

Paper (J)

**Appraisal of Environmental
Options Using WISARD**

Joint Municipal Waste Management Strategy

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1. Introduction

1. The main purpose of this appraisal is to provide rational information on which the main environmental impacts associated with each option (page 4) can be examined and considered for the purpose of Best Practicable Environmental Option (BPEO).

2. An analysis of the environmental impacts arising from each of the disposal options was carried out using WISARD (Waste Integrated Systems and Assessment for Recovery and Disposal), a life-cycle assessment (LCA) tool developed by the Environment Agency to assist Local Authorities with their BPEO assessments. The model evaluates the environmental burdens and impacts of waste management operations. The baseline and ten identified waste disposal option scenarios were created within WISARD using the compositional data from WRAP's "Analysis of Household Waste Composition and Factors Driving Waste Increases" (Parfitt 2002), waste arisings and Mass Flow data.

3. WISARD utilises the "avoided burden" methodology for calculating environmental burdens. This is to say it incorporates into the assessment the avoided environmental impacts of an activity or process not having to take place. For example recycling of steel cans avoids the requirement to smelt additional iron. Thus credits are allocated to recycling activities by calculating the energy and raw materials associated with the production of that product had the recycling not been performed. Credits are also assigned to those options that generate power, as this energy production is off-set against the requirement for fossil fuels (primarily coal for electricity generation).

4. *'A BPEO is the outcome of a systematic and consultative decision making procedure, which emphasises the protection of the environment and the conservation of the environment across land, air and water. The BPEO procedure establishes, for a given set of objectives, the option that provides the most benefits or the least damage to the environment as a whole, at an acceptable cost, in the long term as well as the short term.'* ('Royal Commission on Environmental Pollution, 12th Report BPEO 1988).

5. WISARD has been used to assess the environmental burden against the impacts regarded as significant with regard to waste management practices.

6. **Baseline**

Baseline meets statutory Best Value Performance Indicators (BVPIs) recycling and composting targets for 2005/06. Strategy will be driven by District Councils continuing kerbside collection services and HRC recycling. Landfill continues to be the principal disposal route for residual waste.

- Will not meet obligations set out within the Landfill Directive. Shortfall to be made up through purchase of tradable permits (LATS)

Option 1

As baseline scenario, i.e. meets BVPI targets for 2005/06, but portion of residual waste treated through Energy from Waste (EfW) in order to meet Landfill Directive targets.

- Meets Landfill Directive targets for 2020

Option 2

As baseline scenario, i.e. meets BVPI targets for 2005/06, with residual waste treated by Mechanical Biological Treatment (MBT) with residues disposed to landfill.

- Shortfall in meeting Landfill Directive targets

Option 3

As baseline scenario, i.e. meets BVPI targets for 2005/06, with residual waste treated by MBT with residues sent to EfW in order to meet Landfill Directive targets.

- Meets Landfill Directive targets for 2020

Option 4

Maximised dry recycling and composting by diversion of recyclable waste from kerbside collection. Residual waste to landfill for disposal. Although there is a shortfall in Landfill Directive targets, option 4 meets the Regional Waste Strategy target for household waste (51%).

- Shortfall in meeting Landfill Directive targets

Option 5

As option 4 but residual waste treated within a MRF/MBT plant to stabilise it prior to landfill disposal in order to meet landfill Directive targets.

- Meets Landfill Directive targets for 2020

Option 6

Maximised dry recycling and composting with portion of remaining residual waste treated by EfW in order to meet Landfill Directive targets.

- Meets Landfill Directive targets for 2020

Option 7

As option 5, but tests increased bio-stabilisation through MBT in order to meet or exceed the Landfill Directive.

- Exceeds Landfill Directive targets

Option 8

Maximised dry recycling and composting with all of remaining residual waste treated by EfW in order to exceed Landfill Directive targets.

- Exceeds Landfill Directive targets

Option 9

Maximised dry recycling and composting with remaining residual waste treated by MBT, the Refuse Derived Fuel (RDF) sent to energy recovery and the organic fraction of MBT sent to Anaerobic Digestion to exceed Landfill Directive targets.

