Power** system.
Biological Treatment	Any biological process that changes the properties of waste (e.g. **anaerobic digestion**, **composting**). Biological treatment includes landspreading activities that are licensed.
Bring Recycling	**Recycling** schemes where the public bring material for recycling to centralised collection points, (e.g. bottle and can banks) at **civic amenity sites**, supermarket car parks and similar locations.
Civic Amenity Site	A generic term for a facility provided by the local authority that receives **household waste** delivered by the public. Wastes handled include bulky items

	such as furniture, white goods, garden waste and general household wastes as well as recyclables. Some **CA** sites have facilities to receive certain **hazardous** household wastes, e.g. lead acid batteries and oil. Also called **Household Waste Recycling Centres**.
Clinical Waste	Healthcare waste such as blood, tissue, needles, soiled dressings, drugs etc. that is infectious or could cause harm in some other way. It may be produced from hospitals, medical, nursing, dental, veterinary, pharmaceutical or similar practices or from home treatment, e.g. diabetes.
Combined Heat and Power	The use of a power station to simultaneously generate both heat and electricity. The steam or hot water generated in the process is utilized either in industrial processes or in community heating.
Commercial Waste	Waste arising from premises used wholly or mainly for trade, business, sport, recreation or entertainment, excluding **municipal waste** and **industrial waste**.
Composting	A **resource recovery** process where **biodegradable waste** (such as garden and kitchen waste) is converted, in the presence of oxygen from the air, into a stable granular material which, applied to land, improves soil structure and enriches the nutrient content.
Construction and Demolition Waste	Waste arising from the construction, repair, maintenance and demolition of buildings and structures, including roads. It consists mostly of brick, concrete, hardcore, subsoil and topsoil, but it can also contain quantities of timber, metal, plastics and (occasionally) **hazardous waste** materials.
Controlled Waste	The UK term for wastes controlled under the Waste Framework Directive. Controlled waste includes **household waste**, **commercial waste**, **industrial waste** and **agricultural waste**.
Development Plan	A **land-use planning** document required by Act of Parliament to set the polices and framework for making decisions on planning applications
Development Plan	A **land-use planning** document required by Act of Parliament to set the policies and framework for making decisions on planning applications.
Digestate	The solid and/or liquid residue produced by **Anaerobic Digestion**. Can be used as a fertiliser/compost.
Dioxins	A family of chemicals produced by, among other ways, the burning of PVC plastics at low temperatures (less than 700^{o}C). Some are known to be carcinogenic.
Disposal	According to the **waste hierarchy** the final disposal of waste through **landfill**, **landraise** or **incineration** without **energy recovery** is the least preferred way of managing waste.
Diversion	A term used to refer to avoiding **disposal** of waste in **landfill** and instead diverting it into other waste

	management methods, especially **reuse**, **recycling**, **composting** and **Mechanical Biological Treatment** and **thermal treatment**.
Doorstep Collection	Waste collected from the householder or business doorstep for the purposes of **reuse**, **recycling** and **composting.**
End of Life Vehicles	Scrap cars and other vehicles.
Energy from Waste	A **resource recovery** process where energy in the form of heat and/or power is recovered from burning waste. Energy can be produced from waste through **incineration**, **gasification**, **pyrolysis**, the combustion of **refuse derived fuel**, the combustion of **biogas** produced during **anaerobic digestion**, and the combustion of **landfill** gas.
Environment Agency	The principal environmental regulator in England and Wales. Established in April 1996 to combine the functions of former waste regulation authorities, the National Rivers Authority and Her Majesty's Inspectorate of Pollution. Intended to promote improved waste management and consistency in waste regulation across England and Wales.
Environmental Impact Assessment	A procedure for considering the potential environmental effects of land use change. **EIA** helps to inform decision-making and enables decisions on land use change to be taken with full knowledge of the likely environmental consequences.
Epidemiology	The medical and scientific study of the causes of disease and ill health.
EU Directive	A European Union legal instruction, binding on all Member States but which must be implemented through national legislation within a prescribed time-scale.
Exempt facility	A waste management / **resource recovery** facility registered with, but not licensed by, the **Environment Agency**. Exempt facilities are subject to general rules (e.g. on the types and quantities of wastes received).
Fly tipping	The illegal **disposal** of waste on land.
Gasification	A **resource recovery** process. Gasification can be seen as between **pyrolysis** and **incineration** in that it involves the partial oxidation of a substance. This means that oxygen is added but the amounts are not sufficient to allow the fuel to be completely oxidised and full combustion to occur. The temperatures employed are typically above 750ºC. The main product is a syngas, which contains carbon monoxide, hydrogen and methane. The other main product produced by gasification is a solid residue of non-combustible materials that contains a relatively low level of carbon.
Geographical Information System	A computer system for collecting, managing, analysing and displaying geographically referenced information.
Hazardous Waste	A broad term for a wide range of waste materials that present different levels of risk. Some present a

