Ardley Waste Management Facility, Ardley, Bicester, Oxfordshire

Appendix 3 - Life Cycle Assessment of Technology Options

Viridor Waste Management Ltd

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APPENDICES

Appendix A Sankey Diagrams of Treatment Scenarios

1.0 INTRODUCTION

This briefing note outlines the main assumptions, results and interpretation of a Life Cycle Assessment exercise to support the planning application for Viridor's EfW facility at Ardley Quarry, Oxfordshire.

2.0 METHODOLOGY

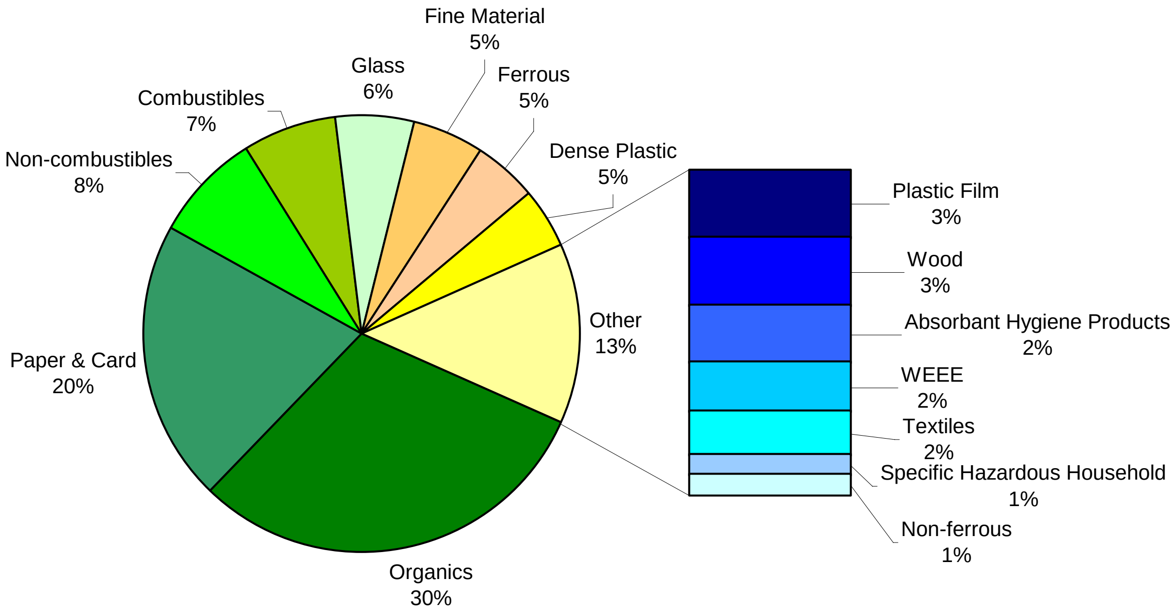
The Environment Agency life cycle assessment software *'Waste and Resource Assessment Tool for the Environment'* (WRATE) was utilised to model the environmental impacts of the proposed facility. The WRATE software is a life cycle assessment tool specifically designed to model environmental impacts of waste and waste management processes. The WRATE tool[1] and its use is endorsed and encouraged by the Environment Agency (EA) and Department for Environment, Food and Rural Affairs (Defra).

In summary, the environmental burdens has been calculated for the processing of 300,000 tonnes of municipal solid waste through a number of waste treatment processes, as follows:

- Landfill;
- Energy from Waste (EfW);
- Advanced Thermal Treatment (ATT);
- Mechanical Biological Treatment (MBT) with Refuse Derived Fuel (RDF) to EfW; and
- Mechanical Biological Treatment (MBT) with Refuse Derived Fuel (RDF) to landfill.

The above scenarios are consistent with options assessment work undertaken for Oxfordshire County Council which informed the Municipal Waste Management Strategy development.

The following municipal waste composition has been assumed (the default MSW composition in the WRATE tool):



1 http://www.environment-agency.gov.uk/wtd/1396237/

Since a number of the waste management processes produce electricity an assumed energy mix must be defined in order to calculate the avoided burdens (from not having to produce the electricity from traditional generation methods). WRATE has default energy mixes for the UK available; the energy mix for the year 2012 has been selected, as the Oxfordshire Joint Municipal Waste Management Strategy states that from April 2012, treatment facilities will be online. As such 2012 is defined as the assessment year for the options appraisal.

WRATE contains a number of default technology templates; these have been used as the basis of the 6 waste management scenarios. For example, the Billingham incinerator has been used to model EfW as this process design most closely matches that of the proposed Ardley Quarry facility; the Billingham facility is a large power only incinerator.