- Exceeds Landfill Directive targets

Option 10

As option 4, with fixed third party contract for 100,000 tonnes of EfW, and 60,000-90,000 tonnes local bio-stabilising MBT, with RDF sent to energy recovery.

- 10a Assumes EfW and RDF sent to third party markets out of county

- 10b assumes RDF is treated in county in an industrial boiler with a CHP unit.
EfW still out of County

2. Impact Assessment

1. Impact Assessment Expressed as
 - *Global Warming Impacts CO2 equivalent*
 - *Air Acidification SO2 equivalent*
 - *Photochemical Oxidation Formation Ethylene equivalent*
 - *Eutrophication PO4 equivalent*
 - *Natural Resource Depletion Year-1*
 - *Dioxins n/a*

2. The Mass Flow Model removes materials from the waste stream based on the performance of collection and treatment systems and materials targeted. The model therefore provides complete compositional data for the mass of material entering any given facility.

3. WISARD was launched by the Environment Agency 1999 and consequently the tool only has options for those technologies that were currently employed at the time. These include a range of landfills, Material Recycling Facilities (MRF), windrow and enclosed composting operations (although these are limited), Anaerobic Digestion (AD) operations and a range of mass burn incinerators. The user can adapt these base options to better represent the technologies to be used in the model. However, WISARD does not include a Mechanical/Biological Treatment (MBT) option. In order to represent the MBT technology within WISARD the system was broken down into four constituent processes:
 - MBT Recycle
 - MBT Compost
 - MBT RDF
 - MBT Residue.

4. Material specific tonnages entering the MBT processes were determined by the Mass Flow Model. Tonnages were allocated to the four constituent processes based on currently available performance data No actual composting phase is to take place in the MBT plant. However there is a need to represent the moisture loss

occurring in the MBT plant and also the physical construction/operation of the plant. It was considered this could be represented best in the form of a user defined enclosed composting operation with the compost outputs set to zero.

5. All MBT recycling is processed through a “Ghost MRF” (all reference data for construction, operation and demolition set to zero) so only the recycling activities are considered. In this way the burdens association with construction, operation and demolition are eliminated. All MBT Residue is sent direct to landfill.

6. The RDF has two possible out-lets, a purpose built RDF combustion facility, or as a substitute fuel in an industrial process. This BPEO assessment has considered both. In Option 3 the RDF has been used as a replacement fuel in an industrial process. For both these options a user defined “incinerator” has been created.

7. In the case of the substitute fuel option (Option 3, and Option 9), construction and decommissioning values are set to zero (the RDF is sent to existing plant). It has been assumed that the RDF is utilised as a replacement fuel in an industrial process and not as a replacement fuel in electricity generation. The energy generation outputs have been altered to produce steam at 10 bar and 350oC, with a boiler efficiency of 80%. The off-set fuel has been assumed to comprise 50% gas and 50% oil. The tonnage of gas cleansing residues was reduced proportionally with respect to the inputs.

8. The waste input tab for both Option 3 and Option 3a has been amended to represent the feedstock of the RDF. In this manner the MBT process has been represented. Whilst it is recognised that this is not ideal and that there have been some gross assumptions made, it does allow the comparison of scenarios that otherwise would not have been possible within WISARD. The reader should also recognise that the technologies within WISARD also make assumptions and, whilst the comparisons cannot be regarded as absolute, the use of this methodology allows an indicative assessment of the relative merits of each option to be made.