	serious and immediate threat to the population and the environment, for example those that are toxic, could cause cancer or infectious disease. Others, such as fluorescent tubes or cathode ray tubes in televisions, pose little immediate threat but may cause long-term damage over a period of time.
Household Waste	It includes domestic waste from household collection rounds, waste from services such as street sweepings, bulky waste collection, litter collection, **hazardous** household waste collection and garden waste collection, waste from **civic amenity sites** and wastes separately collected for **recycling** or **composting** through **bring recycling** schemes and **kerbside recycling** schemes. Household waste is a sub-group of **municipal solid waste**.
Household Waste Recycling Centre	A term for a facility provided by the local authority that receives **household waste** delivered by the public. Wastes handled include bulky items such as furniture and, white goods, garden waste and general household wastes as well as recyclables. Some **HWRC**s have facilities to receive certain **hazardous** household wastes, e.g. lead acid batteries and oil. Also called **Civic Amenity sites**.
Incineration	The burning of waste at high temperatures in the presence of sufficient quantity of oxygen to fully combust / oxidise the waste. Typically, incineration temperatures are in excess of 850ºC. The waste is converted into carbon dioxide and water. Any non-combustible materials (e.g. metals, glass) remain as a solid, known as bottom ash, which contains a small amount of residual carbon. Incineration is used either to reduce the volume of the waste (in the case of **MSW**) or its toxicity (e.g. for organic solvents and **PCB**s). Most modern incinerators are a **resource recovery** process where energy in the form of heat and/or power is recovered from burning waste – see **Energy from Waste**.
Industrial Waste	Waste from any factory or industrial process (excluding mines and quarries).
Inert Waste	Chemically inert, non-combustible, non-**biodegradable waste** and non-polluting waste defined in the **EU Directive** on the **Landfill** of Waste.
Integrated Pollution Prevention & Control	The European Integrated Pollution Prevention and Control applies an integrated environmental approach to the regulation of certain activities. Emissions to air, water and land, plus a range of other environmental effects, must be considered together. Regulators must set permit conditions so as to achieve a high level of protection for the environment as a whole. These conditions are based on the use of the 'best available techniques' that balances the costs to the operator against the benefits to the environment. **IPPC** aims to prevent

	emissions and waste production and where that is not practicable, reduce them to acceptable levels.
In-vessel Composting	A term used to cover a wide range of **composting** systems all of which enclose the activity and therefore allow a higher degree of control over the temperature, oxygen and moisture than is possible with **windrow composting**.
Kerbside Recycling	Collection of recyclable or compostable wastes usually from the pavement (hence the name), outside premises, including collections from commercial or industrial premises as well as from households.
Landfill	Licensed facilities where waste is permanently deposited for **disposal** into land. According to the **waste hierarchy** the final **disposal** of waste through landfill is the least preferred way of managing waste.
Landfill Allowance Scheme	The Landfill Allowances Scheme (Wales) Regulations were made by the National Assembly for Wales on 8 June 2004. They were made under powers conferred by the Waste and Emissions Trading Act 2003. This Act implements in the UK Article 5 of the **EU Directive** on the **landfill** of waste (1999/31/EC). The purpose of the LAS is to require waste **disposal** authorities in Wales to limit the quantities of **BMW** that they landfill in accordance with an allowance allocated to them by the **WAG** in accordance with Section 4 of the Act.
Landfill Tax	A tax that applies to **inert** and non-inert waste, **disposed** at a **licensed landfill** site. The aim of the tax is to send a tough signal to waste managers to switch to less environmentally damaging alternatives to **disposal**.
Landfill Tax Credit Scheme	A Way of reducing tax liability whilst benefiting ‘good causes’. If landfill operators give 20% of their tax liability to environmental projects the Inland Revenue will refund 90% of that amount to the company.
Landraise	Licensed facilities where waste is permanently deposited for **disposal** on to land. According to the **waste hierarchy** the final **disposal** of waste through landfill is the least preferred way of managing waste.
Land-Use Planning	The development planning system that regulates the development and use of land in the public interest.
Leachate	The liquid run-off carrying polluting chemicals from waste deposited in **landfill / landraise** sites.
Life Cycle Assessment	The systematic identification and evaluation of all the environmental benefits and disbenefits that result, both directly and indirectly, from a product or function throughout its entire life from extraction of raw materials to its eventual **disposal** and assimilation into the environment. LCA helps to place the assessment of the environmental costs

