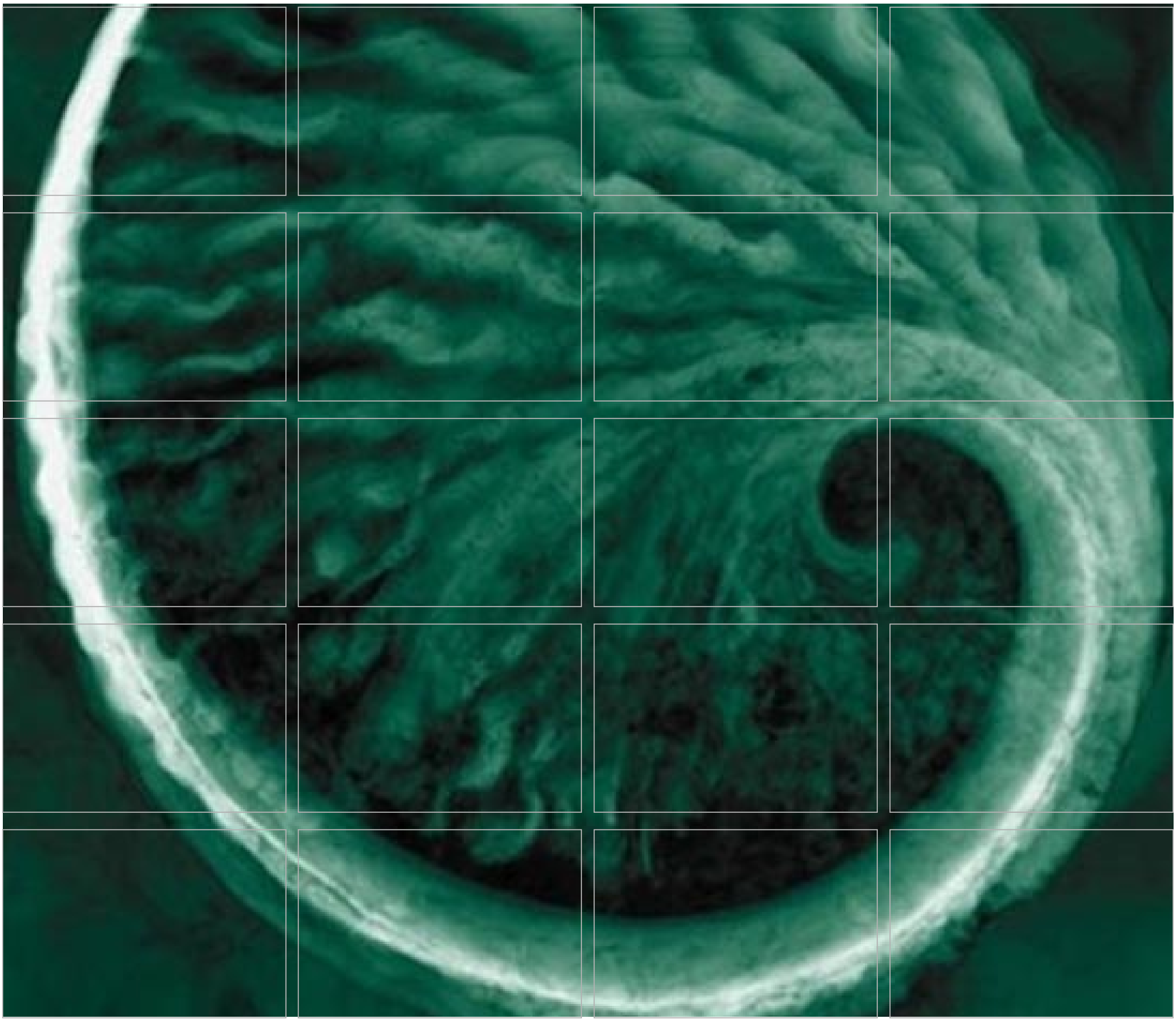

Assessment of the Best Practicable Environmental Option for Waste Management in Northern Ireland: Development and Analysis

Final Report

June 2005

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Assessment of the Best Practicable Environmental Option for Waste Management in Northern Ireland: Development and Analysis

Final Report

June 2005

Reference 0007213

Prepared by: Simon Gandy

Environmental Resources Management

Approved by: Simon Aumônier

Signed:

Position: Partner

Date: 22nd June 2005

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ANNEXES

1 *EXECUTIVE SUMMARY*

This report outlines the process and the results of an assessment of the Best Practicable Environmental Option (BPEO [1]) for the management of MSW, C&I and CD&E wastes in Northern Ireland up to 2020.

The Northern Ireland Department of the Environment and a BPEO Steering Group initially identified eight scenarios for the management of MSW, five for C&I waste and three for CD&E waste. These were assessed using a combination of quantitative and qualitative approaches, including a BPEO workshop in October 2004.

Feedback from that workshop led to the development of eight new MSW scenarios, building on the best aspects of the original eight, and seven C&I waste scenarios. Assessment of these scenarios, using the criteria and methodologies developed previously, culminated in the identification of the BPEO for each of the three waste streams:

- For MSW, the BPEO envisages recycling and composting growing to stretching but achievable levels (35%, 40% and 45% by 2010, 2013 and 2020 respectively), new facilities (MBT and AD early on, and thermal treatment later) being commissioned to deal with the residual waste, and diminishing levels (50%, 40% and 25% in the same years) going direct to landfill.

- Similar technologies are used for the C&I waste BPEO, with recycling rising to 60% by 2020, and a mixture of MBT, AD and thermal treatment diverting all but 12.5% of the residual C&I waste away from landfill.

- For CD&E waste, the differences between the scenarios were limited to the levels of reuse and recycling that might be achieved, and the BPEO was shown to be the most stretching of the scenarios, aiming for 75% reuse and recycling by 2020.

- For the MSW and C&I waste BPEOs, indicative networks of facilities were identified, based on likely plant capacities and the distributions of arisings, and the waste streams were integrated, to produce an overall BPEO.

The results of this study are to be interpreted as guidance to the sub-regional waste groups, as they prepare to revise their WMPs. Sub-regional WMPs should include a technical assessment, to translate this regional framework into a more refined and detailed implementation plan at the sub-regional level.

(1) A glossary of abbreviations is provided in *Section 8*.

2 BACKGROUND AND DESCRIPTION OF PROCESS FOLLOWED

2.1.1 Background

In their response to the consultation on the *Northern Ireland Waste Management Strategy* (1) (NIWMS), in March 2003, the District Councils requested greater guidance in developing their Waste Management Plans (WMPs) from the Northern Ireland Department of the Environment (DOENI – henceforth the Department). In addition, when the three sub-regional WMPs were reviewed (August 2003), differences in their scopes and methodologies made it difficult to integrate their information into one Best Practicable Environmental Option (BPEO) assessment. Furthermore, the Planning Policy Statement on Waste Management (PPS11) requires the use of BPEO analysis in selecting the best approach for waste management facilities. The Department's response to this situation was to prepare this NI-wide BPEO assessment.

2.1.2 BPEO

A full introduction to the process of determining BPEO can be found in the Department's *Decision Makers' Guide* (2), which outlines the BPEO process in ten steps. In summary, and in this context, the BPEO process involves identifying a number of viable scenarios for waste management in Northern Ireland, followed by assessing their performance against a number of decision criteria (such as environment, feasibility and cost), in order to determine which scenario is the BPEO.

2.1.3 Objectives

The scope and objectives of the study were:

- to identify an integrated network of waste management facilities for Northern Ireland which is BPEO and which meets the requirements of the Landfill Directive;
- to consider municipal, commercial & industrial and construction, demolition & excavation wastes;
- to identify broad numbers, capacities and locations for infrastructure;
- to provide direction and guidance for the three Waste Groups to review their WMPs; and
- to facilitate progress on infrastructure procurement and land use planning.

(1) http://www.ehsni.gov.uk/pubs/publications/NIWMS.pdf [21May04 @ 14:06]
(2) http://www.ehsni.gov.uk/pubs/publications/NI_BPEO_Guidance.pdf [26Apr05 @ 11:23]

A number of issues were determined to be specifically outside the scope of the NI-wide BPEO, as follows:

- Agricultural waste. A separate agricultural waste strategy will be prepared once the regulations have been established which will define what agricultural wastes will be classed as controlled waste.

- Hazardous waste and other priority waste streams. These are generally small volume compared to the major waste streams and require specific solutions, including separate BPEO studies if required (eg asbestos BPEO, March 2004).

- Precise capacities and specific locations. Decisions on these require consideration of specific local issues which it is not possible to address at the NI wide level.

- Unproven technologies. It was agreed that the BPEO must be based on technologies which have been proven for similar wastes at a commercial scale in other developed countries.

2.1.4 Process

Stakeholder engagement has been an important part of the BPEO development process. Work on the NI-wide BPEO has included discussions at a workshop in August 2003, a presentation at the Northern Ireland Local Government Association (NILGA) in November 2003 and workshops with each of the three waste planning groups in March 2004. After these workshops, it became apparent that a Steering Group would be desirable, to help guide some of the key steps in the BPEO process. The NI-wide BPEO Steering Group (see *Box 2.1*) met four times between May and December 2004, to review progress and contribute to the participatory approach.

In October 2004, elected representatives and officers from all 26 District Councils across Northern Ireland were invited to a BPEO workshop at Cookstown, to hear progress on the study and to provide opinions on the more subjective and qualitative aspects of the analysis. Following that workshop, a round of sensitivity analysis and optimisation was performed, with further input from the steering group, culminating in the identification of the NI-wide BPEO. The BPEO for MSW was presented at a conference at Galgorm for representatives of all 26 District Councils in January 2005, followed by an interim report in February 2005, with requests for any comments.

2.1.5 Output

The BPEO identifies which mix of technologies is most highly rated for waste management in NI up to 2020, based upon currently available information and assumptions. The underlying modelling has also generated a network of *indicative* locations for the required facilities. *Annex F* explains the methodology used to generate these areas of search. It is emphasised that the results are based on a limited analysis that focuses on minimising transportation distances. The sub-regional assessments are the more appropriate level for considering locations, to take into account local factors not considered at the NI level.

Box 2.1 *Members of the Steering Group*

Michael Bell	NIFDA
John Briggs	SWaMP
Ricky Burnett	arc21
Graham Byrne	SWaMP
Pat Corker	EHS
George Coulter	ACE Representative
Bryan Dane	Invest NI
Simon Gandy	ERM (EHS Consultants)
Ian Henry	CEF Representative
Eugene Kelly	EHS
John Kelpie	NWRWMG
Brian Lewis	Bombardier/CBI Representative
Martin Maguire	Belfast Chamber of Trade
Jim McCorry	SWaMP
Sinead McGlinchey	Planning Service
John Michael	NWRWMG
Ian Morrow	NI Chamber of Commerce & Industry
Jill Murphy	KMM (EHS Consultants)
Neil Patton	Patton Group/CEF Representative
Geraldine Quinn	Federation of Small Business
John Quinn	arc21
Mervyn Rea	arc21
Noel Scott	Planning Service
Victor Wallace	NWRWMG
Anderson Weir	CEF representative

2.1.6 *Proposed Changes to the Decision Making Process in England*

The Department is aware of the recently proposed changes to the decision making principles outlined in *Waste Strategy 2000* [(1)]. Defra's aim is to move away from the process of BPEO and towards a less prescriptive method of assessment that, nonetheless, incorporates the same decision-making principles.

Defra has concluded that the principles behind BPEO remain valid and any new decision-making process should encapsulate its key principles, as follows:

- in taking decisions there should be consideration of alternative options;
- engagement with the community and key stakeholders should be an important and integral part of the decision making process;

(1) Changes to Waste Management Decision Making Principles in Waste Strategy 2000. Department for Environment, Food & Rural Affairs. December 2004.

- the environmental impacts for possible options should be assessed looking at both long term and short term; and

- decisions should seek the best environmental option taking account of what is feasible and what is an acceptable cost.

The Department has ensured that this NI BPEO complements the approaches followed in the other parts of the UK, and the SEA framework. BPEO has been retained as a decision making tool; the NI-wide BPEO is a non-statutory framework which supports policy principles in the NIWMS and will guide development of sub-regional WMPs.

3 MSW BPEO

3.1 BASELINE DATA

In order to generate the scenarios, it is necessary to make some baseline assumptions about the nature of MSW arisings in Northern Ireland. Baseline data available from the 2003 Key Performance Indicator (KPI) reports of the District Councils are presented in *Table 3.1*.

Table 3.1 Fate of MSW Arisings in 2003

Waste Fate	Tonnage	%
Recycled	73 391 tonnes	7.15%
Composted	51 771 tonnes	5.04%
Landfilled	901 517 tonnes	87.81%
Total Arisings	**1 026 679 tonnes**	**100.00%**

The three waste management groups have made different predictions about the rate at which waste arisings will increase in the future. For the purposes of this study, it was agreed by the BPEO Steering Group to assume that waste will grow at 2.4% per annum. This implies that, by 2020, MSW arisings will have reached 1 526 505 tonnes.

The composition of the waste and its biodegradability are another two key factors in the BPEO model. The MSW composition presented in *Table 3.2* is derived from three separate sources, for household waste (from the 2000 NI Survey), commercial waste (from the C&I waste BPEO study – see *Section 4.1*) and civic amenity site waste (from studies at Lisburn and Castlereagh). These were combined according to the fractions that each stream contributed to the total arisings on the KPI sheets.

Table 3.2 MSW Composition and Biodegradability

	MSW	Biodegradability	
Component	**Fraction**	**Component**	**Total**
Paper/Card	16.9%	100%	16.9%
Putrescible	43.5%	100%	43.5%
Textiles	1.4%	50%	0.7%
Fines	8.5%	50%	4.3%
Misc. Combustible	8.1%	50%	4.1%
Misc. Non-Combustible	3.2%	50%	1.6%
Ferrous Metals	2.7%	0%	0.0%
Non-Ferrous Metals	0.7%	0%	0.0%
Glass	6.5%	0%	0.0%
Plastic Dense	4.9%	0%	0.0%
Plastic Film	3.6%	0%	0.0%
Total	**100.0%**		**71.0%**

The biodegradability figures are consistent with the NI landfill allowances legislation, and show that the total biodegradability of MSW is 71%.

3.2 INITIAL SET OF SCENARIOS

This section describes the initial set of MSW scenarios that were assessed in the BPEO study. A brief description is given of each scenario, together with a reference to its schematic diagram in *Annex C*. In due course, this initial set of scenarios was screened and refined to produce a final set (see *Section 3.5*), as part of the iterative process to identify the BPEO.

3.2.1 *Scenario 1 – Current Situation (Figure C2.1)*

- This scenario represented a continuation of the current situation. There was 1% annual growth in recycling and composting and the addition of a 50 000 te anaerobic digestion (AD) plant, to take account of arc21's planned waste management infrastructure. However, by 2020, over one million tonnes (65%) of waste would still be landfilled.

- This scenario was included to provide a baseline against which to judge the other scenarios (relative cost, etc). It would not be practicable because it does not meet the Landfill Directive targets.

3.2.2 *Scenario 2 – High Recycling and Composting (Figure C2.2)*

- This scenario envisaged very high recycling and composting rates, taking whatever action was necessary to meet the Landfill Directive targets. By 2020, only 20% of waste would be landfilled, while the combined level of recycling and composting was 77%. Over 590 000 te of material would be recycled, while in-vessel composting (IVC) would account for 514 000 te, requiring ten plants each with a capacity of 55 000 te.

- The key issues to consider with this scenario were the feasibility of very high recycling rates (ie whether the waste composition would enable such high recycling and composting to be achieved), markets for recyclables and costs relative to other scenarios.

3.2.3 *Scenario 3 – Mechanical Biological Treatment (Figure C2.3)*

- This scenario used mechanical biological treatment (MBT) plants to reduce the amount of waste going to landfill, to meet Landfill Directive targets. By 2020, four large plants (180 000 te capacity) would treat a total of 625 000 te or 40% of all MSW. Recycling and composting would also make a significant contribution accounting for 45% of waste arisings (695 000 te).

- A key issue for this scenario was that one of the main outputs from MBT is refuse-derived fuel (RDF), which can be used as a replacement for coal, for example, in power stations or cement kilns. However, if there is no market for the RDF, the material may have to be landfilled and this would result in failure to meet the Landfill Directive targets. Use of RDF is also perceived by some people as another form of waste incineration.

3.2.4 *Scenario 4 – Anaerobic Digestion (Figure C2.4)*

- This scenario was similar to the previous scenario, but AD was used instead of MBT to reduce the amount of waste going to landfill. By 2020, 35% of waste would be treated by this method (~540 000 te), with recycling/composting again accounting for 45% of waste.

- A key issue for this scenario was the potential market for the liquid digestate produced by the process. Technical/practical feasibility of operating full scale plants also had to be considered, given the lack of proven large-scale experience of this technology with MSW in the UK.

3.2.5 *Scenario 5a – Thermal Treatment with AD (Figure C2.5)*

- This scenario focused on thermal treatment in the form of incineration to deal with about 20% of MSW (330 000 te), with three plants, one in each Waste Group. It was assumed the plants would also take some commercial/industrial and possibly agricultural wastes, so actual capacities would be in the range 150,000-200 000 te. It was assumed that a thermal treatment plant would not be fully available by 2013, so AD was used to help meet the Landfill Directive target for 2010. As with scenarios 3 and 4, recycling/composting accounted for 45% of MSW by 2020.

- The key issues for this scenario were public acceptability and perceptions of health and environmental impacts. Waste incineration does not currently qualify for financial support as renewable energy, while AD and advanced thermal technologies would qualify.

3.2.6 *Scenario 5b – Gasification (Figure C2.6)*

- This scenario was the same as 5a, except that an advanced thermal treatment process (eg gasification or pyrolysis) replaced incineration. The scenario was based on the gasification process.

- The key issue for this scenario was technical/practical feasibility, as there is little experience in the UK of full scale operating plants. Public perception of advanced thermal processes may be similar to incineration, although environmental modelling indicates they have a lower impact.

3.2.7 *Scenario 6 – Low Recycling and MBT (Figure C2.7)*

- This scenario assumed the amount of recycling and composting would stay around current levels, so that, as the amount of waste continued to grow, the level of recycling/composting would actually fall to 8% of total waste. MBT would be used as a 'one-stop solution' for household waste, processing around 69% of waste by 2020 (1,060 000 te). The scenario used six large plants, each with a capacity to process around 180 000 te per year.

- As with scenario 3, a viable market would be required for the RDF, otherwise the material would have to be landfilled, resulting in failure to meet Landfill Directive targets. This scenario was not consistent with sustainable development, and the aim to maximise the recovery of the valuable resources in waste.

3.2.8 *Scenario 7 – MBT and AD Hybrid Scenario (Figure C2.8)*

- This hybrid scenario used a combination of MBT (250 000 te) and AD (215 000 te) to account for the reduction in landfill, as well as maintaining high levels of recycling and composting - 55% by 2020.

- Hybrid scenarios may be regarded as more robust than reliance on a single technology to replace landfill. The strengths and weaknesses of the overall scenario reflect those of the various components.

3.2.9 *The Decision Criteria*

Four basic decision criteria were used in the assessment, each of which must be adequately addressed if the BPEO solution is to be sustainable:

- Environment
- Economic
- Social
- Feasibility

More detailed aspects were identified under each of these criteria (see *Annex A* for details), against which to judge the various options. The five environmental criteria were combined into a single score by setting their impacts in context within the Northern Ireland situation (see *Annex E*).

Some aspects of the BPEO assessment can be carried out using quantitative calculations and these were undertaken using specially designed models. Other aspects, notably feasibility and social issues, are more subjective and qualitative, and these were assessed by means of a BPEO workshop (see *Section 3.4*). Where possible, data were generated to inform this process.

Another key issue was to judge the relative importance of the four decision criteria and this is described in more detail in *Section 3.4.1*.

3.3 *Scenario Analysis and Results*

Each of the scenarios was assessed against the decision criteria, following the process outlined in *Annex A*. A brief description of the methodologies and the results is presented in *Table 3.3*. Some of the results of this analysis were used directly, whilst others were used to inform the decisions at the BPEO workshop.

Table 3.3 A Summary of the Decision Criteria for the NI-BPEO – Methodology of Assessment and Comments on the Results

Criteria	Methodology	Comments on Results
Resource Depletion	Data were extracted from WISARD [1], where available, or taken from supplier information. Account was taken of the impacts of the electricity and other resources used to power the facilities, their emissions, and the power generated, where applicable. Credit was also given for processes (such as recycling and energy production) that offset the use of virgin materials.	All scenarios showed significant net benefits to resource depletion, because of the resources and/or energy offset, and the results reflected the extent of those savings. Processes that used RDF to offset coal perform the best.
Acidification		All scenarios also showed large net benefits against acidification. The figures were dominated by the offsets from recycling materials, which is why scenarios 2 and 7 performed the best, and why scenarios 3, 4 and 5 performed similarly. Scenarios 1 and 6 performed relatively poorly on acidification.
Greenhouse Gas Emissions		Greenhouse gas emissions also all delivered net benefits to the environment from all the scenarios. Generally, the results followed the same pattern as for resource depletion. Scenario 6 was promoted up the order, because offsetting coal use is particularly favourable.
Water Impact Scores	The EA OPRA rating methodology [2] was used, though target scores and 'control and containment' were standardised, meaning that differentiation was based on facility number, type and size.	The OPRA scoring system gives impact scores per plant, so scenario 6, which had significantly fewer MRFs and composting facilities than all the others, was the clear favourite.
Average Landtake	Typical plant sizes for a given throughput (collated from previous studies) were used to assess the landtake required for each scenario in each year; those figures were then averaged, to give a final average landtake.	Scenarios involving landfilling and composting tended to fair poorly against this criterion, as these facilities took the largest amounts of land for a given waste capacity. This also explains why Scenario 6 performed the best.
Relative Costs	The cost figures included estimated collection and gate fees, the landfill tax escalator and £150/te fines in the three target years, if the BMW diversion targets were not met. All sums were based on current prices (no inflation or discounting), and did not include any capital costs or possible credits for generating renewable energy. As such, the figures should only be used for comparative purposes.	Scenario 6 performed very well in comparison with the others, because of the combination of low waste collection costs (separate collection for recycling and composting is expensive) and low landfill costs. Scenario 1 was hit by heavy landfill charges, whilst scenarios 2 and 7 suffered high waste collection costs.
Average Transport to Facilities	Broad locations (chosen from 34 towns and cities) were sought that minimised tonne-kilometres of transportation required to transport waste to facilities. The figures calculated were the average tonne-kilometres per year over the period to 2020.	Scenarios 1 and 2 performed well, because larger numbers of plant mean that distances are reduced. All alternative scenarios involved the development of a smaller number of centralised treatment plants of varying types, so together performed less well.

(1) WISARD (Waste - Integrated Systems Assessment for Recovery and Disposal) is the Environment Agency's approved life cycle assessment tool

(2) http://www.environment-agency.gov.uk/commondata/105385/wasteriskinspectv3_133720.pdf [20Aug04 @ 17:09] p14-15

Criteria	Methodology	Comments on Results
Relative Transport from Facilities	Scenarios were assessed according to the amount of material generated for recycling and recovery, combined with a simple assessment of the likely relative distances that the materials would be sent (local for compost wastes, further a field for the others).	Scenario 1 again performed well, as most of the waste went straight to landfill and required no onward transportation. All scenarios involving MBT performed poorly, because of the large amount of material that has to be transported onwards after the MBT plant.
Human Health Impact Scores	Data from the recent Defra Health Effects report [(1)] and the WHO Global Burden of Disease report [(2)] were combined to assess the relative risks of different technologies.	In general, scenarios that involve thermal treatment, either of waste or RDF, tended to score less well for this criterion. In contrast, scenarios with large amounts of recycling, composting and anaerobic digestion performed well.
Average Employment	Data from previous studies on typical numbers of skilled and unskilled workers, based on number, type and size of plant, were used to calculate the number of jobs required to treat the waste in each year. Employment associated with waste collection was not included, on the basis that this would be similar, regardless of scenario, and depends critically on the details of the collection regimes, which were outside the scope of this study.	Data suggest that the more labour-intensive technologies are recycling and composting, so the two scenarios with the lowest levels of these technologies (1 and 6) performed least well. Of the other technologies, MBT was also judged labour-intensive, so scenarios 3 and 7 performed better than the others.
Relative Risk of Accidents	A very simple assessment was performed, assessing technologies according to the amounts of manual handling and mechanical equipment used. These ratings were then scaled by the volumes of waste handled by technology.	MRFs and MBT plants were rated most likely to suffer accidents, and the results showed that the scenarios' performances reflected this, with scenario 1 performing the best, and scenario 6 the worst.
Relative Producer Responsibility	This criterion gave credit according to the amount of materials that would be recycled or composted, since it was assumed that the producer would be required to source-separate these materials.	Scenarios 1 and 6, with their low levels of recycling and composting, performed poorly for producer responsibility, especially compared to scenarios 2 and 7, which had high levels of these technologies.
Relative Markets for Products	Each technology was judged for the maturity of the market for its products, based upon the amount of material that would be produced. This was a highly subjective assessment, but provided some indication of the likelihood of finding markets for the products of the scenarios.	Clearly, scenario 1 was the most likely to succeed against this criterion, as it represented business as usual. Scenarios that relied on MBT products being substituted for coal were rated poorly, given the particular lack of development of this market.
Compliance with Policies	Each scenario was assessed for its compliance with the Landfill Directive, the NIWMS recycling and composting targets, and the proximity principle (in terms of how many plants would be required).	Scenario 7 over-delivered in terms of all three policies, so was most highly rated. Scenario 2 exceeded two of the three policies, and scenarios 3, 5a and 5b all exceeded the Landfill Directive, so they were next most highly rated. At the other end of the scale, scenario 1 failed all policies, and scenario 6 failed one or more policies.

The other decision criteria (local amenity, social implications and equity, public acceptability, practical and technical feasibility and flexibility) were determined on the basis of stakeholder opinion at the BPEO workshop.

(1) http://www.defra.gov.uk/environment/waste/health-effects/index.htm [01Jun04 @ 15:13]

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

3.3.1 Scenario Screening

The BPEO process includes a step to screen out impractical options before a more detailed assessment is undertaken. The Steering Group identified three scenarios to screen out at this point. This was presented at the BPEO workshop with council representatives in October 2004. The reasons for eliminating these scenarios are outlined below. In response to a request for further clarification on the screening of Scenario 2, a more detailed explanation is provided in *Annex D*.

Scenario 1 was included as a baseline and would not meet the targets. If the existing situation were to continue, Northern Ireland could be subject to fines from the start of the Landfill Allowances Scheme, which, on current projections, would increase to around £140 million per year by 2020. (For comparison, Northern Ireland councils currently spend about £100 million per year in total on waste management including collection and disposal.)

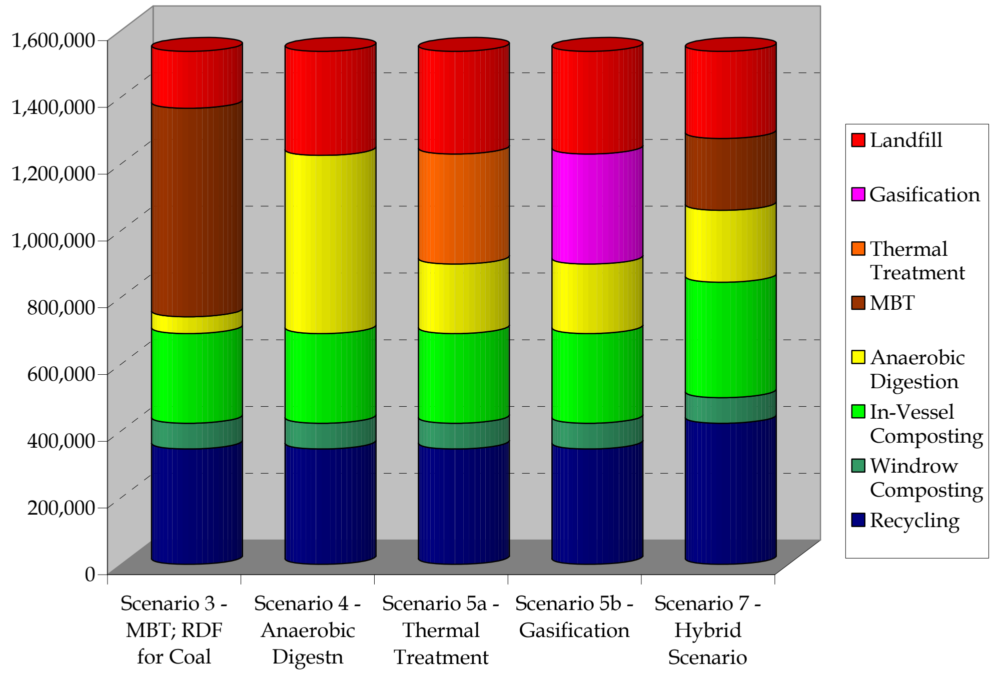
Scenario 2 requires unprecedented recycling and composting levels of around 78%. An analysis of the NI waste composition suggests that there are insufficient recyclable materials to achieve this level (see *Annex D*).

Comparison with the best performing regions in Europe and America indicates that these currently achieve 60% recycling and composting, while urban areas may only achieve 20%, even with a full recycling service to all households. Based on Northern Ireland's population distribution and recycling performance to date, a level of around 45-50% is considered ambitious but realistic and achievable overall. This would be the minimum target across Northern Ireland. Individual councils may be able to achieve higher levels of recycling and composting, perhaps close to the 60% of the best performers, but with no other technology planned to meet any gap there is no contingency and an unacceptable risk that *Scenario 2* would not meet targets.

Although *Scenario 6* is the cheapest option, it was felt this scenario would not be environmentally or socially acceptable, due to the low recycling rates, which are contrary to the waste hierarchy. Furthermore, developing EU policy (the thematic strategy on the prevention and recycling of waste) suggests that new targets may be set for recycling and composting well above those envisaged in this scenario.

The scenarios illustrated in *Figure 3.1* were retained for more detailed assessment at the BPEO workshop. All are designed to meet EU Landfill Directive targets and are founded on high levels of recycling and composting, in the range 45% to 55%. Landfill is reduced to around 20% and the key issue for the BPEO is what technology or combination of technologies should be used to treat the 30-40% of residual waste that is not available or suitable for recycling.

Figure 3.1 *Levels of Technology Employed (tonnes) in Scenarios in 2020*



3.4 *THE BPEO WORKSHOP*

It is appropriate at this point to detail the process at the BPEO workshop in Cookstown in October 2004. Over 100 delegates, organised into groups of about ten sitting at eleven tables, were introduced to all the scenarios, and informed about the proposed screening. Delegates were content to drop scenarios 1 and 6, although there was some concern expressed about dropping scenario 2, as it was not clear to some delegates that it would not be possible to achieve the required levels of recycling and composting. Further clarification on the reasons for screening out scenario 2 is provided in *Annex D*.

Each table of delegates was then asked to assess the remaining scenarios against the social and feasibility decision criteria, taking into account, where available, the additional information provided from the desk-based analysis. This information is reproduced in *Table 3.6* to *Table 3.9*.

Each table scored each scenario on a scale of 1 (lowest) to 5 (highest) against each criterion. The totals for scenario and criteria are presented in *Table 3.4* (social impacts) and *Table 3.5* (feasibility).

Table 3.4 Summary of Social Ratings

	Scenario 3	Scenario 4	Scenario 5a	Scenario 5b	Scenario 7
Employment	35.5	33.5	34	34	34
Public Acceptability	36.5	39	21.5	21.5	40
Health Effects	35	42.5	19.5	22.5	39.5
Accidents	25	36	36	35	30
Public Responsibility	33	33	31	31	39.5
Local Amenity	30	35	32	32	34.5
Social Equity	30	30	30	30	31
Total	**225**	**249**	**204**	**206**	**248.5**

Table 3.5 Summary of Feasibility Ratings

	Scenario 3	Scenario 4	Scenario 5a	Scenario 5b	Scenario 7
Technical Feasibility	31	33	50.5	18.5	31.5
Practical Feasibility	30.5	32.5	33.5	26	32
Flexibility	33.5	31.5	34	30	43.5
Existing Facilities	28	27	26	26	30
Market for Products	19	27	42	37.5	22
Compliance with Policy	36.5	36.5	46.5	44	48
Total	**178.5**	**187.5**	**232.5**	**182**	**207**

3.4.1 Weighting of Decision Criteria

In the afternoon session, delegates were asked to assess the relative importance of the four main decision criteria: environment, cost, social and feasibility. The four sets of data are presented in *Table 3.10*, together with their normalised values. Normalisation simply puts the four criteria onto a single scale from 0% ('worst') to 100% ('best').

Table 3.6 *Summary of Environmental Results*

Scenario Description	Resource Depletion (†) te crude oil eq	Value	Acidification (†) te SO_2	Value	Greenhouse Emissions (†) te CO_2 eq	Value	Water Impact Scores -	Value	Average Landtake Hectares	Value
3 - MBT	5 131 791	100%	2 720 956	6%	7 276 268	100%	1780	55%	150	37%
4 - Anaerobic Digestion	3 485 421	0%	2 696 281	0%	3 652 048	0%	1723	91%	151	27%
5a - Thermal Treatment	4 488 827	61%	2 705 769	2%	5 939 738	63%	1720	93%	142	94%
5b - Gasification	4 570 783	66%	2 812 332	29%	6 764 998	86%	1708	100%	141	100%
7 - Hybrid Scenario	4 470 740	60%	3 094 475	100%	5 589 736	53%	1866	0%	155	0%

Table 3.7 *Summary of Financial Cost Results, and Transport Figures for Local Amenity Criterion*

Scenario Description	Relative Cost Cost: £M pa	Value	Average Transport to Facilities Million te-km pa	Value	Relative Transport from Facilities -	Value
3 - MBT	£132.00 M	100%	36.9	50%	20 427 413	0%
4 - Anaerobic Digestion	£137.85 M	43%	36.0	100%	13 104 659	100%
5a - Thermal Treatment	£133.99 M	81%	37.9	0%	14 477 795	81%
5b - Gasification	£135.29 M	68%	37.8	4%	13 238 869	98%
7 - Hybrid Scenario	£142.20 M	0%	37.2	35%	16 277 215	57%

Table 3.8 *Summary of Other Social Results*

Scenario Description	Health Impacts	Value	Average Employment S	U/S	Value	Relative Risk of Accidents -	Value	Relative Producer Responsibility -	Value
3 - MBT	0.314	0%	64	217	100%	77 255	0%	21 752 154	0%
4 - Anaerobic Digestion	0.102	100%	64	179	0%	59 490	100%	21 752 154	0%
5a - Thermal Treatment	0.293	10%	63	191	24%	59 490	100%	21 752 154	0%
5b - Gasification	0.140	82%	63	196	37%	59 490	100%	21 752 154	0%
7 - Hybrid Scenario	0.154	75%	66	211	100%	65 786	65%	24 656 227	100%

Table 3.9 *Summary of Feasibility Results*

Scenario Description	Relative Markets for Products -	Value	Compliance with Policy -	Value
3 - MBT	0.086	6%	Meets or Exceeds All	33%
4 - Anaerobic Digestion	0.151	100%	Meets All	0%
5a - Thermal Treatment	0.146	92%	Meets or Exceeds All	33%
5b - Gasification	0.146	92%	Meets or Exceeds All	33%
7 - Hybrid Scenario	0.082	0%	Exceeds All	100%

Key

(†) These results are all net *benefits*

Value: Relative score in range 100% (best) to 0% (worst)

Employment: S = Skilled; U/S = Unskilled

Table 3.10 ***Summary of Decision Criteria Assessments, and Normalisation***

	Criteria	Scenario 3	Scenario 4	Scenario 5a	Scenario 5b	Scenario 7
Raw Scores	Environmental (†)	2.01	1.92	2.04	2.21	2.40
	Financial (£/te)	£ 103.16	£ 107.73	£ 104.71	£ 105.73	£ 111.13
	Social	225	249	204	206	248.5
	Feasibility	178.5	187.5	232.5	182	207
Normalised	Environmental	18%	0%	24%	59%	100%
	Financial	100%	43%	81%	68%	0%
	Social	47%	100%	0%	4%	99%
	Feasibility	0%	17%	100%	6%	53%

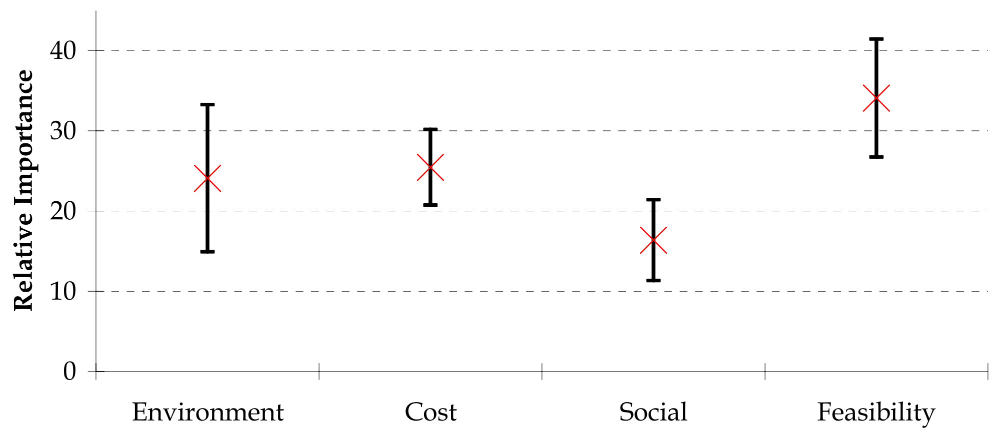
(†) The larger the environmental score, the better the scenario

The results of the delegates' assessments, by table, are presented in *Table 3.11*, and *Figure 3.2*.

Table 3.11 ***Summary of Delegates' Decision Criteria Ratings***

	Environment	Cost	Social	Feasibility
Table 1	25	20	20	35
Table 2	35	25	20	20
Table 3	10	30	20	40
Table 4	25	30	15	30
Table 5	40	20	10	30
Table 6	15	35	5	45
Table 7	30	25	15	30
Table 8	15	20	20	45
Table 9	30	25	15	30
Table 10	20	25	20	35
Table 11	20	25	20	35
Total	**265**	**280**	**180**	**375**
Average	**24.1**	**25.5**	**16.4**	**34.1**
Standard Deviation	*9.2*	*4.7*	*5.0*	*7.4*

Figure 3.2 ***Graphical Depiction of Workshop Delegates' Decision Criteria Rating***



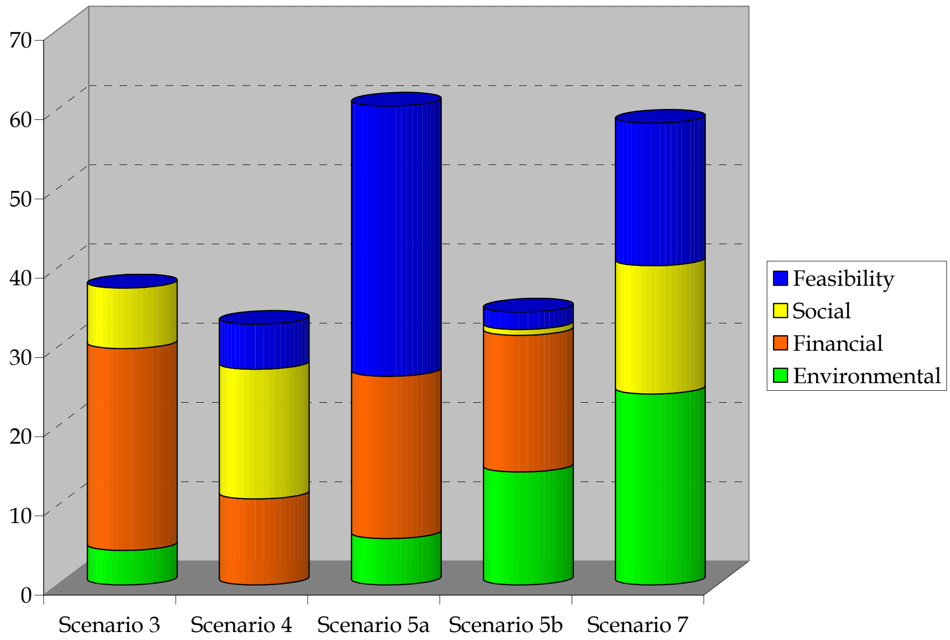
Error bars are ± one standard deviation

By applying the weighting of the decision criteria in *Table 3.11* to the normalised scores in *Table 3.10*, it is possible to produce a BPEO assessment of the different options. This process is shown in *Table 3.12* and *Figure 3.3*.

Table 3.12 Calculation of Final Assessment Score

	Scen 3	Scen 4	Scen 5a	Scen 5b	Scen 7	*Weighting*
Environmental	18%	0%	24%	59%	100%	*24.1*
Financial	100%	43%	81%	68%	0%	*25.5*
Social	47%	100%	0%	4%	99%	*16.4*
Feasibility	0%	17%	100%	6%	53%	*34.1*
Final Score	**37.5**	**32.9**	**60.4**	**34.4**	**58.3**	

Figure 3.3 Graphical Depiction of Final Assessment Score



3.4.2 Conclusions from BPEO Workshop

Scenarios 5a (thermal treatment and AD) and 7 (the MBT and AD hybrid scenario) clearly scored better than the other three alternatives, though it was not possible to differentiate between those two scenarios, as their results were very close.

The key conclusions drawn from the BPEO workshop were that:

- recycling and composting should be maximised to levels that are realistic and achievable;
- the chosen scenario should use proven technologies; and
- a scenario based on several technologies would be more robust than reliance on a single technology.

3.5 *FINAL SCENARIOS*

In accordance with good practice, the BPEO workshop's conclusions were used to draw up a list of revised scenarios for a second iteration of the assessment. The objective was to take the best parts of the leading scenarios analysed previously, and combine them in various ways, to determine which combination would be the BPEO. Eight new scenarios were developed, as detailed below. Once again, a brief description is given of each scenario, together with a reference to its schematic diagram in *Annex C*.

3.5.1 *NS1 – Old Scenario 5a (see Figure C2.9)*

The first new scenario was based on *Scenario 5a*, which performed well at the BPEO workshop. Recycling and composting increases to 45% by 2020, with thermal treatment and AD handling the balance of the waste.

3.5.2 *NS2 – NS1 with Enhanced Recycling and Composting (see Figure C2.10)*

The second new scenario was developed from NS1, but included a higher level of recycling and composting, so that, by 2020, it would account for 55% of the MSW arisings. Levels of thermal treatment and AD were scaled down accordingly.