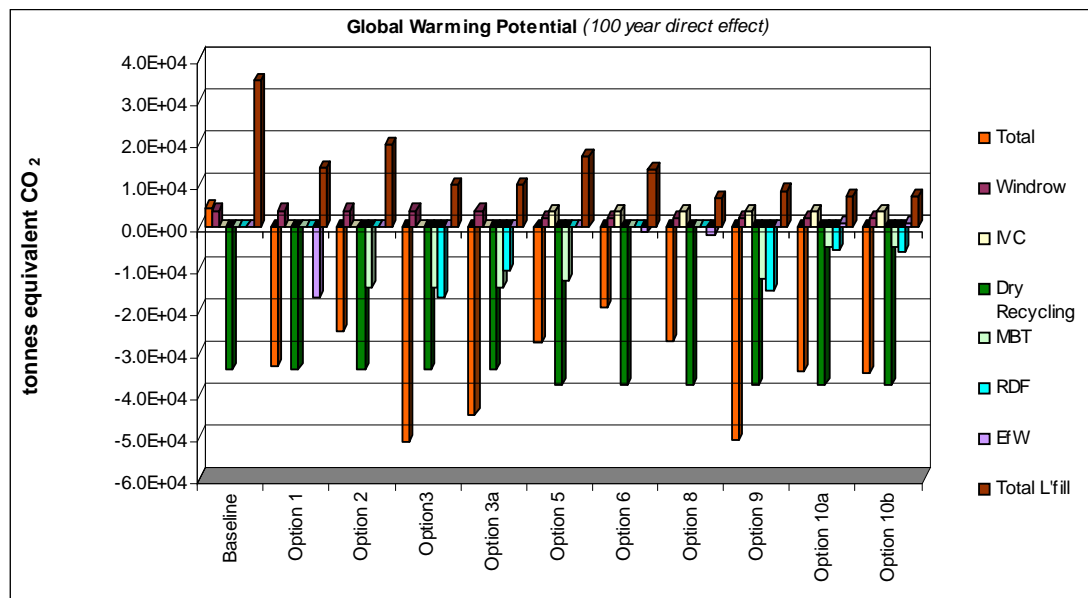
9. In the assessments that follow any measurements above the zero line means that there have been emissions. These emissions are responsible for the impacts. Any measurements below the zero line represent avoided emissions. These avoided emissions will reduce the magnitude of the impact.

2.1 Global Warming Impacts

1. The global warming potential of a waste management system is dominated by the generation of carbon dioxide and methane emissions. Methane is a much more potent greenhouse gas compared to carbon dioxide and consequently is a significant consideration in waste management options (in general terms, landfill gas comprises between 40-65% methane). Thus, the global warming potential of each scenario is linked to the methane emissions, which are dependant upon the amount of biodegradable municipal waste (BMW) disposed of to landfill.

2.1.1 Global Warming Potential

Table 1: Global Warming Potential



2. Only the Baseline scenario (which relies heavily on landfilling residual waste) illustrates a net global warming burden; methane generated by biological waste degradation within the landfill acts as a potent greenhouse gas. The MBT output that is sent to landfill in Options 2, 3, 5, 9 and 10 also generates large amounts of greenhouse gases. The recycling activities taking place in all options result in a significant avoided burden.

3. The composting of kerbside collected biodegradable waste has net emissions of global warming gases due as the aerobic degradation of organic material generates carbon dioxide. However, since BMW releases the more potent greenhouse gas methane when it is disposed in landfill sites, the net global warming burden modelled is lower for composting activities than landfilling.

4. The thermal treatment processes have both positive and negative effects upon the global warming burden. Carbon dioxide is generated through the direct combustion of waste. However emissions of carbon dioxide are off-set through the avoidance of fossil fuel combustion for electricity production. In Options 1, 6 and 8, the off-set emissions are greater than those generated through direct EfW combustion, generating a net avoided global warming burden. In Options 10a and 10b the emissions arising from the transportation to a third party EfW facility outside the county offset most of the benefits. However the total impact is still positive.

5. Similarly where RDF produced by MBT was used as a replacement fuel in an industrial process to generate steam (Options 3, 3a, 9, 10a and b), a net avoided global warming burden was found. The avoided burden was generally greater for RDF energy recovery than EfW since the comparative efficiencies for steam production are much higher. This means that the tonnage of waste used to generate steam offsets a greater tonnage of fossil fuels than the tonnage of waste used to generate electricity.