The outputs from WRATE are life cycle impact assessment (LCIA) indicators (for example global warming potential, human toxicity etc), these can be specified by the user and measure the potential impacts of the waste treatment technologies. Section 3.0 of this briefing paper presents the raw WRATE scores for the 6 default impact assessments. The WRATE default impact assessments are:

- Abiotic Resource Depletion;
- Global Warming Potential (GWP100);
- Human Toxicity (HTP inf.);
- Freshwaster Aquatic Ecotoxicity (FAETP inf.);
- Acidification (AP); and
- Eutrophication (EP19912).

Each technology has been assessed against the 6 sustainability indicators to generate overall performance scores. Performance scores for each indicator represent a quantitative evaluation that can be used to compare the options within a particular impact. Units of measurement vary between different impact categories (for example antimony equivalent for abiotic resource depletion, CO_2 equivalent for global warming etc).

To enable comparison inter-impact, and enable a preferred technology to be identified the scores have been valued. Valued scores are derived by ‘normalising’ the overall performance scores on a scale of 0 to 1, where 0 represents the worst scenario and 1 represents best scenario. Using this methodology, the higher the score the more sustainable the option is considered to be.

Sankey flow diagrams for each of the scenarios are presented in Appendix A.

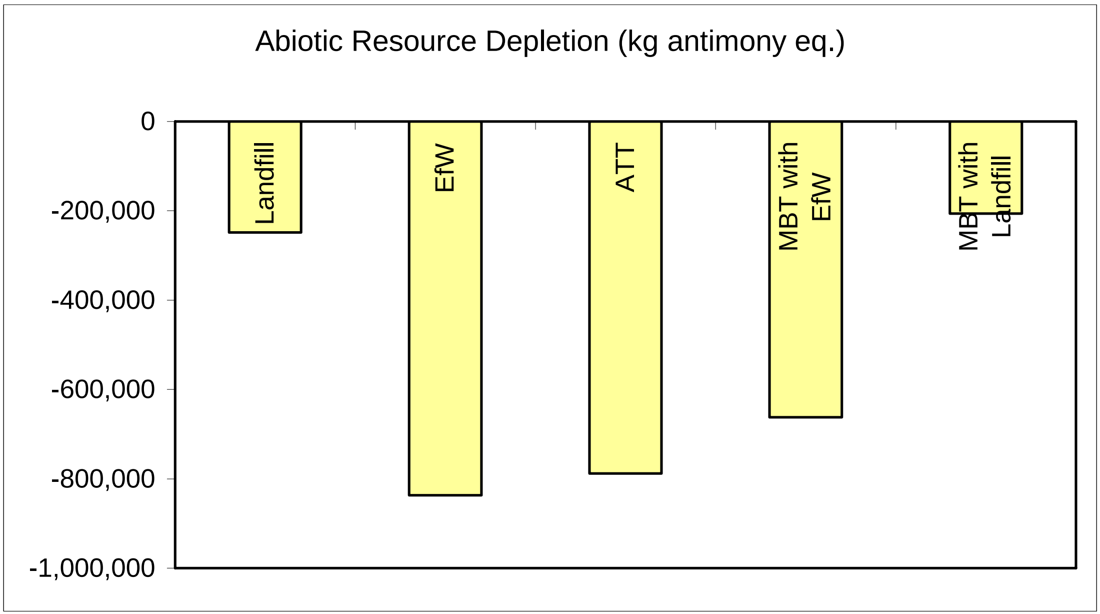
3.0 RESULTS

3.1 Life Cycle Impact Assessment Results

The purpose of appraising the performance of each option against the impact assessments indicators is to inform decision makers about their relative advantages and disadvantages. Summary results from modelling the above residual treatment scenarios in WRATE are presented in Figure 3-1 to Figure 3-6.

3.1.1 Abiotic Resource Depletion

Figure 3-1
Life Cycle Abiotic Resource Depletion



A key sustainable development objective is to use finite natural resources (such as fossil fuels and land) more efficiently. Producing more with less, for example by recovering resources from waste, reduces the environmental pollution and degradation caused by extraction, use and disposal of natural resources. Recovering more materials from waste will offset the requirement of non renewable virgin materials, thus reducing resource depletion.