3.5.3 *NS3 – NS1 with Minimal Anaerobic Digestion (see Figure C2.11)*

This scenario again was based on NS1, but this time the amount of AD was reduced to the minimum that would still allow the 2010 target to be met. The difference was diverted instead to thermal treatment.

3.5.4 *NS4 – Old Scenario 7 (see Figure C2.12)*

This scenario was based on *Scenario* 7, which also performed well in the first iteration. High levels of recycling and composting were assumed (increasing to 55% by 2020), with a combination of AD and MBT used to meet the landfill diversion targets.

3.5.5 *NS5 – NS4 with Lower Recycling and Composting (see Figure C2.13)*

The 55% level of recycling and composting in NS4 will be tough to meet, so this scenario is similar to NS4 but with reduced recycling and composting levels (reaching 45% in 2020). The larger balance was again met using a combination of AD and MBT.

3.5.6 *NS6 – Hybrid of MBT, AD and TT (see Figure C2.14)*

This scenario examined the result of combining all three treatment technologies. The recycling and composting was set to reach 45%, and MBT, AD and thermal treatment (TT) were all used to treat the residual waste and meet the landfill diversion targets.

3.5.7 *NS7 – Fully Integrated Scenario (see Figure C2.15)*

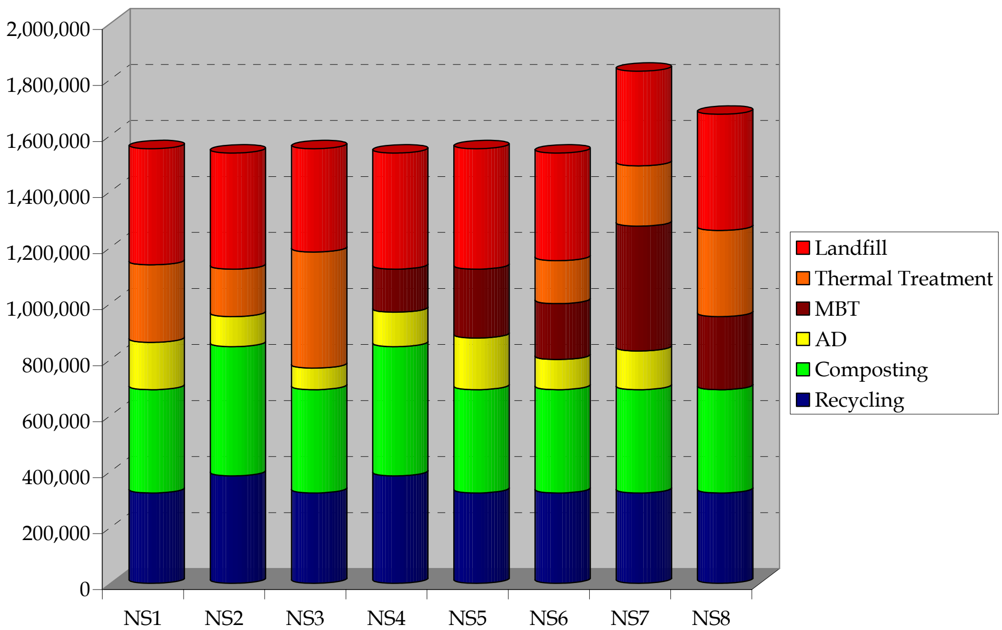
This scenario is similar to NS6, but envisioned a fully integrated waste management process. Waste would go to MBT plants first, and then the main output streams would be sent on to AD and thermal treatment plants as appropriate. This would guarantee a market for the RDF, though transport and numbers of plant would have to increase.

3.5.8 *NS8 – MBT and Thermal Treatment (see Figure C2.16)*

The final new scenario dropped AD altogether, and looked to use just MBT and thermal treatment together with 45% recycling and composting. It is assumed that the organic fraction would be put to some beneficial use (rather than being landfilled), but that no market would be available for the RDF, which would therefore have to be sent to landfill.

The distribution of technologies in 2020 for the eight revised scenarios is presented in *Figure 3.4*.

Figure 3.4 Levels of Technology Employed (tonnes) in Scenarios in 2020



NB Some scenarios (notably NS7) show higher waste levels handled than others, as waste first sent to one technology is subsequently sent to another.

3.6 RESULTS OF FINAL SCENARIOS

The results of the assessment of the new scenarios are presented in *Table 3.13* (environmental), *Table 3.14* (cost and transport) and *Table 3.15* (other social criteria).

Table 3.13 Summary of Environmental Results

Scenario Description	Resource Depletion (†) te crude oil eq	Value	Acidification (†) te SO_2	Value	Greenhouse Emissions (†) te CO_2 eq	Value	Water Impact Score -	Value	Average Landtake Hectares	Value
NS1 - Old 5a	3 359 816	45%	25 204	0%	4 288 066	63%	1847	61%	114	81%
NS2 - NS1+R&C	3 389 179	55%	25 805	20%	4 163 846	42%	1830	68%	114	81%
NS3 - NS1 min AD	3 511 023	100%	26 258	35%	4 519 738	100%	1750	100%	120	20%
NS4 - Old 7	3 391 508	56%	28 178	100%	4 164 890	43%	1806	77%	112	100%
NS5 - NS4-R&C	3 238 354	0%	27 280	70%	3 901 647	0%	1863	55%	113	89%
NS6 - Hybrid AD,MBT,TT	3 380 686	52%	27 630	82%	4 205 418	49%	1815	74%	115	67%
NS7 - Integrated	3 365 354	47%	26 115	31%	4 123 144	36%	1999	0%	121	13%
NS8 - MBT+TT	3 393 078	57%	25 784	19%	4 270 593	60%	1828	69%	122	0%

(†) These results are all net *benefits*

Table 3.14 Summary of Financial Cost Results, and Transport Figures for Local Amenity Criterion

Scenario Description	Relative Cost Collect -ion	Gate Fee	LF Tax	Energy Gen	Total	Value	Average Transport to Facilities Mte-km pa	Value	Relative Transport from Facilities -	Value
NS1 - Old 5a	£58.65	£36.17	£12.18	-£2.95	£104.05	38%	48.8	58%	127 926	92%
NS2 - NS1+R&C	£61.56	£33.02	£13.37	-£2.07	£105.88	0%	45.9	84%	122 497	100%
NS3 - NS1 min AD	£58.65	£33.02	£12.73	-£3.30	£101.10	100%	49.7	50%	135 590	81%
NS4 - Old 7	£61.56	£31.46	£14.12	-£1.58	£105.57	7%	44.2	98%	147 682	64%
NS5 - NS4-R&C	£58.65	£32.67	£14.41	-£1.81	£103.93	41%	44.0	100%	137 032	79%
NS6 - Hybrid AD,MBT,TT	£58.65	£32.25	£13.96	-£2.39	£102.47	71%	51.2	37%	135 889	81%
NS7 - Integrated	£58.65	£35.58	£12.75	-£2.21	£104.77	23%	55.4	0%	192 942	0%
NS8 - MBT+TT	£58.65	£32.99	£13.31	-£2.68	£102.27	76%	50.1	46%	126 207	95%

Table 3.15 Summary of Other Social Results

Scenario Description	Health Impacts	Value	Average Employment S	U/S	Value	Relative Risk of Accidents -	Value	Relative Producer Responsibility -	Value
NS1 - Old 5a	0.260	35%	67	201	5%	59	100%	22.8	60%
NS2 - NS1+R&C	0.204	67%	67	205	10%	61	89%	24.1	100%
NS3 - NS1 min AD	0.321	0%	64	200	0%	59	99%	21.5	23%
NS4 - Old 7	0.145	100%	67	204	9%	64	66%	24.1	100%
NS5 - NS4-R&C	0.152	96%	69	206	14%	63	70%	22.4	49%
NS6 - Hybrid AD,MBT,TT	0.220	58%	68	211	19%	62	76%	21.8	32%
NS7 - Integrated	0.245	43%	83	259	100%	72	0%	21.9	34%
NS8 - MBT+TT	0.299	12%	72	220	36%	66	45%	20.7	0%

The results of the environmental and financial cost assessments are presented in *Table 3.16*.

Table 3.16 ***Assessment of New Scenarios against Environmental and Cost Criteria***

	NS1	NS2	NS3	NS4	NS5	NS6	NS7	NS8	Wt (†)
Resource Depletion	45%	55%	100%	56%	0%	52%	47%	57%	20%
Air Acidification	0%	20%	35%	100%	70%	82%	31%	19%	20%
Global Warming	63%	42%	100%	43%	0%	49%	36%	60%	20%
Water Impacts	61%	68%	100%	77%	55%	74%	0%	69%	20%
Landtake	81%	81%	20%	100%	89%	67%	13%	0%	20%
Environmental Score	**50%**	**53%**	**71%**	**75%**	**43%**	**65%**	**25%**	**41%**	
Normalised	*49%*	*56%*	*91%*	*100%*	*35%*	*79%*	*0%*	*31%*	
Average Cost in £/ te	**104.05**	**105.88**	**101.10**	**105.57**	**103.93**	**102.47**	**104.77**	**102.27**	
Normalised	*38%*	*0%*	*100%*	*7%*	*41%*	*71%*	*23%*	*76%*	

(†) These weightings assume the environmental criteria are equally important.

The transfer of the BPEO workshop assessments of the more subjective criteria to the new scenarios is presented in *Annex G*, and summarised in *Table 3.17.*

Table 3.17 ***Assessment of New Scenarios against Social and Feasibility Criteria***

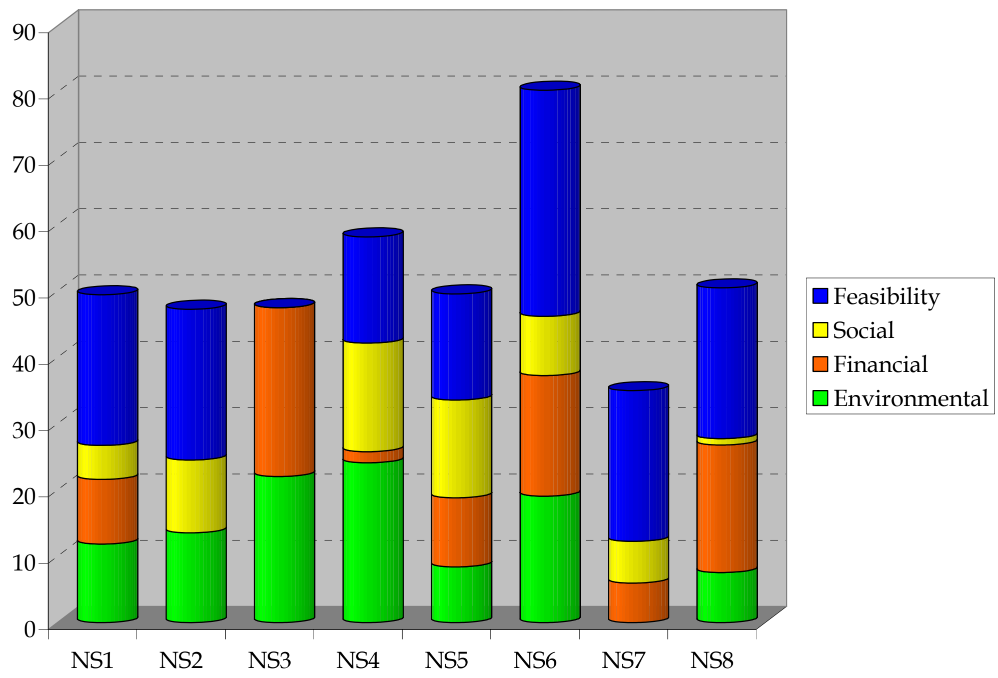
	Decision Criteria	NS1	NS2	NS3	NS4	NS5	NS6	NS7	NS8
Social Criteria	Employment	3.0	3.0	3.0	3.0	3.0	3.0	3.5	3.0
	Public Acceptability	1.7	2.5	1.0	3.5	3.5	2.6	2.3	1.5
	Perception of Health Effects	2.0	3.0	1.0	4.0	3.9	2.7	2.3	1.4
	Risk of Accidents	3.3	3.1	3.2	2.9	3.0	3.0	2.3	2.7
	Public / Producer Responsibility	2.6	3.3	2.5	3.5	3.0	2.8	2.8	2.6
	Local Amenity	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Social Implications / Equity	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Total	**18.7**	**20.9**	**16.7**	**22.9**	**22.3**	**20.1**	**19.1**	**17.1**
	Normalised	*31%*	*67%*	*0%*	*100%*	*90%*	*55%*	*38%*	*6%*
Feasibility Criteria	Technical Feasibility	4.6	4.6	4.6	2.9	2.9	4.6	4.6	4.6
	Practical Feasibility	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0
	Flexibility	3.0	3.0	2.0	4.0	4.0	4.0	3.0	3.0
	Existing Facilities	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Compliance with Policy	4.2	4.2	4.2	4.4	4.4	4.2	4.2	4.2
	Total	**16.8**	**16.8**	**14.8**	**16.2**	**16.2**	**17.8**	**16.8**	**16.8**
	Normalised	*67%*	*67%*	*0%*	*47%*	*47%*	*100%*	*67%*	*67%*

By applying the weighting of the decision criteria in *Table 3.11* to the normalised scores in *Table 3.17* and *Table 3.16*, it is possible to arrive at a final assessment of the highest scoring option. This process is shown in *Table 3.18* and *Figure 3.5*.

Table 3.18 ***Calculation of Final Assessment Score***

	NS1	NS2	NS3	NS4	NS5	NS6	NS7	NS8	Wt
Environmental	31%	67%	0%	100%	90%	55%	38%	6%	24.1
Financial	67%	67%	0%	47%	47%	100%	67%	67%	25.5
Social	49%	56%	91%	100%	35%	79%	0%	31%	16.4
Feasibility	38%	0%	100%	7%	41%	71%	23%	76%	34.1
Final Score	**49**	**47**	**47**	**58**	**50**	**80**	**35**	**50**	

Figure 3.5 Graphical Depiction of Final Assessment Score



3.7 MSW BPEO

The previous plot and table show that NS6 is, by some margin, the highest scoring option. The growth of waste and the technologies by which it is treated are shown in *Figure 3.6*. In the three key target years for the Landfill Directive, summarised with the pie-charts, the status of the waste management infrastructure should be as described in *Table 3.19*.

Table 3.19 Description of the MSW BPEO in the Key Years

	Description
2010	• A recycling & composting rate of at least 35% • A three-bin system for separate collection of dry recyclables, organic waste and residual waste for all households – where practicable • A combination of MBT and AD for about 10% of waste in order to meet EU targets • Only 50% of waste going direct to landfill • No Thermal Treatment possible by 2010
2013	• A recycling & composting rate of at least 40% • A combination of all three technologies – MBT, AD and Thermal Treatment for about 20% of waste is required in order to meet EU targets • Less than 40% of waste going direct to landfill
2020	• A recycling & composting rate of at least 45% • A combination of all three technologies – MBT, AD and Thermal Treatment for over 30% of waste is required in order to meet EU targets • Only around 25% of waste going direct to landfill

Figure 3.6 Schematic Diagram of the MSW BPEO (in terms of Technology used to Treat Waste)

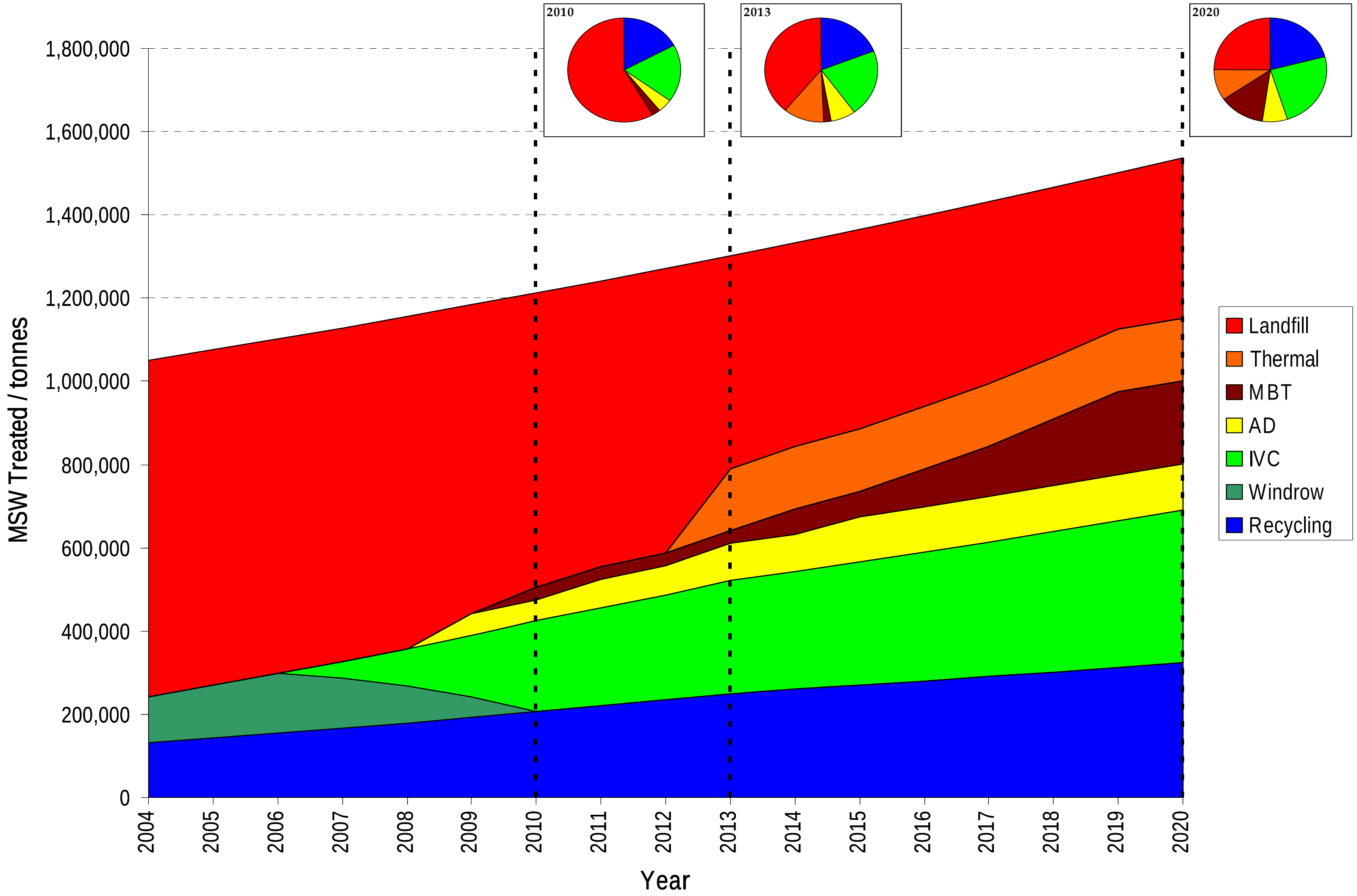
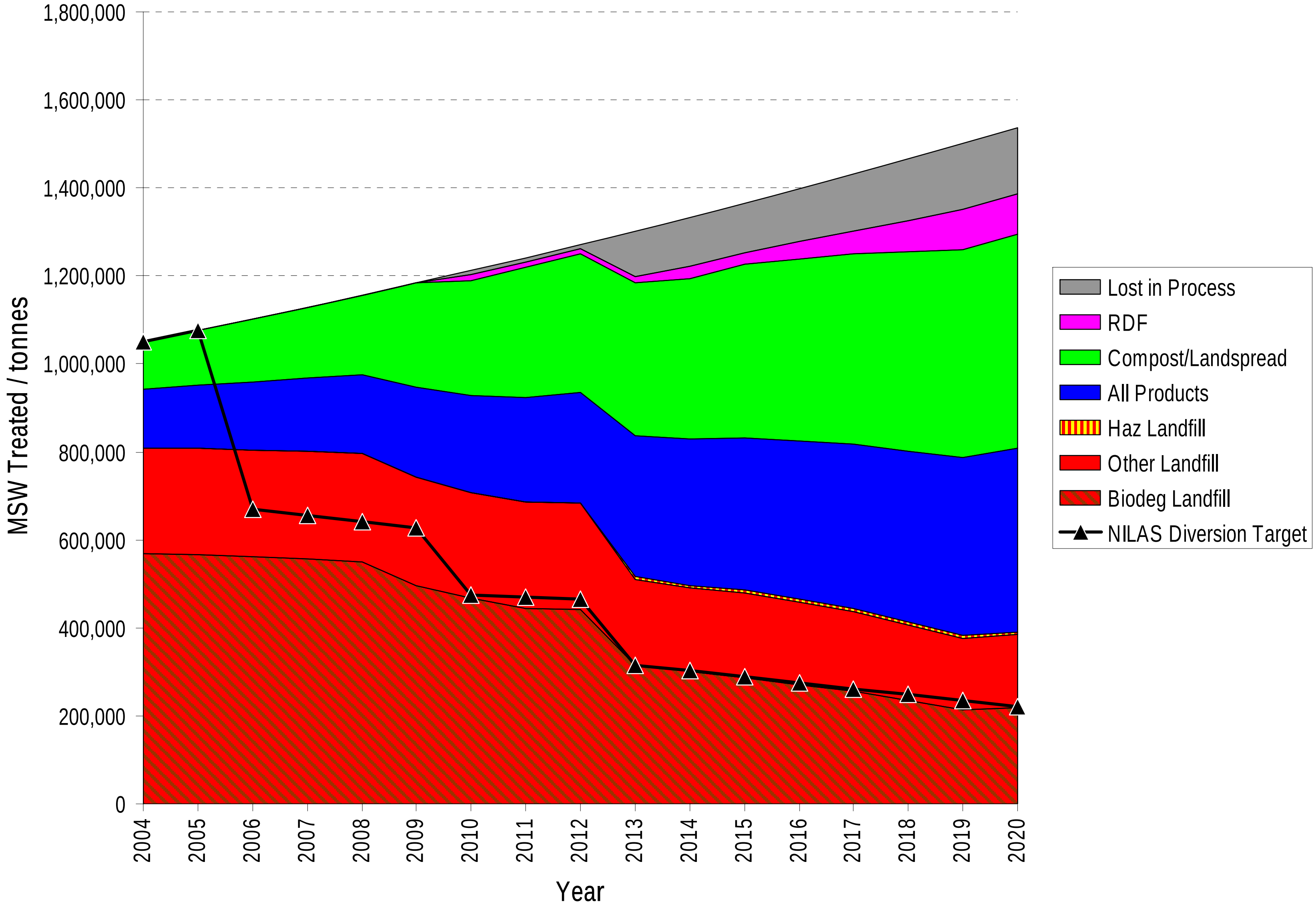


Figure 3.7 Schematic Diagram of the MSW BPEO (in terms of Final Destinations of Waste)



3.7.1 *Numbers, Locations and Capacities of Facilities for MSW BPEO*

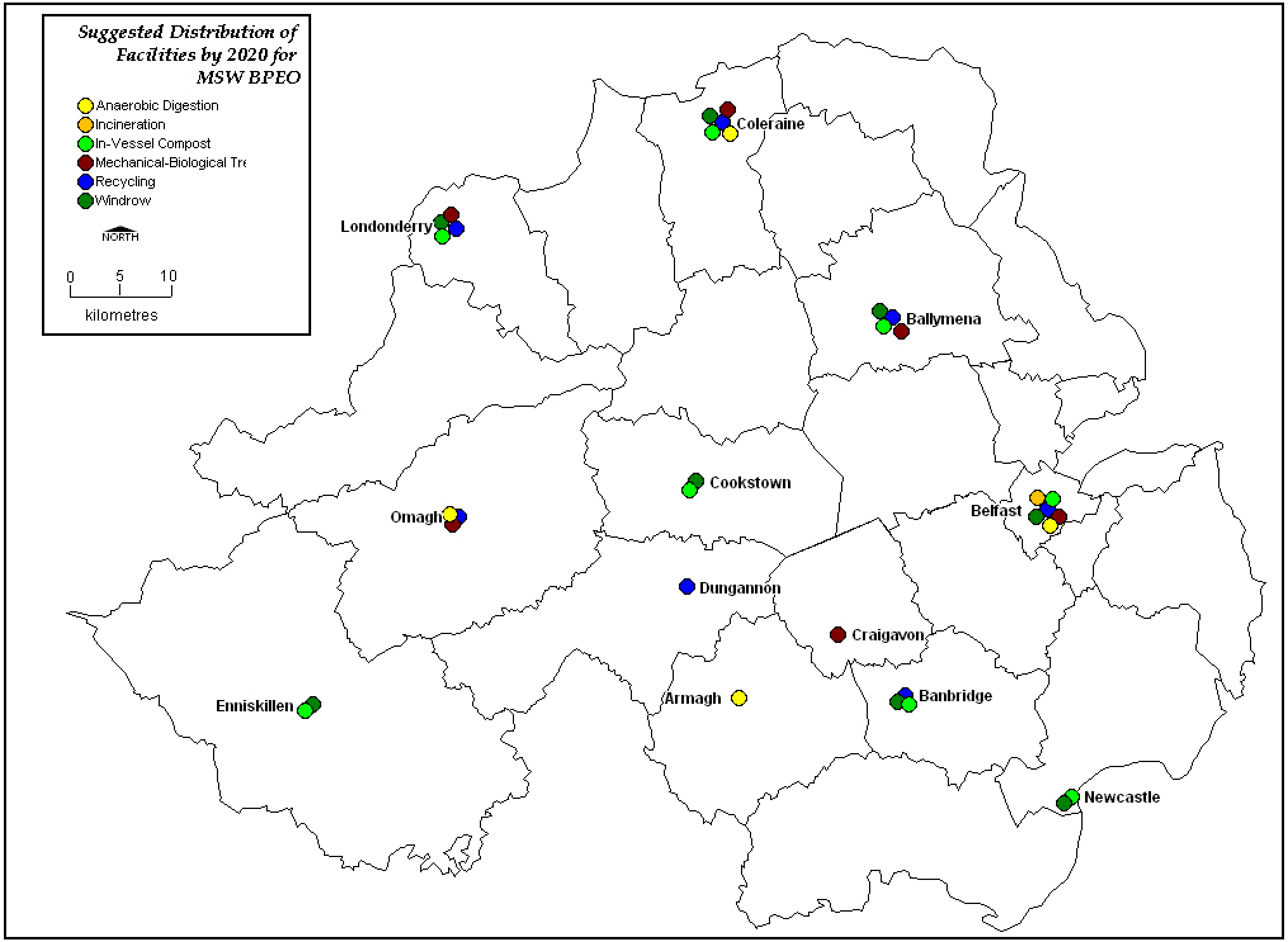
In order to arrive at the BPEO, it was necessary to assume plant numbers, locations and capacities. It should be noted first that 'locations' in this context are more accurately defined as broad areas of search. Therefore, a plant provisionally located in (for instance) Craigavon might actually be better located in (for instance) Lisburn, Dungannon, Banbridge or Armagh, depending on local issues beyond the scope of this study. Potential locations should be addressed in more detail in the WMPs, taking into account local factors and conditions that are beyond the scope of this high-level study.

For this study, the methodology adopted to generate these broad areas of search was a relatively simple calculation designed to minimise waste haulage between 34 representative towns and cities, with no assessment of road types, etc. The process by which this was achieved, together with a map of the locations considered, is presented in detail in *Annex F*. For the BPEO, the process leads to the mix and spread of facilities summarised in *Table 3.20*, and depicted in *Figure 3.8*. The underlying assumptions are tested in the sensitivity analysis.

Table 3.20 ***Indicative Number, Location and Capacity (in tonnes per annum) of Waste Management Facilities for MSW BPEO***

#	Recycling	Windrow	IVC	AD	MBT	Thermal Treatment
1	50 000: Belfast	20 000: Belfast	50 000: Belfast	50 000: Belfast	30 000: Belfast	150 000: Belfast
2	50 000: Derry	20 000: Derry	50 000: Derry	20 000: Omagh	30 000: Derry	
3	50 000: Dungannon	20 000: Banbridge	50 000: Banbridge	20 000: Coleraine	30 000: Craigavon	
4	50 000: Coleraine	20 000: Ballymena	50 000: Ballymena	20 000: Armagh	30 000: Ballymena	
5	50 000: Banbridge	20 000: Enniskillen	50 000: Enniskillen		40 000: Omagh	
6	50 000: Ballymena	20 000: Cookstown	50 000: Cookstown		40 000: Portrush	
7	50 000: Omagh	20 000: Portrush	50 000: Portrush			
8		20 000: Newcastle	50 000: Newcastle			

Figure 3.8 Suggested Distribution of Facilities by 2020 for MSW BPEO



NB: Landfill sites not shown

3.8 SENSITIVITY ANALYSES

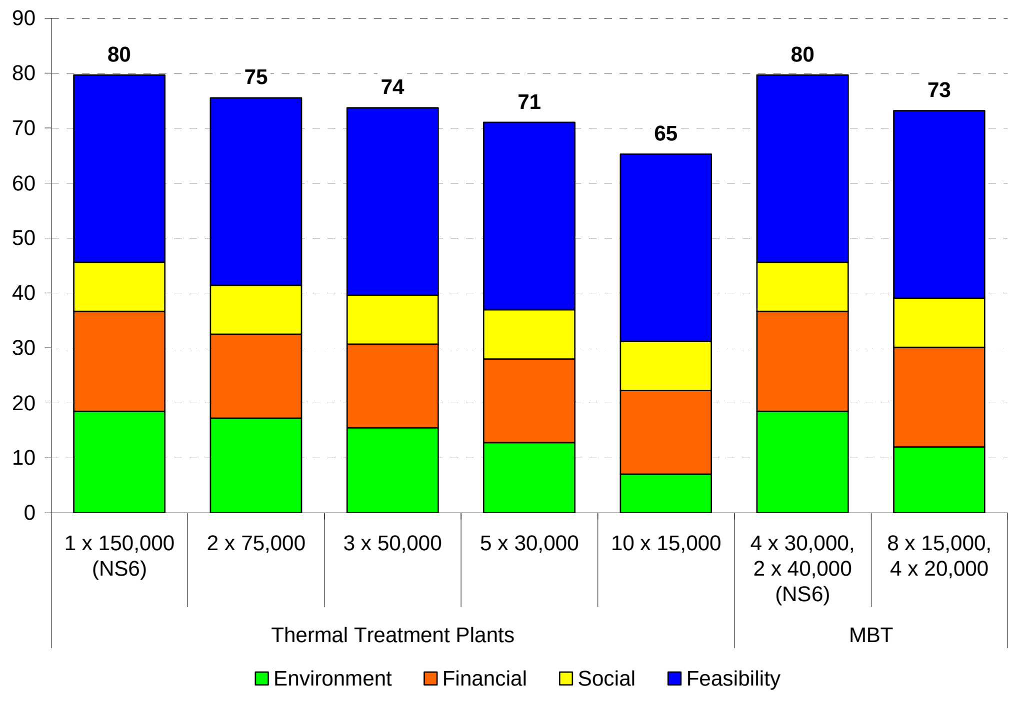
The above conclusion is underpinned by numerous assumptions, all of which are considered valid, but some of which merit further investigation. Sensitivity analysis seeks to test key underlying assumptions, to see where plausible perturbations can change the final result.

3.8.1 *Plant Numbers, Locations and Capacities*

The BPEO scenario includes a relatively small number of centralised facilities. An issue that has been investigated is whether the construction of a larger number of smaller plants might be a better solution.

In order to test the sensitivity of the results to the assumed number of plants, the numbers of thermal and MBT plants were increased (and their capacities reduced), to see the effect on the BPEO assessment. The results are shown in *Figure 3.9*.

Figure 3.9 ***Sensitivity Analysis – Number of Facilities (capacities in tonnes per annum)***



The BPEO scenario, NS6, is plotted on the left. The next four series show the effect on the overall BPEO score as the number of thermal treatment plants increases from 1x150 000 (the BPEO) to 10x15 000. The trend clearly shows that increasing the numbers of plants is detrimental to the overall performance of the scenario. The final two series show the effect of doubling the number of MBT plants. Again, this is seen to have a negative effect on the assessment.

3.8.2 *Fate of RDF from the MBT Process*

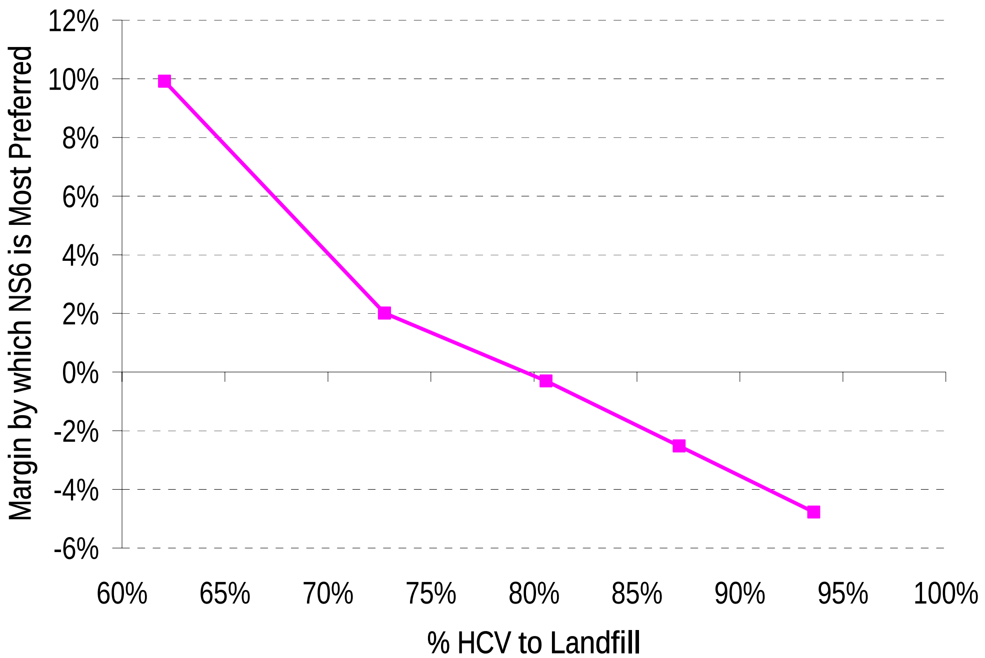
The MBT process generates a number of outputs, and those outputs vary depending on the version of the process being used. This study used an MBT model that generates a recyclate stream (metals and aggregate), an organic stream with a low calorific value (LCV), and a high calorific value (HCV) fraction. It is assumed that the LCV stream is not landfilled, and used for landspreading or as landfill cover.

The BPEO scenario uses MBT technology to treat a fraction of the MSW (13% by 2020). The model assumes that the HCV fraction can be used as a refuse-derived fuel (RDF), but this is by no means a certainty. The question arises, does NS6 cease to be the BPEO if the market for RDF fails?

The spreadsheet model is designed to track the amount of biodegradable material going to landfill. It splits the waste into eleven fractions, of varying biodegradability, and then, for each year, tracks each fraction through the different technologies, to determine how much biodegradability is removed and, by the difference, how much is finally sent to landfill.

A succession of scenarios based upon NS6 was devised in which increasing amounts of the HCV fraction were not used as an RDF but simply landfilled. The percentage by which NS6 continued to be the BPEO, compared with any of the other scenarios, is depicted in *Figure 3.10*.

Figure 3.10 ***Effect of RDF Market on Choice of BPEO***



We conclude from this sensitivity analysis that NS6 continues to be the BPEO as long as more than 20% of the HCV fraction (equivalent to about 18 000 te in 2020) is used as RDF rather than landfill.

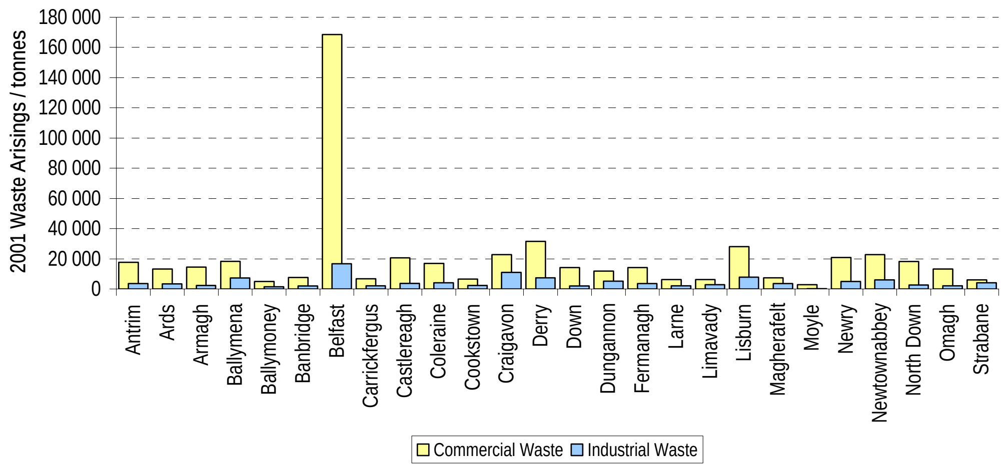
4 C&I WASTE BPEO

4.1 BASELINE DATA

Annex H describes the process undertaken to determine possible growth rates for commercial and industrial wastes in NI. The conclusion was that industrial waste levels will remain flat, with any growth due to increased economic activity cancelled out by increased waste prevention. For commercial waste, an initial growth rate of 1.9% is expected (in line with the employment growth rate), which will decrease to around 1% from 2012 onwards, as changing work practices and further legislation reins in the rate of waste production.

The baseline levels of waste were taken from the most recent NI survey of C&I waste arisings (1), and are plotted by District Council in *Figure 4.1*. The figures are clearly dominated by commercial waste from Belfast.

Figure 4.1 Surveyed Northern Ireland C&I Waste Arisings in 2001



The natural source for data on C&I waste composition would have been the same NI survey of C&I waste arisings, but this had large amounts of waste (over 50%) assigned to the 'mixed' and 'waste from health care' categories, which do not help in determining the detailed waste composition and hence which waste technologies are most appropriate to treat the waste. Therefore, it was decided to use the composition data from the Environment Agency's Strategic Waste Management Assessment (SWMA). (2) These composition data are presented in *Table 4.1*.

The NI survey of C&I waste broke down arisings into five categories, as shown in *Table 4.2*. These were taken to form the baseline for the scenarios. For the purposes of the study, waste going to 'land application' and 'other

(1) *Industrial and Commercial Waste Production in Northern Ireland*, MEL and EnviroCentre, October 2002, Report 02022/01/rev4

(2) Available on the internet via: http://www.environment-agency.gov.uk/subjects/waste/315439/147529/ [22Jun04]

treatment methods' was assumed in all scenarios to halve every year until those practices are phased out by 2010 at the latest. Therefore, any effects these treatment methods might have would be identical for all scenarios, and could therefore be disregarded.

Table 4.1 *C&I Waste Composition Data (EA SWMA) and Arisings (2001 EHS Survey)*

	Commercial		Industrial	
Waste Fraction	**Fraction**	**Arisings**	**Fraction**	**Arisings**
Paper/card	43.3%	225,804	58.2%	66,149
Putrescible	6.3%	32,990	8.6%	9,814
Misc non-combustible	7.8%	40,891	6.9%	7,832
Ferrous metal	5.8%	30,149	4.7%	5,308
Non-ferrous metal	1.9%	10,050	1.6%	1,769
Glass	15.7%	82,060	0.0%	0
Plastic dense	14.3%	74,436	15.1%	17,127
Plastic film	4.8%	24,812	5.0%	5,709
Total	**100.0%**	**521,192**	**100.0%**	**113,708**

Table 4.2 *Baseline C&I Waste Fates, by % Total Arisings*

Fate	**%**
Landfill	39.6%
Recycled/Reused	32.7%
Incinerated/Burned	18.9%
Land Application	2.3%
Other Treatment	6.4%

4.2 INITIAL SET OF SCENARIOS

This section describes the initial set of scenarios that were assessed in the BPEO study. A brief description is given of each scenario, together with a reference to its schematic diagram in *Annex C*.

4.2.1 *Scenario 1 – Current Situation (Figure C3.1)*

This scenario represented a continuation of the current situation. Simple burning of waste was kept at the baseline rate (18.9%), as was recycling/reuse (a small fraction of which was composting). As the land application and other treatment techniques were phased out, the extra waste was diverted straight to landfill. *Scenario 1* was included to provide a baseline against which to judge the other scenarios (relative cost, water pollution impacts, etc).

4.2.2 *Scenario 2 – High Recycling (Figure C3.2)*

This scenario used the same baseline as *Scenario 1*, but diverted increasing amounts of waste from landfill via recycling (and, to the extent possible, composting). By 2020, 55% of C&I waste would be recycled or composted.

4.2.3 *Scenario 3 – MBT (Figure C3.3)*

This scenario was based on using an MBT plant [(1)] as the chief means to handle residual waste. The first plant would be introduced in 2009, and all the waste previously burned would be redirected to it. By 2020, 50% of C&I waste would be handled by the MBT plants.

Two versions of the scenario were run, to test the effect of the final market for the product from the MBT plant, with *Scenario 3a* sending the high-calorific value (HCV) material to landfill, and *Scenario 3b* sending it to RDF. If it could be used as an RDF, the scenario would perform much more positively than if the product had to be landfilled.

4.2.4 *Scenario 4a – Thermal Treatment (Figure C3.4)*

Unlike MSW, the lack of much biodegradable content in C&I waste means that it is not technically feasible to use AD as the single means to treat a large percentage of C&I waste. *Scenario 4* therefore investigated thermal technologies.

Scenario 4a focused on thermal treatment in the form of incineration, with the first facility on-line by 2012, taking 37% of the C&I waste arisings. As with MBT, when the plant comes on line, waste previously burnt would be redirected to the incinerator. By 2020, just over 50% of the waste would be incinerated.

4.2.5 *Scenario 4b – Gasification (Figure C3.5)*

The last C&I waste scenario in the initial assessment directly replaced the incinerator of *Scenario 4a* with an advanced thermal treatment process. The technology chosen was the gasification process.

4.3 *ASSESSMENT OF INITIAL SET OF SCENARIOS*

The results of the assessment of the initial set of C&I waste scenarios are summarised in *Table 4.3*, with numerical results presented in *Table 4.4* (environmental), *Table 4.5* (financial cost, transportation and health effects) and *Table 4.6* (other social and feasibility results).

The results were not assessed any further than presented in these tables. Instead, conclusions from the BPEO workshop were used to form a second round of C&I waste scenarios.

(1) Note that, given the low levels of organic waste in C&I waste, this could be a materials recycling facility able to accept mixed waste (a dirty MRF) rather than what may be commonly understood to be an MBT plant, although the plant components would be similar.