	and benefits of these various options, and the development of appropriate and practical waste management policies, on a sound and objective basis.
Mass Burn Incineration	**Incineration** of the complete **waste stream** without any further sorting, **treatment** or removal of materials for **recycling** and **composting**. Most modern **incinerators** are a **resource recovery** process where energy in the form of heat and/or power is recovered from burning waste – see **Energy from Waste**.
Materials Recovery Facility	A **resource recovery** process of varying scale where materials that can be recycled or composted are separated out of unsorted waste.
Mechanical Biological Treatment	A generic term for a **resource recovery** process which integrates several processes commonly found in other waste management facilities such as **MRF**s, and **composting** facilities. **MBT/BMT** facilities can incorporate a number of different processes in a variety of combinations and can be built for a range of purposes. A common aspect of all **MBT/BMT** plant used for **MSW** management is to sort mixed waste into different fractions using mechanical means and to **recover** materials for **recycling**.
Mechanical Heat Treatment	A term used to describe configurations of mechanical and thermal, including steam, based technologies. The most common system being promoted for the treatment of **MSW** using **MHT** is **autoclave**.
Members Steering Group	The **WAG** has given the responsibility of preparing, monitoring and revising the **RWP** to the South East Wales **Regional Waste Group**. This group is led by a Members Steering Group of councillors from the 11 Local Planning Authorities in the region with a **Regional Waste Technical Group** of officers from local government, the **WAG**, Environment Agency Wales and other government bodies, and representatives from the waste industry and environmental groups.
Municipal Solid Waste	**Household waste** and other wastes collected by a **waste collection authority** or its contractors, such as municipal parks and gardens waste, beach cleansing waste and any **commercial waste** and **industrial waste** for which the collection authority takes responsibility.
Open-gate landfill	A **landfill** run as a commercial operation that receives waste from many waste producers.
PAS 100	A publicly available specification for **compost** materials prepared and published by the British Standards Institution.
Permitted Development	Permission to carry out certain limited forms of development without the need to make a planning application to a **LPA**, as granted under the terms of the Town and Country Planning (General Permitted

	Development) Order.
Pollution Prevention & Control	Pollution Prevention and Control is a regime for controlling pollution from certain industrial activities. Operators must use the best available technique to control pollution from their industrial activities. The aim of the best available techniques is to prevent, and where that is not practicable, to reduce to acceptable levels, pollution to air, land and water from industrial activities while balancing the cost to the operator against benefits to the environment.
Polychlorinated Biphenyls	Highly persistent bioaccumulative pollutants that are immuno suppressive. Their accumulation through the food chain results in them being a serious threat to health, particularly in communities with a large dietary intake of fish.
Primary Resources	Virgin materials that have been extracted from the Earth.
Proximity Principle	Requires that waste should generally be disposed of as near to its place of production as possible.
Pyrolysis	A **resource recovery** process. In contrast to **incineration**, pyrolysis is the thermal degradation of a substance in the absence of oxygen. This process requires an external heat source to maintain the temperature required. Typically, relatively low temperatures of between 300ºC to 800ºC are used during pyrolysis of materials such as **MSW**. The products produced from pyrolysing materials are a solid residue and a synthetic gas (syngas). The solid residue (sometimes described as a char) is a combination of non-combustible materials and carbon. The syngas is a mixture of gases (combustible constituents include carbon monoxide, hydrogen, methane and a broad range of other volatile organic compounds). A proportion of these can be condensed to produce oils, waxes and tars. If required, the condensable fraction can be collected by cooling the syngas, potentially for use as a liquid fuel.
Recovery	The recovery of valuable materials and energy from waste. The **waste hierarchy** states that the recovery of resources is more favourable than their final **disposal**. Reduces the need for **primary resources** – and thus also reduces costs.
Recycling	A **resource recovery** process that involves the reprocessing of wastes, either into the same material (closed-loop) or a different material (open-loop recycling). Reduces the need for **primary resources** – and thus also reduces costs.
Reduction	Reducing the quantity or the hazard of a waste produced from a process. Reduces the need for **primary resources** – and thus also reduces costs.
Refuse Derived Fuel	Fuel, often in pellet form, which is produced form combustible elements of **household waste** and **commercial waste**, and used in industrial boilers to produce **energy from waste**.

Regional Waste Group	The **WAG** has given the responsibility of preparing, monitoring and revising the **RWP** to the South East Wales Regional Waste Group. This group is led by a **Members Steering Group** of councillors from the 11 Local Planning Authorities in the region with a **Regional Waste Technical Group** of officers from local government, the Welsh Assembly Government, Environment Agency Wales and other government bodies, and representatives from the waste industry and environmental groups.
Regional Waste Technical Group	The **WAG** has given the responsibility of preparing, monitoring and revising the **RWP** to the South East Wales **Regional Waste Group**. This group is led by a **Members Steering Group** of councillors from the 11 Local Planning Authorities in the region with a Regional Waste Technical Group of officers from local government, the Welsh Assembly Government, Environment Agency Wales and other government bodies, and representatives from the waste industry and environmental groups.
Residual Waste	Waste remaining to be disposed of after re-use, **recycling**, **composting** and **recovery** of materials and energy.
Resource Recovery	The recovery of valuable materials and energy from waste. The **waste hierarchy** states that the recovery of resources is more favourable than their final **disposal**. Reduces the need for **primary resources** – and thus also reduces costs.
Restricted-User Landfill	Sometimes known as “factory-curtilage **landfill**” sites within ownership of the waste producer or restricted to specific users.
Reuse	Using materials or products again. Reduces the need for **primary resources** – and thus also reduces costs.
Source Separation	The separation of materials suitable for **re-use**, **recycling** and **composting** from waste at the point where it is produced by households and businesses.
Special Waste	Defined by the Environment Protection (Special Waste) Regulations 1996 (as amended). In July 2005 the **Hazardous Waste** (England and Wales) Regulations and the List of Wastes (Wales) Regulations come into force, replacing the Special Waste Regulations.
Stabilised Biowaste	**Biodegradable waste** which is treated so that it is biologically stable and therefore no longer reacts to produce either **leachate** or **landfill** gas.
Stabilised Waste	Waste that has been **treated** so that it is chemically stable.
Strategic Environmental Assessment	A procedure which centres around the production of an ‘Environmental Report’ in which the likely significant effects on the environment of implementing the plan or programme, and reasonable alternatives taking into account the objectives and the geographical scope of the plan or