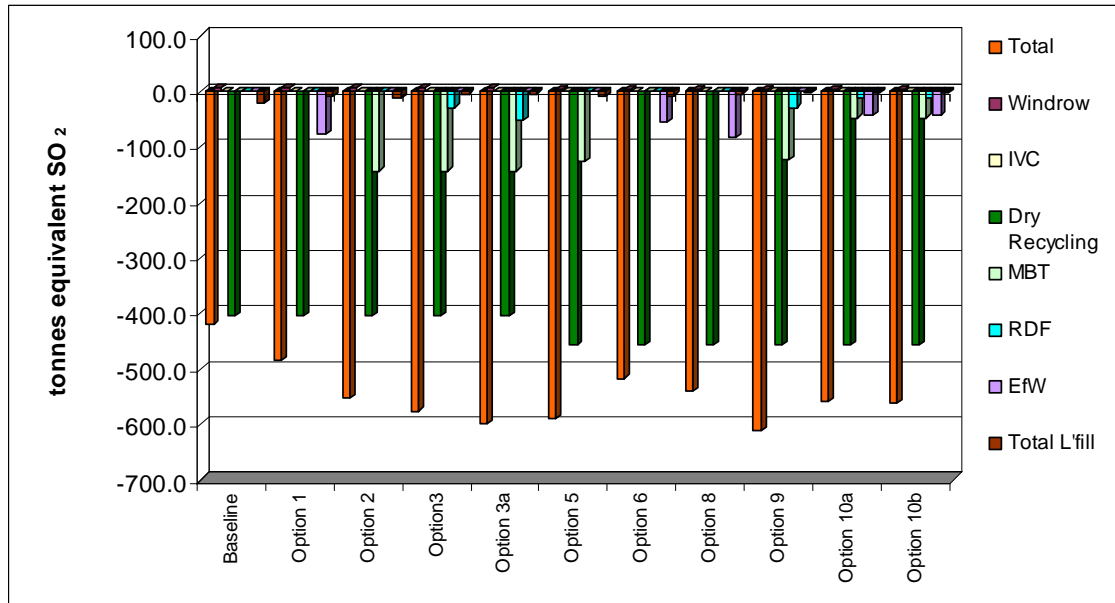
6. Options 3 and 9 have the greatest net avoided global warming burden. The better performance of these options can be linked to their sending MBT produced RDF to energy recovery with steam utilisation, and limited reliance on landfill.

2.2 Air Acidification Impacts

1. The principal gases that contribute to acidification include: sulphur dioxide (SO₂), nitrogen oxides (NO_x), hydrogen chloride (HCl) and hydrogen fluoride (HF). Where the global warming potentials indicate global warming effects as CO₂ equivalents, the acidification potential indicates acidification effects as SO₂ equivalents. In WISARD the acidification potentials have also been calculated assuming that where there is a net energy recovery, emissions have been offset against the avoided acid gases generated from the coal fired power stations. All recycling and recovery operations have a beneficial impact on the emission of gases that cause air acidification. It is the cumulative effects of recycling, composting and energy recovery activities that result in the greatest avoided burdens.

2.2.1 Air Acidification potential

Table 2: Air Acidification Potential



2. The baseline represents the status quo at the start of the contract (2005/06), and it is against this performance that the other options are judged. All the options offer an improvement from the baseline position. The largest contributions to the reduction of gases that cause acidification are from recycling activities. The MBT plants have a varying performance and this is dependant on the tonnage throughput and the additional recycling that is performed. Options 3, 5 and 9, which use MBT/AD to treat a large proportion of the waste have marginally the greatest total avoided acidification, being improved with the use of RDF. The other options which maximise dry recyclables and composting are generally comparable

3. It should be noted that the benefits of the reduced air acidification would be realised across the UK and Europe (reduction in the emissions from power stations or industrial plant), whereas the increased emissions related to collection and the MBT processes may be evident at a local level.