Table 4.3 Summary of the Decision Criteria for the NI-BPEO – Methodology of Assessment and Comments on the Results for C&I Waste

Criteria	Methodology	Comments on Results
Resource Depletion Acidification Greenhouse Gas Emissions	Data were extracted from WISARD, where available, or taken from supplier information. Account was taken of the impacts of the electricity and other resources used to power the facilities, their emissions, and the power generated, where applicable. Credit was also given for processes (such as recycling and thermal treatment) that offset the use of virgin materials.	All scenarios showed significant net benefits on resource depletion, acidification and greenhouse gas emissions, because of the resources and/or energy offset. For all three criteria, processes that used RDF to offset coal performed the best. However, in scenario 3, when a market for the RDF could not be found, landfilling the RDF made the scenario perform poorly.
Water Impact	The EA OPRA rating methodology (1) was used, though target scores and 'control and containment' were standardised, meaning that differentiation was based on facility number, type and size.	Scenario 3 involved two steps to complete the treatment process, so scored poorly for water impacts, which are calculated on a per plant basis. Landfilling large amounts of waste (scenario 1) also performed poorly, leaving scenarios 2 and 4 as highest scoring. The lower amount of material sent to landfill meant that gasification performed marginally better than incineration.
Average Landtake	Typical plant sizes for a given throughput (collated from previous studies) were used to assess the landtake required for each scenario in each year; those figures were then averaged, to give a final average landtake.	Scenarios that involved landfilling and composting tended to fair poorly against this criterion (as these facilities take the largest amounts of land for a given waste capacity), so scenario 4 scored highest. Scenario 2 outperformed the others, despite its composting, because of the low levels involved, and scenario 3 involved two-step treatment.
Relative Costs	These figures included estimated collection and gate fees, and the landfill tax escalator. All sums were based on current prices (no inflation or discounting), and did not include any capital costs or possible credits for generating renewable energy. As such, the figures should only be used for comparative purposes.	Scenario 3 suffered if a market could not be found for the RDF, because of the large amount of waste sent to landfill. The other scenarios scored at a similar level given the general nature of the assessment.
Average Transport to Facilities	Broad locations (chosen from 34 towns and cities) were sought that minimised tonne-kilometres of transportation required to transport waste to facilities. The figures are the average tonne-kilometres per year over the period to 2020.	There was not a large difference in the numbers of plants in the scenarios, so the transport figures were quite tightly ranged, between 20 and 23 million tonne-kilometres per annum. Scenario 1 scored highest, as the majority of the waste went to landfill and these were relatively well spread.
Relative Transport from Facilities	Scenarios were assessed according to the amount of material that was generated for recycling and recovery, combined with a very simplistic assessment of the likely relative distances that the materials would be sent (local for compost wastes, further a field for the others).	Scenario 1 performed well, as most of the waste would go straight to landfill and require no onward transportation. Scenario 3 performed poorly, because of the large amount of material that would have to be transported onwards after the MBT plant.

(1) http://www.environment-agency.gov.uk/commondata/105385/wasteriskinspectv3_133720.pdf [20Aug04 @ 17:09] p14-15

Criteria	Methodology	Comments on Results
Human Health Impact Scores	Data from the recent Defra Health Effects report (1) and the WHO Global Burden of Disease report (2) were combined to assess the relative risks of different technologies.	In general, scenarios that burn the waste or RDF tended to score less well for this criterion, so, scenario 3 with the RDF being landfilled was most highly rated. Scenario 2, with its high recycling and composting, nevertheless had residual waste going to simple combustion, limited its performance. In scenario 4b, this was replaced by gasification, which is why the latter scored second.
Average Employment	Data from previous studies on typical numbers of skilled and unskilled workers, based on number, type and size of plant, were used to calculate the number of jobs required to treat the waste in each year. Employment associated with waste collection was not included, on the basis that this would be similar, regardless of scenario, and depends critically on the details of the collection regimes, which are outside the scope of this study.	The MBT scenario requires higher numbers of employees, so it did well against this criterion. It is also anticipated that gasification plants would require high staffing, so scenario 4b also got a high rating.
Relative Risk of Accidents	A very simple assessment was performed, assessing technologies according to the amounts of manual handling and mechanical equipment used. These ratings were then scaled by the volumes of waste handled by technology.	MRFs were rated most likely to suffer accidents, and the results show that the scenarios' performances reflect this, with scenarios 1 and 4 performing the best.
Relative Producer Responsibility	This criterion gave credit according to the amount of materials that would be recycled or composted, since it was assumed that the producer would be required to source-separate these materials.	All the scenarios had exactly the same levels of recycling and composting apart from scenario 2 (high recycling), which therefore scored best.
Relative Markets for Products	Each technology was judged for the maturity of the market for its products, based upon the amount of material that would be produced. This was a highly subjective assessment, but provided some indication of the likelihood of finding markets for the products of the scenarios.	Clearly, scenario 1 was the most likely to succeed against this criterion, as it represented business as usual. Scenarios that rely on RDF being substituted for coal were rated poorly, given the particular lack of development of this market.

(1) http://www.defra.gov.uk/environment/waste/health-effects/index.htm [01Jun04 @ 15:13]
(2) http://www3.who.int/whosis/burden/manual/other/GBD90 Disability Weights.zip [08Jun04 @ 19:11]

Table 4.4 Summary of Environmental Results

Scenario Description	Resource Depletion (†) te crude oil eq	Value	Acidification (†) te SO_2	Value	Greenhouse Emissions (†) te CO_2 eq	Value	Water Impact Scores -	Value	Average Landtake Hectares	Value
S1 - Current Status	2 402 933	0%	20 210	0%	2 973 482	0%	1136	63%	83.9	49%
S2 - High Recycling	3 294 965	45%	27 746	29%	4 850 103	46%	1032	93%	71.0	86%
S3a - MRF; Landfill	2 810 675	20%	23 795	14%	3 273 773	7%	1353	0%	100.5	0%
S3b - MRF; RDF	4 398 502	100%	46 013	100%	7 045 642	100%	1131	65%	75.6	73%
S4a - Thermal Treatment	3 505 229	55%	30 046	38%	4 802 982	45%	1043	90%	69.4	91%
S4b - Gasification	3 523 384	56%	32 055	46%	6 349 952	83%	1009	100%	66.2	100%

Table 4.5 Summary of Financial Cost, Transport and Health Impact Results

Scenario Description	Relative Cost Cost: £M pa	Value	Average Transport to Facilities Million te-km pa	Value	Relative Transport from Facilities -	Value	Health Impacts -	Value
S1 - Current Status	£ 75.41 M	85%	20.2	100%	8 139 826	100%	0.249	37%
S2 - High Recycling	£ 77.41 M	74%	21.1	62%	11 149 750	54%	0.215	55%
S3a - MRF; Landfill	£ 90.08 M	0%	22.7	0%	14 647 415	0%	0.127	100%
S3b - MRF; RDF	£ 72.88 M	100%	20.3	97%	14 647 415	0%	0.292	16%
S4a - Thermal Treatment	£ 74.76 M	89%	21.2	61%	10 099 927	70%	0.322	0%
S4b - Gasification	£ 75.65 M	84%	21.2	58%	9 238 393	83%	0.168	79%

Table 4.6 Summary of Other Social and Feasibility Results

Scenario Description	Average Employment S	U/S	Value	Relative Risk of Accidents -	Value	Relative Producer Responsibility -	Value	Relative Markets for Products -	Value
S1 - Current Status	42	158	0%	41 255	100%	12 275 790	0%	0.686	100%
S2 - High Recycling	39	166	40%	47 201	67%	16 809 531	100%	0.542	66%
S3a - MRF; Landfill	49	206	100%	59 476	0%	12 275 790	0%	0.303	11%
S3b - MRF; RDF	42	196	73%	59 476	0%	12 275 790	0%	0.257	0%
S4a - Thermal Treatment	40	169	49%	41 465	99%	12 275 790	0%	0.515	60%
S4b - Gasification	47	196	89%	41 255	100%	12 275 790	0%	0.343	20%

Key

(*) These results are all net *benefits*

Value: Relative score in range 100% (best) to 0% (worst)

Employment: S = Skilled

U/S = Unskilled

4.4 *REVISED SCENARIOS*

On the basis of the first round of assessment, and the output from the BPEO workshop, seven new scenarios were developed in two groups, with and without thermal treatment, as detailed below. Once again, a brief description is given of each scenario, together with a reference to its schematic diagram in *Annex C*. The relative proportions of the different waste treatment technologies (as %) for each scenario in the key Landfill Directive years are presented in *Table 4.7*. The mixes of technologies in 2020 are plotted in *Figure 4.2*.

4.4.1 *Scenarios CI1a-CI1c – MBT and AD*

The first three scenarios use a combination of recycling, MBT and AD technology to divert waste from landfill. As soon as a new treatment plant is available, the waste currently being burned is diverted to that facility.

Scenario CI1a 45% Recycling, MBT=AD (see Figure C3.6)

The first scenario would divert 45% of waste to recycling (1) by 2020. The remaining waste that is diverted from landfill is sent in roughly equal amounts (~20%) to MBT and AD technologies.

Scenario CI1b 45% Recycling, MBT>AD (see Figure C3.7)

The second scenario envisages the same amount of recycling, but addresses the concern about possible limits to AD capability by diverting less waste to that technology and more to the MBT.

Scenario CI1c 60% Recycling, MBT=AD (see Figure C3.8)

The third scenario set a more ambitious recycling target of 60% C&I waste recycled by 2020. The remaining waste to be diverted was split roughly equally (~11%) between MBT and AD.

4.4.2 *Scenarios CI2a-CI2d – MBT, AD and Thermal Treatment*

The second set of scenarios includes thermal treatment (TT) as well as MBT and AD technologies. Again, as soon as a new treatment plant is available, the waste currently being burned is diverted to that facility.

Scenario CI2a 45% Recycling, TT=MBT=AD (see Figure C3.9)

The first in this set of scenarios is similar to *Scenario CI1a*, in that recycling increases to 45% in 2020, with the remaining waste diverted roughly equally between the three waste management technologies.

(1) In all these scenarios, 'recycling' includes a small amount of composting.

Scenario CI2b 60% Recycling, TT=MBT=AD (see Figure C3.10)

Scenario CI2b is similar to *Scenario CI1b*, but with a higher target of 60% recycling by 2020, and with the remaining waste that is diverted split roughly equally between MBT, AD and thermal treatment facilities.

Scenario CI2c 50% Recycling, TT>MBT=AD (see Figure C3.11)

This scenario envisages significant waste diversion from landfill. By 2020, 50% would be recycled, and the bulk of the remaining waste (25%) would be sent to thermal treatment facilities, though MBT and AD plants would also be used. In 2020, only 10% of C&I waste would be sent directly to landfill.

Scenario CI2d 60% Recycling, TT>MBT=AD (see Figure C3.12)

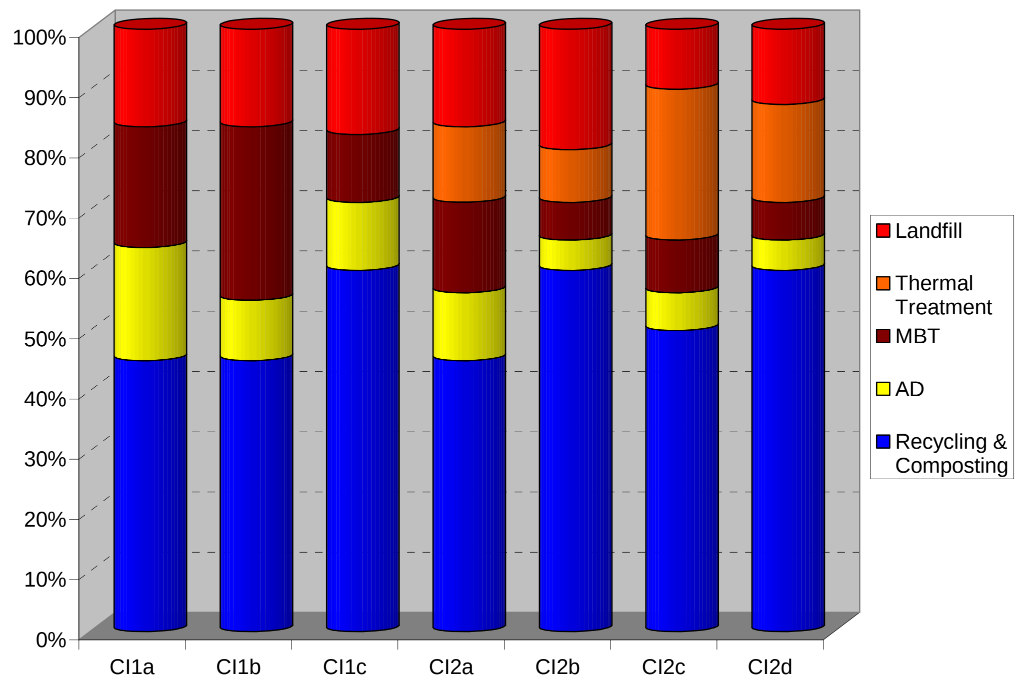
The last scenario further develops *Scenario CI2c*, with a higher recycling rate envisaged of 60% by 2020. The level of thermal treatment is higher than MBT and AD, and only 12.5% of waste would be landfilled in 2020.

Table 4.7 Revised C&I Waste Scenarios – Fates by % Total Arisings

Scenario	***Year***	**Recycling**	**AD**	**MBT**	**Thermal Treatment**	**Simple Combust'n**	**Direct to Landfill**
CI1a 45% Rec, MBT = AD	*2010*	35.0%	6.8%	2.7%		17.2%	38.2%
	2013	40.0%	13.2%	15.9%			30.9%
	2020	45.0%	18.8%	20.0%			16.2%
CI1b 45% Rec, MBT > AD	*2010*	35.0%	2.7%	6.8%		17.2%	38.2%
	2013	40.0%	5.3%	23.8%			30.9%
	2020	45.0%	10.0%	28.8%			16.2%
CI1c 60% Rec, MBT = AD	*2010*	37.5%	9.6%	2.7%		12.0%	38.2%
	2013	50.0%	11.9%	11.9%			26.2%
	2020	60.0%	11.3%	11.3%			17.5%
CI2a 45% Rec, TT = MBT = AD	*2010*	35.0%	6.8%	2.7%		17.2%	38.2%
	2013	40.0%	9.3%	6.6%	13.2%		30.9%
	2020	45.0%	11.3%	15.0%	12.5%		16.2%
CI2b 60% Rec, TT = MBT = AD	*2010*	37.5%	5.5%	2.7%		12.0%	42.3%
	2013	50.0%	5.3%	6.6%	9.3%		28.8%
	2020	60.0%	5.0%	6.3%	8.8%		20.0%
CI2c 50% Rec, TT > MBT = AD	*2010*	35.0%	6.8%	2.7%		17.2%	38.2%
	2013	40.0%	6.6%	2.6%	26.5%		24.2%
	2020	50.0%	6.3%	8.8%	25.0%		9.9%
CI2d 60% Rec, TT > MBT = AD	*2010*	37.5%	5.5%	2.7%		17.2%	37.1%
	2013	50.0%	5.3%	6.6%	17.2%		20.9%
	2020	60.0%	5.0%	6.3%	16.3%		12.5%

Rec = Recycling (with some composting)

Figure 4.2 *Percentages of Technologies Employed in Revised C&I Scenarios in 2020*



4.5 *RESULTS OF REVISED SCENARIOS*

The results of the assessment of the new scenarios are presented in *Table 4.9* (environmental), *Table 4.10* (financial cost, transportation and health effects) and *Table 4.11* (other social and feasibility results). *Annex G* describes how these were applied, using the output from the BPEO workshop, to generate the scores presented in *Table 4.8*.

Table 4.8 *Assessment of New Scenarios against Social and Feasibility Criteria*

	Decision Criteria	CI1a	CI1b	CI1c	CI2a	CI2b	CI2c	CI2d
Social Criteria	Employment	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Public Acceptability	3.0	2.8	3.5	2.0	2.8	1.0	1.8
	Perception of Health Effects	2.9	2.4	4.0	1.9	3.3	1.0	2.0
	Risk of Accidents	3.0	2.8	2.8	3.2	2.9	3.3	2.9
	Public / Producer Responsibility	3.2	3.2	3.5	2.8	3.2	2.5	2.9
	Local Amenity	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Social Implications / Equity	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Total	**21.1**	**20.2**	**22.8**	**18.9**	**21.2**	**16.8**	**18.5**
	Normalised	***73%***	***57%***	***100%***	***36%***	***74%***	***0%***	***30%***
Feasibility Criteria	Technical Feasibility	2.9	2.9	2.9	4.6	4.6	4.6	4.6
	Practical Feasibility	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Flexibility	3.0	3.0	3.0	4.0	3.0	3.0	3.0
	Existing Facilities	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Compliance with Policy	4.4	4.4	4.4	4.2	4.2	4.2	4.2
	Total	**15.2**	**15.2**	**15.2**	**17.8**	**16.8**	**16.8**	**16.8**
	Normalised	***0%***	***0%***	***0%***	***100%***	***61%***	***61%***	***61%***

Table 4.9 Summary of Environmental Results

Scenario Description	Resource Depletion		Acidification		Greenhouse Emissions		Water Impact Scores		Average Landtake	
	te crude oil eq	Value	te SO_2	Value	te CO_2 eq	Value	-	Value	Hectares	Value
CI1a 45% Rec, MBT=AD	3 392 369	0%	30 008	30%	4 232 312	5%	1435	94%	60.4	96%
CI1b 45% Rec, MBT>AD	3 566 278	36%	32 599	100%	4 527 863	39%	1531	0%	61.8	77%
CI1c 60% Rec, MBT=AD	3 757 959	77%	32 149	88%	4 980 489	91%	1450	80%	60.1	100%
CI2a 45% Rec, TT=MBT=AD	3 418 423	5%	29 149	7%	4 185 417	0%	1509	21%	66.0	19%
CI2b 60% Rec, TT=MBT=AD	3 776 958	81%	31 611	73%	4 932 449	85%	1485	45%	67.4	0%
CI2c 50% Rec, TT>MBT=AD	3 524 149	28%	28 878	0%	4 323 156	16%	1429	100%	62.2	71%
CI2d 60% Rec, TT>MBT=AD	3 869 250	100%	32 166	88%	5 062 008	100%	1488	42%	63.5	53%

Table 4.10 Summary of Financial Cost, Transport and Health Impact Results

Scenario Description	Relative Cost		Average Transport to Facilities		Relative Transport from Facilities		Health Impacts	
	Cost: £M pa	Value	Million te-km pa	Value	-	Value	-	Value
CI1a 45% Rec, MBT=AD	£47.52	0%	29.8	70%	125 802	77%	0.162	65%
CI1b 45% Rec, MBT>AD	£46.76	28%	27.4	100%	107 233	100%	0.184	45%
CI1c 60% Rec, MBT=AD	£46.22	48%	28.7	84%	113 486	92%	0.124	100%
CI2a 45% Rec, TT=MBT=AD	£47.28	9%	31.8	46%	189 364	0%	0.199	31%
CI2b 60% Rec, TT=MBT=AD	£45.76	65%	29.8	71%	167 708	26%	0.150	76%
CI2c 50% Rec, TT>MBT=AD	£44.87	98%	35.6	0%	187 585	2%	0.233	0%
CI2d 60% Rec, TT>MBT=AD	£44.83	100%	32.1	43%	184 473	6%	0.196	33%
CI1a 45% Rec, MBT=AD	£47.52	0%	29.8	70%	125 802	77%	0.162	65%

Table 4.11 Summary of Other Social and Feasibility Results

Scenario Description	Average Employment			Relative Risk of Accidents		Relative Producer Responsibility	
	S	U	Value	-	Value	-	Value
CI1a 45% Rec, MBT=AD	62	226	0%	48.8	47%	15.6	20%
CI1b 45% Rec, MBT>AD	67	245	100%	50.3	10%	14.9	0%
CI1c 60% Rec, MBT=AD	62	233	29%	50.7	0%	18.0	100%
CI2a 45% Rec, TT=MBT=AD	65	235	50%	47.5	80%	15.2	7%
CI2b 60% Rec, TT=MBT=AD	63	234	38%	49.6	27%	17.5	83%
CI2c 50% Rec, TT>MBT=AD	64	233	38%	46.7	100%	15.4	14%
CI2d 60% Rec, TT>MBT=AD	65	245	92%	49.9	21%	17.5	83%
CI1a 45% Rec, MBT=AD	62	226	0%	48.8	47%	15.6	20%

The results of the environmental and financial cost assessments are presented in *Table 4.12*.

Table 4.12 *Assessment of C&I Waste Scenarios against Environmental and Cost Criteria*

	CI1a	CI1b	CI1c	CI2a	CI2b	CI2c	CI2d	Wt (†)
Resource Depletion	0%	36%	77%	5%	81%	28%	100%	20%
Air Acidification	30%	100%	88%	7%	73%	0%	88%	20%
Global Warming	5%	39%	91%	0%	85%	16%	100%	20%
Water Impacts	94%	0%	80%	21%	45%	100%	42%	20%
Landtake	96%	77%	100%	19%	0%	71%	53%	20%
Environmental Score	**45%**	**50%**	**87%**	**11%**	**57%**	**43%**	**77%**	
Normalised	*45%*	*52%*	*100%*	*0%*	*61%*	*42%*	*87%*	
Average Cost in £/te	**£47.52**	**£46.76**	**£46.22**	**£47.28**	**£45.76**	**£44.87**	**£44.83**	
Normalised	*0%*	*28%*	*48%*	*9%*	*65%*	*98%*	*100%*	

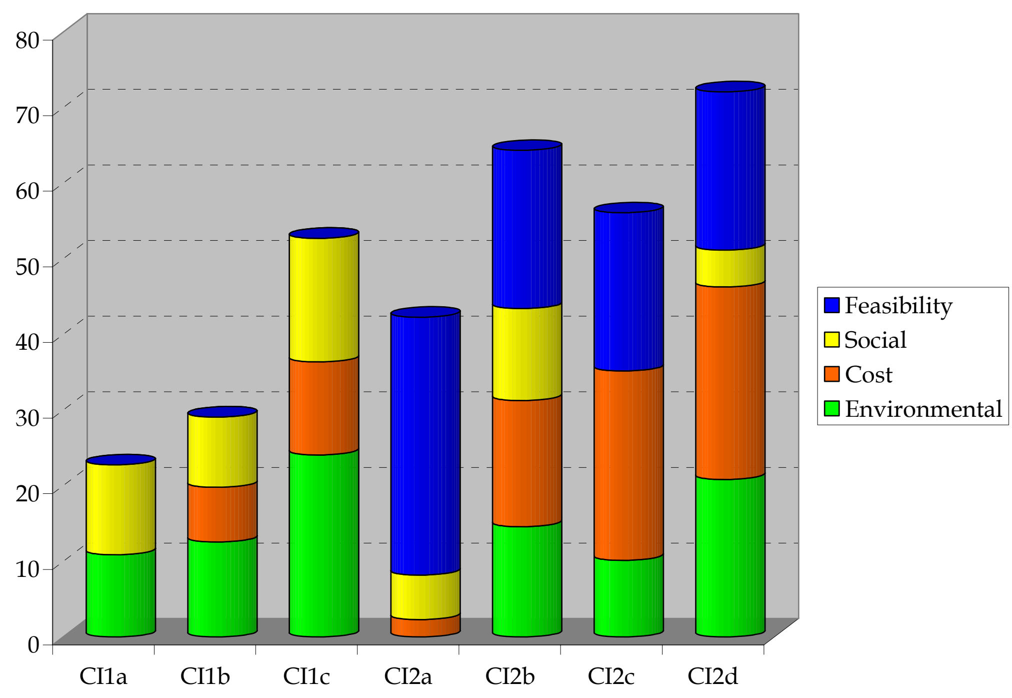
(†) These weightings assume the environmental criteria are equally important.

By applying the same weighting of the decision criteria as for MSW (see *Table 3.11*) to the normalised scores in *Table 4.8* and *Table 4.12*, it is possible to conduct a final assessment to identify the highest scoring option. The outcome of this process is shown in *Table 4.13* and *Figure 4.3*.

Table 4.13 *Calculation of Final Assessment Score*

	CI1a	CI1b	CI1c	CI2a	CI2b	CI2c	CI2d	Wt
Environmental	11	13	24	0	15	10	21	24.1
Financial	0	7	12	2	17	25	25	25.5
Social	12	9	16	6	12	0	5	16.4
Feasibility	0	0	0	34	21	21	21	34.1
Final Score	**23**	**29**	**53**	**42**	**64**	**56**	**72**	

Figure 4.3 *Graphical Depiction of Final Assessment Score*



4.6 C&I WASTE BPEO

The previous plot and table show that CI2d is the highest scoring C&I waste option. The growth of waste and the technologies by which it is treated are shown in *Figure 4.4*. By 2020, recycling rises to 60%, with a mixture of thermal treatment, MBT and AD diverting all but 12.5% of the residual C&I waste away from landfill.

4.6.1 Numbers, Locations and Capacities of Facilities for MSW BPEO

The BPEO assessment also provides guidance on the numbers and capacities of waste treatment facilities and possible areas of search for suitable locations for these facilities based on the distribution of waste arisings throughout Northern Ireland. The process by which this was achieved is described in detail in *Annex F*. The output of this process is summarised in *Table 4.14*, and depicted in *Figure 4.5*.

Table 4.14 Indicative Number, Location and Capacity (in tonnes per annum) of Waste Management Facilities for C&I Waste BPEO

#	Recycling	IVC	AD	MBT	Thermal Treatment	Landfill
1	50 000: Belfast	6 000: Belfast	40 000: Belfast	20 000: Belfast	130 000: Belfast	100 000: Belfast
2	50 000: Derry	6 000: Derry		30 000: Derry		100 000: Derry
3	50 000: Craigavon	6 000: Craigavon				100 000: Craigavon
4	50 000: Antrim	6 000: Ballymena				100 000: Ballymena
5	50 000: Omagh					
6	50 000: Coleraine					
7	50 000: Newcastle					
8	50 000: Newtownards					
9	60 000: Magherafelt					

NB The scenario also assumed seven combustion facilities in the region

Figure 4.4 *Schematic Diagram of the C&I Waste BPEO*

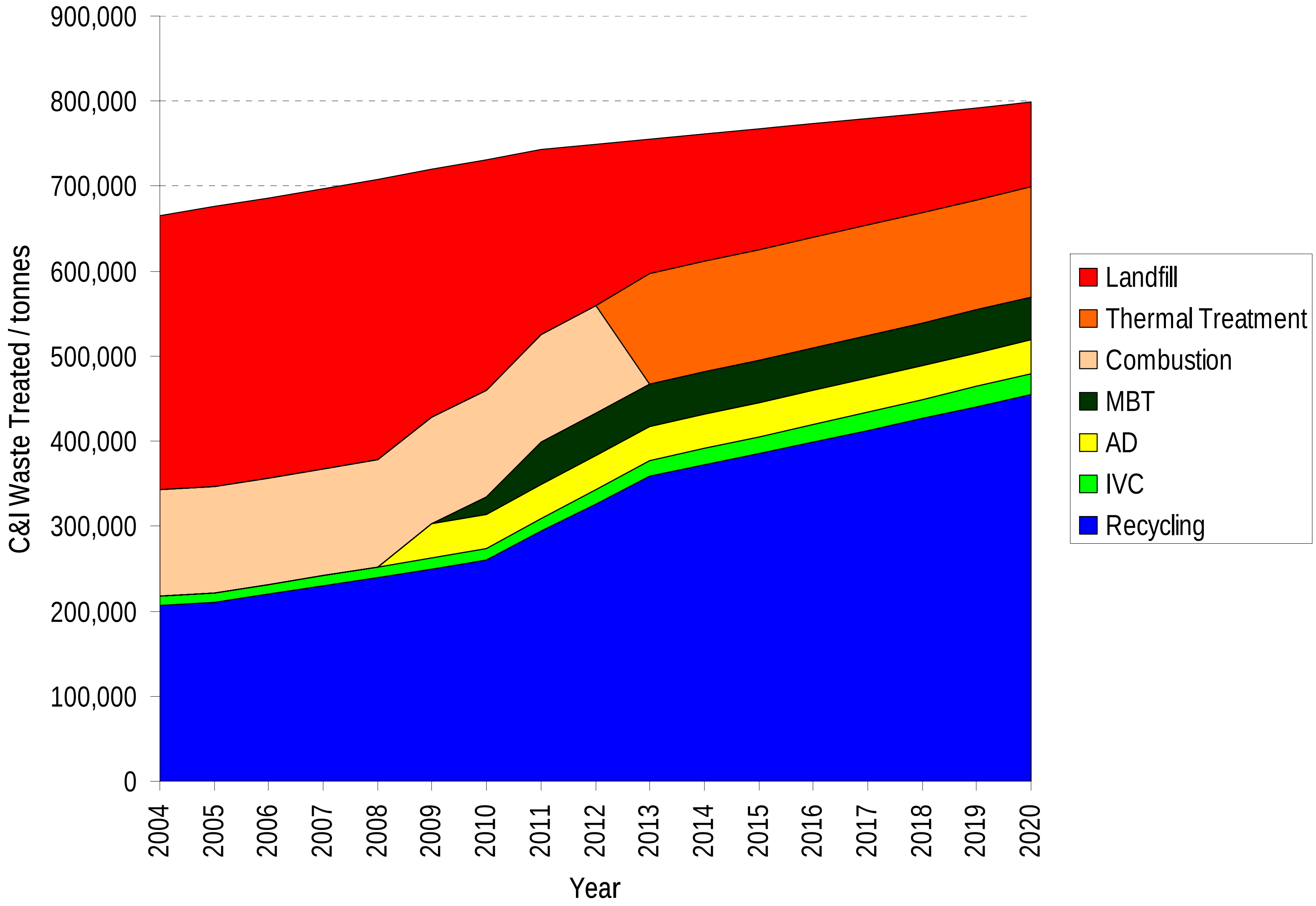
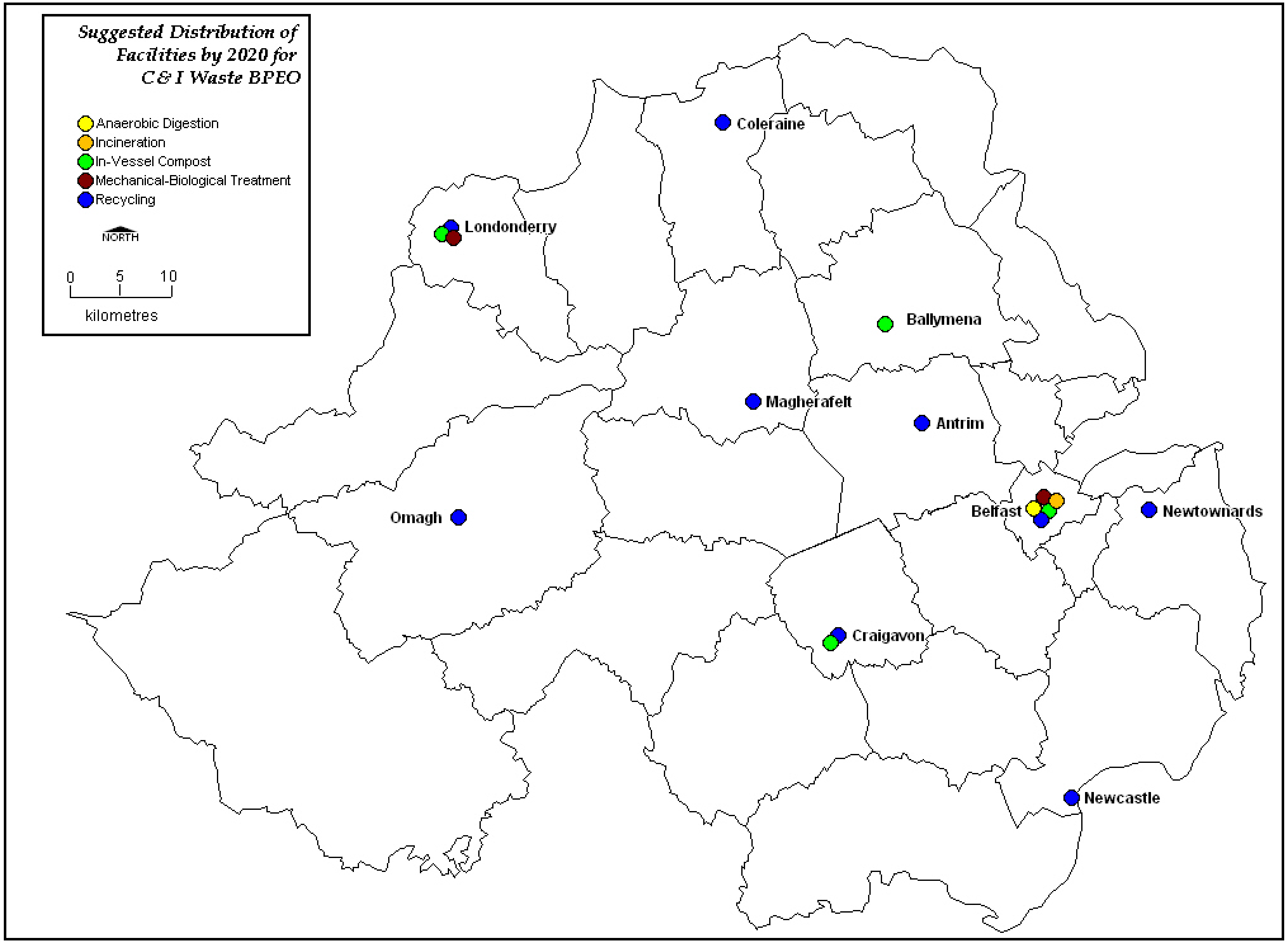


Figure 4.5 Suggested Distribution of Facilities by 2020 for C&I Waste BPEO



4.7 SENSITIVITY ANALYSIS

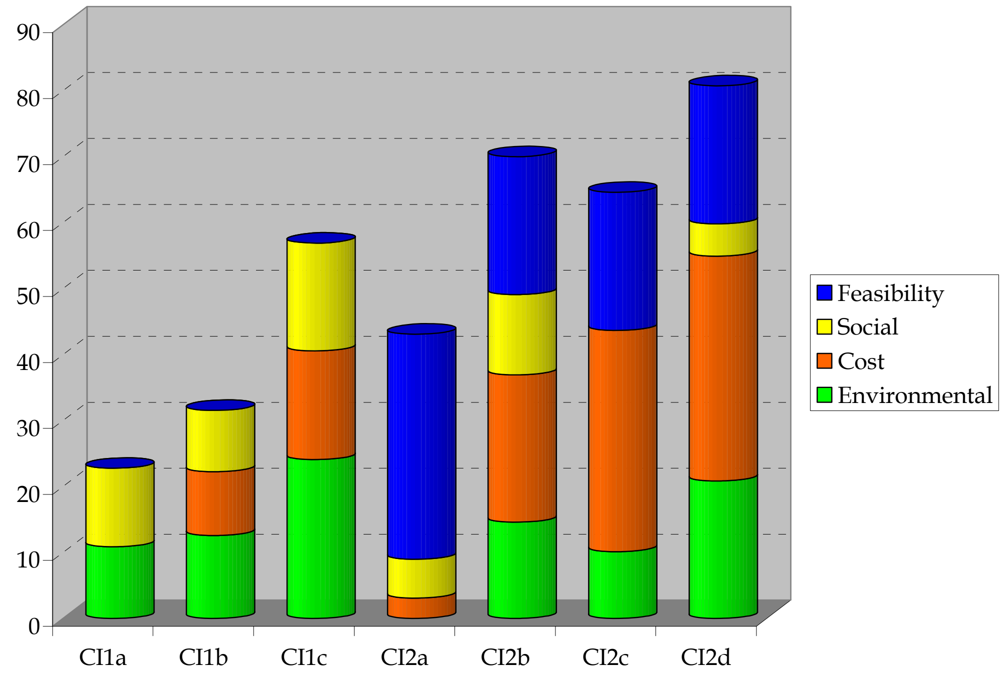
A clear assumption in this assessment has been that the weighting of the decision criteria for MSW, derived at the BPEO workshop, is equally valid for C&I waste. Feedback from the C&I sector representatives on the BPEO Steering Group suggested that cost was the most significant factor for C&I waste management.

A simple means to analyse this is to promote the weighting of the financial criterion, so that it matches the highest other criterion – feasibility. As shown in *Table 4.15* and *Figure 4.6*, the effect on the assessment is minor, but further increases the margins between the highest scoring and the other scenarios.

Table 4.15 Calculation of Revised Assessment Score

	CI1a	CI1b	CI1c	CI2a	CI2b	CI2c	CI2d	Wt
Environmental	11	13	24	0	15	10	21	24.1
Financial	*0*	*10*	*16*	*3*	*22*	*34*	*34*	*34.1*
Social	12	9	16	6	12	0	5	16.4
Feasibility	0	0	0	34	21	21	21	34.1
Final Score	**23**	**32**	**57**	**43**	**70**	**65**	**81**	

Figure 4.6 Graphical Depiction of Revised Assessment Score



5 CD&E WASTE BPEO

5.1 BASELINE DATA

The third waste stream included in this study was construction, demolition and excavation (CD&E) wastes.

Waste Arisings

The most recent EHS survey on CD&E waste (1), in 2002, estimated that arisings were in the region of 4.76 million tonnes. However, the report also recognised that there was a large degree of uncertainty with this figure, due to lack of information, and that actual arisings were somewhere within the range of 2 to 8 million tonnes.

The construction sector representatives on the BPEO Steering Group recommended the Symonds report as a more accurate source of data. This estimates total CD&E waste arisings to be in the region of 2.5 and 3.75 million tonnes. The upper value was taken as a conservative best estimate for current waste arisings, given the uncertainties inherent with the data. This is also supported by per capita comparisons with England and Wales, which suggests that two tonnes per person, plus or minus 10%, seems a reasonable estimation of arisings.

There was little Northern Ireland-specific information to guide the selection of a growth rate for the arisings, so advice was taken from other waste strategies that have been completed. As *Annex I* shows, the conclusion from these studies, and taking into account NI infrastructure investment plans, was that a growth rate of 1% through to 2020 should be assumed for CD&E waste in Northern Ireland.

Waste Composition

Waste composition data were taken from EHS's most recent Waste Survey (1), and is presented in *Table 5.1*.

Table 5.1 CD&E Waste Arisings Composition

Component	Arisings
Concrete, bricks, tiles and ceramics, soils, stones and dredging spoil	79.0%
Wood, glass and plastic	2.0%
Metals (including their alloys)	0.4%
Insulation materials and asbestos containing construction materials	0.2%
Other construction and demolition wastes including mixed wastes	18.5%

(1) *Construction and Demolition Waste Survey*, completed by Enviros Consulting Ltd for EHS, 2002

Waste Fates

CD&E waste may basically experience one of two fates – it is either reused/recycled, or landfilled. Data from EHS's survey led to an estimation of around 35% of CD&E waste currently being reused or recycled.

Geographical Origin

EHS's survey did not provide any detail on where the waste originated. For the purpose of transport calculations to treatment facilities, it was assumed that the geographical distribution of CD&E waste arisings would strongly reflect economic activity, and hence the percentage of CD&E waste arising in each District Council area would be the same as the proportion of C&I waste arising in each Council area (see *Figure 4.1*).

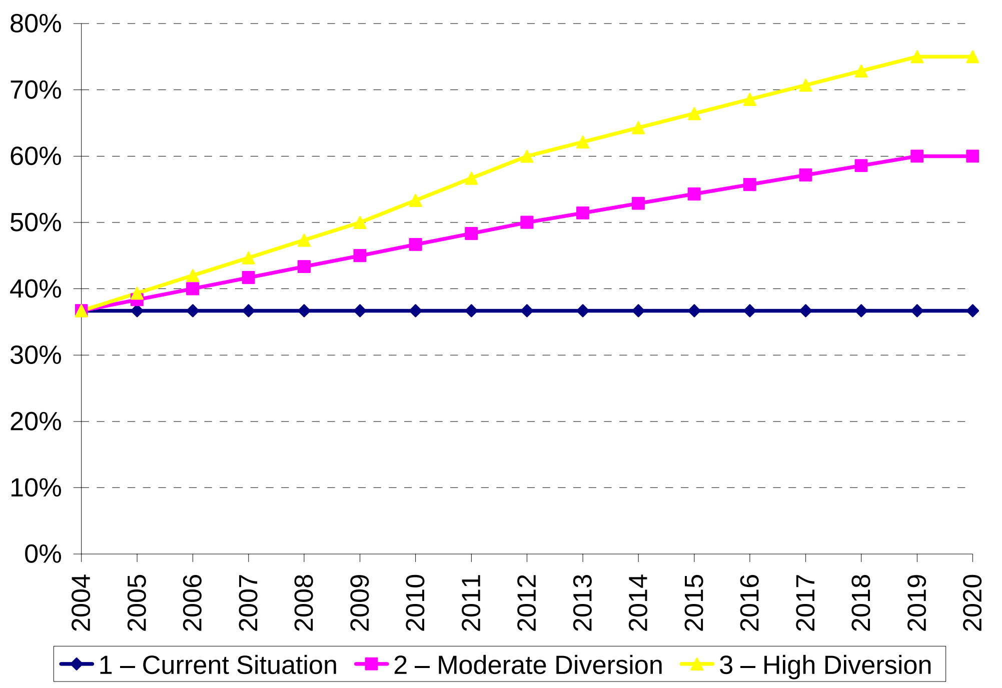
5.2 CD&E WASTE SCENARIOS

With only two fates available, the three options modelled continue with the existing split (current situation), and then model increasing levels of diversion from landfill, as shown in the figures in *Annex C*. The increasing diversion rates are presented in *Table 5.2* and *Figure 5.1*.

Table 5.2 CD&E Scenarios Landfill Diversion Levels

Scenario	2004	2010	2013	2020
CD&E Scenario 1 – Current Situation	37%	37%	37%	37%
CD&E Scenario 2 – Moderate Diversion	37%	47%	51%	60%
CD&E Scenario 3 – High Diversion	37%	53%	62%	75%

Figure 5.1 CD&E Scenarios – Reuse/Recycling Rates



5.3 CD&E BPEO RESULTS

The analysis of the CD&E scenarios against the decision criteria was completed with input from relevant Steering Group members, discussions with public sector clients, construction industry companies and trade bodies and also with respect to CD&E reuse and recycling performance in other EU countries.