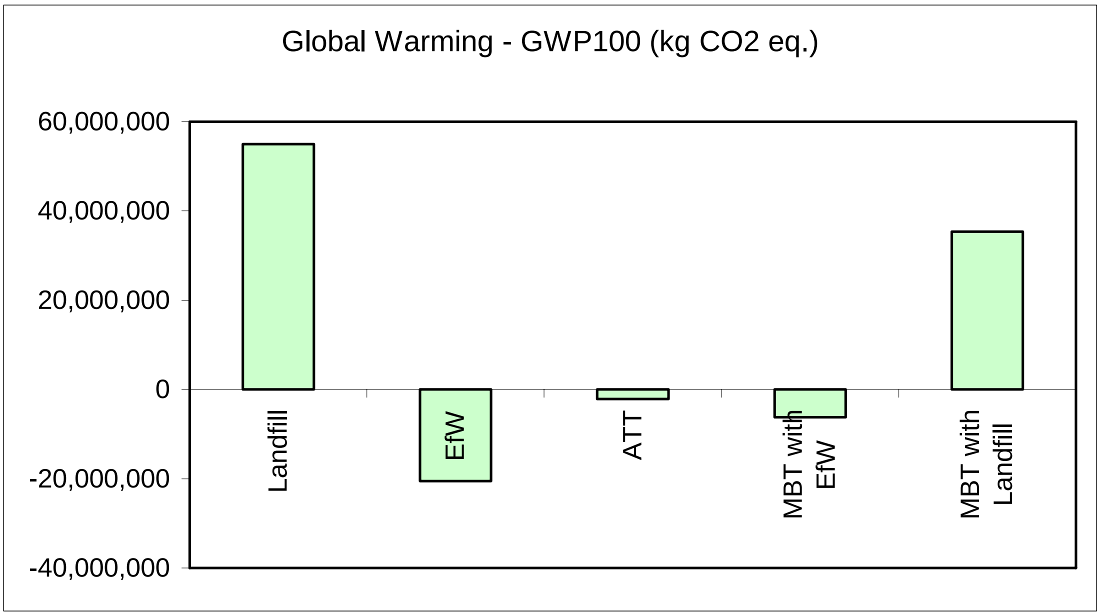
The construction, maintenance and operation of all treatment options requires the use of natural resources, however the individual set up of each technology can also result in offsetting the use of natural resources. All scenarios result in an overall reduction in life cycle abiotic resource depletion which can be explained as follows:

Landfill	Methane gas captured from the landfill site is combusted in gas turbines to create electrical energy. The production of electrical energy from landfill gas offsets energy production using fossil fuels and therefore reduces the depletion of resources
EfW	Recovery of metals from the bottom ash and recycling of incinerator bottom ash offsets the extraction of raw materials. In addition the electrical energy produced offsets the requirement to extract primary fuels for energy generation energy.

ATT	Recovery of metals following processing and recycling of the char/incinerator bottom ash offsets the extraction of raw materials. In addition the electrical energy produced offsets the requirement to extract primary materials to generate energy.
MBT with EfW	Front end ferrous metal recovery, the recovery of metals from the bottom ash and recycling of incinerator bottom ash offsets the extraction of raw materials. In addition the electrical energy produced through incineration of the RDF (and some energy generation from landfill gas) reduces the need for primary resources to generate energy.
MBT with Landfill	Front end ferrous metal recovery offsets the extraction of raw materials and subsequent processing requirements. The capture and combustion of methane from the landfill of biostabilised waste creates some electrical energy which offsets the need to extract raw materials for energy production. The fact that the waste is biostabilised prior to going to landfill means that its methane generation potential is less and therefore less energy is recovered

3.1.2 Global Warming Potential

Figure 3-2
Life Cycle Global Warming Potential (GWP100)



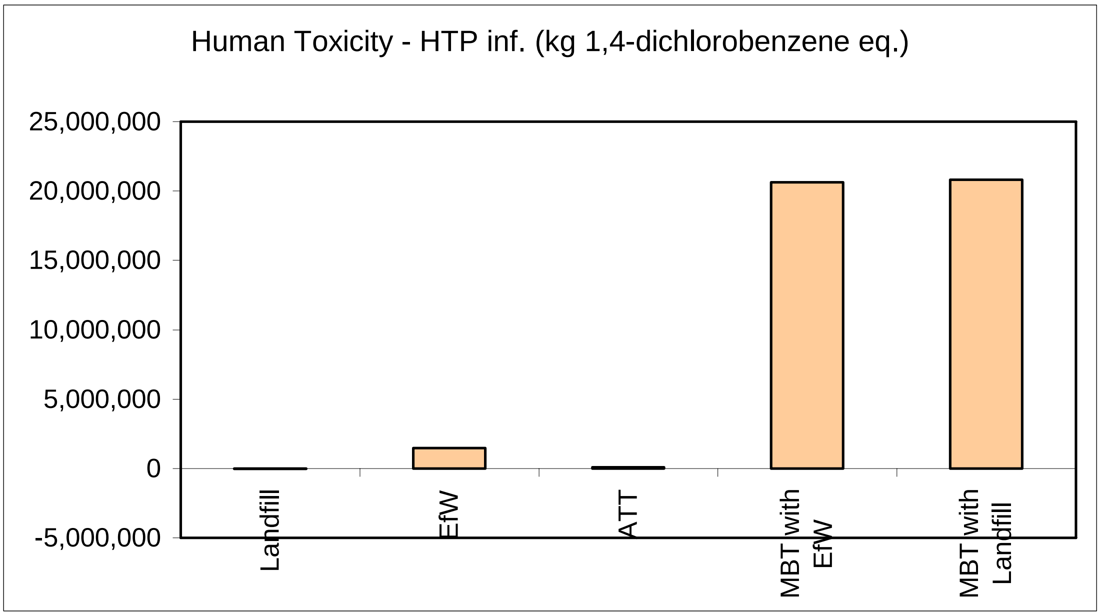
Life cycle global warming potential presented in Figure 3-2 can be explained as follows:

Landfill	Combustion of recovered methane generates electricity, which avoids the need to produce electricity from non-renewable (fossil) sources, however this saving is negligible and there is a positive overall impact associated with fugitive emissions of methane and other GWP compounds.
EfW	EfW releases carbon dioxide from combustion of plastics and other fossil fuel derived materials. Recovered energy avoids the need to produce electricity from non-renewable (fossil) sources which in turn reduces emissions associated with the extraction and combustion of fossil fuels. Recovery of ferrous metals displaces production from virgin materials, and subsequently reduces energy requirements.
ATT	ATT releases carbon dioxide from the processing of plastics and other

	fossil fuel derived materials. Recovered energy avoids the need to produce electricity from non-renewable (fossil) sources which in turn reduces emissions associated with the extraction and combustion of fossil fuels. Recovery of ferrous metals displaces production from virgin materials, and subsequently reduces energy requirements. Although the benefits of energy production are similar for ATT and EfW, the direct emissions associated with the ATT process are higher
MBT with EfW	RDF combustion releases carbon dioxide from plastics and other fossil fuel derived materials. Recovered energy avoids the need to produce electricity from non-renewable (fossil) sources which in turn reduces emissions associated with the extraction and combustion of fossil fuels. Recovery of ferrous metals displaces production from virgin materials, and subsequently reduces energy requirements. Benefits are less than those for EfW only, despite the increase in calorific value, due to the smaller quantity of material combusted, the additional burdens associated with construction of the MBT facility, higher electricity input for operation of front end equipment and due to the production of nitrous oxide from the biological oxidation of nitrogen containing compounds.
MBT with Landfill	Recovery of recyclable ferrous metals from front end processing displaces production from virgin materials, and subsequently reduces energy requirements. Positive impact is associated with fugitive emissions of GWP compounds from biostabilised material consigned to landfill and nitrous oxides from the biological oxidation of nitrogen containing compounds.

3.1.3 Human Toxicity

Figure 3-3
Life Cycle Human Toxicity (HTP inf.)

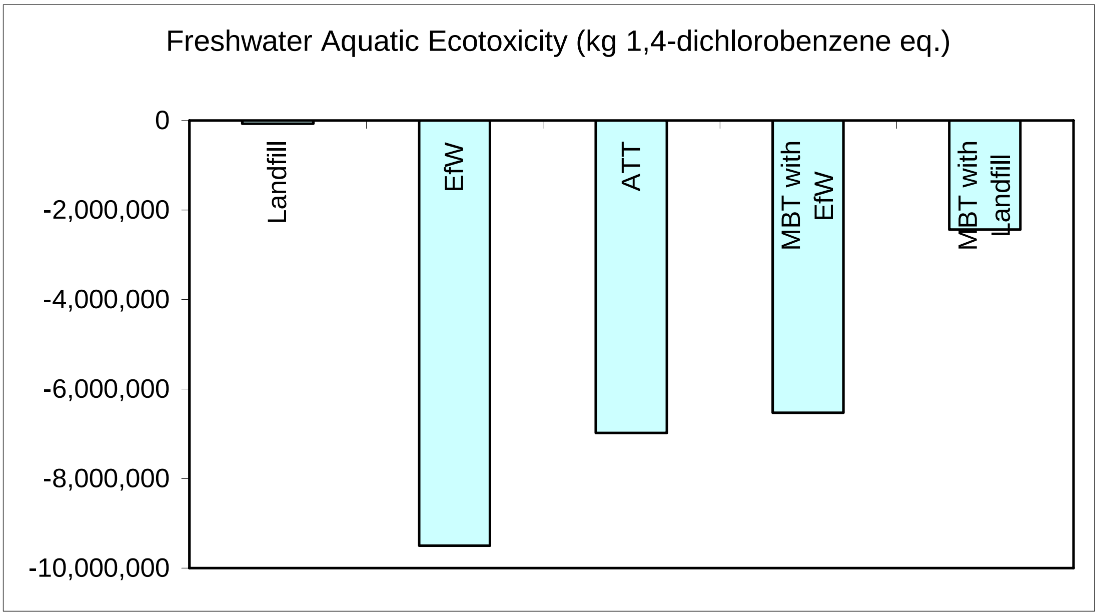


All non-landfill processes result in a positive value, i.e. a burden for human toxicity.