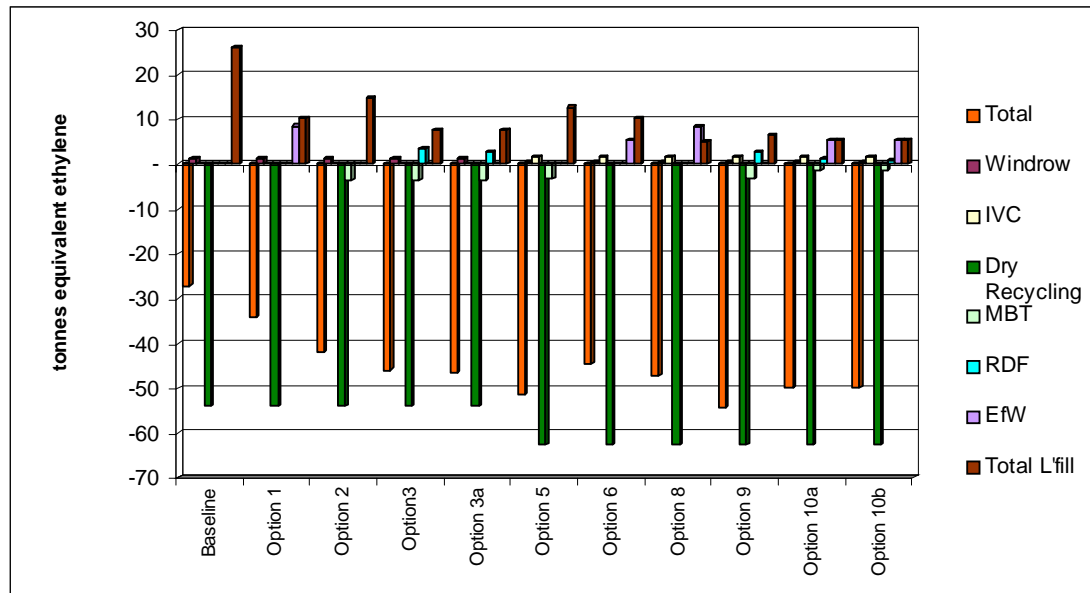
2.3 Low Level Ozone Formation

1. Ozone, occurring naturally in the upper atmosphere (the “ozone layer”), is a pollutant at ground level. Ground level ozone is harmful to health irritating the eyes and air passages causing breathing difficulties and may increase susceptibility to infection. Ozone is also toxic to some crops, vegetation and trees. Ground-level ozone is not emitted directly into the atmosphere, but is a secondary pollutant

produced by reactions between nitrogen dioxide (NO₂), hydrocarbons, volatile organic compounds (VOC's) methane and sunlight. Once formed, ozone can remain in the atmosphere for many days and is often transported over long distances.

2.3.1 Low level Ozone Formation Potential

Table 3: Low Level Ozone Formation Potential



2. All options lead to avoided burdens. Recycling is the principal activity which reduces the emissions of the trigger gases in low level ozone formation. Thermal treatment has an associated off-set burden through the production of energy. Thermal treatments in Option 3 and Option 9 have the better performance.

3. The MBT impact associated with the MBT activities arises from assumed emissions of VOCs during the composting phase of the operation. As discussed in the introduction to this section, WISARD does not have an MBT technology. Future MBT operations are likely to require such emissions eliminated as far as possible through operation under a slight negative pressure with internal air passing through a bio-filter prior to release to the atmosphere.

4. The best performing option is Option 9.

2.4 Eutrophication

1. Eutrophication is a natural process, occurring where there is an increase of mineral and organic nutrients in a water body (principally nitrogen and phosphorous). The enrichment promotes both plant growth and microbial activity which, providing an unlimited nutrient supply, eventually results in the de-oxygenation of the water body. De-oxygenation of a water body results in fish kills and an alteration to the ecology of the system.