	programme, are identified, described and evaluated.
Sustainable Waste Management	Using material resources efficiently to cut down on the amount of waste produced. And, where waste is generated, dealing with it in a way that actively contributes to the economic, social and environmental goals of sustainable development. The concepts of the **waste hierarchy** and **resource recovery** are central to sustainable waste management.
Sustainable Waste Management Option	An assessment technique that supplements the technique of **Best Practicable Environmental Option** to ensure that social and economic, as well as environmental, issues are taken into account in the consideration of waste management options.
Thermal Treatment	The **treatment** of waste using elevated temperatures as the primary means to change the chemical, physical, or biological character or composition of the waste. Examples of thermal treatment processes are **gasification**, **incineration**, and **pyrolysis**.
Transfer Station	A waste management facility to which waste is delivered for separation or bulking up before being removed for **resource recovery**, **treatment** or **disposal**.
Treatment	A catch-all term for a very wide range of physical, thermal, chemical or biological processes that change the nature of waste in some way.
Wales Spatial Plan	One of the high-level strategic guidance ‘building blocks’ of the **WAG**. It aims to make sure: that decisions are taken with regard to their impact beyond the immediate sectoral or administrative boundaries; that there is co-ordination of investment and services through understanding the roles of and interactions between places; and that sustainable development is a core value in every WAG activity.
Waste Arisings	The amount of waste generated in a given locality over a given period of time.
Waste Collection Authority	A local authority responsible for the collection of **municipal solid waste** in its area.
Waste Disposal Authority	A local authority responsible for the management of the waste collected and delivered to it by constituent collection authorities. The processing and/or final **disposal** of the waste is usually contracted to the private sector waste management industry.
Waste Electrical & Electronic Equipment	Electrical or electronic equipment that is waste, including all components, subassemblies and consumables that are part of the product at the time of discarding.
Waste Hierarchy	Hierarchical ranking of waste management options based on their relative environmental benefits: **reduction**, **reuse**, recovery (**resource recovery** of materials through **recycling** and **composting** and **energy from waste**) **disposal**.
Waste Management Licence	A waste management / **resource recovery** facility licensed under the Environmental Protection Act.

Waste Management Licensing	The system of permits operated by the **Environment Agency** under the Environmental Protection Act to ensure that activities authorised to **recover** or dispose of waste are carried out in a way which protects the environment and human health.
Waste Stream	A way of classifying waste according to its source and nature.
Windrow Composting	A **resource recovery** process where **composting** of **biodegradable waste** is undertaken in elongated piles called windrows. The windrows are monitored throughout the **composting** process to ensure that the optimum temperature, oxygen concentration and moisture content are maintained. The windrows are turned periodically, to introduce fresh air, and watered to maintain the ideal conditions for **composting**.

Appendix 5 - Glossary of Acronyms for RWG documents

AD	Anaerobic Digestion
AMR	Annual Monitoring Report
ATF	Authorised Treatment Facility
BPEO	Best Practicable Environmental Option
BMT	Biological Mechanical Treatment
BMW	Biodegradable Municipal Waste
CA	Civic Amenity
C&I	Commercial & Industrial
C&D	Construction & Demolition
CFC	Chloro Fluoro Carbons
CHP	Combined Heat and Power
COMAH	Control Of Major Accident Hazards
CP	Conditioning Plan
DEFRA	Department for Environment, Food and Rural Affairs
DTLR	Department for Transport, Local Government and the Regions.
EA	Environment Agency
EfW	Energy from Waste
EIA	Environmental Impact Assessment
ELV	End of Life Vehicle
EU	European Union
EWC	European Waste Catalogue
GIS	Geographical Information System
HIA	Health Impact Assessment
HWRC	Household Waste Recycling Centre
IPPC	Integrated Pollution Prevention and Control
ISO	International Organisation for Standardisation
LAS	Landfill Allowance Scheme
LCA	Life Cycle Assessment
LDP	Local Development Plan
LPA	Local Planning Authority
MBT	Mechanical Biological Treatment
MHT	Mechanical Heat Treatment
MRF	Materials Recycling Facility
MSG	Members Steering Group
MSW	Municipal Solid Waste
NAW	National Assembly for Wales
NPA	National Park Authority
NSCA	National Society for Clean Air and Environmental Protection
NWSW	National Waste Strategy for Wales
PA	Per Annum
PCB	Polychlorinated Biphenyls
PCN	Policy Clarification Note
PPC	Pollution Prevention & Control
ODPM	Office of the Deputy Prime Minister
RDF	Refuse Derived Fuel
RRR	Recycling, Reuse & Recovery
RWA	Regional Waste Assessment
RWG	Regional Waste Group