5.3.1 Discussion of the Assigned Rankings

It was recognised within the BPEO Steering Group that there was a lack of hard evidence and information with regard to CD&E waste, in comparison to the other two waste streams. This was the case not only concerning current waste arisings and treatment methods, but also in terms of how to assess the effect of increasing the reuse and recycling rate against the different decision criteria. Due to this lack of information, the three scenarios have been primarily assessed by means of qualitative ranking against each other rather than by calculating absolute scores. These rankings have been derived from discussions with construction sector representatives and also by analogy with other EU countries, especially in terms of what it is feasible to achieve in the long term by 2020. The results of the assessment are presented in *Table 5.3*.

Technical and Practical Feasibility

All scenarios score equally because they are all achievable. The current situation is, by definition, practically feasible. However, reuse and recycling rates in other EU countries demonstrate that much higher levels are achievable under current global economic conditions – for example, Holland and Denmark achieve over 90%. The Republic of Ireland target of 85% by 2013 also demonstrates high levels are achievable in a similar economy to NI. By comparison, the *Scenario 3* target of 75% reuse/recycling in NI by 2020 is more modest, allowing time for the cultural and structural changes required in the NI construction industry, both with public & private sector clients and all sections of the industry.

Flexibility

Scenario 2 is given the best ranking for flexibility, as an improvement from the current position regarding available infrastructure and opportunities for reuse and recycling would provide greater flexibility for clients and companies that are generating waste materials. *Scenario 1* scores lower as current reuse and recycling opportunities are insufficient to provide the industry with flexible choices.

Scenario 2 scores more highly than *Scenario 3* because the latter will perhaps limit choices, as 75% reuse/recycling is a challenging (though achievable) target. The cost and availability of landfill disposal for CD&E wastes is expected to become increasingly more restrictive with time, which will limit options.

Table 5.3 Summary of CD&E BPEO Results

Criteria	Sub-criteria	'Units'	CD&E Scenario 1. Current Situation	2. Moderate Diversion	3. High Diversion
Environment	Resource use	te oil saved	62 000	108 500	139 500
	Climate change	te CO_2 saved	128 500	254 000	338 500
	Acidification	te SO_2 saved	603	897	1093
	Water impact	relative score	0	0.499	1
	Land take	hectares	171	145	126
Economic	Cost	£M	836	767	723
Social	Employment	jobs	293	326	345
	Public acceptability	ranking (†)	3	2	1
	Producer responsibility	ranking	3	2	1
	Risk of accidents	ranking	1	2	3
	Local amenity	ranking	equal	equal	equal
Feasibility	Tech./pract. feasibility	ranking	1	1	1
	Flexibility	ranking	2	1	2
	Use of existing facilities	ranking	2	1	2
	Market for products	ranking	1	2	3
	Compliance with policy	ranking	3	2	1

(†) The ranking figures range from '1' (best) to '3' (worst). Where there is no preference, all scenarios are scored '1'.

Use of existing facilities

Current recycling infrastructure is under utilised, and therefore *Scenario 1* does not make good use of existing facilities. *Scenario 2* equates to maximising the use of existing infrastructure, supported by modest expansion to fill gaps, and thus is ranked the highest. Significant additional development of facilities would be required to deliver *Scenario 3*, so this is scored lower than *Scenario 2*.

Market for products

It is recognised across the industry that the reluctance to use recycled materials in place of virgin materials is a major barrier to increasing recycling rates. Therefore, as more and more materials are presented for reuse and recycling, the difficulties of finding markets for them are anticipated to increase. This said, the problem has been acknowledged by public sector clients and the industry, and is likely to change significantly over the next few years, as NI adopts best practice from Great Britain, the Republic of Ireland and other EU countries. Nevertheless, this criterion has been assessed according to the current situation, and so *Scenario 1* ranks above *Scenario 2*, which in turn ranks above *Scenario 3*.

Compliance with policy

The NIWMS is firmly based on the waste hierarchy, with reuse and recycling at the top and disposal at the bottom, therefore the scenarios are ranked from *Scenario 3* (best) to *Scenario 1* (worst).

Overall Feasibility Score

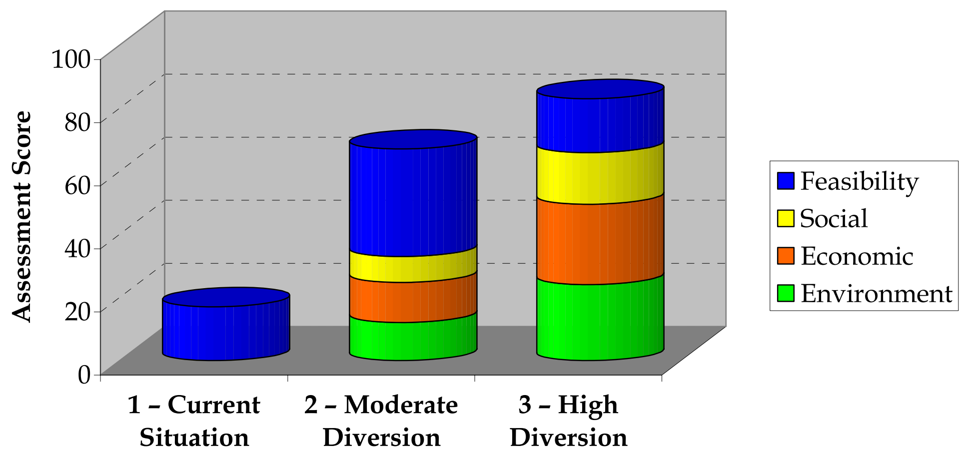
Totalling the individual assessments for feasibility shows that *Scenario 2* scores most highly for feasibility, while *Scenario 1* and *Scenario 3* are equal second.

This reflects the fact that the current situation is under-utilising the available infrastructure and limiting the opportunities for the industry to reuse and recycle more. *Scenario 2* would be relatively easy to achieve with modest improvements. *Scenario 3* is a more challenging but achievable target.
The above assessments can be summarised into a 1-2-3 ranking for each of the four major criteria, as shown in *Table 5.4*. This table also presents the decision criteria weightings as determined at the BPEO workshop, and combines the figures to arrive at final assessment scores for the three scenarios, which are also plotted in *Figure 5.2*.

Table 5.4 ***Final Scenario Ranking and Weighting***

		CD&E Scenario		
Criteria	**1. Current Situation**	**2. Moderate Diversion**	**3. High Diversion**	**Decision Criteria Weighting**
Environment	3	2	1	24.1
Economic	3	2	1	25.5
Social	3	2	1	16.4
Feasibility	2	1	2	34.1
Final Score	**17.0**	**67.0**	**83.0**	

Figure 5.2 ***Schematic Plot of CD&E BPEO Assessment Results***



The table and figure show that *Scenarios 2* and *3* clearly score more highly than *Scenario 1*, and, moreover, that *Scenario 3* exceeds *Scenario 2*, indicating that the BPEO for CD&E waste in Northern Ireland is to aim for much higher reuse and recycling of waste materials, reaching 75% by 2020.

5.4 SENSITIVITY ANALYSIS

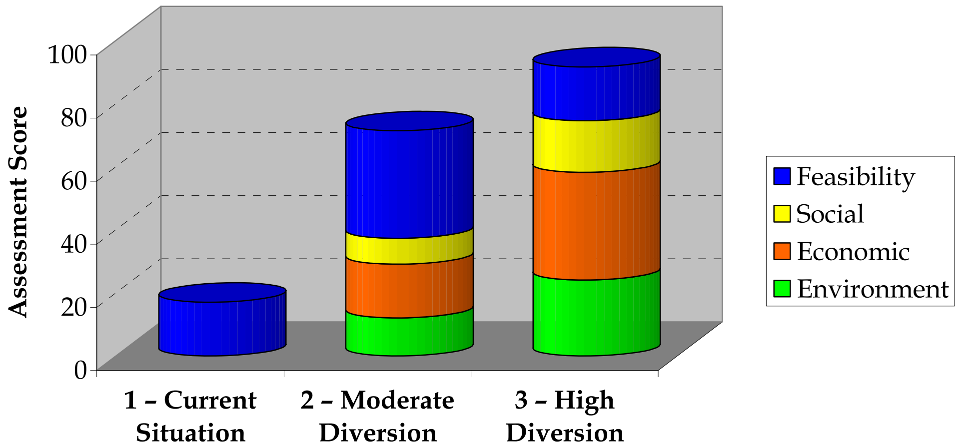
As with the C&I waste, a clear assumption in this assessment has been that the weighting of the decision criteria for MSW, derived at the BPEO workshop, is equally valid for CD&E waste. Feedback from the construction sector representatives on the BPEO Steering Group suggested that cost was the most significant factor for CD&E waste management.

A simple means to analyse this is to promote the weighting of the financial criterion, so that it matches the highest other criterion – feasibility. As shown in *Table 5.5* and *Figure 5.3*, the effect on the assessment is minor, but slightly increases the margins between the highest scoring and the other scenarios

Table 5.5 Calculation of Revised Assessment Score

	CD&E Scenario			
Criteria	**1. Current Situation**	**2. Moderate Diversion**	**3. High Diversion**	**Decision Criteria Weighting**
Environment	3	2	1	24.1
Economic	3	2	1	34.1
Social	3	2	1	16.4
Feasibility	2	1	2	34.1
Final Score	**17.0**	**71.4**	**91.6**	

Figure 5.3 Graphical Depiction of Revised Assessment Score



Having determined the BPEOs for MSW, C&I and CD&E waste, using a common set of assumptions and baseline data, the final task is to integrate the three sets of data into one scenario. However, while there are significant synergies between MSW and C&I waste, there are not the same opportunities for CD&E wastes. Data suggests that wood, glass, plastic and metals together make up less than 2.5% of the CD&E waste arisings, which are dominated by soil and rubble fractions not present in the other waste streams. For this reason, this integration section focuses on combining the MSW and C&I waste fractions.

This has been done at a relatively high level for this study, by combining the infrastructure requirements as outlined in *Table 3.20* (for MSW) and *Table 4.14* (for C&I waste). Where two facilities of the same type have been proposed in the same area of search, the integrated scenario recommends building a single, larger facility to cover the needs of both waste streams.

The mix of facilities required by the integrated scenario is presented in *Table 6.1*, and the areas of search are shown in *Figure 6.2*. The schematic diagram for the combined scenario is presented in *Figure 6.1*.

Table 6.1 Indicative Number, Location and Capacity (in tonnes per annum) of Waste Management Facilities for Integrated BPEO

#	Recycling	Windrow	IVC	AD	MBT	Thermal Treatment
1	100 000: Belfast	20 000: Belfast	56 000: Belfast	90 000: Belfast	50 000: Belfast	280 000: Belfast
2	100 000: Derry	20 000: Derry	56 000: Derry	20 000: Coleraine	60 000: Derry	
3	100 000: Coleraine	20 000: Coleraine	50 000: Coleraine	20 000: Omagh	30 000: Coleraine	
4	50 000: Ballymena	20 000: Ballymena	56 000: Ballymena	20 000: Armagh	40 000: Ballymena	
5	100 000: Omagh	20 000: Banbridge	50 000: Banbridge		40 000: Omagh	
6	50 000: Banbridge	20 000: Newcastle	50 000: Newcastle		30 000: Craigavon	
7	50 000: Newcastle	20 000: Cookstown	6 000: Craigavon			
8	50 000: Craigavon	20 000: Enniskillen	50 000: Cookstown			
9	60 000: Magherafelt		50 000: Enniskillen			
10	50 000: Antrim					
11	50 000: Dungannon					
12	50 000: Newtownards					

Figure 6.1 Schematic Diagram of the Integrated Waste BPEO

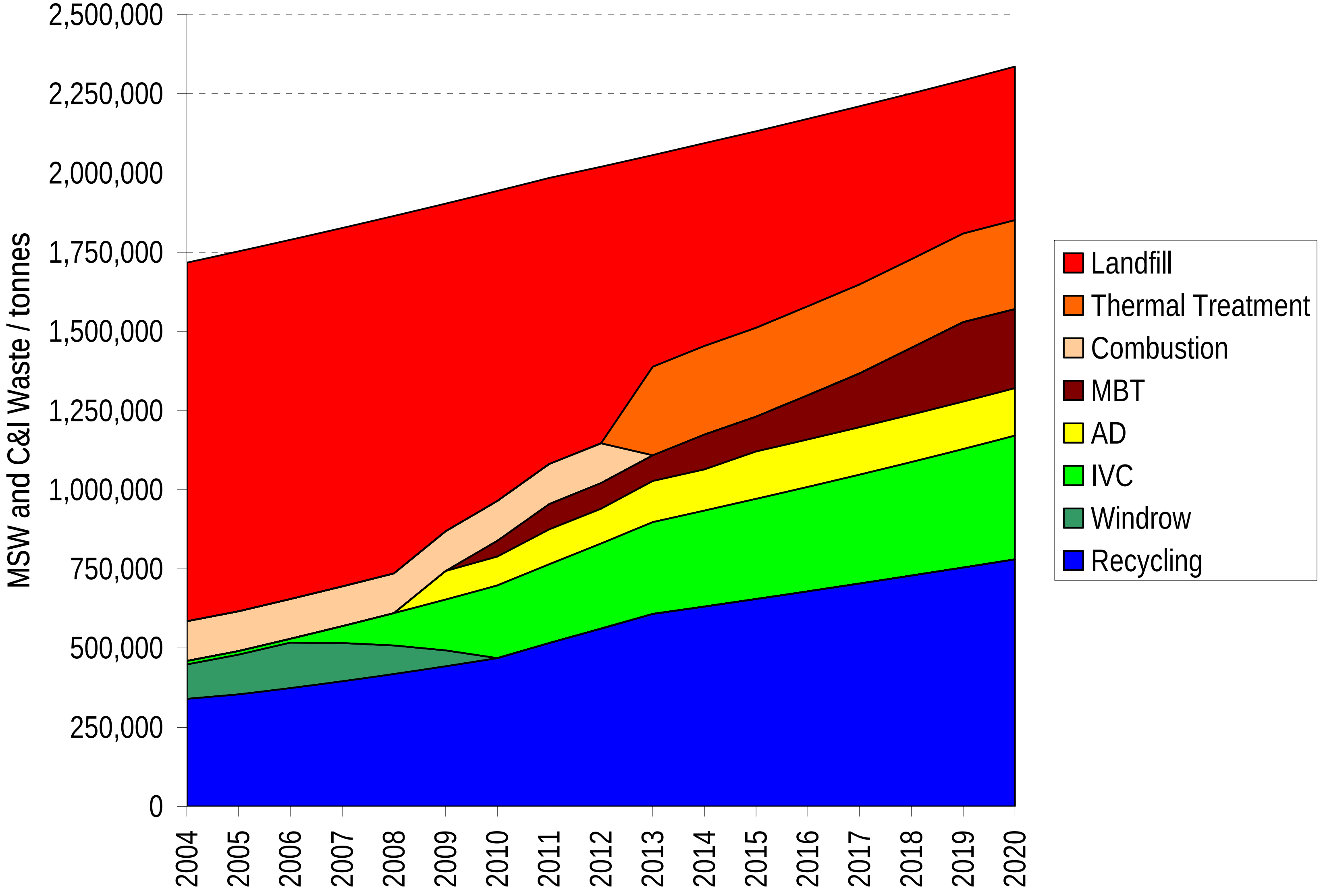
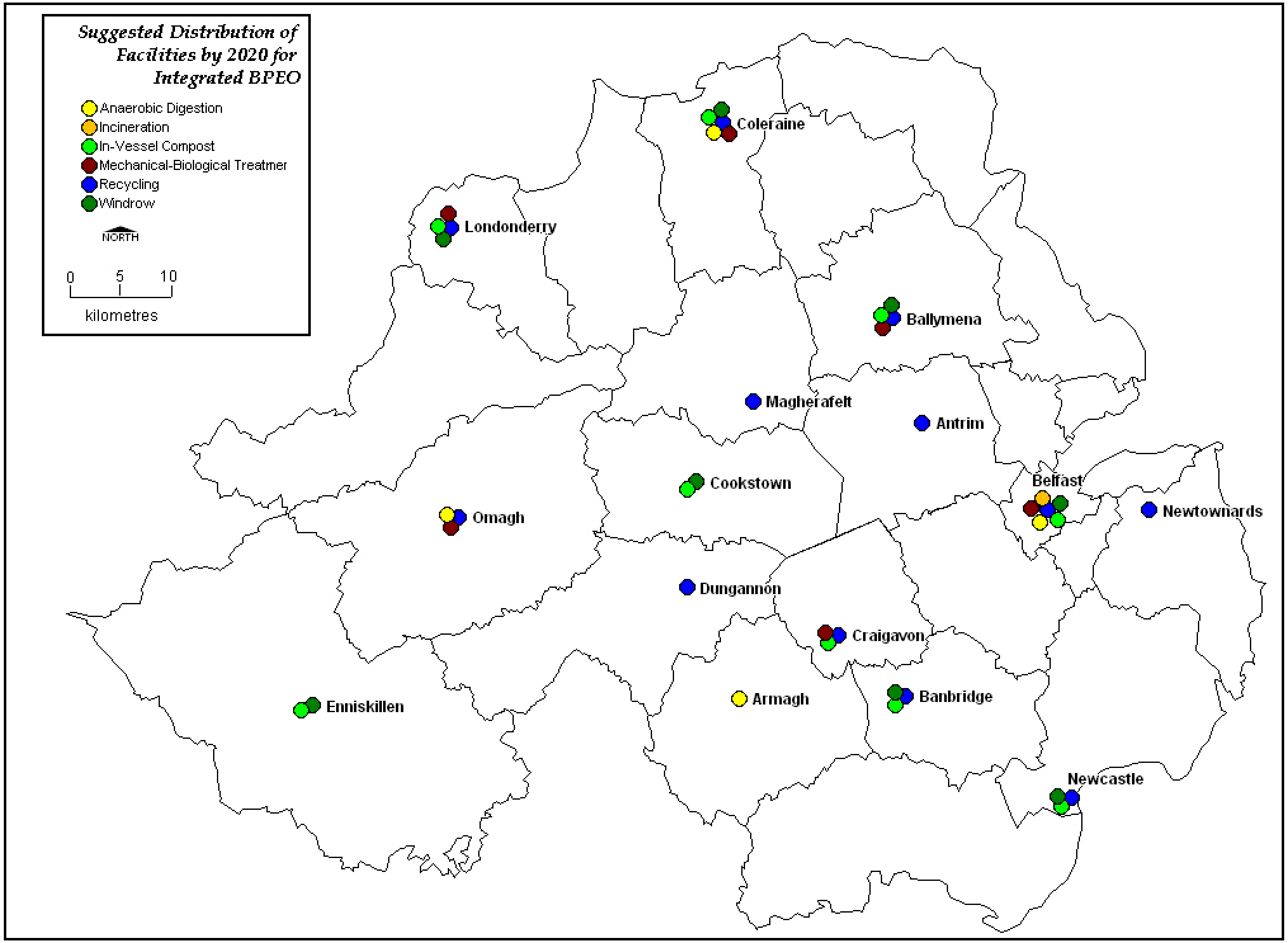


Figure 6.2 Suggested Distribution of Facilities by 2020 for Integrated Waste BPEO



7 GUIDANCE FOR SUB-REGIONAL WASTE MANAGEMENT PLANS

The NI BPEO provides a high level assessment of the required waste management infrastructure to enable compliance with Landfill Directive targets. It provides guidance on the mix of technologies and their total capacities required in future years. Assumptions on typical plant sizes allow the determination of the number of plants required year by year, which leads in turn to the identification of areas of search for the plants. As the Waste Management Groups plan their future requirements for waste management facilities, they should use the NI BPEO as baseline guidance.

The NI BPEO has had to be performed at a high level, without regard to local circumstances. More detailed locations and sizes of facilities will need to be determined on a local basis, so local studies will be required. This study has assumed a certain performance from (for example) MBT plants, but such plants vary in design, and more are becoming available all the time. For the purposes of this study, it is assumed that the organic output can be used on land (as opposed to landfilled), that the HCV material can be used as an RDF, and that the process produces a 40% decrease in biodegradability. Furthermore, the EA guidance on the measurement of reduction of biodegradability achieved by MBT is still not available. All these factors should be revisited during the development of the sub-regional plans.

Similar variations exist for all of the other technologies, too, ranging from advances in MRF technology to increasingly tight controls on thermal treatment facilities. The sub-regional plans will need to be underpinned by detailed assessments that fully justify the type, size and location of facilities identified.

8 GLOSSARY OF ACRONYMS

This glossary defines the various acronyms used in the main section of this report.

AD	Anaerobic Digestion
BPEO	Best Practicable Environmental Option
C&I	Commercial and Industrial
CD&E	Construction, Demolition and Excavation
CV	Calorific Value
DC	District Council
Defra	Department for the Environment, Food and Rural Affairs
DOENI	Department of the Environment, Northern Ireland
EA	Environment Agency
EHS	Environment and Heritage Service
EU	European Union
LF	Landfill
HCV	High Calorific Value
IVC	In-Vessel Composting
KPI	Key Performance Indicator
LCV	Lower Calorific Value
MBT	Mechanical-Biological Treatment
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
NI	Northern Ireland
NILGA	Northern Ireland Local Government Association
NIWMS	Northern Ireland Waste Management Strategy
OPRA	Operator and Pollution Risk Appraisal
PPS	Planning Policy Statement
RDF	Refuse-Derived Fuel
SEA	Strategy Environmental Assessment
SWMA	Strategic Waste Management Assessment
TT	Thermal Treatment
UK	United Kingdom
WHO	World Health Organisation
WMP	Waste Management Plan
WISARD	Waste – Integrated Systems Assessment for Recovery and Disposal

Annex A

Decision Criteria and Assessment Techniques

A1 DECISION CRITERIA AND ASSESSMENT TECHNIQUES

This section explains the methods used for the assessment of the scenarios against the decision criteria. The criteria were divided into four categories – environmental, financial, social and feasibility – most with several sub-categories. The first two categories were assessed using desk-based methodologies and computer modelling. The last two categories were assessed at the BPEO workshop at Cookstown, using supporting information provided by desk-based work, where appropriate.

The criteria are as follows:

A2 Environmental Criteria

- *A2.1 Resource Depletion*
- *A2.2 Air Acidification*
- *A2.3 Greenhouse Gas Emissions*
- *A2.4 Landtake*
- *A2.5 Extent of Water Pollution*

A3 Financial Costs

- *A3.1 Financial Costs*

A4 Social Criteria

- *A4.1 Health Effects*
- *A4.2 Employment*
- *A4.3 Public Acceptability*
- *A4.4 Risk of Accidents*
- *A4.5 Producer Responsibility*
- *A4.6 Local Amenity*
- *A4.7 Social Equity*

A5 Feasibility Criteria

- *A5.1 Technical Feasibility*
- *A5.2 Practical Feasibility*
- *A5.3 Flexibility*
- *A5.4 Existing Facilities*
- *A5.5 Compliance with Policy*

A glossary of abbreviations is provided at the back of the annex.

A2 ENVIRONMENTAL CRITERIA

Five environmental criteria were assessed, covered resource depletion, air acidification, greenhouse house gas emissions, landtake and extent of water pollution.

A2.1 RESOURCE DEPLETION

Resource depletion is an important concern because current levels of resource consumption associated with economic growth are unsustainable. Abiotic resources are natural, and essentially limited, resources, such as iron ore, crude oil and natural gas, as opposed to renewable, biotic sources such as biomass. Resource depletion is one the most frequently assessed impact categories in life cycle assessment (LCA) studies. The scope of this assessment includes the phenomena cited in *Box A2.1*.

Box A2.1 Scope of Assessment of Resource Depletion

Grid electricity	Resources were consumed in order to generate the grid electricity that powers the waste management facilities.
Coal electricity	Any electricity generated by the waste management facilities was assumed to offset coal-fired electricity generation, rather than default grid electricity.
Diesel generation	Some facilities use diesel-powered machinery to process the waste, so it is necessary to know what resources are used in generating diesel.
Steam generation	Autoclaving uses steam, whose generation requires resource consumption.
Material recycling	In recycling (for example) aluminium, there are significant energy savings by comparison with the extraction of aluminium from bauxite. The resource depletion burdens of recycling versus virgin production were ascertained, so that the difference could be credited to those processes that included material recycling.
Transportation	Significant amounts of fuel are used in moving the waste from facility to facility, and these must be included in the resource depletion calculations.

A2.1.1 Methods and Assumptions Used

WISARD (1) determines the abiotic depletion factor (ADF) for the extraction of individual minerals and fossil fuels, based on concentration reserves and rate of de-accumulation, and expresses the results in 'kg antimony equivalents/kg extraction'.

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

(1) ***WISARD*** is the Environment Agency's life cycle assessment software for waste management. Details of ***WISARD*** software can be found in *Annex C*.

A2.1.2 *Calculating Emission Factors*

Figures for the three depleted materials (plus emissions data for sulphur dioxide, methane and carbon dioxide) were extracted from LCI databases (BUWAL 250, ETH and IDEMAT 2001). *CML 2000* provides resource depletion figures for the three species, in terms of kilograms of antimony. These were compared, as shown in *Table A2.1*, to generate a single figure representing the resource depletion of each of the options, in terms of *'tonnes of crude oil equivalents'*. These equivalents were applied to the LCI data, to generate the resource depletion emission factors in *Table A2.2* (see the following sections for explanations of the other data).

Table A2.1 Resource Depletion Equivalents (data from CML 2000)

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

Table A2.2 Emission Factors Used in BPEO Assessment

	Activity	Resource Depletion Crude oil eq / g	Acidification SO_2 / g	Global Warming CO_2 eq / g
Recycling of 1kg of…	Aggregate	3	0.02	9
	Aluminium	3177	54.76	9495
	Cotton	2045	7.73	1852
	Ferrous	735	3.32	1994
	Glass	263	2.42	481
	Paper	118	3.54	380
	Plastic	1734	6.12	1766
	Polyester	1871	25.00	2378
	Textiles	1958	16.37	2115
Generation or consumption of…	1kg of copper	1710	136.00	5424
	1kg of mixed salt	35	0.59	99
	1kg of oxygen	63	1.13	225
	1kg of sulphur	86	63.70	274
	1kg of zinc	1569	30.40	4899
	1MJ of steam	33	0.04	75
	1l of diesel	934	2.30	499
	1kg coal	1153	16.30	3085
	1kg crude oil	1216	52.03	3859
	1m3 natural gas	1065	1.29	2427
	1kWh grid electricity	234	1.62	634
	1kg natural gas	885	1.07	2017
	Transport in a 28 te truck (per te-km travelled)	75	0.49	214

A2.1.3 *Calculation of the Impact Scores*

The resource requirements (tonnes of diesel, kWh of electricity, tonne-kilometres waste transported, etc.) were calculated for the various facilities and processes involved in each scenario. It was then simply a case of applying the emission factors (which provide emissions per tonne of diesel, etc.), in order to determine the resource depletion associated with the activities.

A2.2 AIR ACIDIFICATION

Acidification is the process whereby air pollution (mainly ammonia, sulphur dioxide and nitrogen oxides) results in the deposition of acid substances. 'Acid rain' is best known for the damage it causes to forests and lakes. Less well known are the many ways it affects freshwater and coastal ecosystems, soils and even ancient historical monuments. Acid deposition can increase the environmental mobility of metals, resulting in the pollution of water sources and increased uptake of metals by biota.

Gases contributing to acidification are aggregated according to their acidification potential. These potentials have been developed for potentially acidifying gases such as SO_2, NO_x, HCl, HF and NH_3, on the basis of the number of hydrogen ions that can be produced per mole of a substance, using SO_2 as the reference substance.

As well as having resource depletion implications, all of the activities cited in *Box A2.1* are also associated with SO_2 emissions. There are two additional considerations, highlighted in *Box A2.2*.

Box A2.2 ***Additional Scope of Assessment of Acidification***

Diesel Usage	In addition to the SO_2 emissions when diesel is generated, there are also emissions when it is consumed.
Plant Emissions	Some of the waste management options (notably thermal treatment) involve combustion, with the attendant SO_2 emissions.

A2.2.1 Method and Assumptions Used

For this study, SO_2 emissions were used as a proxy for all the acidifying gases. It was therefore assumed that SO_2 emissions alone are satisfactorily indicative of the overall acidification potential of the options.

A2.2.2 Calculation of the Impact Scores

Having calculated the resource requirements (tonnes of diesel, kWh of electricity, tonne-kilometres waste transported, etc) of the various facilities and processes, it was again simply a case of applying the emission factors tabulated in *Table A2.2* to determine the acidification impacts.

A2.3 GREENHOUSE GAS EMISSIONS

Human activities have altered the chemical composition of the atmosphere through the build-up of greenhouse gases, primarily carbon dioxide, methane, and nitrous oxide. The higher the concentration of these gases, the higher the heat-trapping capability of the earth's atmosphere. As a result, temperatures and sea levels are expected to rise.

A2.3.1 *Method and Assumptions Used*

Gases contributing to the greenhouse effect are aggregated according to their impact on radiative warming, compared to carbon dioxide as the reference gas. The characterisation model as developed by the Intergovernmental Panel on Climate Change (IPCC) was selected for development of characterisation factors, the figures being shown in *Table A2.3*.

Table A2.3 Greenhouse Gas Characterisation Factors (†)

Gas	Formula	Characterisation Factor	Units
Carbon Dioxide	CO_2	1	CO_2 equivalent
Methane	CH_4	21	CO_2 equivalent

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

For the carbon dioxide emissions, a firm distinction was made between renewable and non-renewable carbon dioxide, with only the latter, from the combustion of fuels and plastics, contributing to the greenhouse gas figures. Renewable carbon dioxide is the result of combusting carbon taken up by organisms which can be considered to be part of a closed loop due to the short time frames between take-up and release. The carbon dioxide released from burning paper is an example of this as paper in Europe is predominantly from sustainably managed forests.

A2.3.2 *Calculation of the Impact Scores*

The calculation of the impact scores followed the same pattern as for resource depletion and acidification. The emissions factors for the two gases were scaled according to the total amount of gases generated, and converted into CO_2 equivalents using the figures in *Table A2.3*, to generate the figures in *Table A2.2*). These were simply scaled by the amounts of waste handled.

A2.4 LANDTAKE

The original list of decision criteria from the Department of the Environment's *BPEO Decision Makers' Guide* (1) included two criteria, Natural and Cultural Heritage, that focus primarily on the impact of new infrastructure development on the local area. The high-level nature of this assessment meant that it was not possible to assess whether any required infrastructure development in the scenarios would impinge on areas of natural or cultural significance.

It was therefore decided that the study would simply estimate the additional land-take required by infrastructure developments, and use that as a (rather blunt) tool to assess the possible impacts on heritage sites, on the basis that some waste management technologies require significantly more land than others. When the sub-regional Waste Plans come to consider more specific

(1) See http://www.ehsni.gov.uk/pubs/publications/NI_BPEO_Guidance.pdf [03May05 @ 17:27]

questions of where new infrastructure might be located, they will need to assess the possible impacts on natural and cultural heritage more thoroughly.

A2.4.1 Method and Assumptions Used

Landtake was measured using professional judgment based on the typical size of different facilities, drawn from a number of public studies, and simplified to straight-line plots through the available data points. The results are presented in *Table A2.4*.

Table A2.4 Landtake Assumption Data

Plant Type	Slope / Hectares per thousand tonnes per annum	Intercept / Hectares
MRF	0.0369	0.07
Windrow	0.4516	-0.01
IVC	0.1045	-0.02
AD	0.0137	0.01
MBT	0.0070	1.37
Thermal Treatment	0.0111	0.72
Gasification	0.0200	0.00
Landfill	0.0034	10.69

To provide an example of how the calculations were performed, an MRF plant of capacity 25 000 tpa would require [0.0369 x 25 + 0.07 =] 1.0 hectares of land. The required number and throughputs of all facilities for each scenario for each year were converted into hectares, summed and averaged, to provide an assessment of the average landtake required by the scenario over the period of the study. This allowed the assessment to take into account not just the final number of plants, but the point in time at which they would be built.

A2.5 EXTENT OF WATER POLLUTION

For assessing the environmental risk to water for the scenarios, the Environment Agency's OPRA (Operator & Pollution Risk Appraisal) for Waste scoring methodology was used. The OPRA model is based on the consideration of the likelihood of problems arising and a measure of their consequences. Evaluation of risk involves, firstly, the probability of an occurrence of an undesirable event, and, secondly, the consequence of such an event. The OPRA system comprises of two elements:

- environmental appraisal; and
- operator performance appraisal

Since this risk assessment was for proposed waste management scenarios, the operator performance appraisal could not be carried out.

A2.5.1 *Method and Assumptions Used*

The various types of waste management operations were considered in terms of sources of pollution, inherent risks at these sites and the potential longer term impacts. Two main category bases and six sub-categories (see *Table A2.5*) were used for the environmental appraisal. The methodology allocated a score for each of the categories, where the higher the score, the higher the potential risk.

Table A2.5 OPRA Assessment Scores

Basis	Subcategory	Detail
Source	Type of facility	Assessment of the inherent risk to water arising from the type of facility, ranging from a borehole [5] to a hazardous waste landfill [60] (see *Table A2.6*)
	Throughput	The higher the throughput, the more risk there will be: less than 50 tpa scores [2] 50 to 5000 tpa scores [7] 5000 to 50 000 tpa scores [12] more than 50 000 tpa scores [20].
	Levels of control and containment	Cannot be assessed for an unbuilt plant, so a score of [5] was allocated, indicating a Quality Assurance system in place and two control mechanisms such as liners, gas controls, leachate containment etc.
Target	Proximity to: - human dwellings - groundwater - surface water	Without knowing the exact locations of the facilities, it is not possible to assess their proximity to potential water pollution receptors. Respective mid-range values of [15], [10] and [7] were assigned, given a consistent target-based score of [32] per facility.

Table A2.6 Types of Facility Assessed in this Study

Facility	OPRA	Description	Score
Materials Recycling Facility	A15	Material Recycling Facility	15
Windrow Composting	A22	Composting Facility	15
In-Vessel Composting	A23	Biological Treatment	15
Anaerobic Digestion	A23	Biological Treatment	15
MBT – Basic	A23	Biological Treatment	15
MBT – Autoclaving	A17	Physico-chemical Treatment	25
Thermal Treatment	A18	Incinerators	20
Gasification	A18	Incinerators	20
Coal Displacement	A18	Incinerators	20
Landfill	A4	HCI &/or household waste Landfill	40
Inert Landfill	A5/6	Large Non-biodegradable Landfill (†)	20
Land Application / Other Treatment	A6	Other waste Landfills	20
Simple Combustion	A18	Incinerators	20

(†) Including C&D waste

Number of Facilities

OPRA impact scores were allocated *per facility*, so multi-facility scenarios scored more poorly against this criterion. For example, two 75 000 tpa MRFs would score [2 x (15 + 20 + 5 + 32) =] 144 points, whereas six 25 000 tpa MRFs would score [6 x (15 + 12 + 5 + 32) =] 384 points. Despite treating the same amount of waste using the same technology, the greater number of facilities increases the risk of water pollution.

Average score

All scores were worked out per year, because facilities would be added in certain years, rather than being present for the duration of the study. In order to facilitate comparison, the score for source and target OPRA impacts were totalled by year and then averaged across all the years assessed, to generate a single score for each scenario.

A3 FINANCIAL COSTS

A3.1 FINANCIAL COSTS

Unlike the other three top level criteria, 'financial costs' was a criterion in itself, and had no sub-criteria.

It was outside the scope of this piece of work to develop a detailed and precise cost model with which to appraise the scenarios, and the level of data available would make such a task extremely difficult and costly. A problem commonly associated with waste cost data is the acquisition of detailed, reliable and up to date information, and the necessity to rely on small historical data sets to base future trends. In addition, some technologies are not as well established as others, resulting in additional difficulties in making accurate cost predictions. Another significant barrier is that this information is often commercially sensitive and so not readily available.

Despite these facts, it was necessary to include an assessment of financial costs in the study, since the solution must be practicable, and this requirement encompasses having a reasonable cost.

A3.1.1 *Method and Assumptions Used*

Four cost aspects were included in this assessment, covering waste collection, gates fees, revenue streams and landfill tax. Costs were based on current costs as at 2004. The exception to this was landfill tax, which was assumed to increase at a rate of £3/te/annum until it reaches £35/te, in 2012.

Collection Fees

Waste collection regimes can vary according to numerous parameters, including the number of bins, the types of waste collected, the frequency of the collections and the coverage of the collection schemes employed. Different District Councils have adopted and will continue to adopt different combinations of these parameters, making accurate modelling difficult. Faced with this, collection costs have been set, per tonne, at one of just two levels, depending on whether or not the waste needs to be source-separated before reaching the waste management facility.

Gate Fees

Treatment costs associated with each technology were assessed on a gate fee basis. A gate fee represents a unit payment per tonne made by a waste producer/carrier to the service provider. Gate fees were collected from a variety of sources in the waste industry, to generate typical figures, with some reliance on the size of the facility, acknowledging the associated economies of scale involved. The evaluation did not consider capital costs associated with the development of a new facility, as it was assumed that they would be borne by the developer, and built in to the gate fees.

Revenue Streams

There are considerable uncertainties associated with the market value/cost of potential products from waste management processes, such as the RDF from MBT processes. For the purpose of this study, these revenues/costs were excluded from the analysis.

Following feedback from stakeholders, the second round of assessment included estimated revenues from energy sales associated with three of the processes – thermal treatment, anaerobic digestion and MBT where RDF could be burned to generate energy. These processes were awarded a credit of £20/MWh of energy generated, and an additional £40/MWh up to 2015, for those processes where Renewable Obligations Certificates (ROCs) could be awarded.

Combination

Each of the above cost/revenue streams were determined in terms of costs per tonne, and then scaled by the amounts of waste going to the appropriate technologies each year. These were summed for the period of the study and finally divided by the total waste handled over the period, to give an overall average cost per tonne figure for each scenario.

A4 SOCIAL CRITERIA

The most appropriate approach to addressing the social criteria is a qualitative, subjective assessment, and this was achieved by means of a BPEO workshop. The details of that process are presented in *Section 2.4*. Where possible, pertinent data were gathered in advance of the meeting, to inform the stakeholders, and that data preparation is explained below.

A4.1 HEALTH EFFECTS

A significant cause of public concern surrounding the construction of a new waste management facility is the perceived health effects that may result for the local community. There are numerous reports in the public domain, frequently presenting conflicting opinions on the relative merits of different technologies.

To try to address this situation, Defra recently published a Health Effects report [(1)] that aimed to bring together in one place information from all the studies conducted to date. Although there are a number of data gaps (notably on composting and emerging technologies such as autoclaving), this is the best reference information that is available and has been used as the basis for assessment in this BPEO study.

It should be noted that displaced health impacts have not been accounted for in this assessment. These include the benefits of recycling over the offset health impacts that would have occurred from manufacturing materials, and the offset impacts from energy production instead of burning coal. Although these offset impacts may be considerable, it was decided that the chief concern is in local health impacts near the facilities, so the assessment was kept within those limits.

A4.1.1 *Method and Assumptions Used*

The specific starting point was *Table 4.5* of the Defra report, on page 206, which is reproduced in *Table A4.2*. This quantifies, to the degree possible from the data sources, the various health impacts that might be expected to occur as a result of waste management operations.

As can be seen, the table presents impacts for six classes of process; composting, MBT, anaerobic digestion, pyrolysis/gasification, thermal treatment and landfill. Autoclaving is missing, and there are no impacts for composting. The approximations used in this study are presented in *Box A4.1*. These assumptions are used to generate the data in *Table A4.3*.

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(1) *Review of Environmental and Health Effects of Waste Management: Municipal Solid Waste and Similar Wastes*, Enviros Consulting Ltd and University of Birmingham with Risk and Policy Analysts Ltd, Open University and Maggie Thurgood, 2004, available at http://www.defra.gov.uk/environment/waste/research/health/index.htm [03May05 @ 16:47]

Box A4.1 ***Health Impact Technology Assumptions***

Composting:	Given that the release of bioaerosols from composting plants can be an issue, it has been decided to assign to composting the higher of the impacts in each category from the most similar processes – MBT and anaerobic digestion.
Landfill:	Data is given on six different landfill types, using flares or engines at small, medium and large sites. A typical value has been deduced by averaging the impacts from medium-sized flare and medium-sized engine landfill sites.
Cement Kiln:	One of the options sends residual waste to a cement kiln. This is outside the remit of the Defra study, so we have assumed that impacts from a kiln are similar to those from thermal treatment plant.

A4.1.2 Comparing the Impacts

Clearly, a 'death brought forward' is more serious than a 'respiratory admission', and some processes do not have estimated impacts for all four categories, so it is not appropriate simply to total the columns to generate overall impacts.

The World Health Organisation (WHO), as part of its Global Burden of Disease project, has developed a table of Disability Weights associated with various conditions [1]. Illnesses, referred to in general as *sequelae*, are rated on a scale from 0.0 (perfect health) to 1.0 (death), and this dataset was used to determine scores for the four health effects listed, as explained in *Table A4.1*. These figures were used in *Table A4.4* to calculate the final scores for each waste management technology.

Table A4.1 ***Health Impact Disability Weighting Assumptions***

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

(1) http://www3.who.int/whosis/burden/manual/other/GBD90 Disability Weights.zip [03May05 @ 16:49]

Table A4.2 Defra Report Estimated Health Impacts due to Emissions to Air (per Billion (10^9) Tonnes of Waste Processed) (†)

Health Effects	Composting	MBT	Anaerobic Digestion	Pyrolysis / Gasification	Thermal Treatment / Cement Kiln	Landfill – Medium + Flare (‡)	Landfill – Medium + Engine (‡)
Deaths brought forward	No Data	18.2	1.48	30.8	64	15	12
Respiratory admissions	No Data	49.5	72	293	1500	24	110
Cardiovascular admissions	No Data	No Data	No Data	5.45	0.41	1.3	1
Additional cancer cases	No Data	No Data	0.00108	0.019	0.02	0.048	0.05
Data quality	n/a	Poor (3)	Moderate (5)	Moderate (6)	Moderate (6)	Poor (4)	Poor (4)

(†) Figures multiplied by 10^9 versus the report, to show their relative values more clearly

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

Table A4.3 Processed Estimates of Health Impacts due to Emissions to Air (per Billion (10^9) Tonnes of Waste Processed) (†)

Health Effects	Composting	MBT	Anaerobic Digestion	Pyrolysis / Gasification	Thermal Treatment / Cement Kiln	Active Landfill – Medium
Deaths brought forward	18.2	18.2	1.48	30.8	64	13.5
Respiratory admissions	72	49.5	72	293	1500	67
Cardiovascular admissions	No Data	No Data	No Data	5.45	0.41	1.15
Additional cancer cases	0.00108	No Data	0.00108	0.019	0.02	0.049

(†) Figures multiplied by 10^9 versus the report, to show their relative values more clearly

Table A4.4 Health Impact Scores with Disability Weightings Factored into the Calculations

Health Effects	Composting	MBT	Anaerobic Digestion	Pyrolysis/ Gasification	Thermal Treatment / Cement Kiln	Landfill	Disability Weighting
Deaths brought forward	18.2	18.2	1.48	30.8	64	13.5	**0.809**
Respiratory admissions	72	49.5	72	293	1500	67	**0.149**
Cardiovascular admissions	No Data	No Data	No Data	5.45	0.41	1.15	**0.26**
Additional cancer cases	0.00108	No Data	0.00108	0.019	0.02	0.049	**0.165**
Final 'Score' (†)	**8.48**	**11.05**	**3.97**	**17.48**	**68.78**	**5.3**	

(†) The Final 'Score' represents a relative value that combines the number and the severity of incidents resulting from the handling of a given weight of waste by the stated waste management technique.