The recovery of recyclable materials results in an avoided burden to the environment as this prevents energy intensive processing of raw materials which emits substances harmful to humans. Overall, the emissions associated with the treatment process itself (direct process burdens) outweigh the benefits from recycling. The MBT processes, as modelled in WRATE, emit considerable quantities of Chromium and Chlorofluorocarbons (CFCs), resulting in the highest burden and therefore the lowest performance of all the technologies assessed. The combustion of waste also results in emissions injurious to humans, although the energy recovered and bottom ash recycled offsets a higher proportion of the direct process burdens than for the MBT processes.

3.1.4 Freshwater Aquatic Ecotoxicity

Figure 3-4
Life Cycle Freshwater Aquatic Ecotoxicity



All waste management options will create potential impacts on water as they involve the following:

- the **storage of waste** (e.g. run off from rain and dust suppression sprays, leaching of contaminants);
- the **transport of waste** (e.g. run off from the delivery and tipping of materials, wheel washing); and
- the **operation of plant and vehicles** (e.g. potential pollution from oil and solvents, including the risk of accidental spillage).

Some waste management options present a greater risk to water quality than others. The risk of water contamination will depend on the type of residual treatment used; enclosed technologies pose a reduced risk, as do processes that involve covered storage of waste. Risks are also minimised if water releases from the process are minimal, for example:

- **Landfill** - the risk of pollution depends on the characteristics of the wastes, the standard of site engineering, the underlying geology and the proximity of water courses and abstraction points[2]
- **EfW** - cooling and cleaning water may contain high levels of contaminants, whilst the storage and disposal of ash and air pollution control residues poses a further threat to water quality. EfW facilities are enclosed and involve minimal water releases, so the risk is low;

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

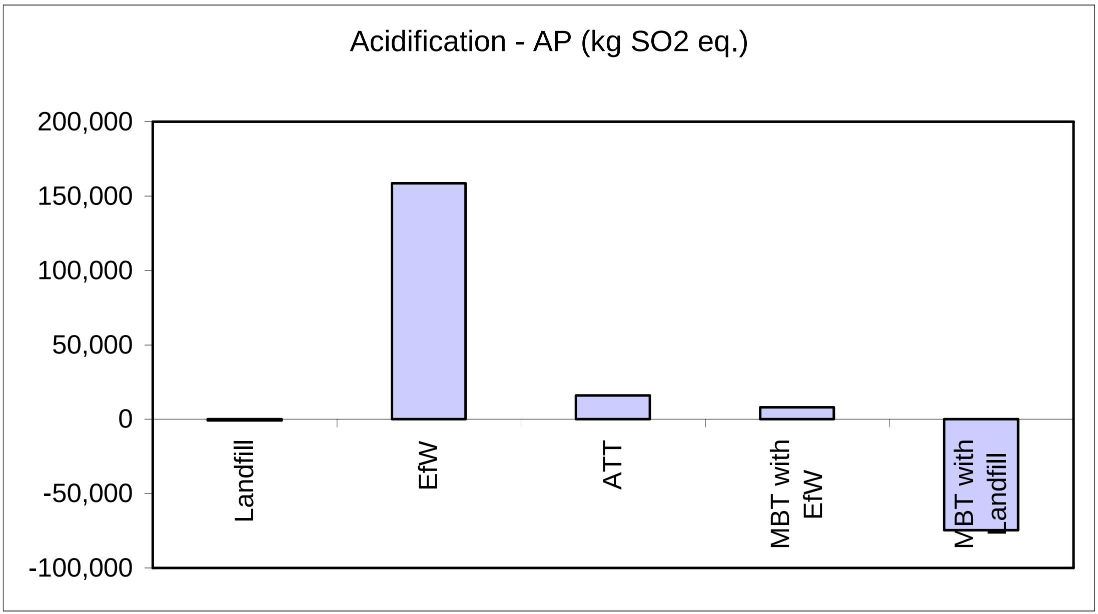
- **ATT** – similar requirements to the EfW process for cooling and cleaning water, and the storage of process outputs.
- **MBT** – will generally produce small quantities of leachate that may require biological treatment. MBT is also an enclosed process, however the reject fractions produced increase the risk to water when they are sent to landfill for disposal.

Landfill poses the greatest risk of water contamination as it is an open air technology and problems associated with leachate are common. It is unlikely that waste management activities will significantly affect human health if facilities are well managed.[3]

In contrast, the recovery of recyclable materials results in an avoided impact due to the prevention of raw material extraction and processing which can emit substances which are toxic to freshwater aquatic ecosystems. The production of electrical energy also results in an avoided burden associated with freshwater aquatic ecotoxity, due the prevention of fuel extraction and preparation. All options show a negative result, i.e. an avoided burden to the environment, which demonstrates that the recyclables and energy recovered, outweighs the direct burdens of the process and its construction, operation and maintenance.