RWP	Regional Waste Plan
RWTG	Regional Waste Technical Group
SEA	Strategic Environmental Assessment
SWMA	Strategic Waste Management Assessment
SWMO	Sustainable Waste Management Option
TAN	Technical Advice Note
TPA	Tonnes Per Annum
UDP	Unitary Development Plan
WAG	Welsh Assembly Government
WEEE	Waste Electrical & Electronic Equipment
WISARD	Waste: Integrated Systems Analysis for Recovery and Disposal
WML	Waste Management Licence
WRATE	Waste: Integrated Systems Analysis for Recovery and Disposal
WSP	Wales Spatial Plan

Appendix 6 – Indicator Methodology

Three principal methodologies were applied to determine a score for each of the indicators list in table 44 of part two. The life cycle assessment tool WRATE generates eight of the twenty-two indicators used to determine BPEO/SWMO.

Eight indicators were determined using generic data through a combination of published data and the range of modelling assumptions made.

The remaining six indicators were derived through professional judgement. This section explains the derivation of each of these sets of indicators.

Each indicator produces a numerical result but the units are different for each indicator and so it is impossible to compare across indicators. To remedy this, each indicator is given a valued score between 0 and 1 where 0 is the worst performing option and 1 is the best. This enables comparison between indicators and also allows a total valued score to be created for each option by summing the valued indicators.

The valued scores can also be weighted in accordance with the weightings agreed by each of the RWGs. This weighted option score enables a final rank to be generated to determine which is the preferred option.

WRATE output indicators

Impact Assessment methods are used to define the Life Cycle Impact Assessment (LCIA) of a system or service. The Impact Assessment method is a methodology for defining the potential environment impacts and benefits associated with environmental burdens generated by a service or a system. WRATE is provided with a number of default Impact Assessment Methods databases including the following:

- Problem oriented approach (CML, 1999);
- Damage Approach EPS (Steen, 1999);
- ECOINDICATOR 99;
- IMPACT 2002+ (Midpoint); and
- IMPACT 2002+ (Endpoint).

Further information about Impact Assessment Methods can be found at http://www.pre.nl/simapro/impact_assessment_methods.htm

Abiotic Resource Depletion

There are finite resources that will eventually be used up at current rates of consumption. These are abiotic resources i.e. non-living, such as metals and other inorganic materials and fossil fuels. “Abiotic resource depletion” indicators represent this environmental impact in WRATE.

Global warming (GWP100)

Man-made global warming is caused by emissions of greenhouse gases (GHGs) that cause heat radiation to be reflected and retained in the atmosphere rather than being lost into space. The main contributor to global warming is carbon dioxide, although other GHGs such as methane can have an effect. “Global warming potential” indicators represent this environmental impact in WRATE.

Emissions injurious to human health - human toxicity

Persistent toxic substances can slowly accumulate in living organisms (e.g. when exposed through the lungs, skin from food, etc.), increasing the risk that toxic concentrations will be reached. Persistent means highly resistant to degradation and refers to the longevity of chemical substances in the environment. Mercury, DDT and dioxins are some of the best known of these substances. Acute effects results from short-term exposure. “Toxicity potential” indicators represent these environmental impacts in WRATE.

Extent of water pollution - Freshwater aquatic ecotoxicity

Toxic effects on ecosystems can be either chronic (causing prolonged illness) or acute (short-term/immediate effects). “Ecotoxicity” indicators for land, water and air represent these environmental impacts in WRATE.

Emissions contributing to air acidification

Emissions to air, water and land of acidifying compounds to such as sulphur dioxide (SO_2) and nitrogen oxides (NO_X) can contribute to the destruction of plants and acidify the soil, which can result in changes to ecosystems. “Acidification potential” indicators represent this environmental impact in WRATE.

Emissions contributing to eutrophication

Emission of nitrogenous compounds, especially ammonia (NH_3) and nitrogen oxides (NO_X) and phosphates, can stimulate increased growth due to a fertilisation effect, leading to altered species in nutrient-poor ecosystems. In water, algal blooms can occur, replacing other species or using up all the oxygen in the water. “Eutrophication potential” indicators represent this environmental impact in WRATE.