Applying the Impact Scores to the Options

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

A4.2 EMPLOYMENT

Waste management systems have the potential to impact positively or negatively on employment, in terms of the number of jobs, their quality and distribution. Employment enables people to meet their needs and improve their living standards, and is the single most effective and sustainable way of tackling poverty and social exclusion for those who can work.

Development of new waste management facilities will create temporary construction employment, and their long-term operation will also create jobs, the nature and number of which will depend on the type of facility. Options involving labour-intensive technologies will offer additional employment opportunities. This will result in reducing unemployment and contribute to wider benefits for social inclusion. If these jobs are located in an area of high unemployment and high levels of out-migration caused by lack of jobs, their social benefit may be even greater.

The impact of each scenario on employment was appraised by estimating the number of jobs required to support that scenario, taking into account whether the jobs would be skilled or unskilled. The number of staff required to run the facilities was assessed using employment data from existing plants, and the number of shifts that would be required was also taken into account. The employment data is presented in *Table A4.5*.

Final numbers for the skilled and unskilled jobs associated with each scenario were generated by determining the number and capacity of each type of facility required by the scenario in each year, and using the table to generate the associated number of man-year jobs. These were totalled and then divided by the number of years of the study, to arrive at figures for the average number of skilled and unskilled jobs per year that each scenario would support.

Table A4.5 Estimated Numbers of Skilled and Unskilled Jobs Required in Different Facilities as Throughput Changes (†)

Throughput / tpa	MRF		Windrow		IVC		AD		MBT		Thermal		Gasification		Landfill	
	S	U/S	S	U/S	S	U/S	S	U/S	S	U/S	S	U/S	S	U/S	S	U/S
0	3	13	2	4	3	3	2	5	4	14	4	14	4	17	3	4
15 000			2	4												
25 000	3	13			3	3										
30 000			2	6												
45 000			2	7												
50 000	3	20			3	5	2	5								
60 000			2	8												
75 000	3	24	2	9	3	6										
90 000			2	10												
100 000	6	27			3	6	2	8	4	14	4	14			3	4
105 000			3	10												
120 000			3	11									11	50		
125 000	6	30			3	7			4	21	4	21				
135 000			3	11												
150 000	6	32	3	12	6	7	4	9	4	26	4	26				
165 000			3	12												
175 000	6	34			6	8			4	29	4	29				
180 000			3	12												
195 000			3	13												
200 000	9	35			6	8	4	10	8	32	8	32	11	50	3	6
210 000			4	13												
225 000	9	37	4	13	6	8			8	34	8	34				
240 000			4	14												
250 000	9	38			6	9	4	11	8	36	8	36				
255 000			4	14												
275 000									8	38	8	38				
300 000							6	12	12	40	12	40			3	7
325 000									12	41	12	41				
350 000							6	13	12	42	12	42				
400 000															3	8
(†)	100 000				150 000		100 000		100 000		100 000					

S Skilled (site managers, assistant managers and foremen)
U/S Unskilled (operatives, weighbridge operators and machine operators)
(†) Assumed new shift required every (†) tpa [tonnes per annum]

A4.3 *PUBLIC ACCEPTABILITY*

Public acceptability is a very important issue to consider when looking at waste management plans, and needs to be assessed on two levels.

Firstly, for a waste management option that requires the public to do things differently (eg involving increased participation on their part), it is critical that they find this acceptable, and are prepared to play the role required of them in order for the system to work.

Secondly, waste management options that require the development of new facilities may also encounter resistance from the public, owing to the perceived impacts on local amenity, environmental quality and health risks. As a result, planning permission for the development may be more difficult to obtain.

The nature of this criterion is highly subjective, and therefore the scenarios were reviewed and assessed at the BPEO workshop. The delegates were asked to assign a score to each of the scenarios on the basis of perceived public acceptability. Qualitative comments on the basis of the scores assigned were also recorded.

A4.4 *RISK OF ACCIDENTS*

A safe and healthy environment for employees and the public in the waste management industry is a basic requirement of health and safety law, and employers are required to take necessary measures to comply with the legal requirements. However, no operation in any business is 100% safe; there is some element of risk associated with all tasks, in the waste management industry ranging from workers using heavy and mechanical plant, to the handling of hazardous wastes and waste transportation.

The risk of accidents was assessed at the stakeholder forum, but the delegates were provided with some basic information, based upon the qualitative data in *Table A4.6*. Scores for each scenario were generated by scaling the relative risk rating of each technology used in the scenario by the total throughput for that technology.

A4.5 *PRODUCER RESPONSIBILITY*

In the context of a waste management plan, producer responsibility means making the households and businesses that generate waste more responsible for that waste. A scenario that encourages this might make households and businesses more conscious of what happens to their waste and why it matters to minimise waste arisings. Emphasis might be put on encouraging maximum participation in schemes for materials separation at source.

Table A4.6 *Qualitative Assessment of Risks of Accidents, by Facility Type*

Facility	Degree of... (†) Manual Handling	Mechanical Equipment	Total
MRF	3	3	6
Windrow Composting	1	1	2
In-Vessel Composting	1	1	2
Anaerobic Digestion	1	1	2
MBT - Basic	2	3	5
MBT - Autoclaving	2	2	4
Thermal Treatment	1	1	2
Gasification	1	1	2
Coal Displacement	1	1	2
Landfill	1	1	2
Inert Landfill	1	1	2
Land Application / Other Treatment	1	1	2
Simple Combustion	1	1	2

(†) Range from 1 [low] to 3 [high]

Producer responsibility was assessed at the BPEO workshop. Delegates were provided with some basic supporting information, based on the qualitative data in *Table A4.7*. Scenarios received credit for material send to MRF and composting facilities, on the basis that source separation has taken place and would make the producers more aware of the waste they generate. IVC requires less extensive separation than windrow (or recycling), so received less credit, and AD could be fed by source-separated green waste, so got a smaller credit.

Table A4.7 *Qualitative Assessment of Encouragement to Producer Responsibility, by Facility Type*

Facility Type	Score (†)
MRF	3
Windrow Composting	3
In-Vessel Composting	2
AD	1
All Other Facilities	0

(†) Scores range from 3 [greatest encouragement to producer responsibility] down to 0.

Scores for each scenario were generated by scaling the relative risk rating of each technology used in the scenario by the total throughput for that technology.

A4.6 LOCAL AMENITY

Local amenity was used to assess the impact that the waste management facilities are likely to have on the local area. This impact may take all sorts of forms, including noise, odour, dust, traffic levels and visual effects (positive and negative). Without knowing the specific location of the facilities, these assessments could only take a general form, based on relative impact versus one another.

The BPEO assessment involved analysis of the possible number and location of facilities (see *Annex F*), and this was used to estimate the amount of waste haulage (in tonne-kilometres [(5)]) to the facilities. A very much more simplistic assessment was adopted for the onward transport of materials from the waste management facilities. Facilities were rated from 0-2 for the amount of onward transport that would be required, with landfill scoring zero (no onward transport), the composting and AD technologies scoring one and all others scoring two. The total throughputs through each of the facility types were scaled by these scores, to arrive at a relative assessment of the onward transport required.

The stakeholders were presented with these data on numbers of facilities and potential transport impacts, and were asked to take into account potential noise, dust, odour, visual impacts, etc, and assign a relative score to each of the scenarios.

A4.7 SOCIAL EQUITY

The waste management techniques used for each scenario may have the potential to impact positively or negatively on society at a local and national level. A key objective of sustainable development is to tackle poverty and social exclusion, and the subsequent unemployment, low educational achievements, poor quality housing and poor health. Another key issue is equity. Different scenarios can result in different winners and losers, and equitable distribution of costs and benefits is therefore a factor to be considered. If any of the competing scenarios showed signs of performing better in one or more areas, then this should be reflected in the appraisal.

It was not possible to give the stakeholders any data support with this criterion, since it is largely a case of personal perception. Instead, delegates were asked to assign a relative score to each of the scenarios based on a qualitative comparison with the other scenarios.

(5) A tonne-kilometre represents the movement of one tonne of material a distance of one kilometre.

A5 FEASIBILITY CRITERIA

Like the social criteria, the feasibility criteria required subjective assessment at the BPEO workshop (see *Section 2.4*). Relevant supporting data were provided at the meeting to inform the delegates. The preparation of these data is explained below.

A5.1 TECHNICAL FEASIBILITY

There must be some degree of confidence that the chosen waste management techniques are technically feasible. There are many different waste treatment technologies available. Some are mature, well proven technologies with a successful track record of operations in other countries. Other more advanced technologies may offer significant advantages but may have less of a track record to demonstrate successful implementation at full scale. Even when a technology is well proven in other countries, the assessment still needs to consider any technical issues as to whether it is also deliverable in the local context.

A series of posters based on the latest Defra guide on alternative waste treatment technologies were prepared for the BPEO workshop. These presented information on the different technologies – how they work, what they produce, and their limitations, including the current level of implementation. Delegates were asked to assign a relative score for technical feasibility for each scenario.

A5.2 PRACTICAL FEASIBILITY

Aside from the question of the technical feasibility of the technologies, there is the question of practical feasibility, which can take several forms. On one level, it is necessary to 'reality check' the assumed level of producer participation. If a scenario relies on recycling of source-separated materials, will sufficient quantities of those materials be provided by the households? Even where a technology is technically feasible and well proven in other countries, the assessment needs to consider whether it is also deliverable in the local context on the basis of practical considerations, such as markets for products.

On a more fundamental level, it must also be assured that the desired performance of a scenario is possible. For example, it may not be possible to recycle more than a certain tonnage of a material (eg aluminium from household waste), simply because there is only a limited amount of that material in the waste stream.

Delegates were asked to assign a relative score for practical feasibility to each of the scenarios based on a qualitative comparison with the other scenarios.

A5.3 FLEXIBILITY

It is generally recognised in waste management planning, that scenarios which have some flexibility are best able to deal with perturbations in the underlying assumptions or with unforeseen circumstances. Scenarios that rely heavily on one particular technology are less flexible than those that employ a balanced mix of different waste management technologies.

Delegates were asked to assign a relative score for flexibility to each of the scenarios based on a qualitative comparison with the other scenarios.

A5.4 EXISTING FACILITIES

The development of new waste management infrastructure is expensive, and is inevitably associated with impacts on the environment. Therefore, it is important first to make the best use of existing resources – this is simply good practice in sustainability.

That said, all of the scenarios required significant new infrastructure development, so the question of existing facilities, and expertise at those facilities, was not particularly relevant to the discussions. Nevertheless, the delegates were asked for their opinions against this criterion.

A5.5 COMPLIANCE WITH POLICY

It is important that the chosen waste management scenario does not conflict with areas of local, national or EU policy, either on environmental issues or on other relevant areas. Examples of relevant environmental policy areas that might be included in the assessment include sustainable development, integrated resource management, biodiversity, groundwater protection, integrated pollution prevention and control and COMAH regulations.

The level of compliance of each of the scenarios with three key policies: the Landfill Directive; the Northern Ireland Waste Management Strategy recycling and composting, and recovery, targets; and the proximity principle. Delegates were given an assessment as to what level each scenario satisfied these policies, and asked to assess them on that basis.

A6 GLOSSARY OF ABBREVIATIONS IN THIS ANNEX

AD	Anaerobic Digestion
ADF	Abiotic Depletion Factor
BPEO	Best Practicable Environmental Option
CML	Centrum voor Milieuwetenschappen Leiden (Centre for Environmental Studies, University of Leiden, Holland)
CO_2	Carbon Dioxide
COMAH	Control of Major Accidents
EHS	Environment and Heritage Service
ERM	Environmental Resources Management
EU	European Union
HCl	Hydrogen Chloride or Hydrochloric Acid
HF	Hydrogen Fluoride or Hydrofluoric Acid
IPCC	Intergovernmental Panel on Climate Change
IVC	In-Vessel Composting
LCA	Life Cycle Assessment
MBT	Mechanical-Biological Treatment
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
MW	Mega-watt
NH_3	Ammonia
NO_x	Oxides of Nitrogen
OPRA	Operator and Pollution Risk Appraisal
PPP	Public-Private Partnership
RDF	Refuse-Derived Fuel
ROC	Renewable Obligations Certificate
SO_2	Sulphur Dioxide
tpa	tonnes per annum
WHO	World Health Organisation
WISARD	Waste - Integrated Systems Assessment for Recovery and Disposal

Annex B

Technology-Specific Calculation Assumptions

B1 TECHNOLOGY-SPECIFIC CALCULATION ASSUMPTIONS

B1.1 INTRODUCTION

In order to perform some of the calculations and assessments in the BPEO process, it was necessary to make some assumptions about how the processes operate and their outcomes. The assumptions made for each process are detailed below. Reference is made a few times to the *Defra Health Effects Report*, whose details are provided in the footnote here. (1)

Some further assumptions were made during the assessment of the scenarios against the decision criteria, and these are detailed under the descriptions of the individual criteria, in *Annex A*.

A number of the facilities require the same general data, such as electricity demand/output and other utility usage. The basic data, where calculations were simple, are presented in *Table B1.1*. As can be seen, the data is assumed to be proportional to the weight of waste processed, so no economies of scale were factored into these calculations.

Table B1.1 Summary of General Technology Data Assumptions

	Input				Output	
Technology	**Electricity Demand**	**Diesel**	**Natural Gas**	**Oxygen**	**Electricity**	**SO_2**
MRF	24.97	0	0	0	0	0
Composter	0.104	7.44	0	0	0	0
AD	0	0.4	0	0	143.89	see text
MBT (†)	65	0	0	0	0	0
Thermal Treatment	0	1.2	0	0	820 (†)	90.53
Gasification	0	1.2	14 (‡)	500 (‡)	514 (‡)	0
Landfill	0	1	0	0	see text	see text
Cement	30.3	0	0	0	0	90.53
Unit per te of waste	*KWh*	*l diesel*	*kg*	*kg*	*kWh*	*g*

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

(†) *Fichtner* - Modern Energy Recovery Plant for MSW

(‡) *Thermoselect*

B1.2 VEHICLE EMISSIONS

Where vehicles are used in the plants, ***WISARD*** estimates the amount of diesel the vehicles use, per tonne of waste processed, as shown in *Table B1.1*. For all diesel vehicles, standard emissions levels were assumed, presented in *Table B1.2*.

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

Table B1.2 Assumed Emissions from Diesel Vehicles

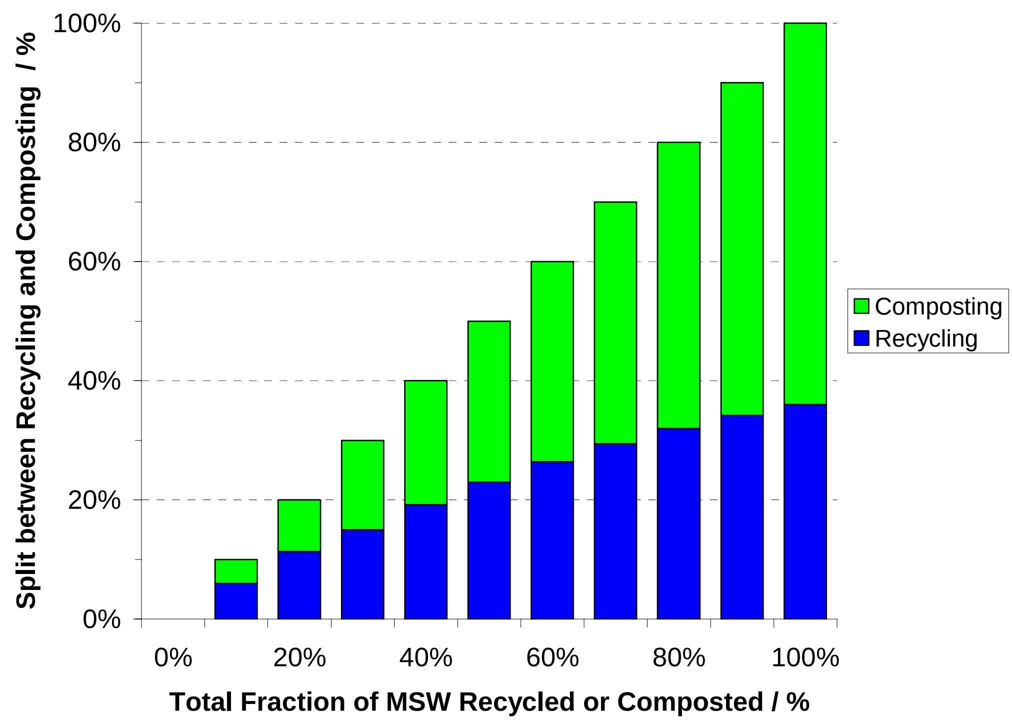
Gas	Formula	Emissions (†)
Fossil Carbon Dioxide	CO_2	2640
Sulphur Dioxide	SO_2	0.76
Methane	CH_4	0.16

(†) Units are grammes of gas emitted per litre of diesel consumed

B1.3 RECYCLING/COMPOSTING

For MSW, each scenario set recycling and composting targets for 2005, 2010, 2013 and 2020, with levels in intervening years interpolated. It was assumed that, at low levels of recycling and composting, the recycling component would outweigh composting, such that 60% of the total amount of waste sent to recycling and composting would be recycled, with the remainder composted. As the percentage of waste sent to recycling and composting increases, the fraction that is composted must also increase, as the available waste to be recycled diminishes. The changing split between recycling and composting is shown in *Figure B1.1*.

Figure B1.1 Schematic Plot of Changing Split between Recycling and Composting



It was assumed that the recyclates would be separated at a clean MRF, while the composting plant would be covered and the compost aerated. Two composting techniques were assumed, with all the waste currently composted assumed to be treated in windrows. 100% windrowing was assumed to continue until 2007, when it would be progressively phased out over four years in favour of in-vessel composting, which meets the requirements of the Animal By-Products Regulations. In reality, it is likely that windrow facilities will continue, taking separately collected garden waste, but this assumption was made across all scenarios, and was not expected to generate any inconsistencies.

The *Defra Health Effects Report* does not have any data on composting health effects in its Table 4.5, so, in order to take account of the possible health effects of this extra activity, it was necessary to estimate an impact for composting. Given that the release of bioaerosols from composting plants can be an issue, it was decided to assign to composting the higher of the impacts in each category from the most similar processes, MBT and AD.

B1.4 ANAEROBIC DIGESTION (AD)

The AD plant was modelled on the high solids option from ***WISARD***. The composition of the biogas is given in *Table B1.3*. ***WISARD*** estimates that 0.199kg of biogas are generated per kg of waste treated, and a total biological activity reduction of 60% was also assumed. [(1)]

Table B1.3 Anaerobic Digestion – Biogas Composition

Gas	Formula	Composition (g/kg)
Methane	CH_4	564
Carbon Dioxide	CO_2	339
Hydrogen Sulphide	H_2S	0.245

As the methane is combusted, and the carbon dioxide is biogenic, the main emission of concern is hydrogen sulphide, which is combusted with the biogas in the generator, to produce sulphur dioxide. This is therefore dependent on the biodegradable content of the incoming waste stream, as is the electricity generation rate. The generation factors that result are as follows:

- SO_2 generation rate: 132.8 g / te of biodegradable waste
- Electricity generation rate: 208.2 kWh / te of biodegradable waste

The AD process generates two product streams – digestate and residue – and the scenarios assume that both these streams are suitable for landspreading.

B1.5 MECHANICAL BIOLOGICAL TREATMENT (MBT) FACILITIES

WISARD does not have any data for an MBT plant, but the majority of the parameters in *Table B1.1* are zero. One key statistic is the energy demand, which was taken from an estimate by *Fichtner* to be 65 kWh per tonne of waste. In order to model the waste composition and material flows, some additional assumptions were made, as follows:

(1) Figure taken from a brochure from AWG mbH (www.awg-bassum.de)

- 40% loss of biodegradability of input waste [1], through a combination of water evaporation and carbon emissions. For the purpose of modelling, this was assumed to equate to loss of material from the putrescible and paper/card waste fractions;

- 100% of textiles, fines, plastics and miscellaneous combustible material is assigned to the high-CV fraction;

- 90% of ferrous and non-ferrous materials removal for recycling; and

- 99% glass removal (to model extraction of grit/glass through MBT).

B1.5.1 HCV Fraction

The default assumption was that the HCV fraction would be used as a refuse-derived fuel (RDF), to replace coal in combustion processes (for example, in a cement kiln or a power station). Calculations of the benefits of doing this assumed that the CV of the RDF would be around 16 MJ/kg, and that the CV-swap would be 100% efficient.

Where this took place, calculations were also carried out to ensure that fossil CO_2 emissions associated with combusting any residual plastics in the RDF were included. This also meant taking into account any health impacts from the emissions.

B1.6 THERMAL TREATMENT FACILITIES

Thermal treatment plants were modelled to be new facilities, with all the state-of-the-art emission controls that entails. Data from *Fichtner* was used to model the energy generation, yielding 820 kWh/te waste, based on a waste calorific value of 11 MJ/kg (assumed to be the same for all thermal treatment options).

In addition to the information in *Table B1.1*, it is necessary to estimate the fossil CO_2 emissions from burning plastics. *SIMAPRO* was used to calculate that each tonne of plastic burnt would generate, on average, 2.283 tonnes of fossil CO_2.

For the mass balance, it was assumed that 80% of incoming ferrous metal would be recycled, and that the fly ash from the process would be sent to a hazardous landfill. Data from ***WISARD*** suggested that around 27% of incoming waste would emerge as bottom ash, 3.7% as fly ash and the balance would be combusted, and the calculations were driven towards those figures.

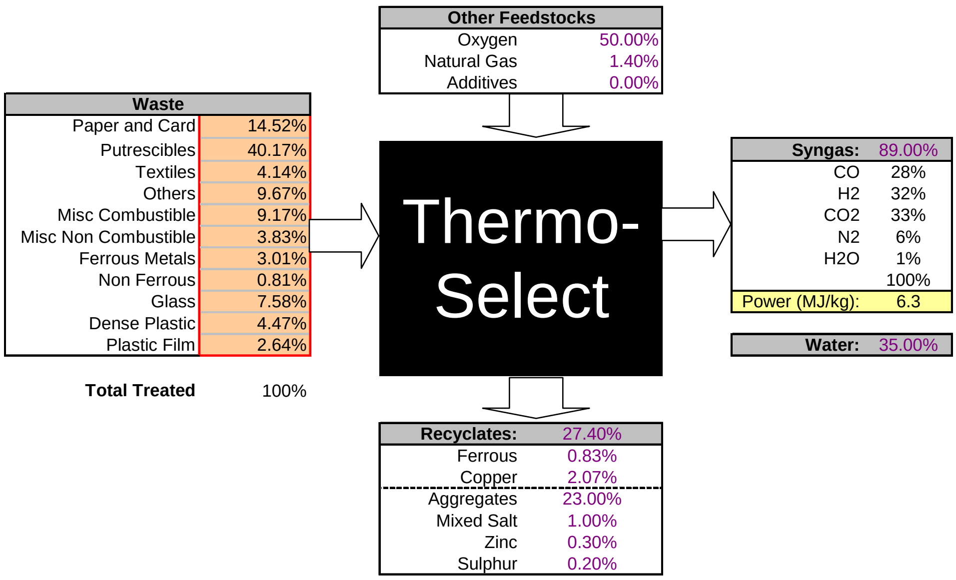
For the scenario that sent MBT HCV to the thermal treatment plant, the energy that could be generated was calculated on a straight CV-swap basis.

(1) This is taken as a mid-range figure from the various results reported in *Estimating biodegradable MSW diversion from landfill: monitoring BMW removal in a MBT process*, EA R&D Technical Report P1 - 513 (EP 0173)

B1.7 GASIFICATION

Again, gasification does not appear in ***WISARD*** and information on the technologies was rather limited. At the time the project began, the most well studied plant in Europe was Thermoselect's plant at Kahlsrühe, so data was used from Thermoselect to model the gasification plant, as presented in *Figure B1.2*.

Figure B1.2 Gasification Mass Balance



Data extracted from: http://www.thermoselect-karlsruhe.de/mengen.html [26Jul04 @ 15:19]
..combined with presentation provided by Thermoselect

B1.8 LANDFILL

The landfill model used from ***WISARD*** was for a large, wet, composite-lined landfill. A number of assumptions were made, in order to complete the modelling, based upon the rate of generation of gases and the fate of the landfill gas. Firstly, it was assumed that the gases generated were dependent on the incoming waste composition, as shown in *Table B1.4*.

Table B1.4 Landfill Gas Generation (kg Gas per tonne Waste Component)

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

Secondly, it was assumed that the fate of the landfill gas was as given in *Table B1.5*.

Table B1.5 Landfill Gas Fate

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

Finally, the gas engines were assumed to have an efficiency of 32.5%, with methane having a CV of 50.0 MJ/kg. With this information, it is possible to calculate (for example) the electricity generation, as shown in *Box B1.1*.

Box B1.1 Formula for the Calculation of Landfill Engine Electricity Generation

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

The *Defra Health Effects Report* provides data on six different landfill types in its *Table 4.5*, using flares or engines at small, medium and large sites. For the purposes of estimating the health effects of landfills in this study, we have taken the average values for the two types of medium-sized facilities.

Annex C

Schematic Diagram of Scenarios

C1 SCHEMATIC DIAGRAMS OF SCENARIOS

C1.1 INTRODUCTION

The scenarios are presented below in a series of schematic diagrams in three sections, for MSW, C&I waste and CD&E waste. The figures themselves are summarised in the table below:

Table C1.1 Table of Figures in Annex

Figure C2.1 MSW Scenario 1 – Current Situation

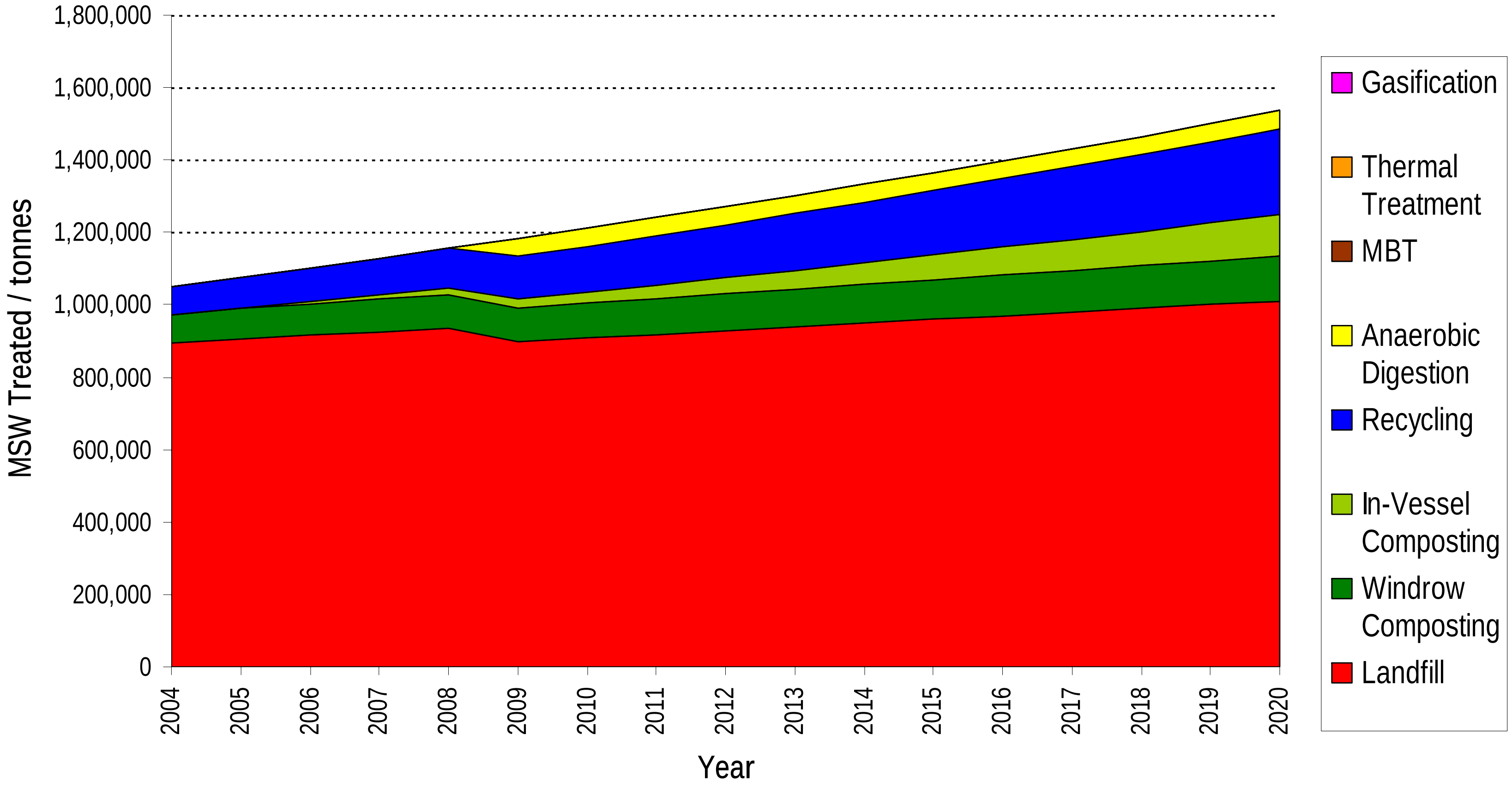


Figure C2.2 MSW Scenario 2 – High Recycling and Composting

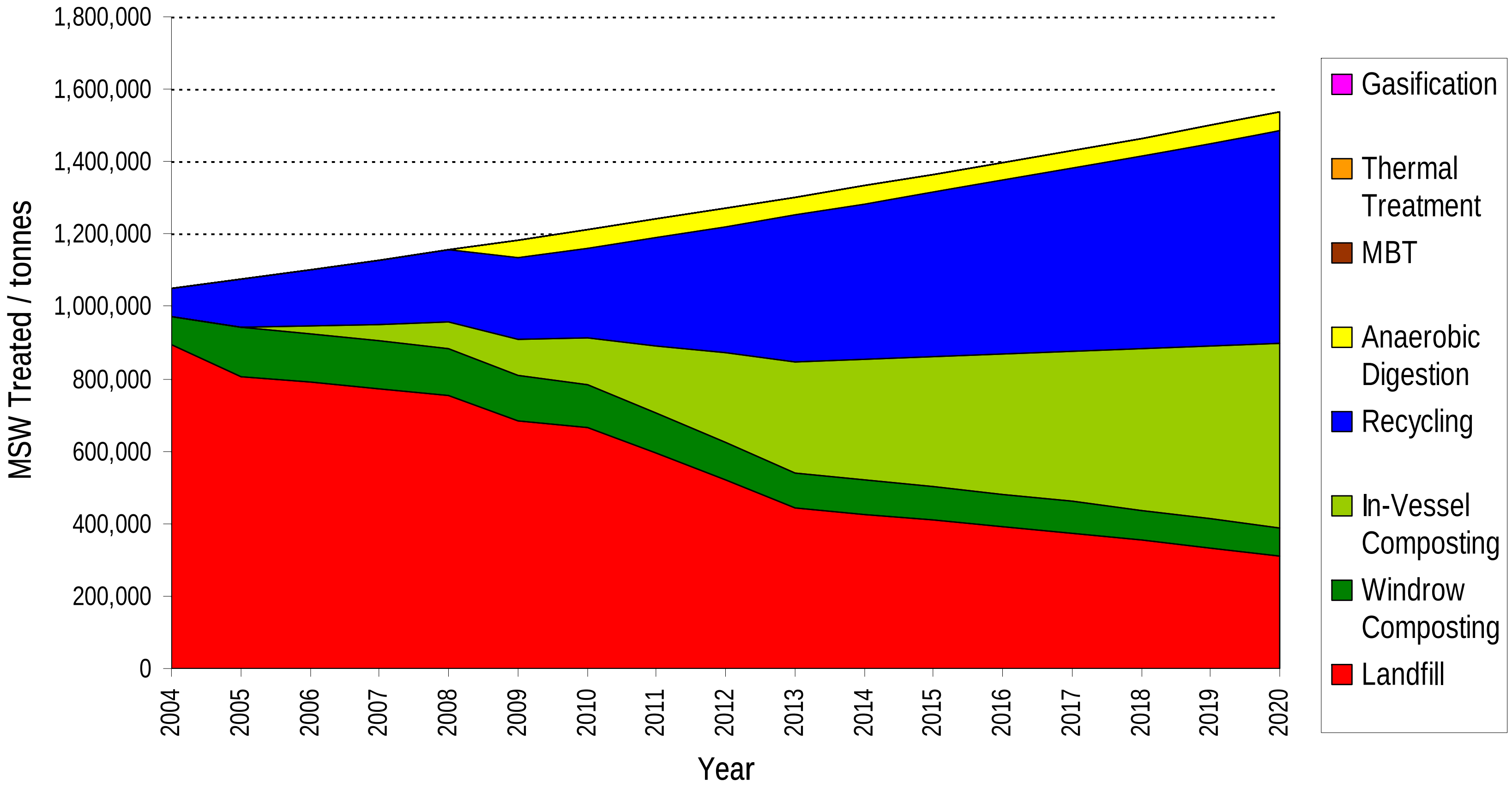
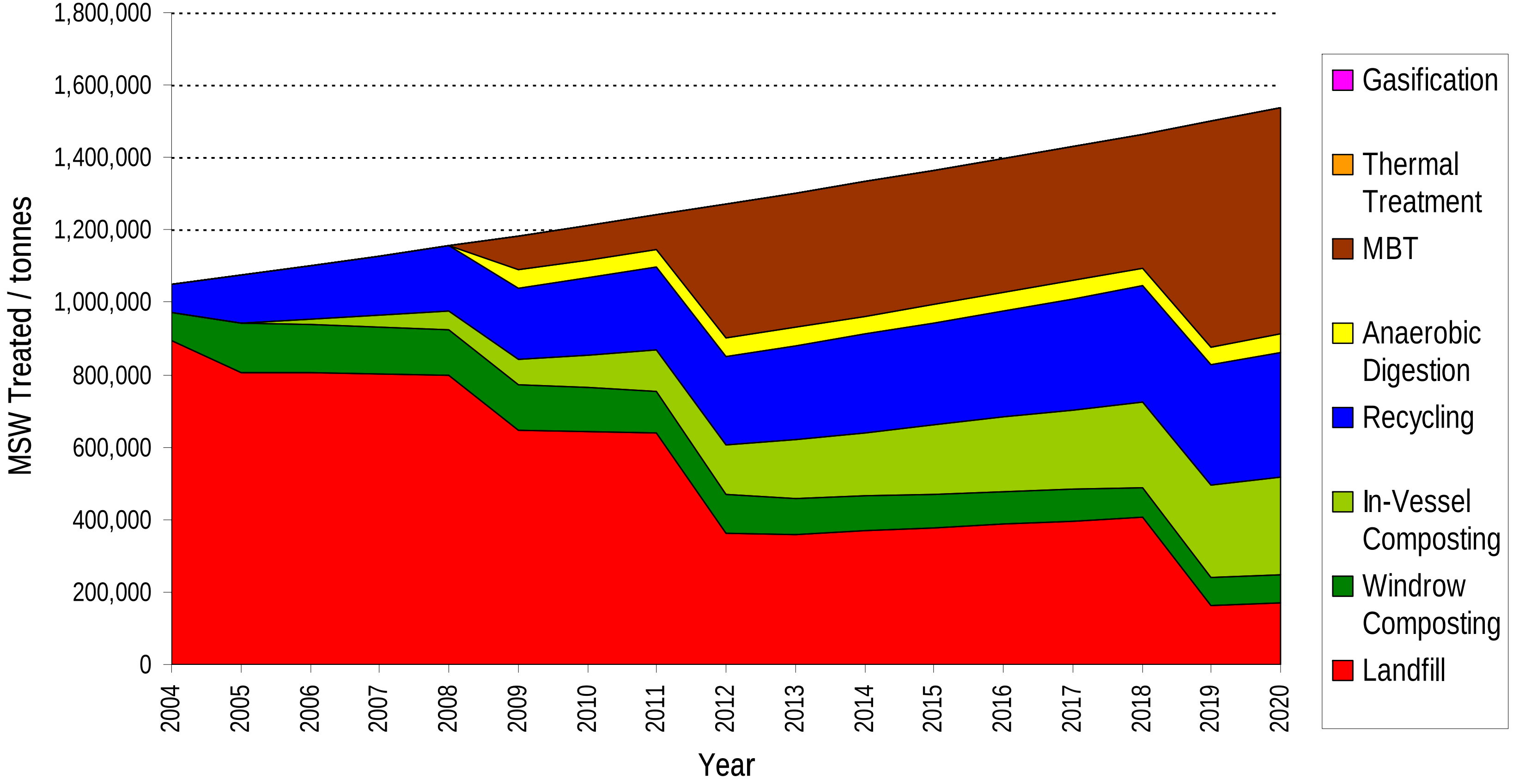


Figure C2.3 MSW Scenario 3 – Mechanical Biological Treatment



Two versions of this scenario were modelled, with the high-CV material from the MBT process either being used as a refuse-derived fuel, or being landfilled.