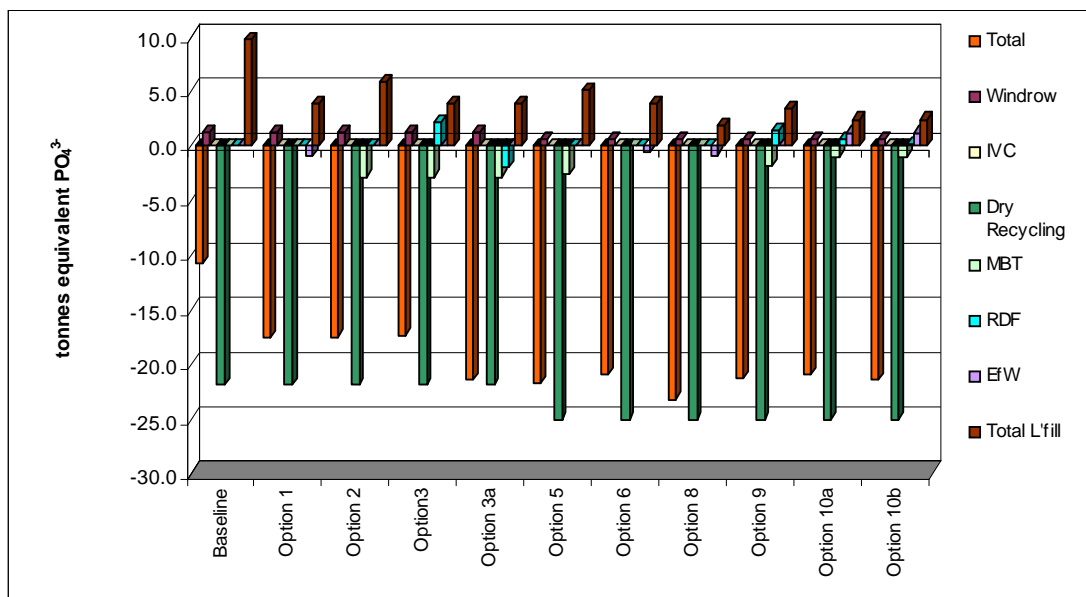
2. As anthropogenic activities increase the nutrient loading to surface waters (though direct discharges: sewage effluent, industrial discharges and indirect discharges: atmospheric deposition (wet), fertiliser run-off) so the occurrences and magnitude of this natural process escalates. Costs are not confined to the eco-system, but arise from loss of amenity value, damage to commercial fishing, increased costs for water treatment and additional costs required to manage the systems.

3. Leachate from landfills has high mineral and organic content which in turn makes a high demand on the oxygen content of waters. All landfills produce leachate and this liquor will at some stage “leach” from the landfill. Strict engineering and monitoring measures are designed to minimise such leaching, but cannot eliminate it altogether. Thus there is scope for leachate to enter water courses.

4. Nitrogen oxides are released from combustion processes into the atmosphere. These gases can be “scavenged” from the atmosphere as rain drops develop and fall; increasing the concentration of nutrients in a water body.

2.4.1 Eutrophication Potential

Table 4: Eutrophication Potential



5. Although measured in tonnes equivalent phosphates (PO₄³⁻) it is the discharges of nitrogen oxides (NO_x) and ammonia (NH₃) that create the impacts. Table 4 illustrates that all Options have activities generating emissions which increase the loading of nutrients to water bodies. With regard to landfill the impacts are a function of ammonia discharges, for most other activities (recycling, combustion) the impacts are a function of nitrogen dioxide emissions.

6. All recycling activities produce an avoided burden; off-set nitrogen oxide emissions associated with the avoidance of manufacturing metal, glass and paper. The EfW/ RDF generate emissions of NO_x through direct combustion, but at the same time offset emissions of NO_x through the avoidance of coal combustion. As explained in the “Global Warming Potential” indicator text, the use of RDF in an industrial process replaces a greater amount of coal than if it was used in an electricity generating process. Thus RDF combustion in Option 3 and Option 9 have a net benefit, whilst in Options 1, 3a, 6 and 8 there are net emissions of gases which cause eutrophication.

7. Options 3 and 8 both illustrate a net avoided burden, although the margin is small in both cases. All other options have negative effects in relation to eutrophication, however all options illustrate an improvement on the base case.