Emissions contributing to depletion of the ozone layer

The stratosphere is part of the atmosphere at an altitude of 15–40 km. Originally the formation and breakdown of ozone in the stratosphere was in balance. The breakdown of ozone has been accelerated by man-made emissions of halocarbons, i.e. organic compounds containing chlorine or bromine – sometimes referred to as chlorofluorocarbons (CFCs). A reduction of ozone in the stratosphere means higher intensity ultraviolet (UV) radiation in sunlight can reach the surface of the earth. Such radiation is associated with increased prevalence of cancer in humans and mutagenicity in other biota. “Ozone depletion potential” indicators represent this environmental impact in WRATE.

Dioxin emissions

Using the principals described in the human toxicity indicators, WRATE describes in its life cycle inventory the amount of dioxins released by a waste management system. The indicator quantifies the amount of dioxins and furans released by a waste management system.

Generic Data indicators

Land take

This indicator estimates the amount of land required to accommodate all of the waste facilities in each option. The data was taken from information held about individual sites in the WRATE model.

This data has been adjusted pro rata from the capacity of the site in the model to reflect the required capacity of each facility type as agreed by the RWGs. The land take for each facility type is shown in the table below.

Facility type	Nature of authority	Land take (ha)
Civic amenity site	Urban	**0.26**
	Rural	**0.10**
Transfer station	Urban	**2.43**
	Rural	**2.43**
Inert reprocessing	Urban	**1.77**
	Rural	**0.89**
MRF - clean	Urban	**2.40**
	Rural	**1.20**
MRF - dirty	Urban	**1.42**
	Rural	**0.71**
MRF - Dirty and Gasification	Urban	**4.49**
	Rural	**2.25**
Composting - windrow	Urban	**1.90**
	Rural	**0.95**
Composting - IV	Urban	**1.05**
	Rural	**0.53**
MBT	Urban	**8.00**
	Rural	**4.00**
MBT with Anaerobic Digestion	Urban	**7.53**
	Rural	**2.82**
MBT with Pyrolysis	Urban	**11.00**
	Rural	**3.67**
MBT with Gasification	Urban	**11.08**
	Rural	**5.54**
MBT with co located with Incinerator	Urban	**9.40**
	Rural	**5.80**
Remaining in capacity to receive RDF from satellite MBT plants	Urban	**4.00**
	Rural	**3.00**
Satellite MBT to feed incinerator plant	Urban	**5.40**
	Rural	**2.80**
MHT - autoclave	Urban	**4.05**
	Rural	**2.02**
MHT - autoclave + gasification	Urban	**8.66**
	Rural	**5.10**
MHT - autoclave + pyrolysis	Urban	**6.71**
	Rural	**3.36**
MHT - Autoclave co located with incinerator	Urban	**8.05**
	Rural	**5.02**
Remaining incinerator capacity to receive floc from satellite MHT plant	Urban	**4.00**
Satellite MHT to feed incinerator plant	Urban	**4.05**
Incinerator - CHP	Urban	**4.00**
	Rural	**3.00**
Advanced thermal treatment plant (pyrolysis)	Urban	**2.00**
	Rural	**0.67**
Advanced thermal treatment plant (gasification)	Urban	**3.08**
	Rural	**1.54**
Off-site RDF use		**0.00**
		0.00
Landfill - non hazardous	Urban	**62.00**
	Rural	**16.00**
Landfill - hazardous	Urban	**10.00**
	Rural	**10.00**
Landfill - inert	Urban	**10.00**
	Rural	**5.00**

These figures were then multiplied by the number of facilities required in each scenario to give an overall estimated land take score for each scenario.

Total waste kilometres

Two types of transport distance were used in the modelling process. All estimations of transport distance have been based upon straight-line distance. For waste being delivered to existing reprocessing facilities a fixed distance was applied. In each case this was calculated by making an assumption about the likely location of the facility and measuring the straight-line distance between the geographical centre of the region and the facility. The assumed distances to each of the types of re-processors are shown in figure A10 below.

Reprocessor	Trip Distance North Wales (km)	Trip Distance SE Wales (km)	Trip Distance SW Wales (km)
Aluminium Recyling	88.10	172.50	196.20
Ferrous recycling	153.60	48.00	53.10
Paper recycling	51.20	266.30	334.70
Textile recycling	149.50	220.00	254.00
Glassphalt recycling	61.00	49.50	42.80
Glass recycling	165.10	225.00	263.60
Dense plastic recycling	53.00	16.00	70.20
Wood recycling	19.68	16.78	21.96
Plastic film recycling	237.00	354.00	352.00
IBA recycling	20.00	20.00	20.00
PAS 100 Compost use	20.00	20.00	20.00
APEX Compost use	20.00	20.00	20.00

For modelled facilities within the region, it is assumed that they will be equally distributed across the region and so scenarios with a greater number of facilities will generate shorter trip distance. The relationship between number of facilities and transport distance is explained in appendix 2.