Figure C2.4 MSW Scenario 4 – Anaerobic Digestion

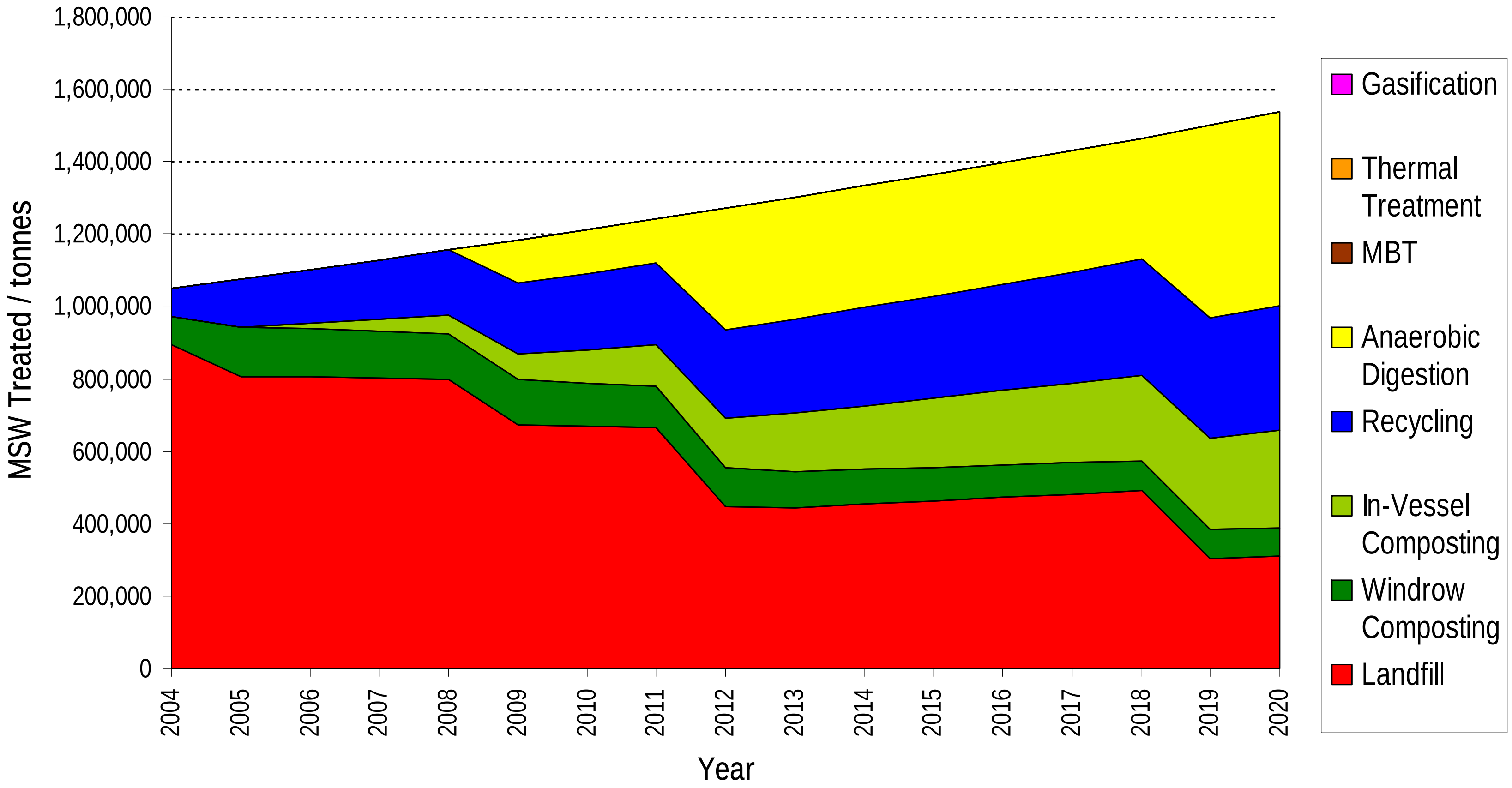


Figure C2.5 MSW Scenario 5a – Thermal Treatment

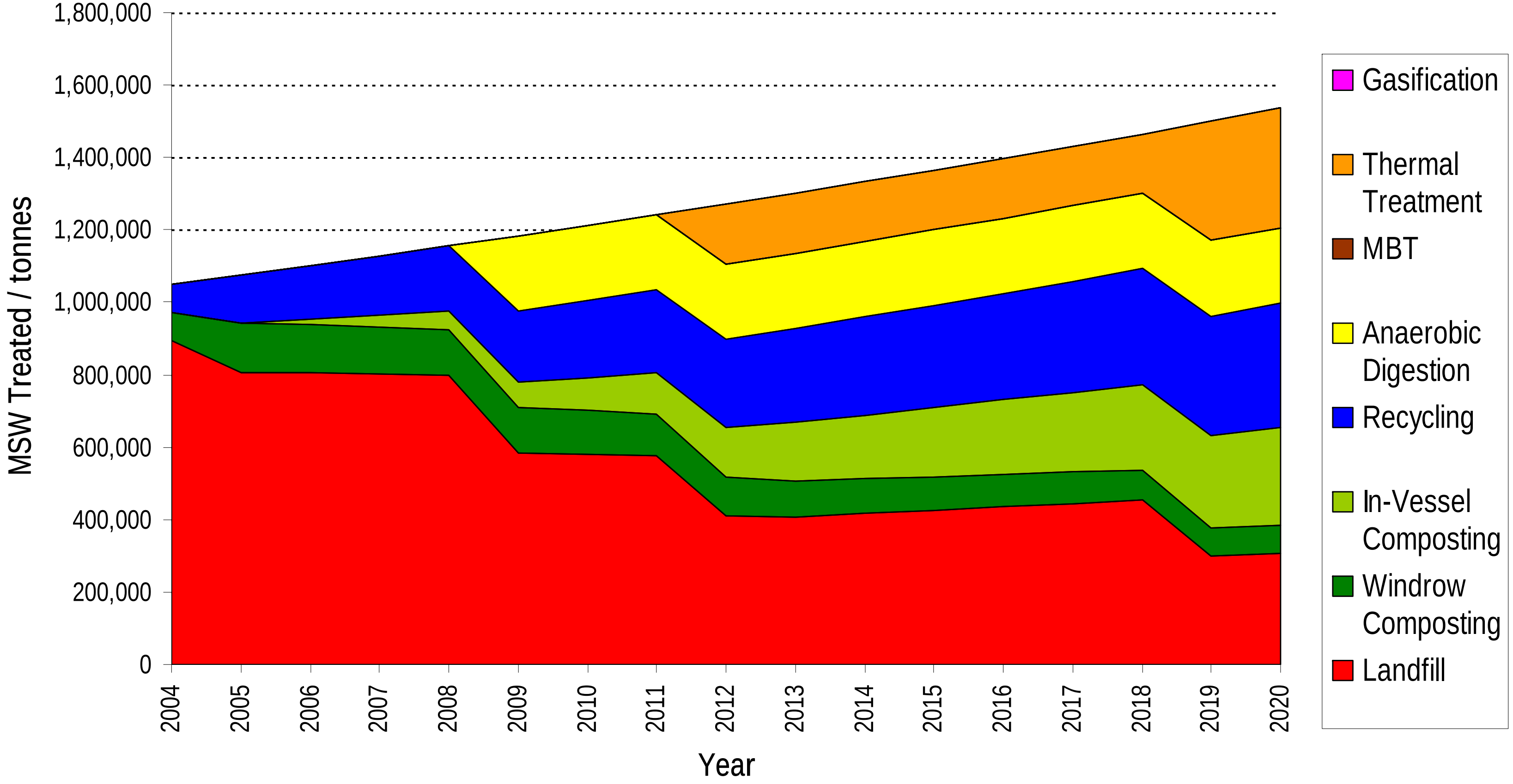


Figure C2.6 MSW Scenario 5b – Gasification

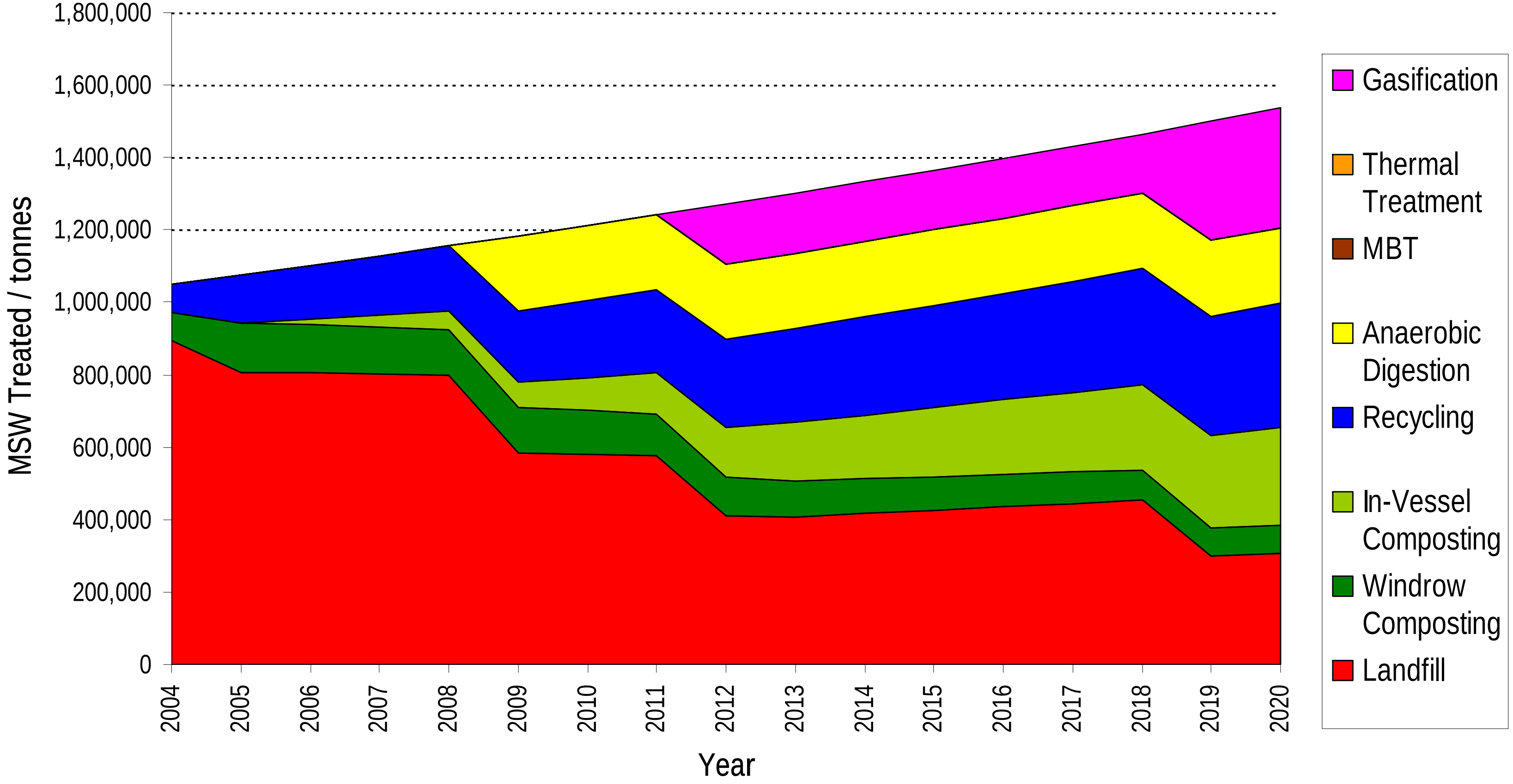


Figure C2.7 MSW Scenario 6 – Low Recycling and MBT

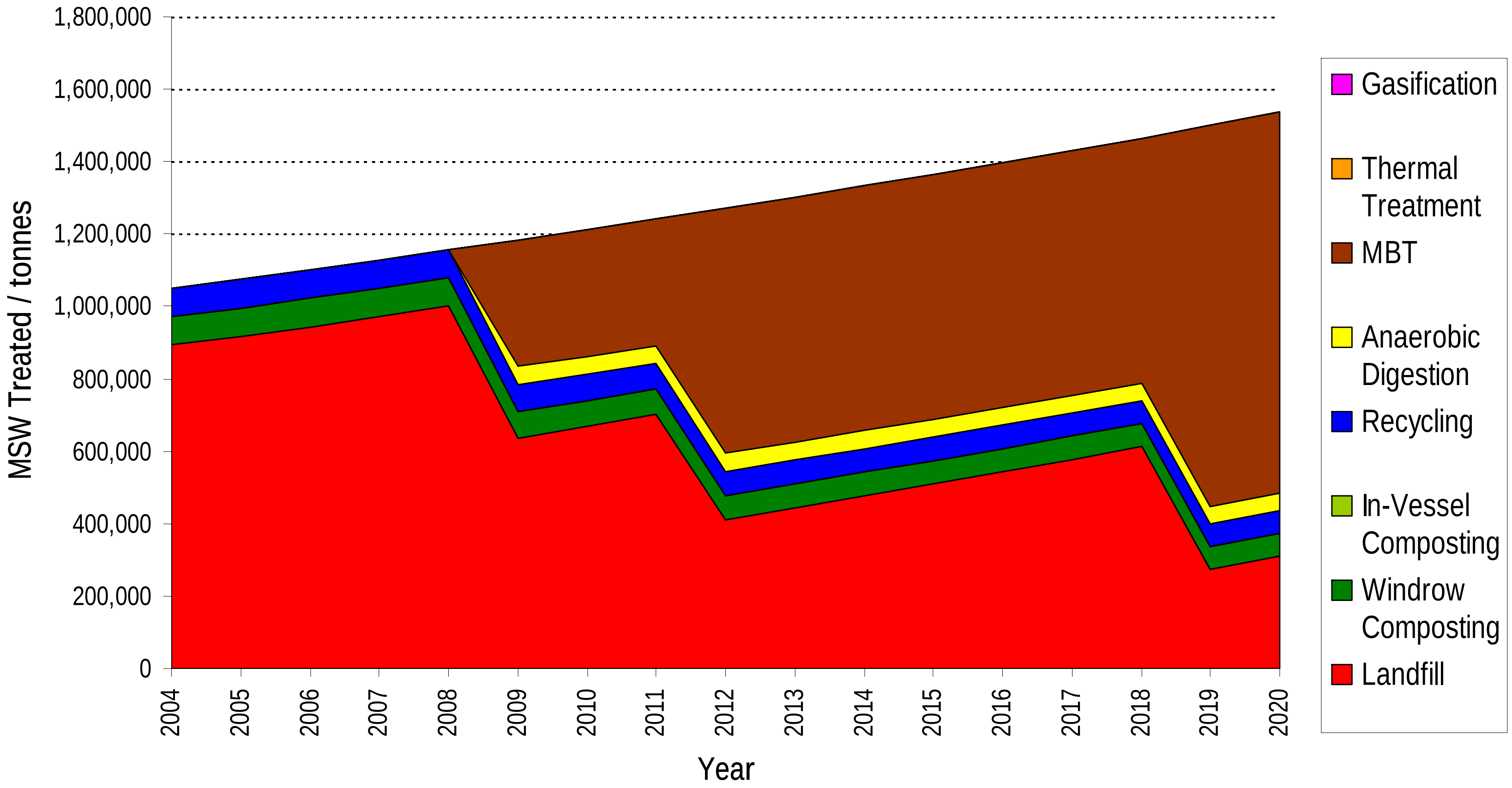


Figure C2.8   MSW Scenario 7 – Hybrid Scenario

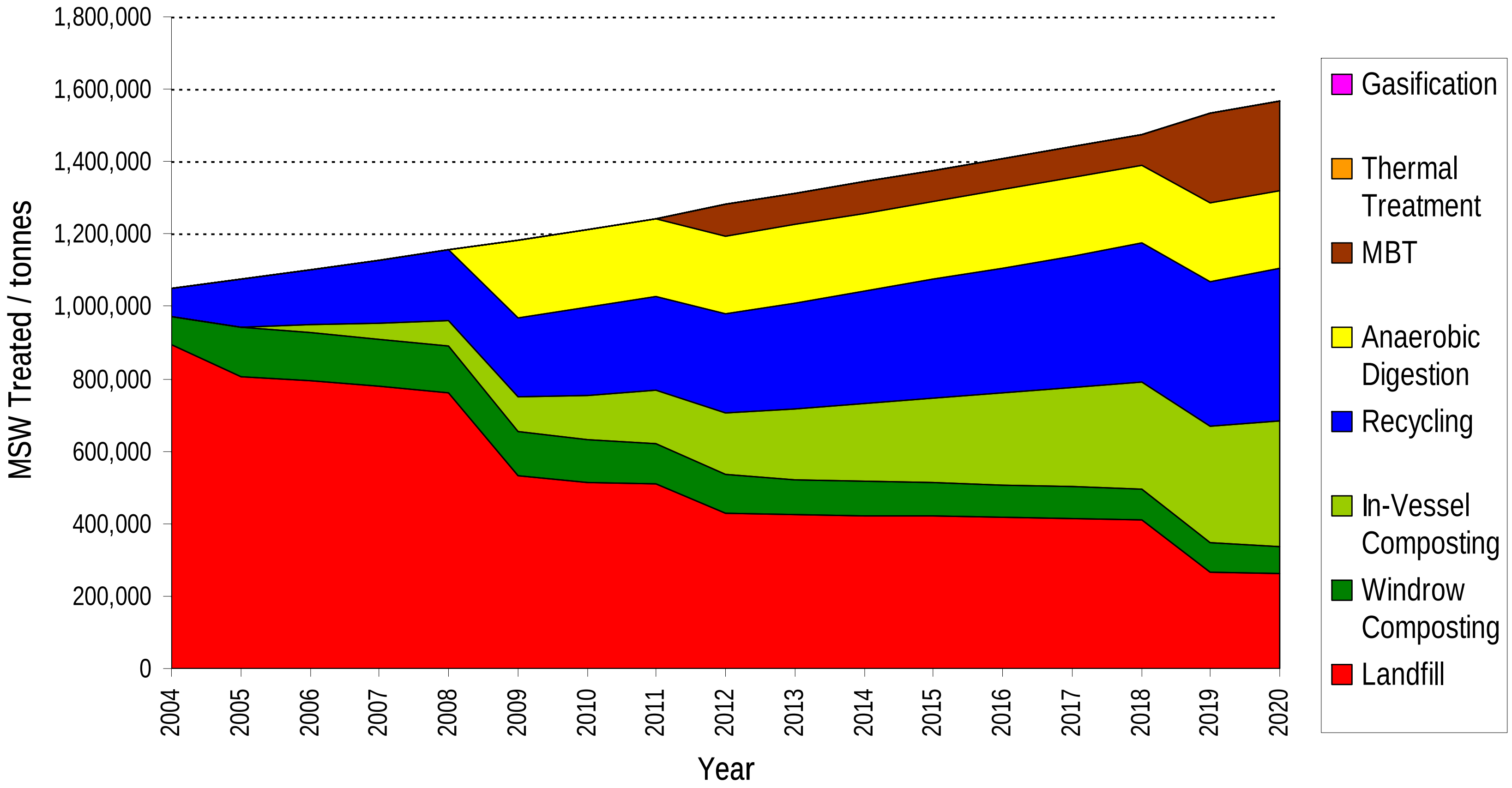


Figure C2.9 MSW Scenario NS1 – Revised Version of Original Scenario 5

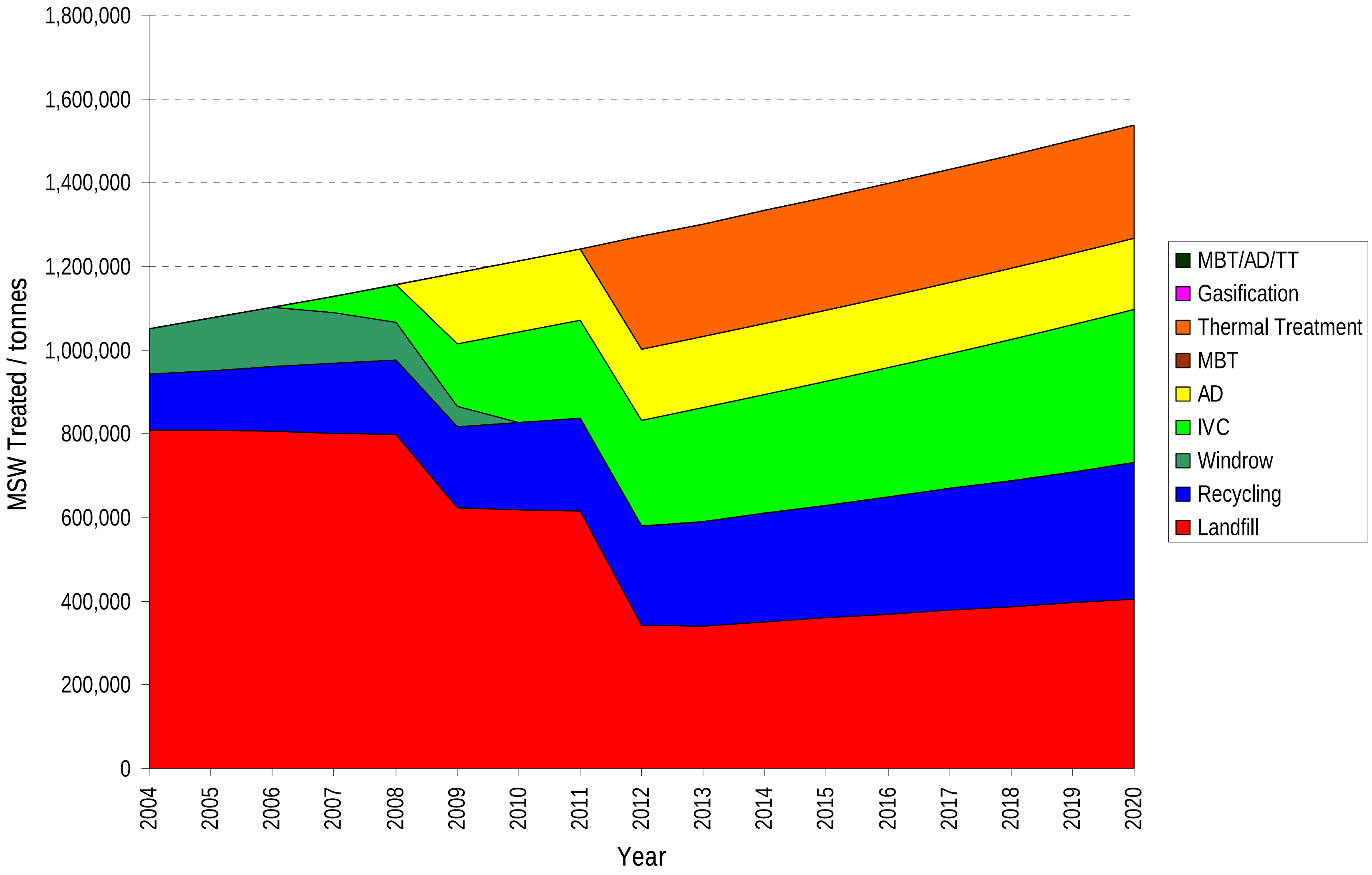


Figure C2.10 MSW Scenario NS2 – Scenario NS1 with Extra R&C

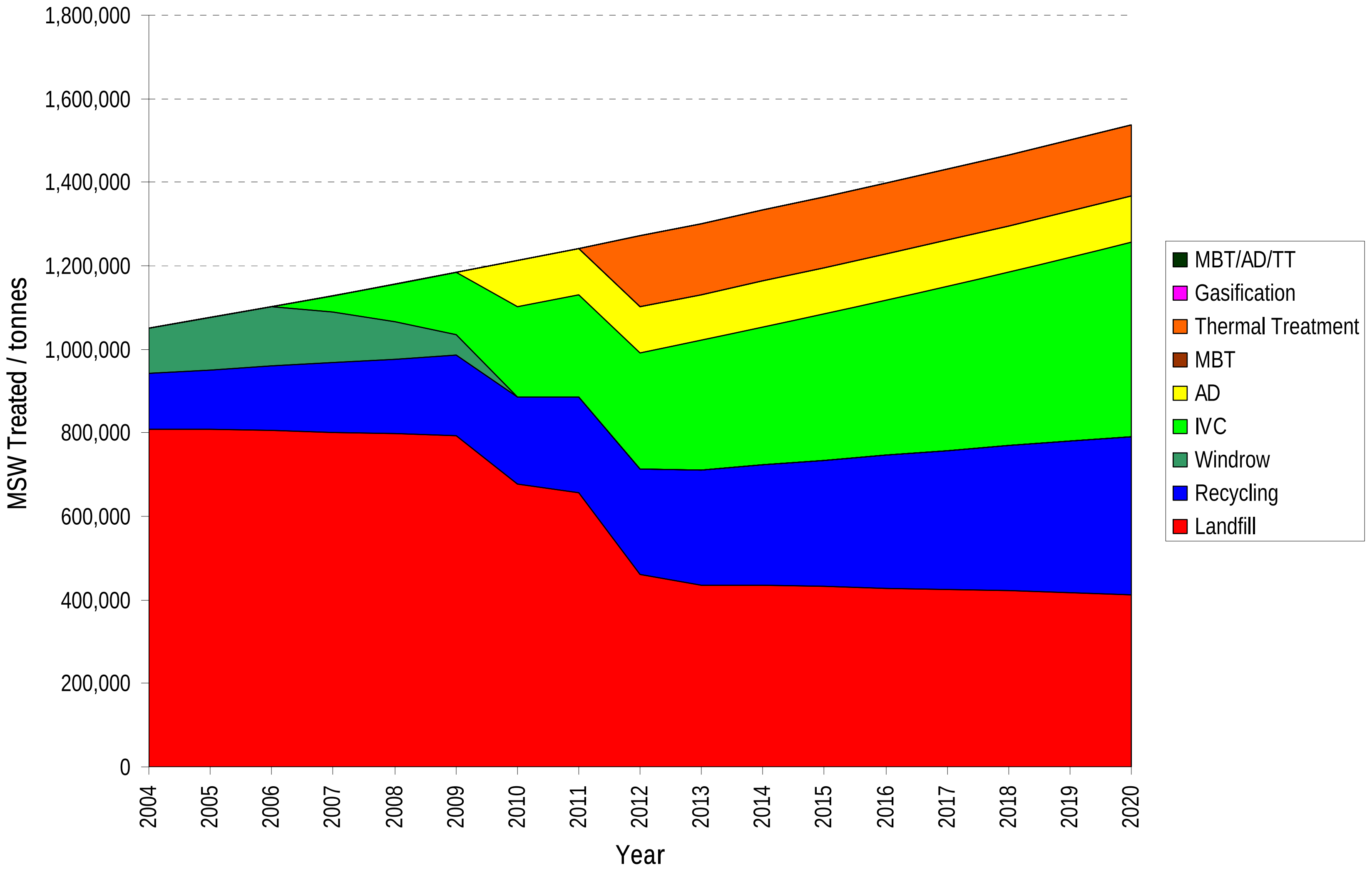


Figure C2.11 MSW Scenario NS3 – Scenario NS1 with Minimal AD

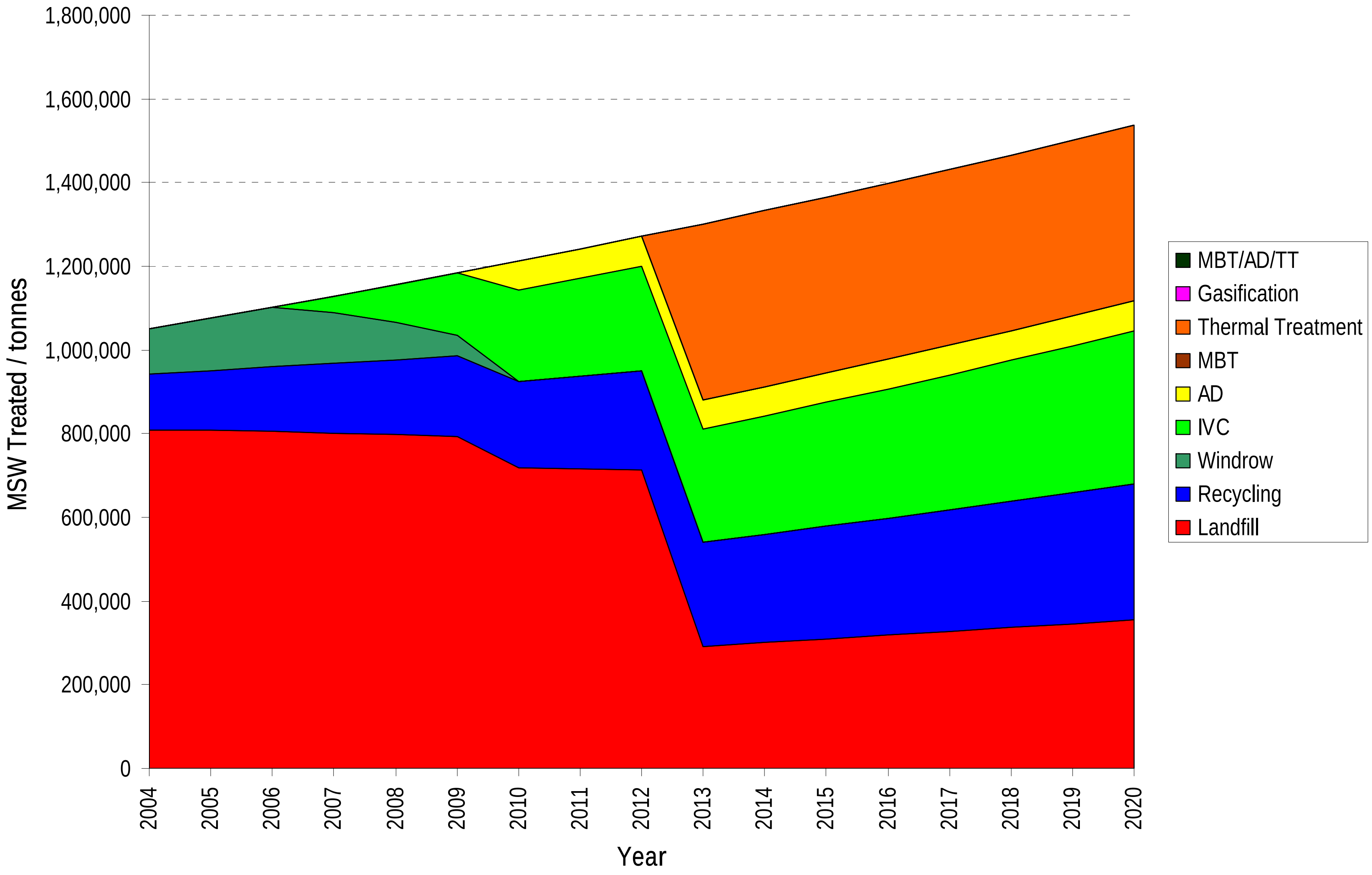


Figure C2.12 MSW Scenario NS4 – Revised Version of Original Scenario 7

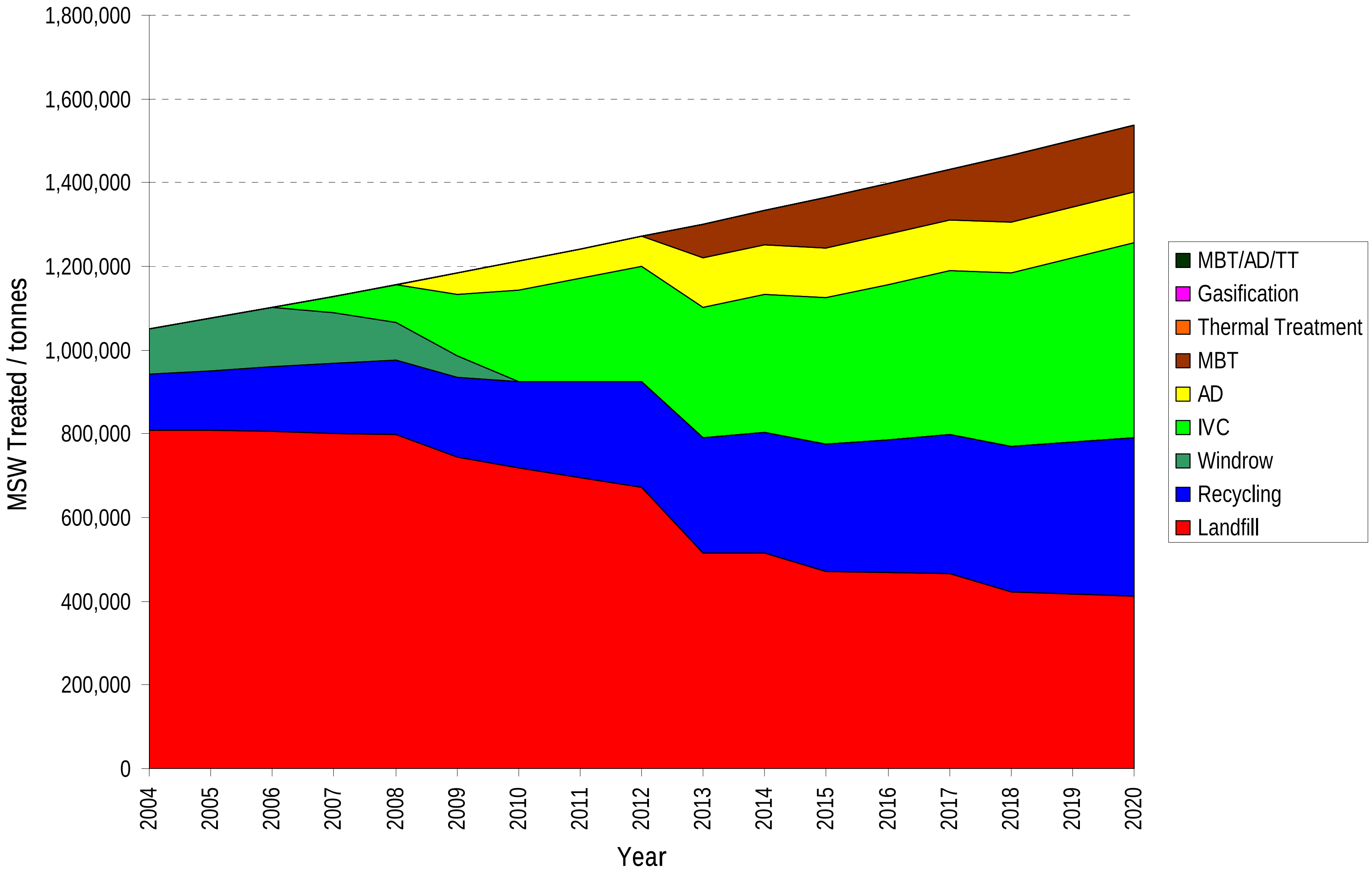


Figure C2.13   MSW Scenario NS5 – Scenario NS4 with Reduced R&C

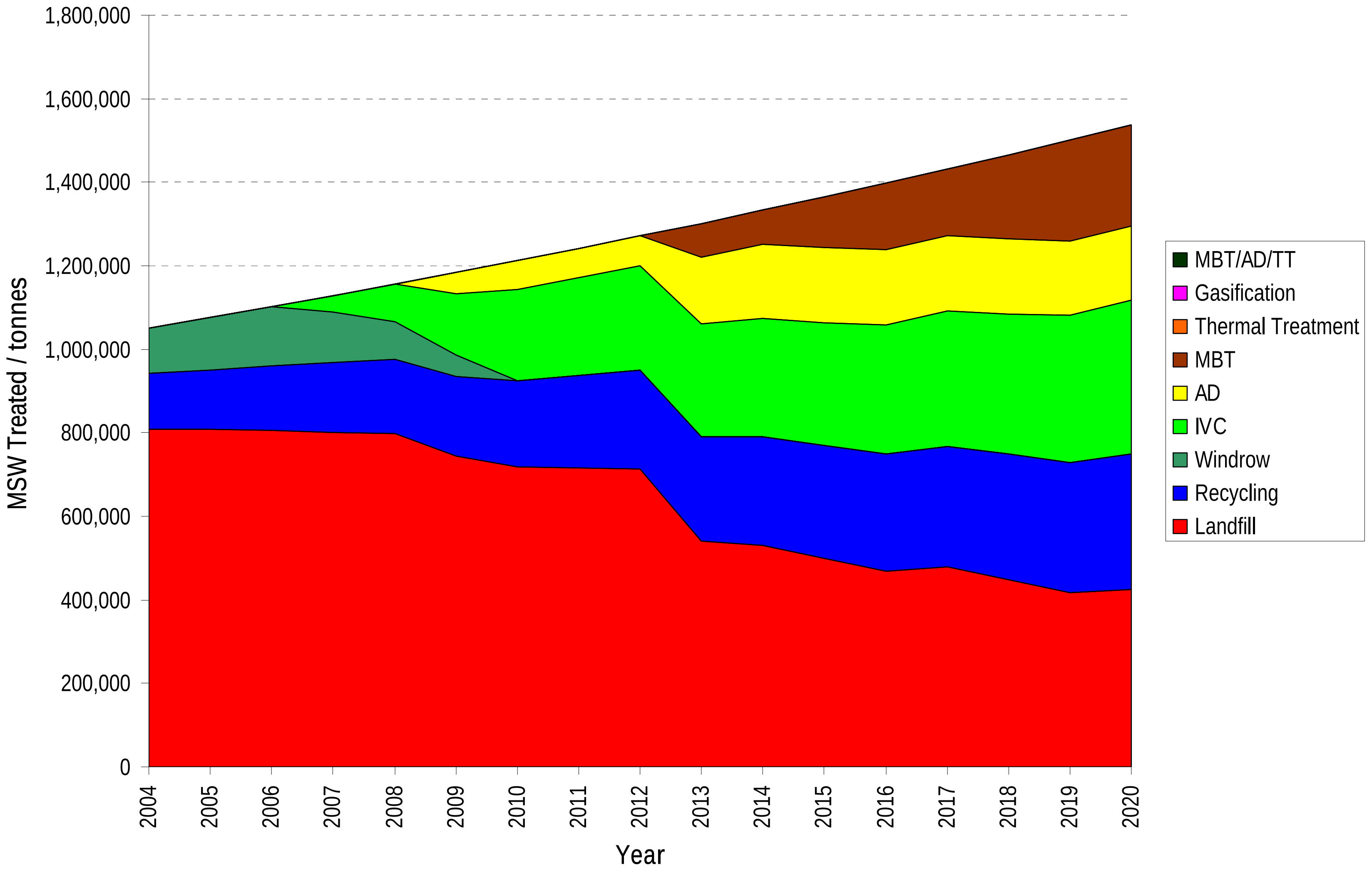


Figure C2.14 MSW Scenario NS6 – Hybrid Combination of AD, MBT and Thermal Treatment

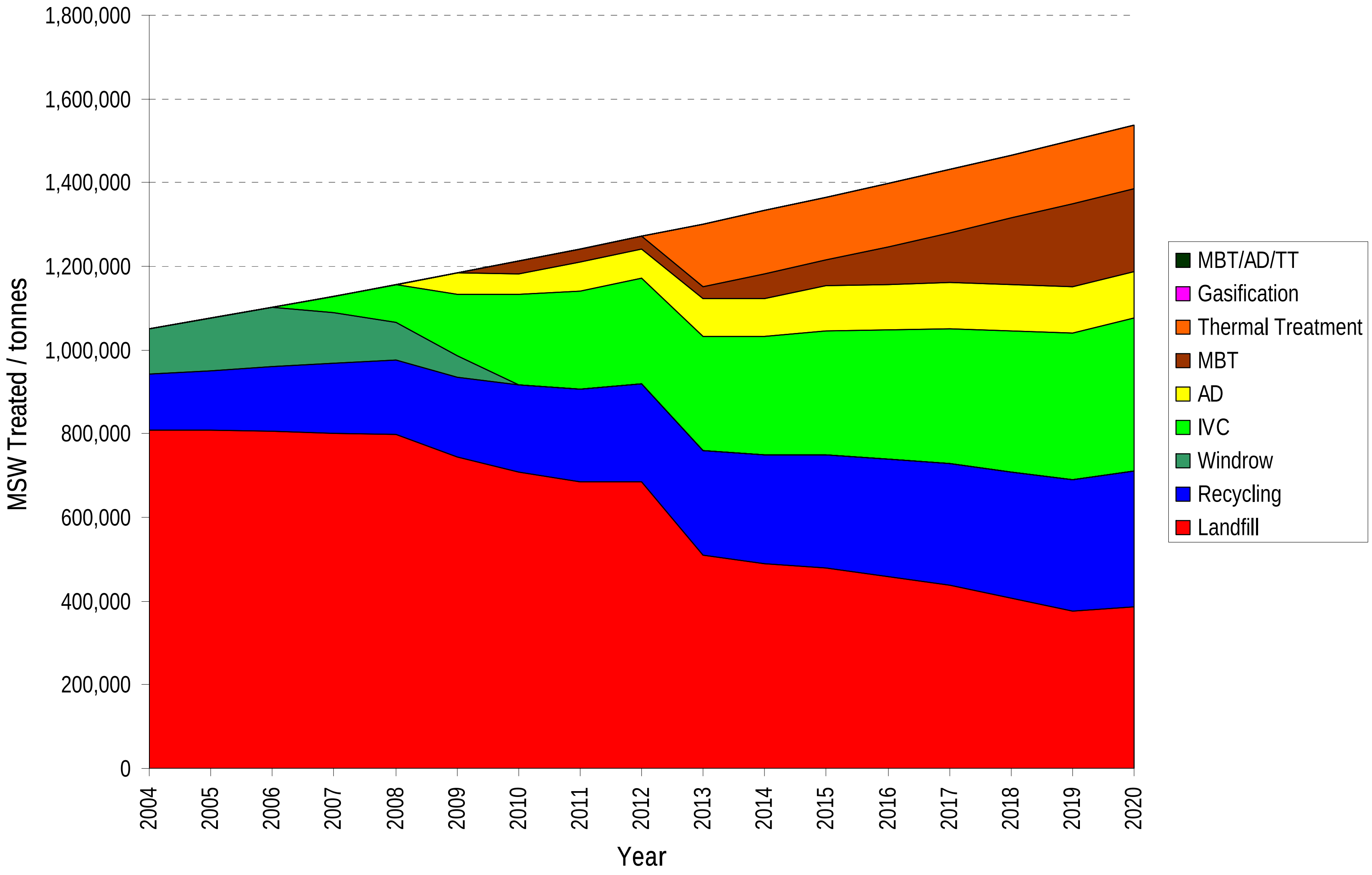


Figure C2.15 MSW Scenario NS7 – Fully Integrated Scenario

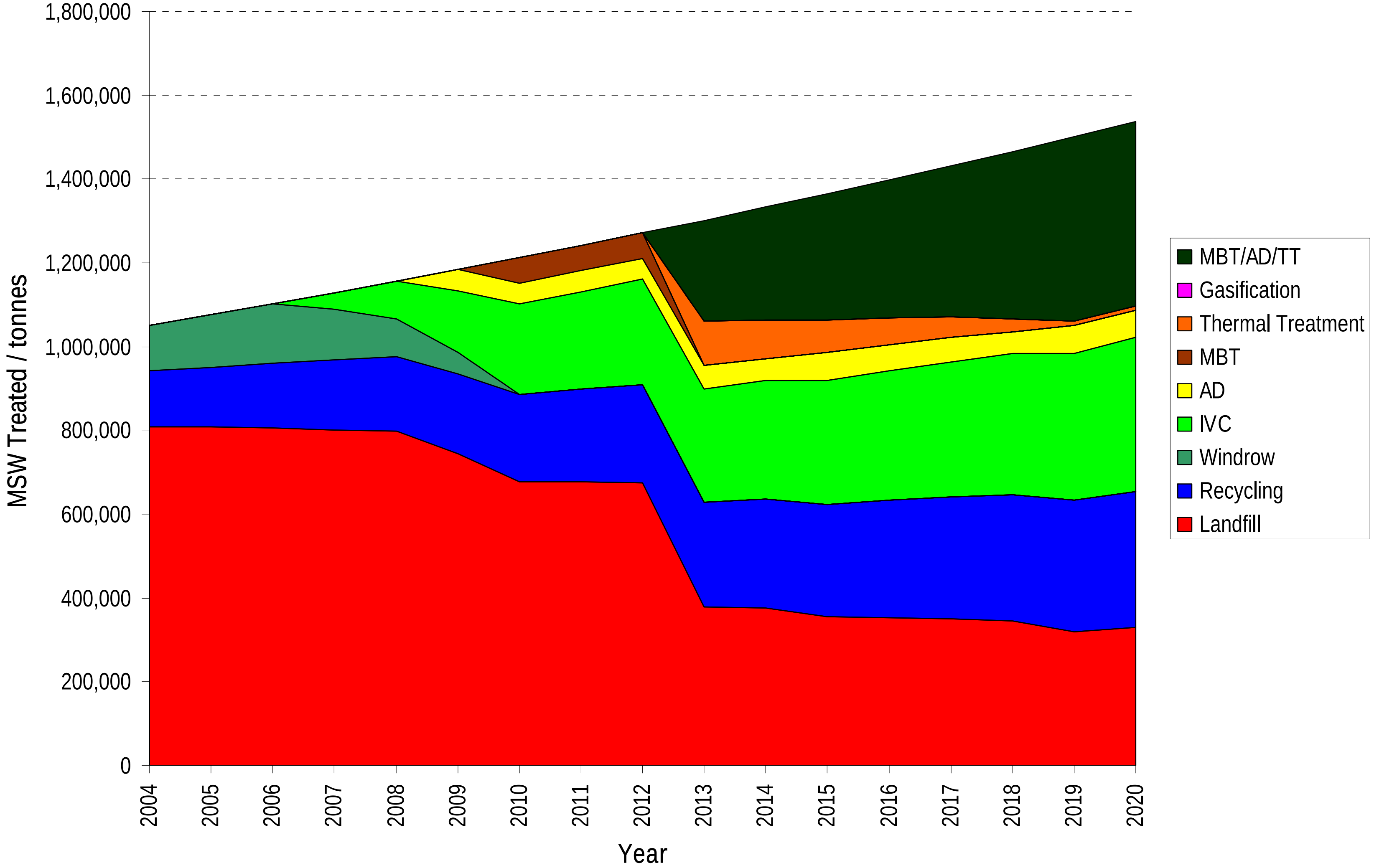


Figure C2.16 MSW Scenario NS8 – MBT and Thermal Treatment Only

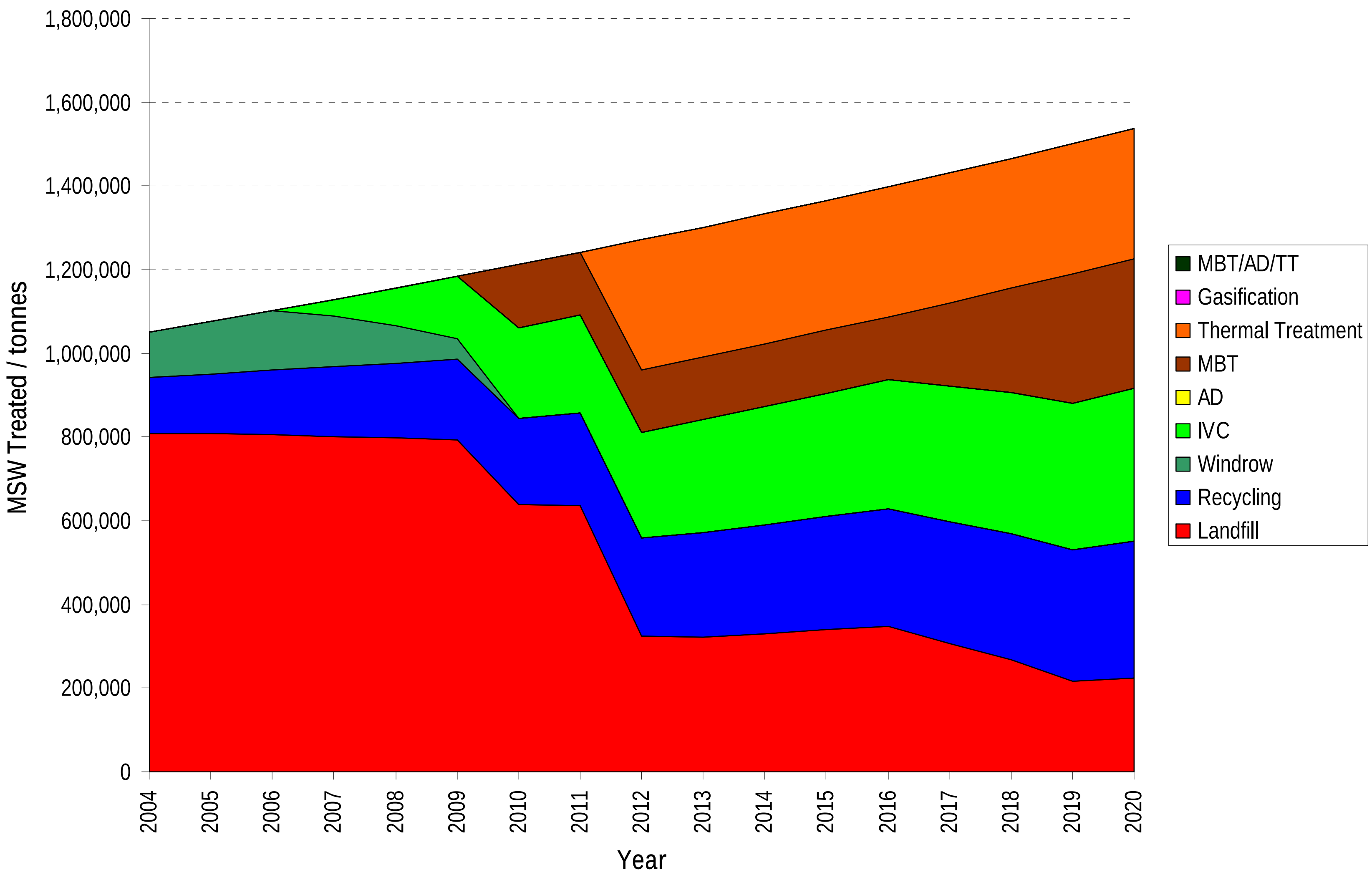
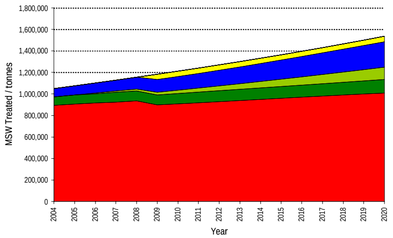
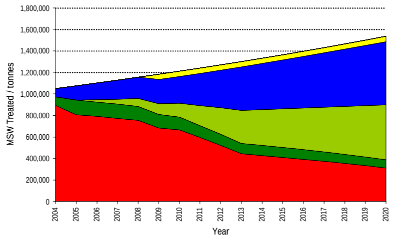