3.1.5 Acidification

Figure 3-5
Life Cycle Acidification (AP)



Recovery of recyclates will reduce energy production associated with the processing of raw materials, reducing the production of compounds that contribute to acidification. Increasing the recovery of materials will have a positive impact on air acidification through the offset in requirement for processing of virgin materials. MBT processes require up front processing or sorting of waste, separating further recyclates from the residual waste, therefore recovering the greatest amount of materials.

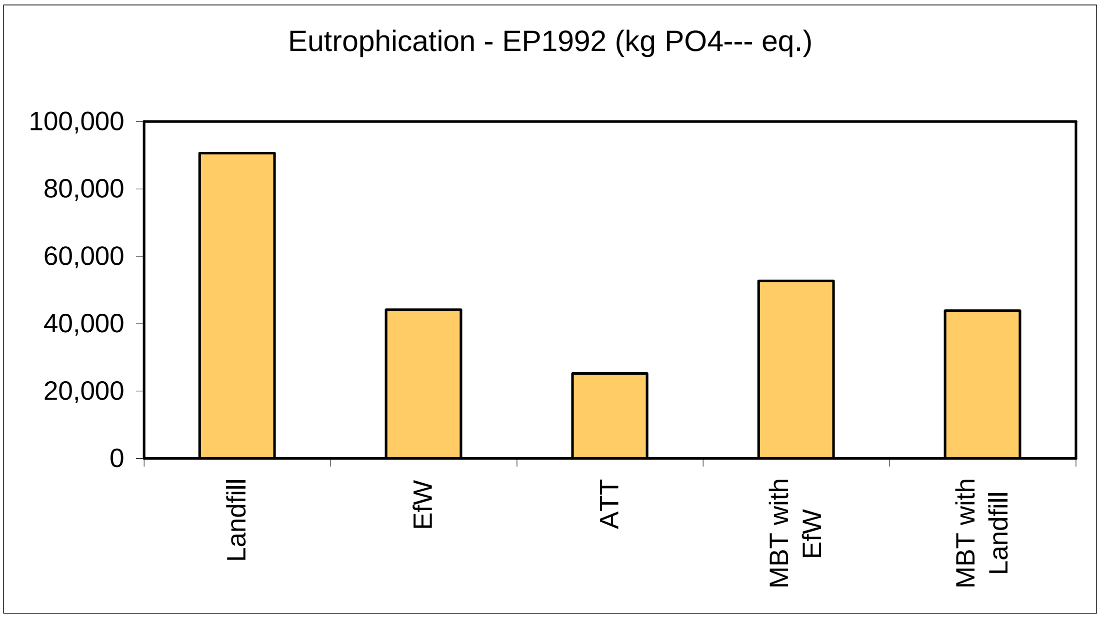
EfW gives rise to emission of NOx and SOx which explains the positive acidification burden.

[3] Review of Environmental and Health Effects of Waste Management. Municipal Solid Waste and Similar Wastes. Enviros et al on behalf of Defra (2004)

The management of waste through non combustion processes reduces the emissions associated with acidification and therefore the landfill and MBT with landfill processes perform well, both of which result in an avoided burden for the acidification impact. MBT with landfill also benefits from the ferrous metal recovery.

3.1.6 Eutrophication

Figure 3-6
Life Cycle Eutrophication (EP1992)



All options show a positive result, i.e. a burden to the environment.

Landfilling poses the greatest risk to eutrophication due to the potential for run off. MBT processes pose a greater risk of eutrophication occurrence than EfW or ATT; this can be attributed to the output (rejects and biostabilised material) from the MBT process. MBT technologies produce greater reject fractions requiring disposal. These fractions contain nitrates and phosphates, and if applied to land can leach through the soil into water courses, contributing to eutrophication.

3.2 Overall Performance and Valued Scores

The performance of each technology process is assessed through the overall performance scores of each option obtained from WRATE, and through the calculation of 'valued' performance scores.

The overall performance scores (as represented in Figures 3-1 to 3-6) are collated and numerically presented in Table 3-1. Analysis of overall performance scores is difficult because of the matrix's complexity and the use of different units for each sustainability criterion. Establishing 'valued' performance scores provides a possible solution to this problem.

'Valued' performance scores interpret overall performance scores on a scale of 0 to 1, where 0 is the worst performance, and 1 the best. This enables the discrepancy between scores to be retained, whilst allowing the performance of options against all criteria to be placed on a common scale. In this report it is assumed that a linear relationship exists between the best and worst 'value' scores. This approach is used to apply a linear function relationship to the performance scores and the resulting 'valued' performance scores are summarised in Table 3-2.