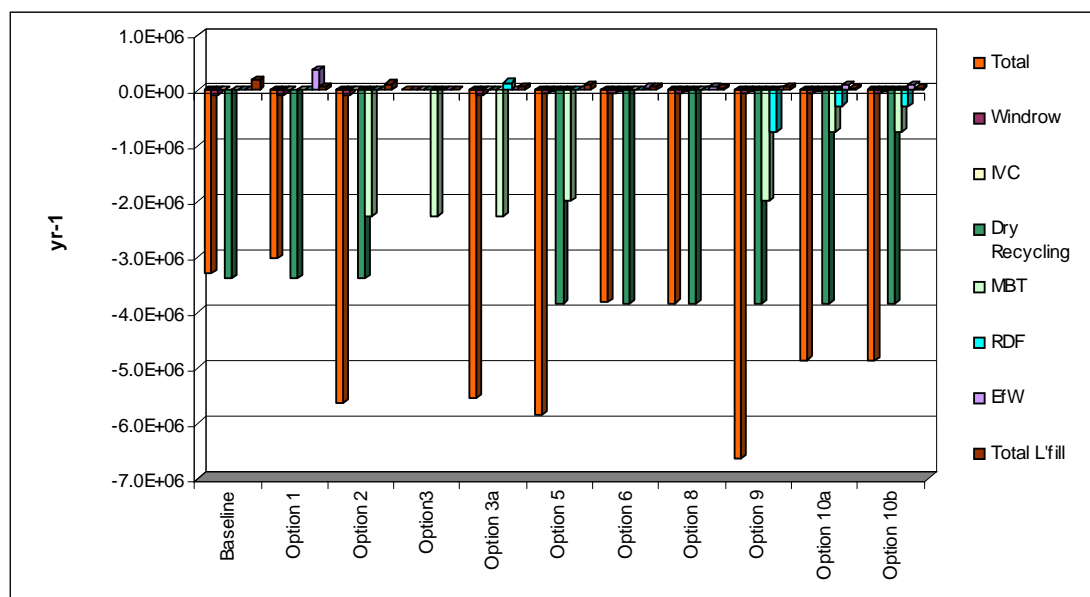
2.5 Depletion of non-renewable resources.

1. Our world has a finite supply of resources in terms of minerals and fossil fuels. The rate at which these resources are consumed is important when assessing the sustainability of any activity. Recycling of metals and plastic preserves both the mineralogical value of the item, as well as its intrinsic energy content (i.e. the energy consumed in production of the material).

2. Although EfW/RDF facilities produce electricity and heat that is assumed would otherwise be generated from a fossil fuel, they also consume resources during construction, operation and decommissioning. The use of RDF as a replacement fuel, however, does not require the construction of any additional facilities and the consequent consumption of resources. As Options 3 and 9 have the combined conservation of resources from kerbside recycling, additional recycling at the MBT plant, and the use of the RDF they perform best in this indicator.

2.5.1 Depletion of Non-Renewable Resources

Table 5: Depletion of Non-Renewable Resources



3. Recycling demonstrates the largest avoided burden in all options.

2.6 Dioxins

1. The term “dioxin” generally refers to a both group of compounds called polychlorinated dibenzoparadioxins, a group of chemicals thought to be carcinogenic at low exposure levels.