Figure C2.17 Condensed Summary View of All MSW Scenarios

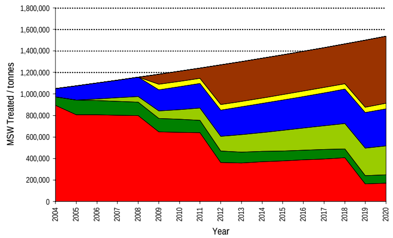
Scenario 1 – Current Situation



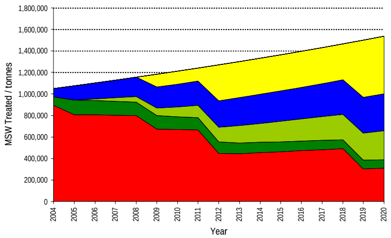
Scenario 2 – High Recycling



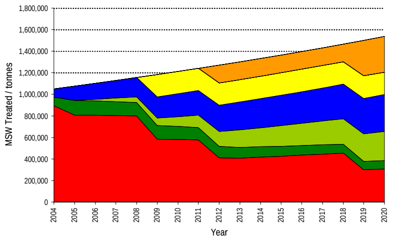
Scenario 3 – MBT



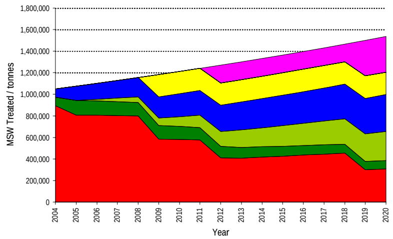
Scenario 4 – Anaerobic Digestion



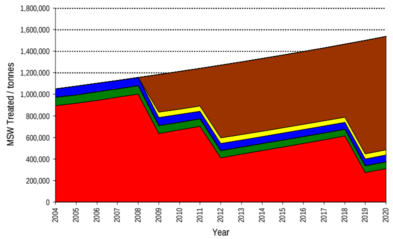
Scenario 5a – Thermal Treatment



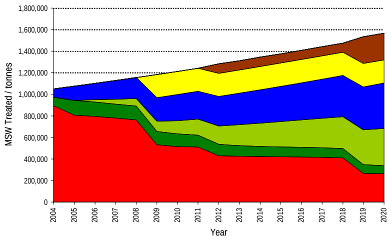
Scenario 5b – Gasification



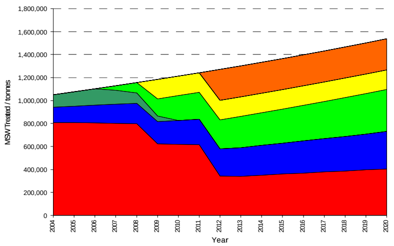
Scenario 6 – Low Recycling



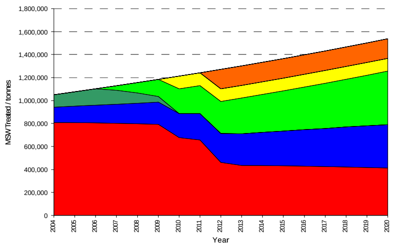
Scenario 7 – Hybrid Scenario



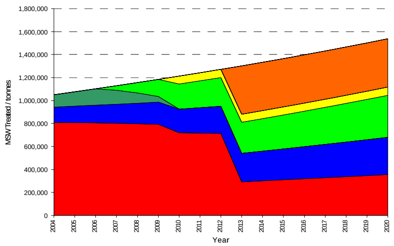
Scenario NS1 – Revised Version of Original Scenario 5



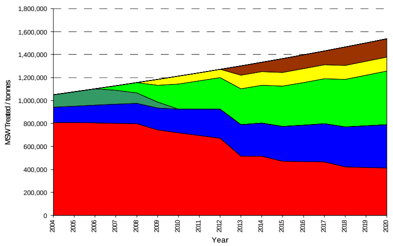
Scenario NS2 – Scenario NS1 with Extra R&C



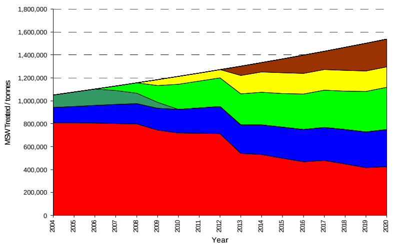
Scenario NS3 – Scenario NS1 with Minimal AD



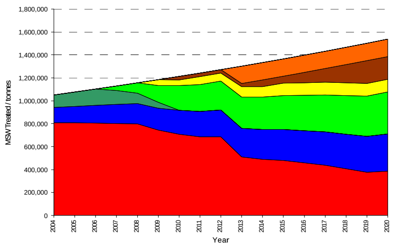
Scenario NS4 – Revised Version of Original Scenario 7



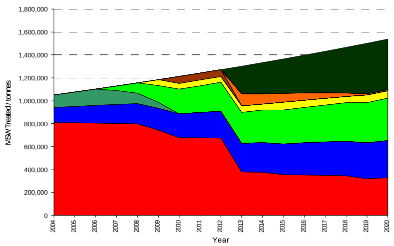
Scenario NS5 – Scenario NS4 with Reduced R&C



Scenario NS6 – Hybrid AD, MBT and Thermal Treatment



Scenario NS7 – Fully Integrated Scenario



Scenario NS8 – MBT and Thermal Treatment Only

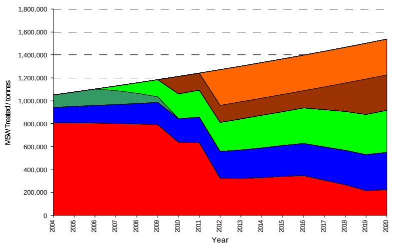


Figure C3.1 C&I Scenario 1 – Current Situation

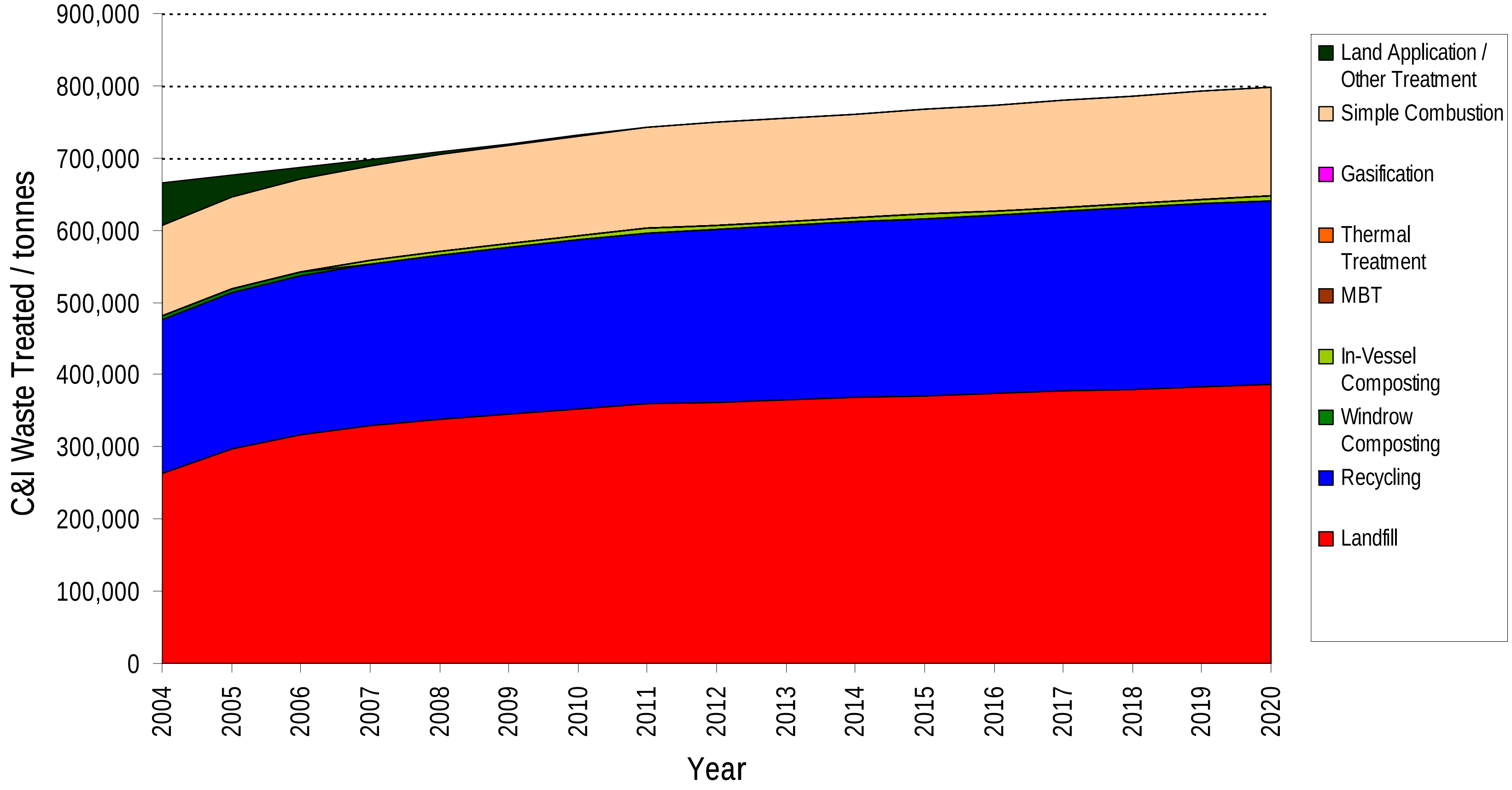


Figure C3.2 C&I Scenario 2 – High Recycling

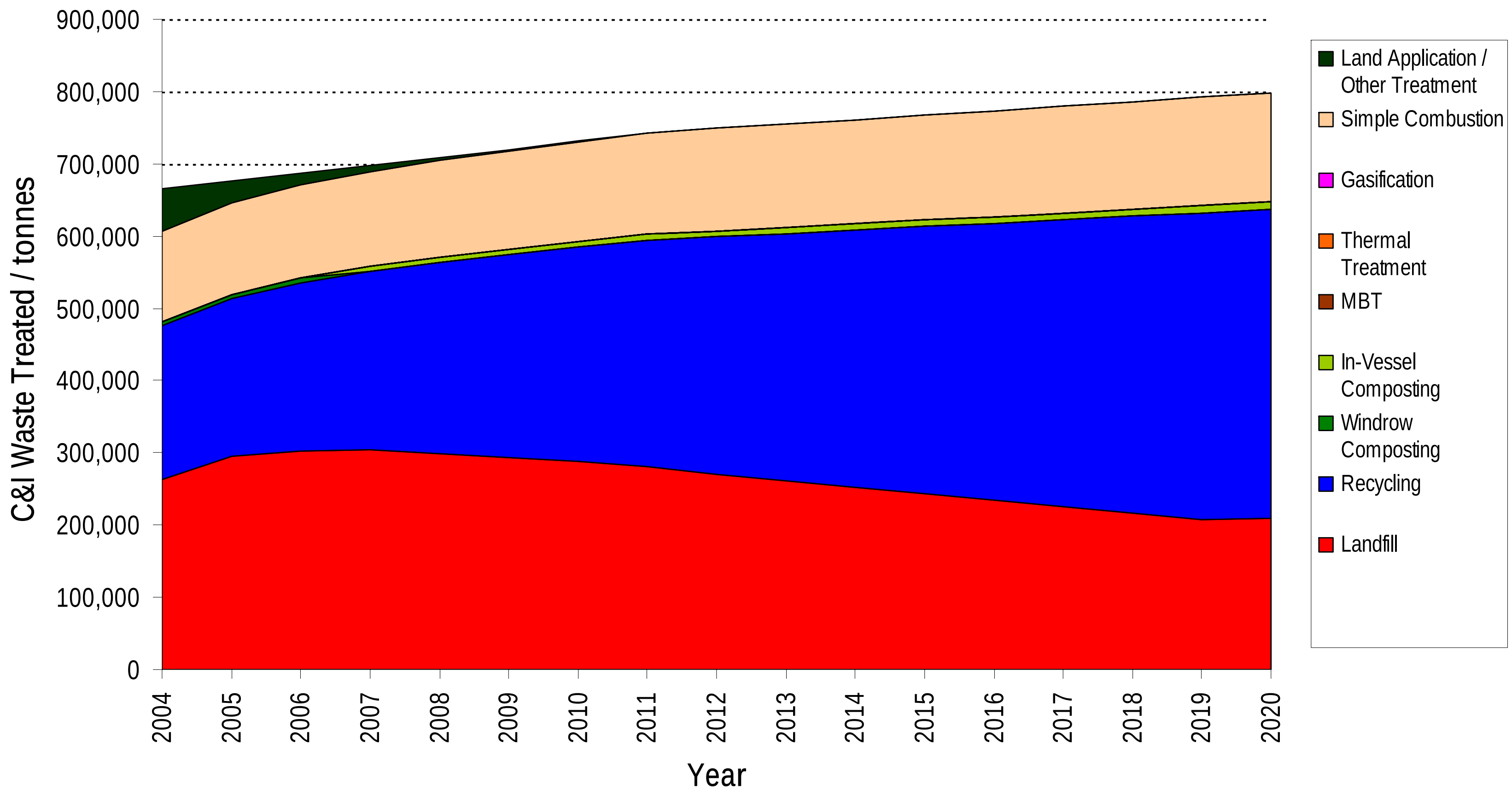
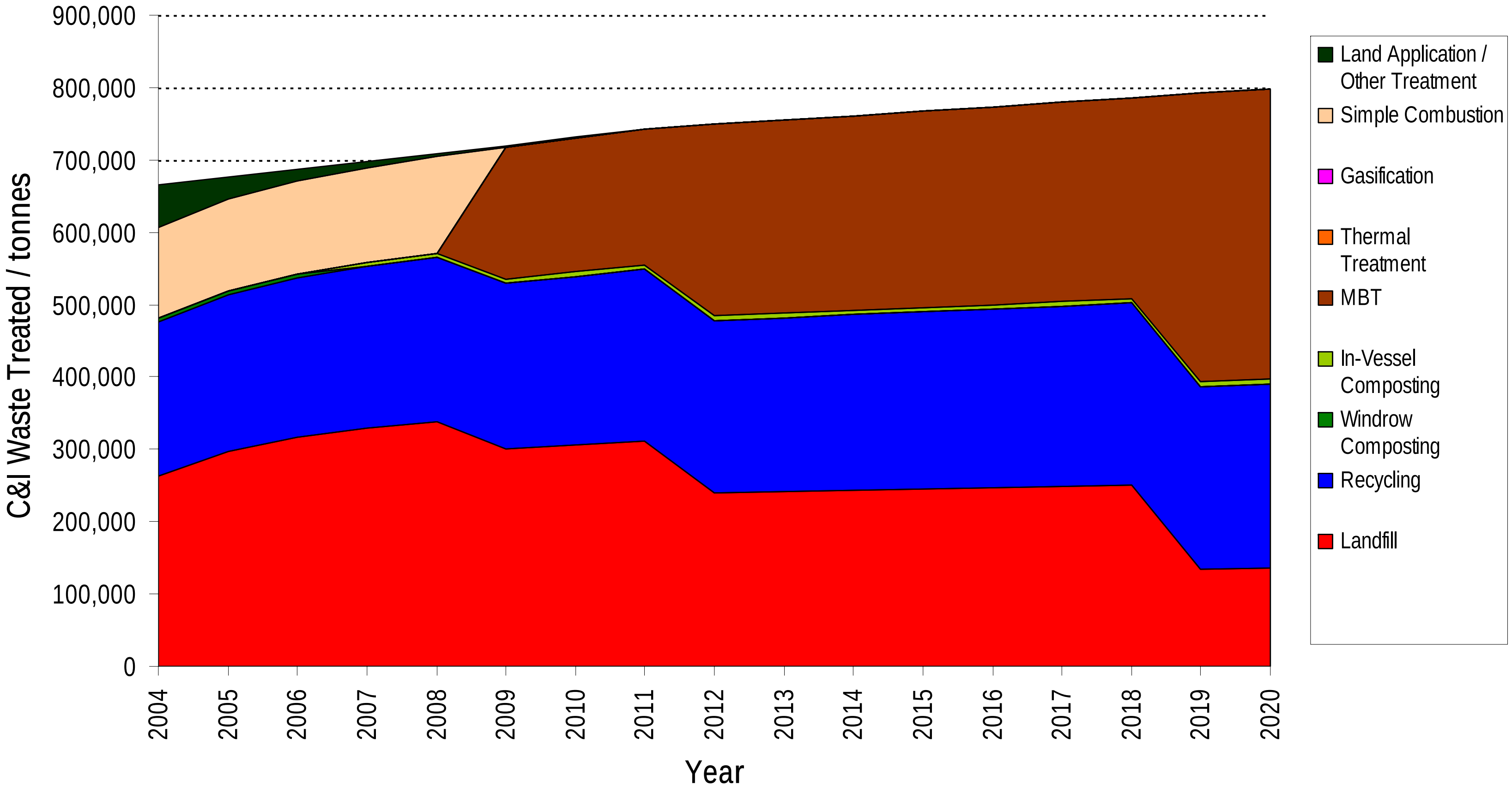


Figure C3.3 C&I Scenario 3 – MBT



Two versions of this scenario were modelled, with the high-CV material from the MBT either being used as a refuse-derived fuel, or being landfilled.

Figure C3.4 C&I Scenario 4a – Thermal Treatment

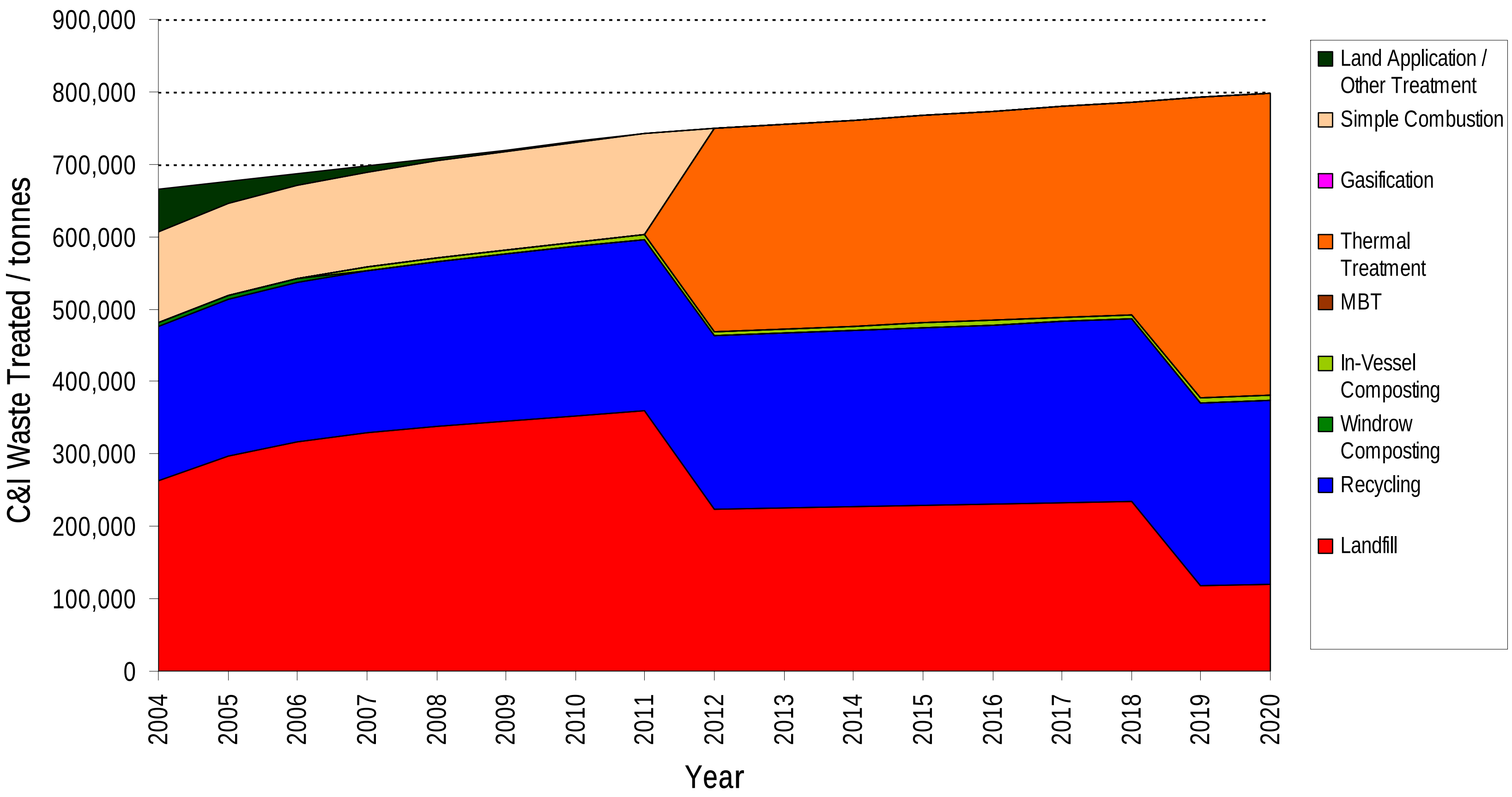


Figure C3.5 C&I Scenario 4b – Gasification

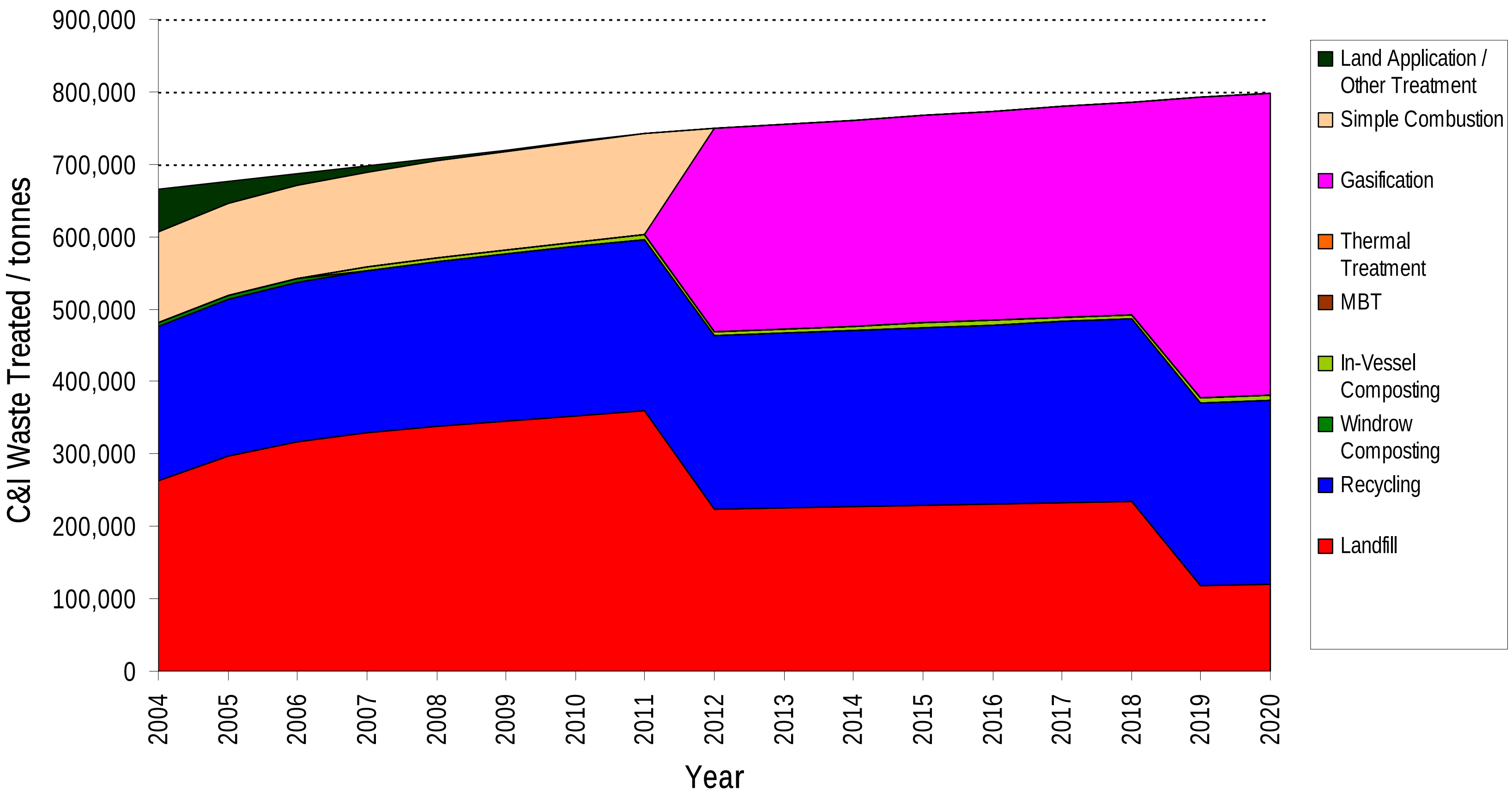


Figure C3.6 C&I Scenario CI1a – 45% Recycling, Equal Levels of MBT and AD

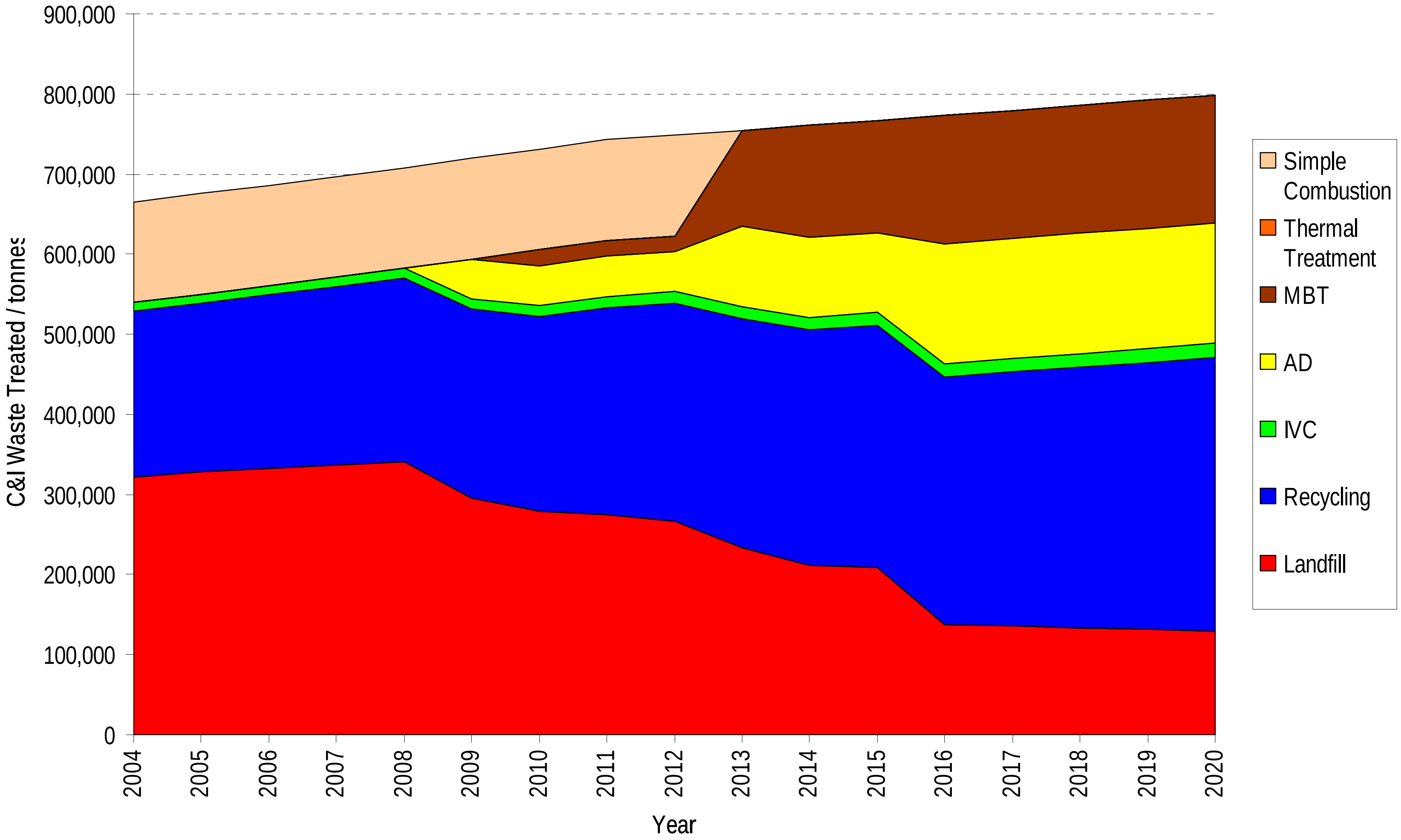


Figure C3.7 C&I Scenario CI1b – 45% Recycling, MBT greater than AD

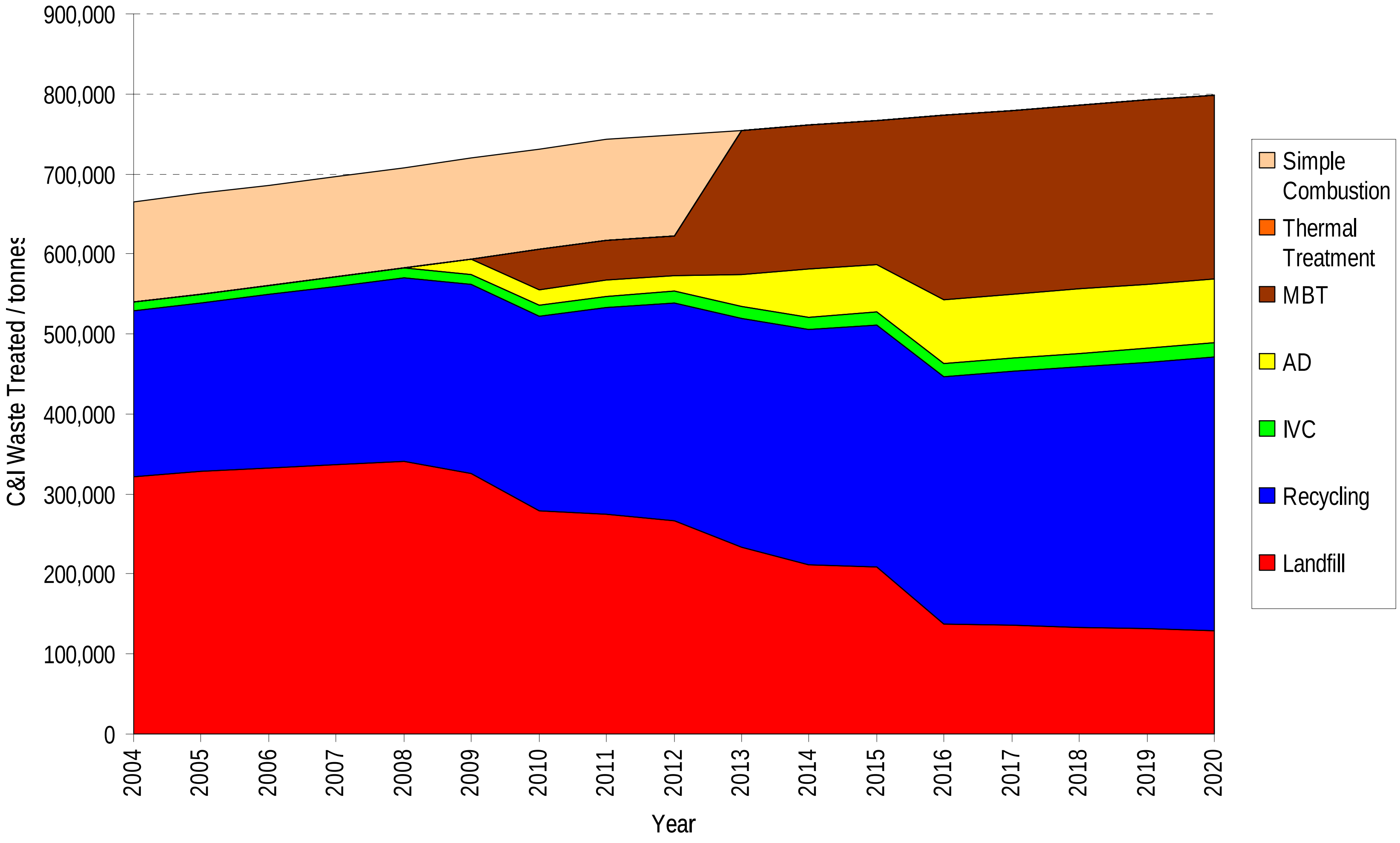


Figure C3.8 C&I Scenario CI1c – 60% Recycling, Equal Levels of MBT and AD

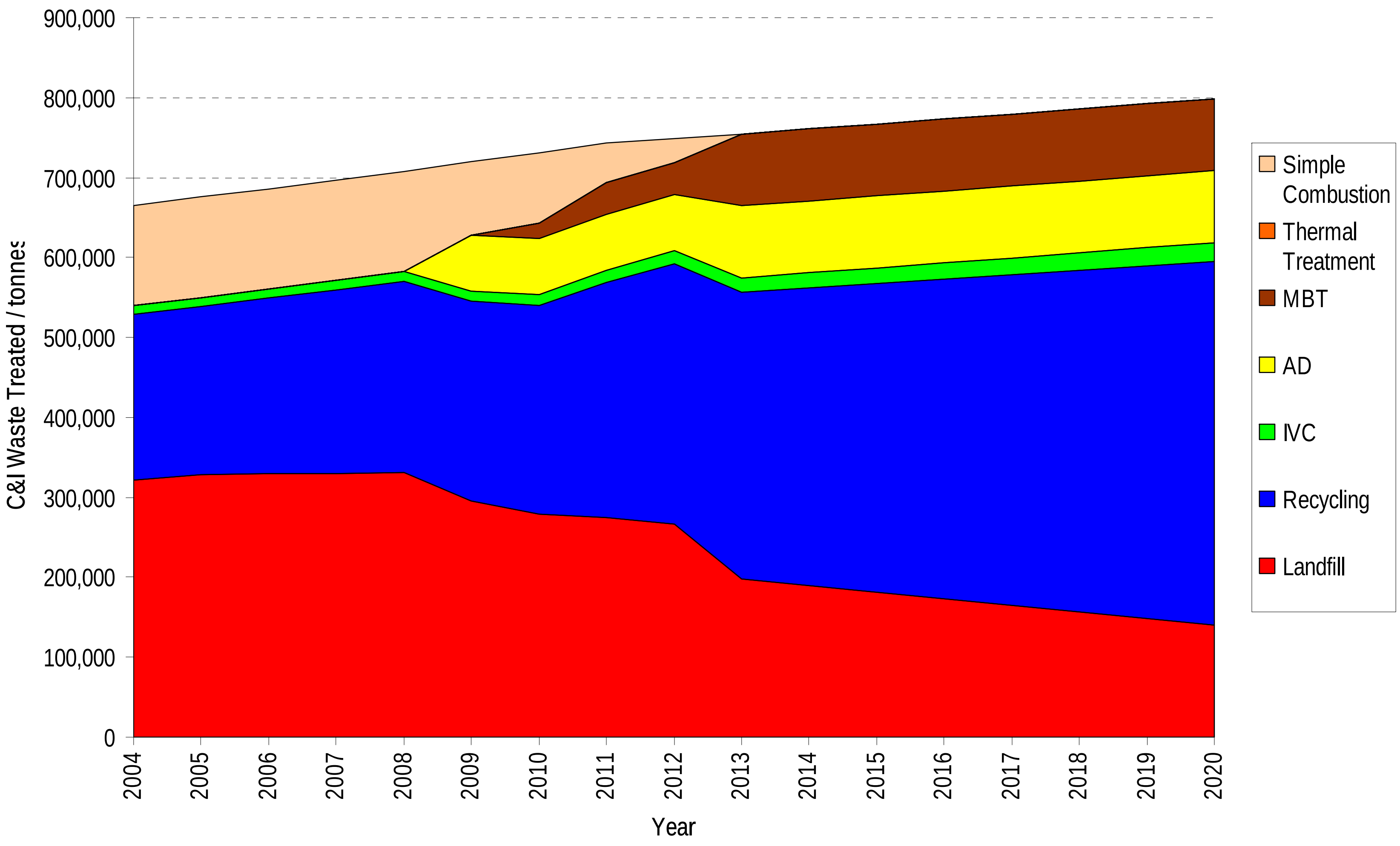


Figure C3.9 C&I Scenario CI2a – 45% Recycling, Equal Levels of Thermal Treatment, MBT and AD

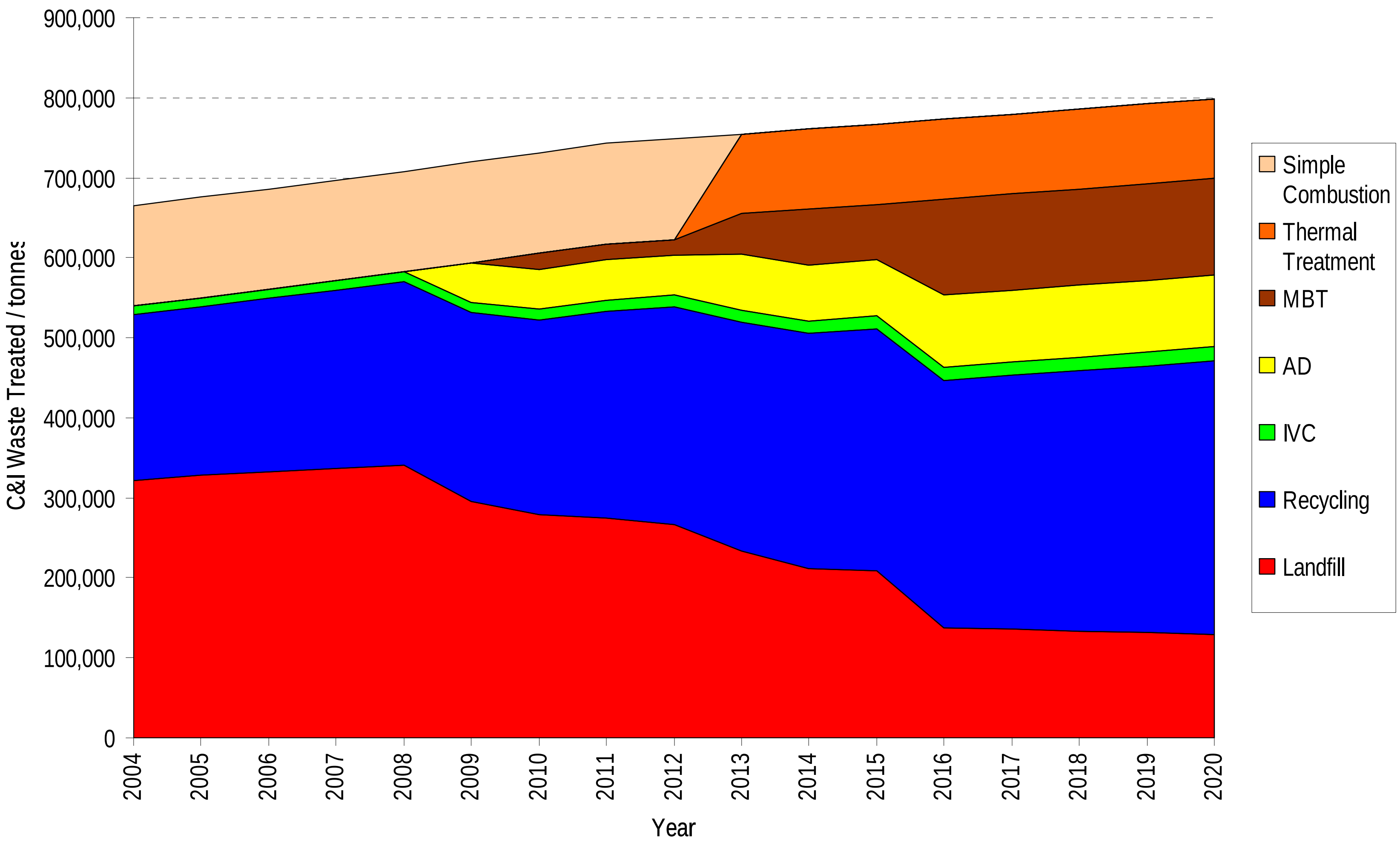


Figure C3.10 C&I Scenario CI2b – 60% Recycling, with Thermal Treatment, MBT and AD