Table 3-1
Overall Performance Scores

Impact Assessment	Unit	Landfill	EfW	ATT	MBT with EfW	MBT with Landfill
Abiotic resource depletion	kg antimony eq.	-248,513	-837,142	-788,365	-662,384	-206,487
global warming (GWP100)	kg CO2 eq.	54,981,787	-20,554,873	-2,106,445	-6,240,222	35,404,682
human toxicity (HTP inf.)	kg 1,4-dichlorobenzene eq.	-23,586	1,469,235	81,308	20,622,471	20,810,988
Freshwater aquatic ecotoxicity (FAETP inf.)	kg 1,4-dichlorobenzene eq.	-72,602	-9,498,100	-6,979,047	-6,529,895	-2,437,521
acidification (AP)	kg SO2 eq.	-750	158,563	15,996	8,078	-74,663
eutrophication (EP1992)	kg PO4--- eq.	90,663	44,188	25,186	52,667	43,869

Table 3-2
Valued Performance Scores

Impact Assessment	Unit	Landfill	EfW	ATT	MBT with EfW	MBT with Landfill
Abiotic resource depletion	valued score	0.07	1.00	0.92	0.72	0.00
global warming (GWP100)	valued score	0.00	1.00	0.76	0.81	0.26
human toxicity (HTP inf.)	valued score	1.00	0.93	0.99	0.01	0.00
Freshwater aquatic ecotoxicity (FAETP inf.)	valued score	0.00	1.00	0.73	0.69	0.25
acidification (AP)	valued score	0.68	0.00	0.61	0.65	1.00
eutrophication (EP1992)	valued score	0.00	0.71	1.00	0.58	0.71
TOTAL VALUED PERFORMANCE SCORES		**1.75**	**4.64**	**5.02**	**3.45**	**2.22**

Table 3-2 indicates that should each evaluation criteria be given equal weighting the highest scoring technology is ATT, closely followed by EfW. The worst performing technology is landfill with a score below 2. All technologies result in a reduction in environmental impact compared to landfill (the baseline technology).

The top 2 scores from Table 3-2 (ATT and EFW) are within 0.38 points across the six indicators, which indicates that either a weighting should be applied to the environmental indicators (based on perceived significance of each environmental issue), or that additional indicators (for example treatment cost) may be a deciding factor as the scores are relatively close.

It should be noted that although the 6 impact assessments that have been considered offer a good indication of the environmental impact a residual treatment facility may have, social and economic factors such as cost, build time, facility size and whether the technology is proven, all play important roles in the decision making process.

4.0 CONCLUSIONS

This report presents the environmental burdens (including global warming potential[4], commonly known as carbon footprint) for the processing of 300,000 tonnes of municipal solid waste through a number of different residual waste treatment processes. Modelling has been carried out using the Environment Agency's Life Cycle Assessment Tool, WRATE.

The WRATE modelling results indicates that when considering the six environmental impact criteria in WRATE, the best performing options are Energy from Waste and Advanced Thermal Treatment. Energy from Waste scores highest on 3 criteria (abiotic resource depletion, global warming and freshwater aquatic ecotoxicity) and ATT scores highest on 1 criterion (eutorphication), but close to the top scoring technology on two other criteria (abiotic resource depletion, human toxicity).

Although scoring comparably to EfW on the life cycle impact assessment it should be considered that ATT is not currently a bankable solution for the treatment of municipal waste, and there are no full scale operational plants in the UK. It is also unclear if ATT is a viable technology for quantities of waste as large as 300,000 tonnes per annum.

In conclusion, through the use of the WRATE life cycle assessment software, it can be demonstrated that Energy from Waste yields an environmental impact that is comparable to Advanced Thermal Treatment, and better than other competing technologies. On this basis it is concluded that the proposed Ardley EfW facility will result in a negative environmental footprint, that is, an overall reduction in environmental impacts such as global CO_2 emissions.

It is further concluded based on the assumptions within that the same level of environmental footprint is unlikely to be deliverable via an MBT type treatment technology.

[4] WRATE Life Cycle Impact Assessment - Default Impact Assessment, Global Warming (GWP100)

5.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

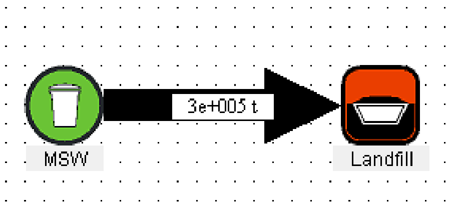
The conclusions presented herein are relevant to, and only to, the set of assumptions that form the basis of the Life Cycle Assessment modelling. The results of this modelling should not be used to infer benefits for other similar, but unrelated projects.