These principals were used in combination with the expected throughput at a given facility and the agreed capacity to generate the required number of facilities. This generated the one way trip distance.

The overall transport kilometres were then calculated by multiplying the number of trips to each facility type (a function of the expected throughput and the capacity of the vehicle) and the assumed one way trip distance. The transport distance indicator is summarised for all options in table 55 of part two. The information is further broken down to show how much of this distance is for waste to modelled facilities within the region and how much is for the transport of recyclate to a re-processor.

Transport along roads other than motorways

The same derivation for this indicator was used as for total waste kilometres but only for urban and rural roads in accord with the assumptions in appendix 2.

Number of jobs likely to be created

This indicator looked solely at the expected number of staff required for the residual treatment/disposal facilities only (i.e. for option 1a this would be staff at the pyrolysis plant and the landfill sites).

For job creation, it is the facilities that treat the mixed residual waste stream that are variable between each option. The tonnage of waste (and thus the number and type of facilities) that is source separated for either recycling or composting is constant for each option and so the number of jobs has not been considered for this indicator.

The table below shows the number of employees assumed to be required for each of the residual treatment technologies. The data for treatment has been derived from case study data held on the Environment Agency's (EA) Waste Technology Data Centre[5] (WTDC).

Costs of management and disposal, including material and energy revenues

As with jobs indicator, only the costs of the residual treatment/disposal facilities have been considered. This indicator needs to be viewed with some caution as often the data is taken from one case study particularly with the newer technologies and it is acknowledged that many factors may influence the cost of waste management technologies.

The majority of the data was derived from information held on the EA WTDC. To create the indicator, capital and operational costs and revenues were considered and annualised to create a per annum cost indicator.

The capital cost was divided by the lifespan of the facility to give a capital cost per year and by the annual capacity to give a capital cost per tonne. This was then combined with the likely operational cost per tonne to create a combined capital and operational cost per tonne of throughput. This figure has then been multiplied by the required annual throughput for each option to create the final option score. The cost data per facility is summarised in the table below.

It should be noted that the costs relate to specific plant and will have applied at the time of commissioning/construction.

Landfill operational costs include landfill tax at 2006 rate (£21 per tonne for active waste and £2 per tonne for inert waste) and not at the expected level of £35 in 2013. This is to ensure comparability as other operational and capital costs are based on current data.

For all types of facility apart from the cement kiln, costs are those estimated to procure, build and run the facility and do not represent a gate fee that a third party user may pay. All cost data was supplied by the Environment Agency WTDC apart from landfill costs which were taken from a European Commission report by Eunomia Research and Consulting Ltd[6]. And uplifted by 3% per annum to 2005 to account for inflation.

For cement kiln, it assumed that the gate fee charged would be market led. The figure applied represents a gate fee per tonne equal to the cheapest per tonne cost from the other facilities.

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

[6] http://www.ec.europa.eu/environment/waste/studies/pdf/euwastemanagement_annexes.pdf

Facility type	Nature of authority	Capacity (t/annum)	Lifespan of facility	Total Capex (£m)	Capex per year (£m)	Capex per Year (£)	Opex per tonne	Opex per facility per year (£)	Cost Score	Annual Capex and Opex per tonne
MBT/MRF	URBAN	160,000	15	30.32	2.02	£2,021,333	£34.24	£5,477,600	£7,498,933	£46.87
	RURAL	80,000	15	15.16	1.01	£1,010,667	£34.24	£2,738,800	£3,749,467	£46.87
MBT with Anaerobic Digestion	URBAN	160,000	15	50.56	3.37	£3,370,667	£24.55	£3,928,000	£7,298,667	£45.62
	RURAL	60,000	15	18.96	1.26	£1,264,000	£24.55	£1,473,000	£2,737,000	£45.62
MHT - Autoclave	URBAN	200,000	15	30	2.00	£2,000,000	£36.96	£7,392,000	£9,392,000	£46.96
	RURAL	100,000	15	15	1.00	£1,000,000	£36.96	£3,696,000	£4,696,000	£46.96
Incinerator - CHP	URBAN	216,000	15	44.064	2.94	£2,937,600	£15.37	£3,319,920	£6,257,520	£28.97
	RURAL	56,000	20	28	1.40	£1,400,000	£39.26	£2,198,560	£3,598,560	£64.26
ATT (Pyrolysis)	URBAN	90,000	15	32.93	2.20	£2,195,333	£25.65	£2,308,500	£4,503,833	£50.04
	RURAL	30,000	15	10.98	0.73	£732,000	£25.65	£769,500	£1,501,500	£50.05
ATT (Gasification)	URBAN	80,000	10	15	1.50	£1,500,000	£6.01	£480,800	£1,980,800	£24.76
	RURAL	40,000	10	7.5	0.75	£750,000	£6.01	£240,400	£990,400	£24.76
Off-site RDF use		50,000			0.00	£0				£28.97
		25,000			0.00	£0				£28.97
Landfill - non hazardous	URBAN	250,000	20	73.33	3.67	£3,666,564	£27.89	£6,971,514	£10,638,078	£42.55
	RURAL	112,500	20	33.00	1.65	£1,649,954	£27.89	£3,137,181	£4,787,135	£42.55
Landfill - hazardous	URBAN	50,000	20	14.67	0.73	£733,313	£30.03	£1,501,681	£2,234,994	£44.70
	RURAL	50,000	20	14.67	0.73	£733,313	£30.03	£1,501,681	£2,234,994	£44.70
Landfill - inert	URBAN	50,000	20	14.67	0.73	£733,313	£11.03	£551,681	£1,284,994	£25.70
	RURAL	25,000	20	7.33	0.37	£366,656	£11.03	£275,841	£642,497	£25.70