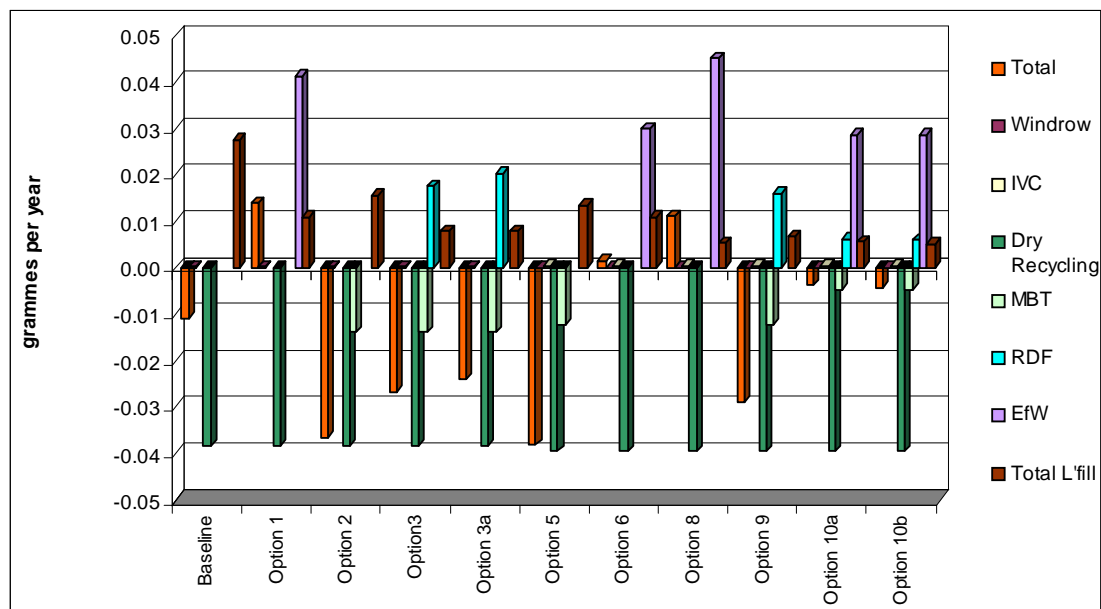
2. Dioxins are ubiquitous in the environment, and have been so for thousands of years. Their formation can arise from various industrial as well as natural activities, for example most combustion processes generate dioxins (power generation, forest fires). As well as being widespread in the environment dioxins are persistent and consequently remain in waste after collection and may be released in landfills or when combusted. Dioxins have been measured in compost, landfill gas and leachate, gases and residues from recycling, as well as the more commonly cited waste combustion gases and ashes.

3. The environmental impacts of dioxins are not so much dependant on the absolute emissions, but on the pathway to humans and the potential to cause harm to health. Dioxins released into the air from the combustion of waste can affect humans by absorption through the lungs or skin.

4. Additionally where dioxins are deposited onto vegetation and consumed by grazing animals the compounds accumulate in the animal's tissue and are passed onto human consumers, who in turn accumulate dioxins in the body.

2.6.1 Dioxin Emission

Table 6: Dioxin Emissions



5. The largest source of dioxin emissions is from combustion processes, thus those options which have an element of combustion in them (be it for power generation or as a fuel in an industrial process) will have associated dioxin

emissions. The largest emissions are generated from the combustion of the RDF.

6. Only Options 1, 6 and 8 have a net emission of dioxins to the environment, which can be attributed the proportion of waste that is sent to EfW facilities. The other Options generate a net avoided dioxin emission burden, which is enhanced by the MBT processes. The extent to which the other options cause an avoidance of dioxin emissions varies depending upon their reliance upon thermal processes. There is no difference between 10a and 10b as transport contribute a negligible amount of dioxins to the overall impacts

3. Summary

1. The following table provides a quick visual summary of the performance of each option against the impacts. Option 3, 3a and Option 9 have the better overall ratings. Options 10a, 10b and 5 also score highly, ranking in the top three for all criteria. The Baseline Option has the lowest overall ranking.

Joint Municipal Waste Management Strategy

Table 7: Summary of the Environmental Impact Assessment for the Wiltshire Waste Management Options

Indicator	Baseline	Option 1	Option 2	Option 3	Option 3a	Option 5	Option 6	Option 8	Option 9	Option 10a	Option 10b
Global Warming	*	✓	✓	✓✓✓	✓✓✓	✓✓	✓	✓	✓✓✓	✓✓	✓✓
Air Acidification	✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓✓	✓✓	✓✓
Low level Ozone Formation	✓	✓	✓✓	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓	✓✓
Eutrophication	✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓	✓✓
Depletion of Non-Renewable Resources	✓	✓	✓✓	-	✓✓	✓✓	✓	✓	✓✓	✓✓	✓✓
Dioxins and Furans	✓	*	✓✓	✓	✓	✓✓	*	*	✓✓	✓	✓

Key: - no significant change
 ✓ net benefit with respect to indicator
 * increased loading with respect to indicator.