This report is for the exclusive use of Viridor; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

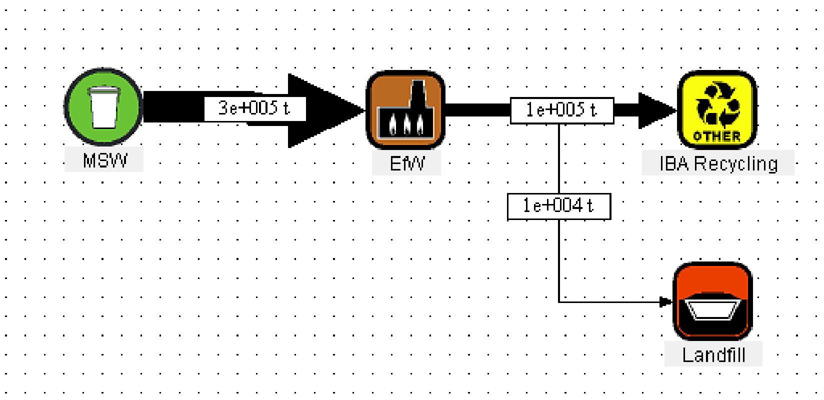
SLR disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.

Appendix A Sankey Diagrams of Treatment Scenarios

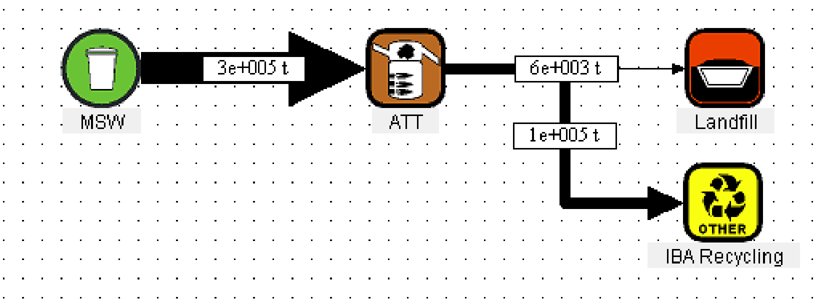
Landfill



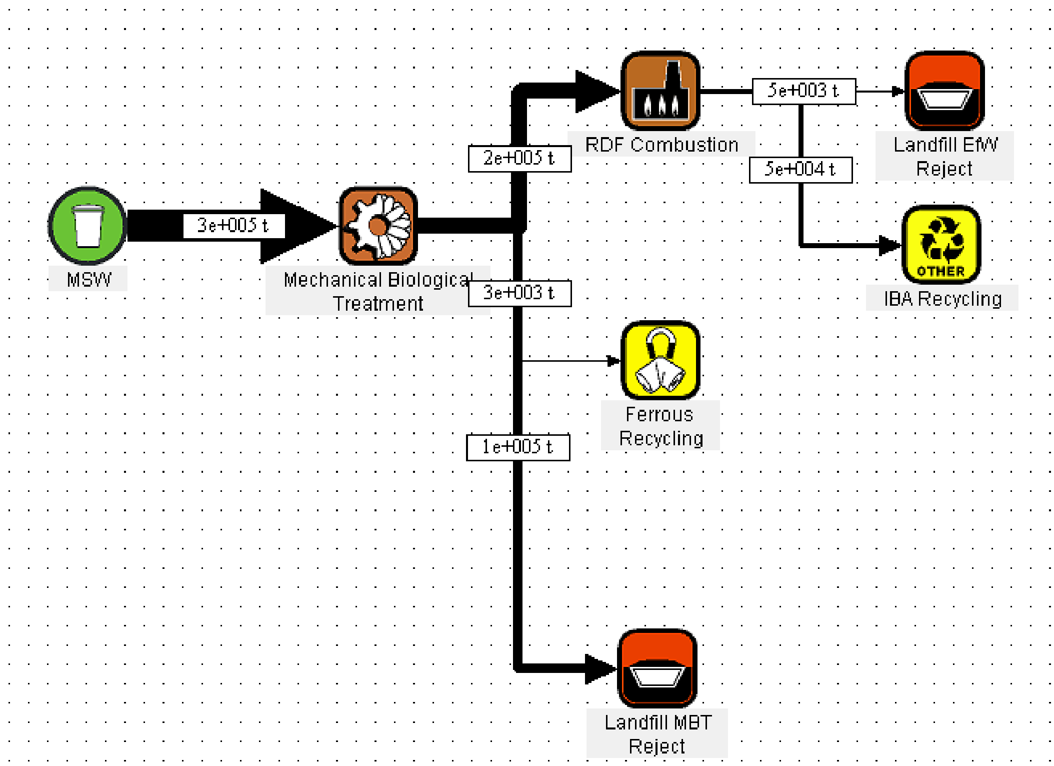
Energy from Waste



Advanced Thermal Treatment



MBT with RDF to EfW



MBT with RDF to landfill