Percentage composted, percentage recycled, percentage landfilled

This indicator was calculated based on the performance of each scenario. The composting indicator is the same for each option as this only includes source separated composting which is constant across all options.

The recycled tonnage includes source separated recycling, which is constant across all options and also includes construction and demolition wastes which have been crushed as aggregate, recyclate recovered from intermediate facilities, for example ferrous metal mechanically extracted from MBT, and the recycling of incinerator bottom ash.

The landfill tonnage includes the inert landfill of construction and demolition wastes, non hazardous landfill taking directly delivered wastes or rejects from intermediate facilities and hazardous landfill receiving Air Pollution Control residues (fly ash) from thermal treatment processes.

The percentage indicator is derived by dividing each these figures by the overall modelled tonnage.

Professional Judgement Indicators

The remaining six indicators relied on professional judgement rather than a quantitative measure. A panel of waste experts was convened to consider how these indicators could be scored. The panel consisted of Adrian Jones (WAG), Don Ridley (EA), Cathy O'Brien (EA), Nadia De Longhi (EA), Rhiannon Jones (EA), Lucy Thomas (EA) and Mark Watson (EA).

A scoring methodology was developed for each of the indicators. Thought was given as to what effect each technology type would have on the indicator in question. A number of component parts were considered to make up the final score for each facility. The results of this can be found in tables 46-50 in part 2.

Odour indicator

Four components were agreed to make up the final odour score for a facility. For each component in all the professional judgement indicators a scoring system of 1-10 was employed with 1 representing the least impact and 10 the most.

The type of waste received by the site was agreed to influence the potential odour impact. Each facility was scored for the type of waste received. MBT with Anaerobic Digestion was given a score of 10 for waste type as it would receive mixed wastes from a range of sources and could be operated to co-digest with sewage sludges. Inert re-processing and inert landfill scored 1, as they would not be handling any putrescible wastes.

The second component considered was whether waste on site was likely to be stored undercover or not as this would impact on the likelihood of site odour problems.

The third component concerned whether the site operation would be undercover or in the open as again this would influence the likelihood of odour issues.

The fourth component, and one used in a number of indicators, was a score given relative to the expected number of vehicle movements at the site as again this may impact on the scale of odour issues.

The final score was derived by adding each of the components. The final score was then valued giving the worst performing facility for odour a score of 10 and the best performing a score of 0.

Dust indicator

As with the odour indicator, the same four components were considered to contribute towards the likely impact of dust on a site. However, the scores were different for waste type as now the inert re-processing scored worst for this as dry inert wastes were most likely to dusty.

The activity on site was considered to be an additional component contributing towards the likely impact of dust on a site. A Civic Amenity site, for example, has a relatively low scores as there is no mechanical sorting or moving of wastes whereas the inert re-processor scores highly as the site activity clearly is a confounding factor in the production of dust.

Noise, Litter and Vermin Indicator

A separate score was derived for noise and it was agreed that different factors would influence the noise impact of a site from litter and vermin. The noise indicator was calculated by considering whether the onsite plant would be noisy, whether the site was undercover or open, the contribution of vehicle movement and the hours of site operation.

For litter and vermin, the same components were applied as used to determine the impacts of odour. These two values were added together to generate the final noise, litter and vermin indicator.

Visual and Landscape Indicator

To determine the visual and landscape impact of a facility, the perceived impact of the visual appearance of the site was first considered and scored 1-10. This was then combined with a score related to the likely height of the facility and then in terms of the land take of the facility (the same figures were used per site as in the land take indicator)

Likelihood of implementation Indicator

Two principal factors were considered to contribute to the likelihood of a technology being implemented. The proveness/bankability of the technology were considered on a scale of 1-10. This score was then combined with a score related to the timescale required to procure and commission a facility[7].

The final facility score was valued on a scale of 0-10 and applied on a per tonne basis to the residual waste treatment technologies in the WRATE model giving an overall likelihood score based only on delivery of the residual treatment facilities.

Opportunities for Public Involvement 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. The opinions of the professional judgement panel are detailed in table 58 of part 2.

[7] From Enviros New Technologies Training Programme (2006), WAG/WLGA

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