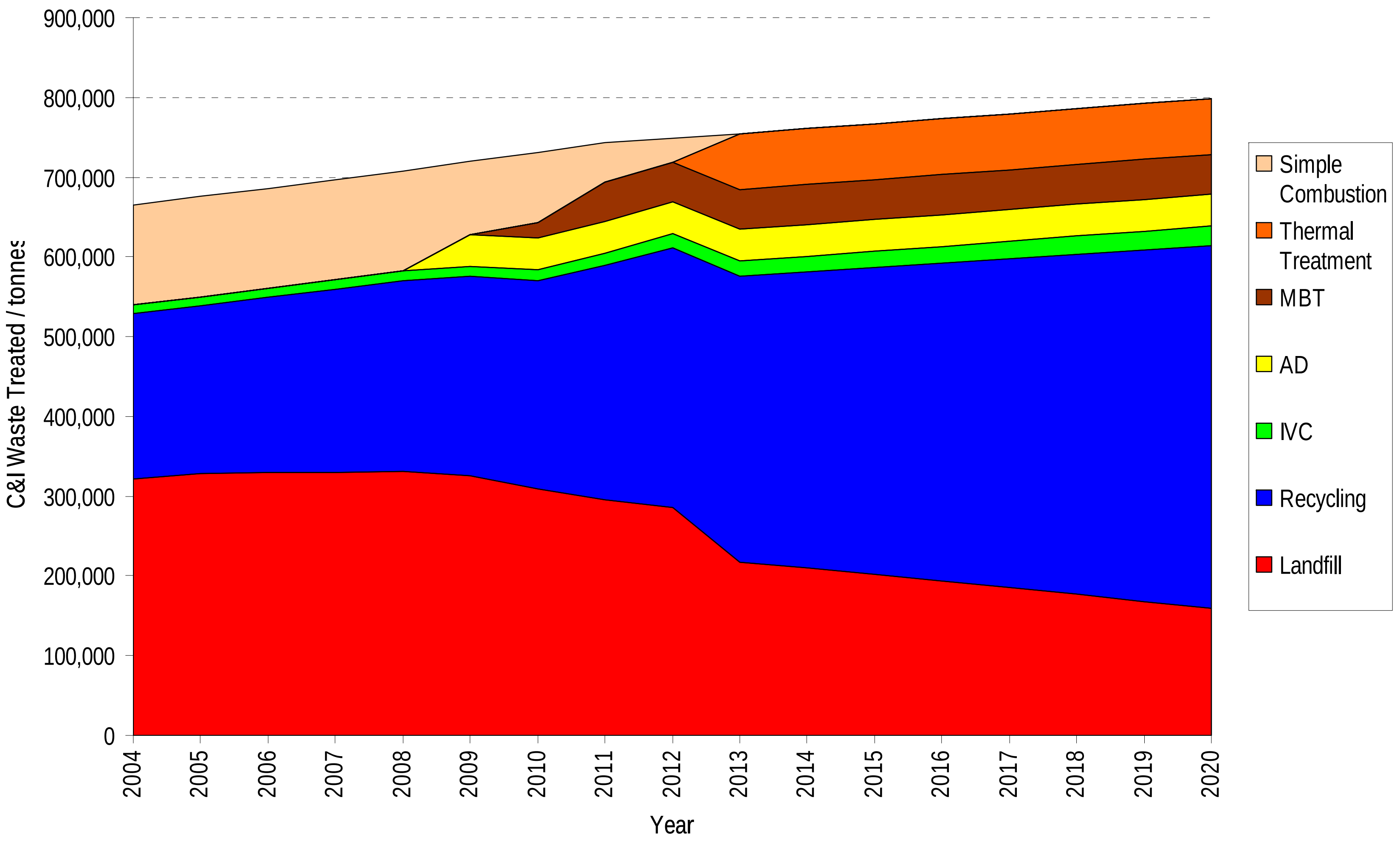


Figure C3.11 C&I Scenario CI2c – 50% Recycling, High Thermal Treatment with MBT and AD

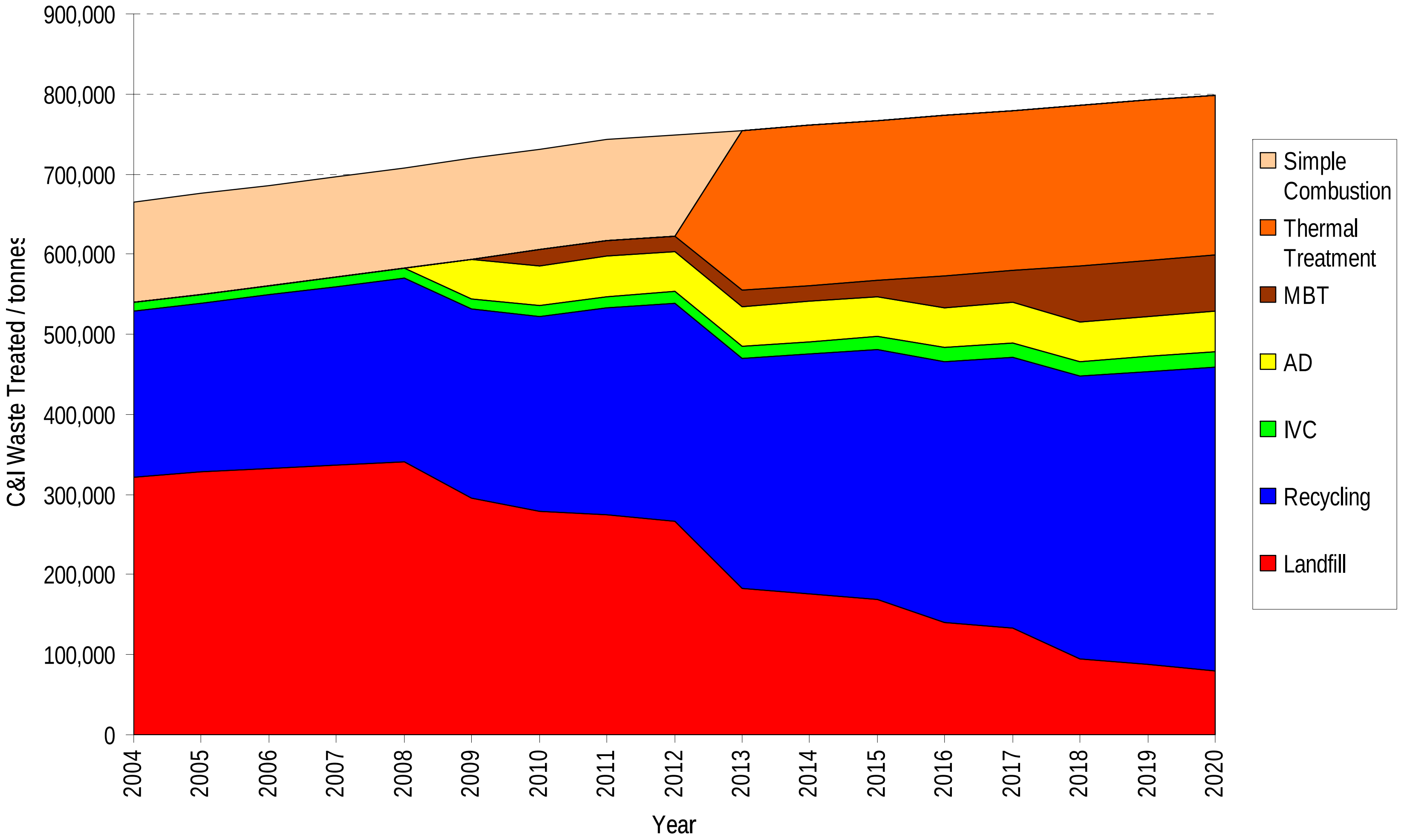


Figure C3.12 C&I Scenario CI2d – 60% Recycling, Moderate Thermal Treatment with MBT and AD

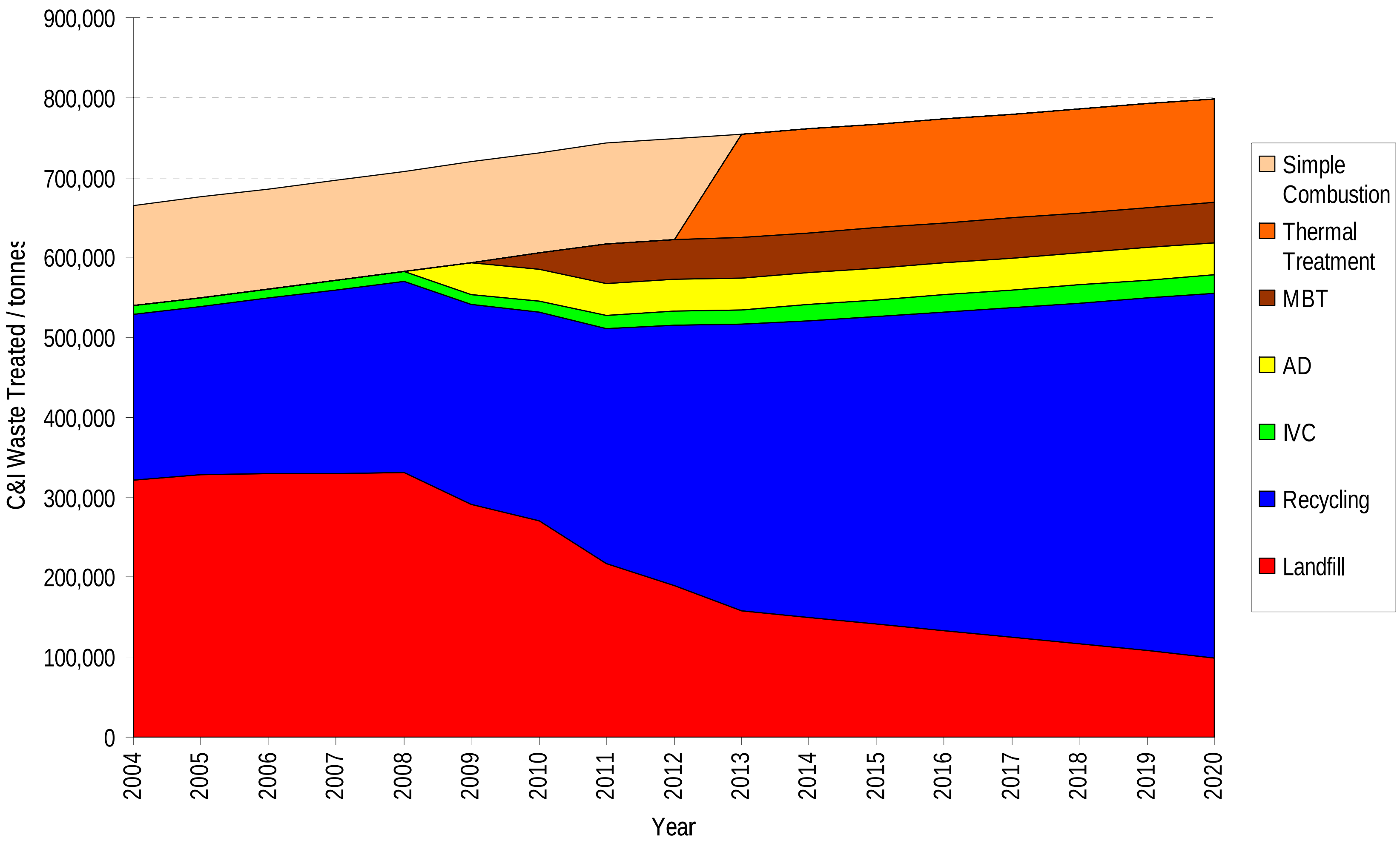
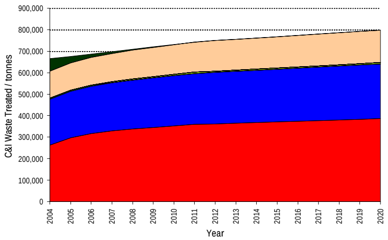
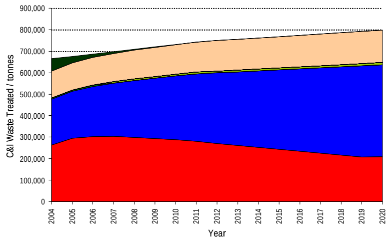


Figure C3.13 Condensed Summary View of All C&I Scenarios

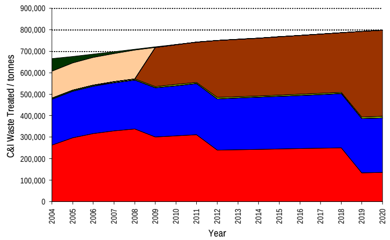
Scenario 1 – Current Situation



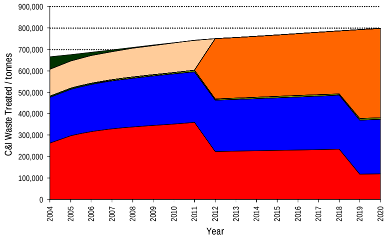
Scenario 2 – High Recycling



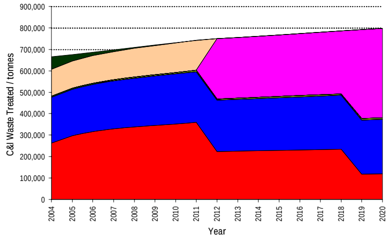
Scenario 3 – MBT



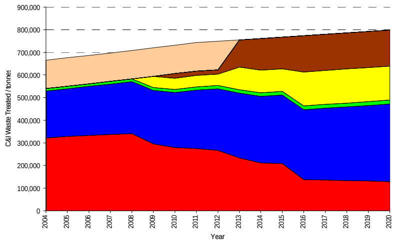
Scenario 4a – Thermal Treatment



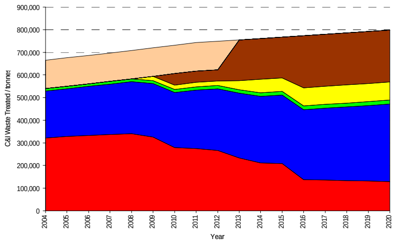
Scenario 4b – Gasification



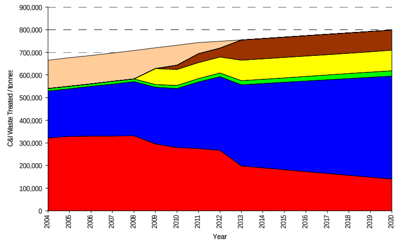
C&I Scenario CI1a – 45% Rec, Equal Levels of MBT and AD



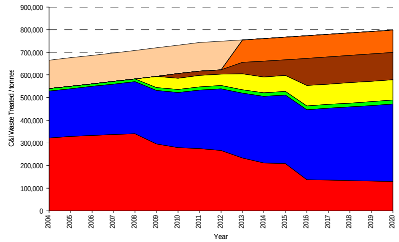
Scenario CI1b – 45% Rec, MBT greater than AD



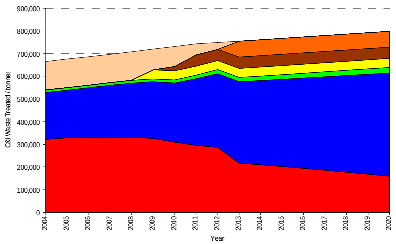
Scenario CI1c – 60% Rec, Equal Levels of MBT and AD



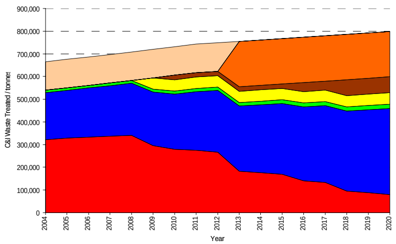
Scenario CI2a – 45% Rec, Equal Levels of TT, MBT and AD



Scenario CI2b – 60% Rec, with TT, MBT and AD



Scenario CI2c – 50% Rec, High TT with MBT and AD



Scenario CI2d – 60% Rec, Moderate TT with MBT and AD

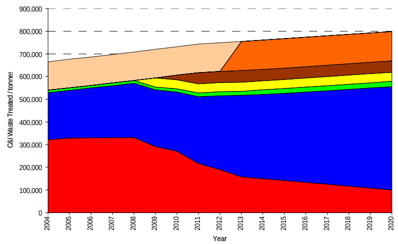


Figure C4.1 CD&E Scenario 1 – Current Situation

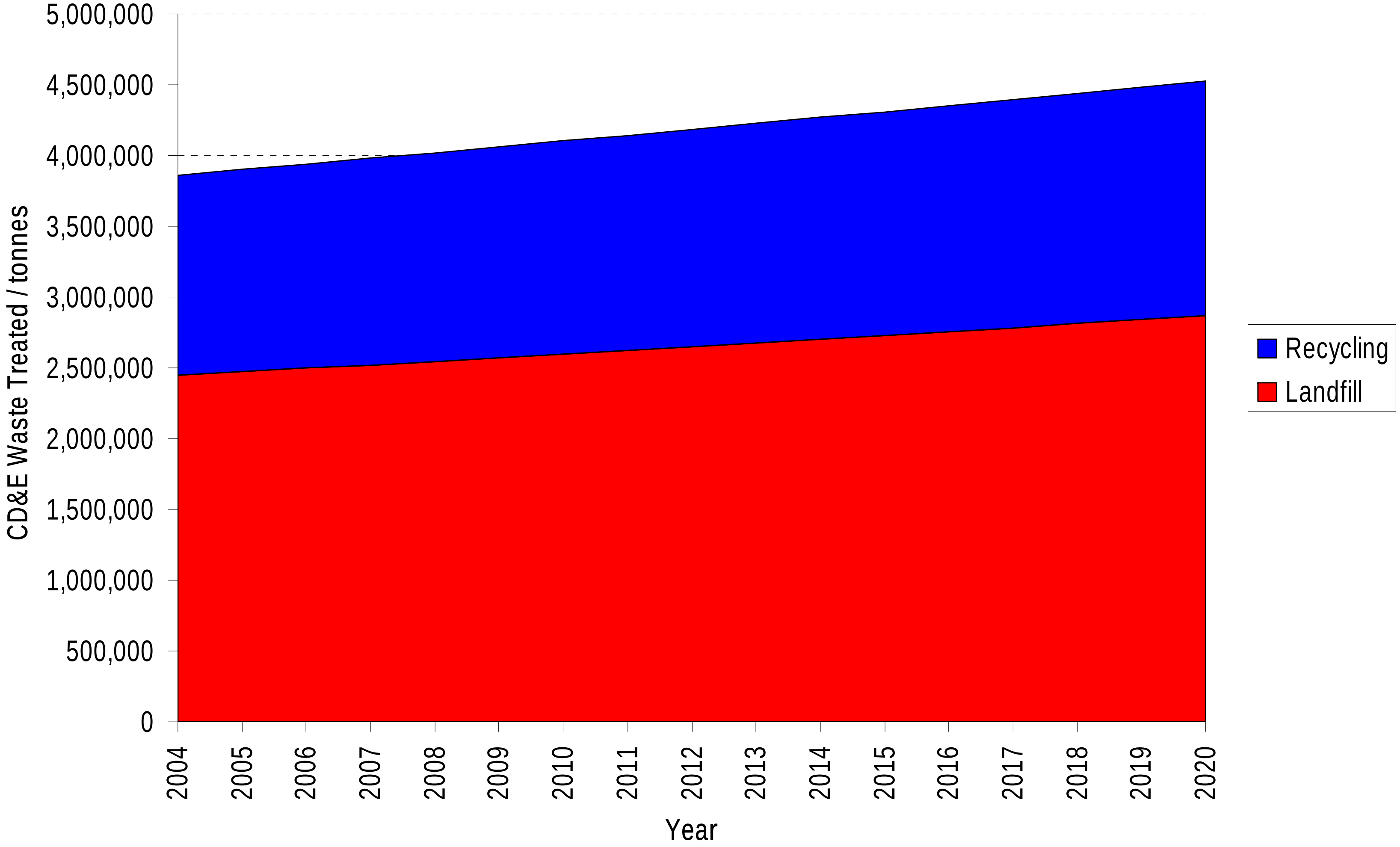


Figure C4.2 CD&E Scenario 2 – Moderate Diversion

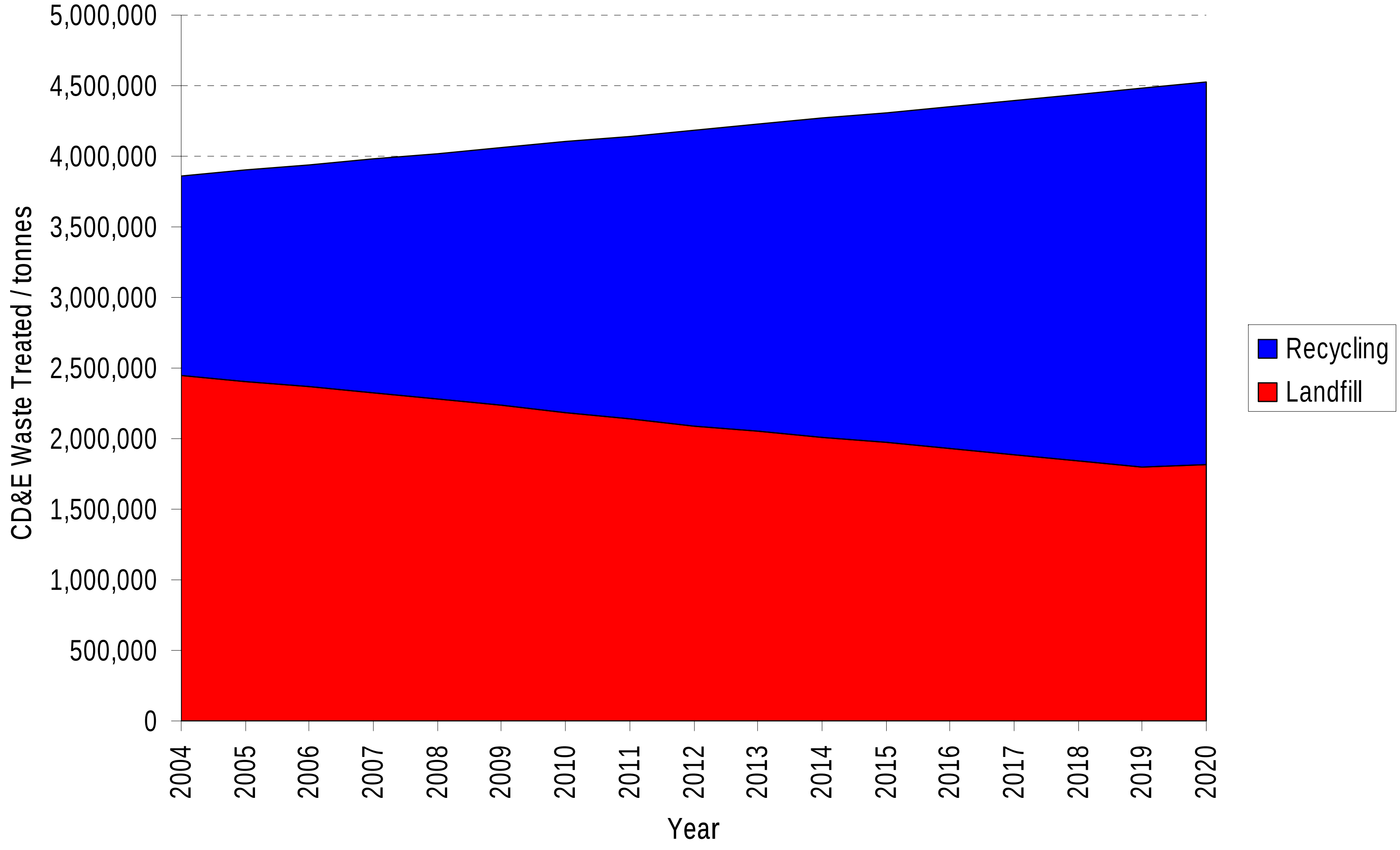


Figure C4.3 CD&E Scenario 3 – High Diversion

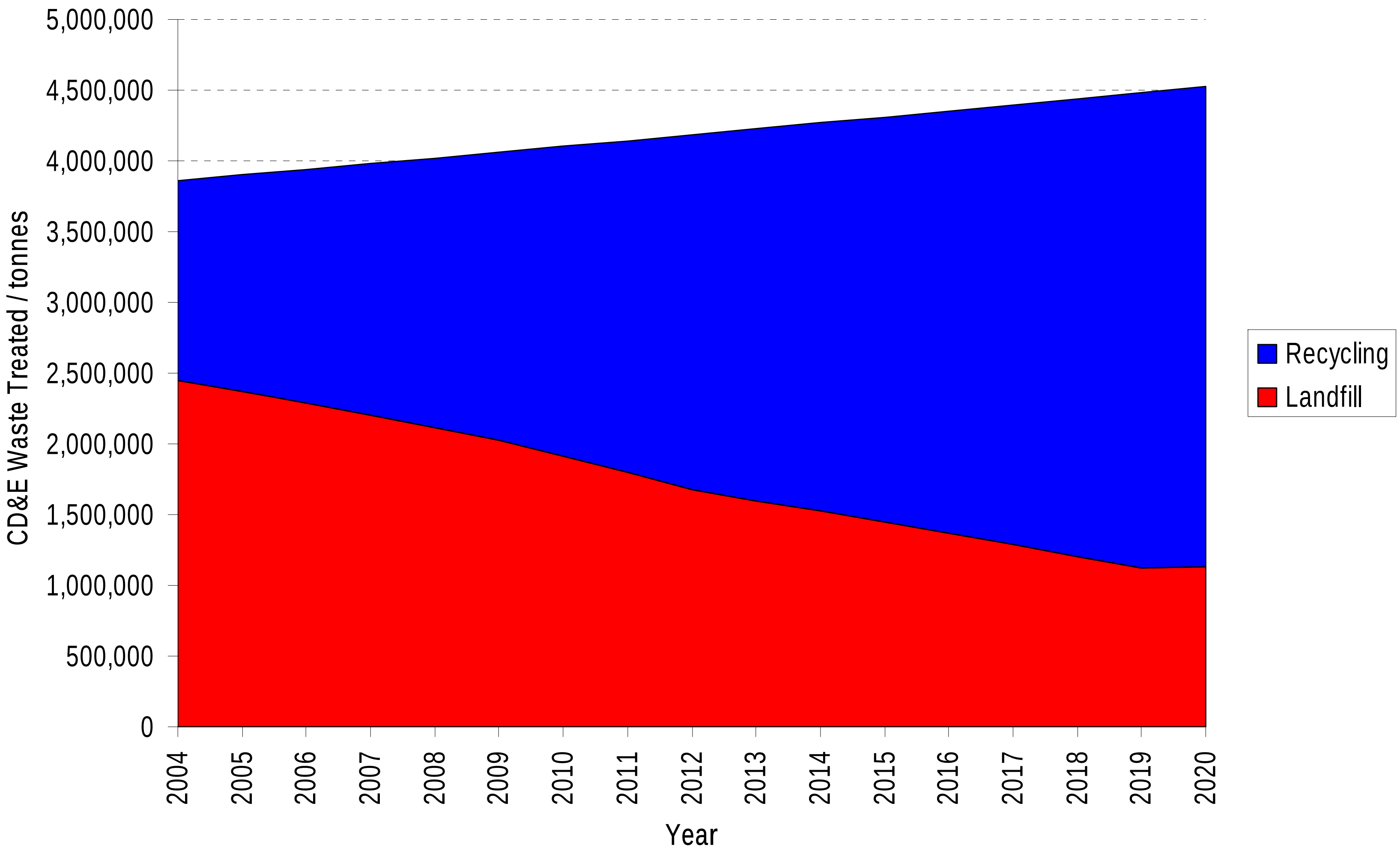
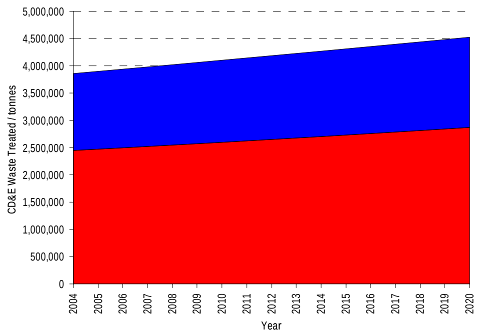
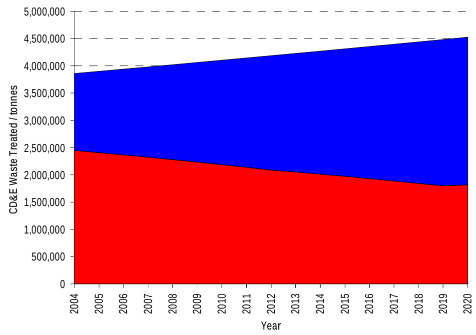


Figure C4.4 Condensed Summary View of All CD&E Scenarios

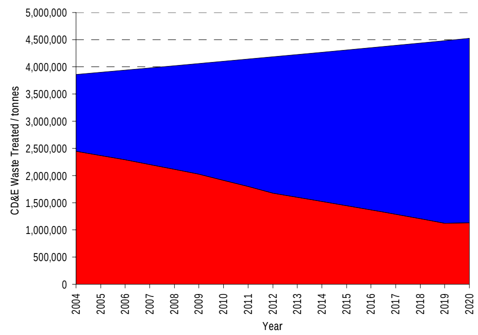
Scenario 1 – Current Situation



Scenario 2 – Moderate Diversion



Scenario 3 – High Diversion



Annex D

Screening of Scenario 2

D1 REASON FOR SCREENING OUT SCENARIO 2 – HIGH RECYCLING & COMPOSTING

This annex provides more information on the decision to screen out *Scenario 2* from consideration at the BPEO workshop.

D1.1 BACKGROUND

This BPEO Scenario was designed to evaluate the feasibility of relying solely on recycling and composting, without the use of any other alternative technology, to replace landfill to meet the EU Landfill Directive targets. To achieve the Landfill Directive target for 2020 would require a recycling and composting rate of 78.5%, as illustrated in *Table D1.1*.

Table D1.1 Calculation of Required Recycling and Composting Rate in 2020

Parameter	Value	Notes
Projected MSW by 2020	1 544 208 te	Based on projected 2.4% growth rate
Landfill Directive limit for BMW by 2020	221 165 te	This value is fixed
Projected limit of landfilling MSW by 2020	331 500 te	Based on BMW = 71% of total MSW
% of MSW which can be landfilled	21.5%	
% of MSW to be recycled & composted	78.5%	

A recent report by the Resource Recovery Forum [(1)] reviewed international experience on recycling and identified the best performing regions in Europe and North America. Maximum diversion rates of 60% have been achieved in several largely rural areas with low population densities. The best performing provincial cities and urban areas achieve recycling and composting rates of around 45%. Recycling rates in metropolitan areas tend to be lower. For example, recycling has been mandatory in New York since 1989 and the city provides a weekly multi-material kerbside service to 100% of its households. Despite this level of service provision, the recycling rate has never exceeded 21%. The city's own detailed analysis suggests that 25% is probably the highest recycling rate achievable. It is likely that some deprived areas of Belfast and other urban areas may only attain recycling rates at this level.

A report by Eunomia Research & Consulting and Friends of the Earth [(2)] reviewed current best practice in England and identified that the best performing local authorities achieve recycling rates in the range 27% to 36%. The report notes that, 'local authorities with current good practice recycling services and low deprivation should be able to achieve recycling rates well above 27-36% but providing the same services in areas of high deprivation is currently likely to result in lower recycling rates.' Looking ahead, the report concludes, 'the analysis suggests that a recycling rate of 62% for household waste should be achievable in England. However, securing sufficient public participation to achieve this level of recycling will be a difficult challenge.'

(1) *High diversion – is it achievable?* Resource Recovery Forum, 2004
(2) *Maximising recycling rates, tackling residuals* Eunomia, Friends of the Earth and Network Recycling, 2002

There are several key factors that need to be taken into account when considering achievable recycling rates:

- % coverage – how many households have a kerbside collection service or easy access of recycling sites;
- % participation – how many people participate in recycling schemes;
- % capture – of the total amount of a material in the waste (e.g. paper) how much is actually recycled by the people who are participating;
- contamination – inappropriate items in a recycled waste stream which means some material has to be rejected e.g. plastics/glass in an organic waste stream; and
- items which cannot be recycled – normally composites of several different materials, e.g. envelopes, paper with paint.

Detailed calculations (see *Table D1.2*), based on the NI waste composition and assuming 100% coverage of households, with very high participation and capture rates of 80-90%, indicate that an ambitious target for recycling and composting would be 45% of all MSW.

Table D1.2 Calculation of Ambitious Rate of Recycling and Composting

Material	**Waste composition**	**% Participation**	**% Capture**	**MSW diverted**	**MSW undiverted**
Paper/card	18.2%	80%	80%	12%	6.6%
Putrescible	34.0%	80%	80%	22%	12.2%
Textiles	1.8%	50%	90%	1%	1.0%
Fines	5.4%	-	-	0%	5.4%
Misc. combustible	12.2%	-	-	0%	12.2%
Misc. non-combustible	8.9%	-	-	0%	8.9%
Ferrous metal	3.7%	80%	80%	2%	1.3%
Non-ferrous metal	0.9%	80%	80%	1%	0.3%
Glass	6.6%	50%	90%	3%	3.6%
Plastic dense	5.3%	80%	80%	3%	1.9%
Plastic film	3.0%	80%	80%	2%	1.1%
Total	**100%**			**45.4%**	**54.6%**

To achieve a 78.5% recycling and composting rate would effectively require 100% coverage, 100% participation, 100% capture of materials and zero contamination. This has not been achieved anywhere in the world and it would therefore not be sensible to base a long term strategy for waste management on such a scenario, with the risk of substantial EU infraction fines for failure to meet targets.

Annex E

Context Setting for Environmental Criteria

This annex explains how the environmental decision criteria were combined into a single assessment, within the Northern Ireland context.

In order to determine Northern Ireland-specific information, it was necessary to scale down UK energy data (see below). This was done on the basis of the number of households, using the data in *Table E1.1*.

Table E1.1 Data on Number of Households in UK and NI

Region	Households	Source
UK	24 479 439	http://www.statistics.gov.uk/census2001/profiles/uk.asp
NI	626 718	http://www.nisra.gov.uk/census/Excel/KS20DC.xls

From this, we conclude that the NI fraction of UK households is 2.56%. This figure was used to scale the energy data from DUKES, in *Table E1.2*.

Table E1.2 DUKES Energy Consumption Data 2003 (†)

Domestic consumption of…	UK	Units	NI	Units
Coal	944	000 tonnes	24 168 111	kg
Natural gas	385 985	GWh		
	28 563	000 000 m^3	731 261 746	m^3
Petroleum	3 093	000 tonnes	79 186 405	kg
Electricity	115 761	GWh	2 963 691 382	kWh

(†) DUKES = Digest of UK Energy Statistics. See http://www.dti.gov.uk/energy/inform/dukes/index.shtml [29Sep04 @ 10:49]

Using the environmental emission factors in *Table A2.2* these consumption figures can be converted into the same environmental impacts that were used to assess the scenarios. The results are presented in *Table E1.3*.

Table E1.3 Summary of Environmental Impact Context Setting

Environmental Impact	Value	Units
Resource Depletion	2 717 228	Crude Oil Tonne Equivalents
Greenhouse Gas Emissions	4 967 349	Carbon Dioxide Tonne Equivalents
Acidification	43 344	Sulphur Dioxide Tonne Equivalents
Landtake (†)	175	Hectares
Extent of Water Pollution (†)	1738	OPRA Units

(†) In the absence of obvious benchmarks for the two other environmental decision criteria, it was decided to adopt the values for the current situation scenario (*Scenario 1*) as the baseline against which the scenarios would be assessed.

The environmental impacts of the scenarios were calculated (see *Annex A* for methodology) and scaled by these contextual figures, as a means to compare and combine them. The second figure in each column of *Table E1.4* is the scaled figure, so, for example, scenario 1 gets a scaled score of 0.05 for resource depletion, as its impact is about 5% of the Northern Ireland context figure.

Table E1.4 Scaling of Environmental Impacts, using Context Reference Data

Units	Resource Depl *te crude oil eq*		GHG Emissions *te CO_2 eq*		Acidification *te SO_2*		Landtake *Hectares*		Water Poll. *OPRA*	
Ref	**2 717 228**		**4 967 349**		**43 344**		**175**		**1738**	
Scen 1	124 100	0.05	26 637	0.01	101 669	2.35	175	1.00	1738	1.00
Scen 2	279 856	0.10	303 262	0.06	230 577	5.32	157	0.90	1838	1.06
Scen 3	301 870	0.11	428 016	0.09	160 056	3.69	150	0.86	1780	1.02
Scen 4	205 025	0.08	214 826	0.04	158 605	3.66	151	0.86	1723	0.99
Scen 5a	264 049	0.10	349 396	0.07	159 163	3.67	142	0.81	1720	0.99
Scen 5b	268 870	0.10	397 941	0.08	165 431	3.82	141	0.81	1708	0.98
Scen 6	266 367	0.10	442 673	0.09	50 020	1.15	131	0.75	1424	0.82
Scen 7	262 985	0.10	328 808	0.07	182 028	4.20	155	0.89	1866	1.07

Final scores for the scenarios were generated by summing their scores for each of the five environmental impacts, taking into account the fact that, for the first three criteria, the scores are benefits (amounts of impact avoided), whereas, for the last two, the scores are impacts. This process is shown in *Table E1.5*. All of the scenarios show a net benefit to the environment (positive score), except scenario 6, whose low recycling rate results in a net impact to the environment.

Table E1.5 Calculation of Final Environmental Scores

	Resource Depl	GHG Emissions	Acidification	Landtake	Water Poll.	Total
Scen 1	0.05	0.01	2.35	-1.00	-1.00	0.40
Scen 2	0.10	0.06	5.32	-0.90	-1.06	3.53
Scen 3	0.11	0.09	3.69	-0.86	-1.02	2.01
Scen 4	0.08	0.04	3.66	-0.86	-0.99	1.92
Scen 5a	0.10	0.07	3.67	-0.81	-0.99	2.04
Scen 5b	0.10	0.08	3.82	-0.81	-0.98	2.21
Scen 6	0.10	0.09	1.15	-0.75	-0.82	-0.23
Scen 7	0.10	0.07	4.20	-0.89	-1.07	2.40

Annex F

Discussion of Waste Management Facilities Distribution

F1 DISCUSSION OF WASTE MANAGEMENT FACILITIES DISTRIBUTION

The discussion below explains how the possible areas of search for the waste management facilities were identified, with the objective of minimising the tonne-kilometres required to bring the waste to the identified locations.

It should be stressed up front that the locations are no more than indicative, and critically dependant on the assumed plant capacities and therefore the number of facilities required. If it is suggested that a facility be located in, for example, Craigavon, this means in the general region of Craigavon – so includes Portadown, Lurgan and other neighbouring locations.

Furthermore, a plant provisionally located in Craigavon might actually be better located in (for instance) Lisburn, Dungannon, Banbridge or Armagh, depending on local issues beyond the scope of this study. Therefore, it is perhaps more appropriate to think less in terms of facilities than in 'areas of search'. It will therefore be necessary for the sub-regional Waste Plans to assess relevant local issues before determining the optimum number, capacities and locations of facilities.

F1.1 METHODOLOGY

First of all, 34 major towns and cities in Northern Ireland were identified as possible locations for facilities, with between one and two locations in each District Council (see *Figure F1.1*). The distances between adjacent locations along major roads were determined using GIS software. Conditions were set that no town should have more than one facility of the same type, and all facilities should be the same size.

The second piece of information required was the fraction of waste arisings in each District Council. For the purposes of this analysis, the waste was assumed to arise from the 34 towns selected as possible locations for the waste management facilities. Figures were generated using each council's waste arisings data, with the waste split equally where two towns are located in the same District Council. With the waste arisings in each town and the distances between the towns known, it became a case of selecting the optimal spread of locations, to minimise the transportation of waste.

The final piece of data is the number of facilities required. This was determined by choosing a typical plant capacity, and dividing that by the total capacity required.

For any combination of locations, a computer programme determines the nearest facility for each town, and totals the demand for that facility. If its capacity exceeds its demand, all the identified towns' wastes are sent to the facility. However, frequently the demand for a facility exceeds its capacity. In that instance, its capacity is shared between the closest towns, leaving the more distant towns to use other facilities. Once the destinations of all the wastes are known, the programme calculates the total tonne-kilometres associated with that combination of facilities.

Given that, for example, there are 286 million possible combinations of 11 locations out of 34, it was not possible to assess every combination. Therefore, the programme repeatedly selects a combination of locations at random, and works out the transport implications for that combination, keeping track of the most efficient combination. After the process has been allowed to run for a set period, an apparent best combination was identified. This was then manually tested for close variations (eg keeping all but one plant the same), to check if any better combinations could be identified.

Having identified the best apparent combination of, for example, seven locations, a similar process was used to identify in which order these ought to be built, to minimise the transport demands at each stage. This completed the analysis.

The results are presented below in four tables. The first two tables present the locations of the MSW facilities, and the associated tonne-kilometres of waste transport per 100 000 tonnes of waste generated. The second two tables provide the same information for C&I waste.

Figure F1.1 Network of 34 Towns and Cities and the Roads Used to Link Them

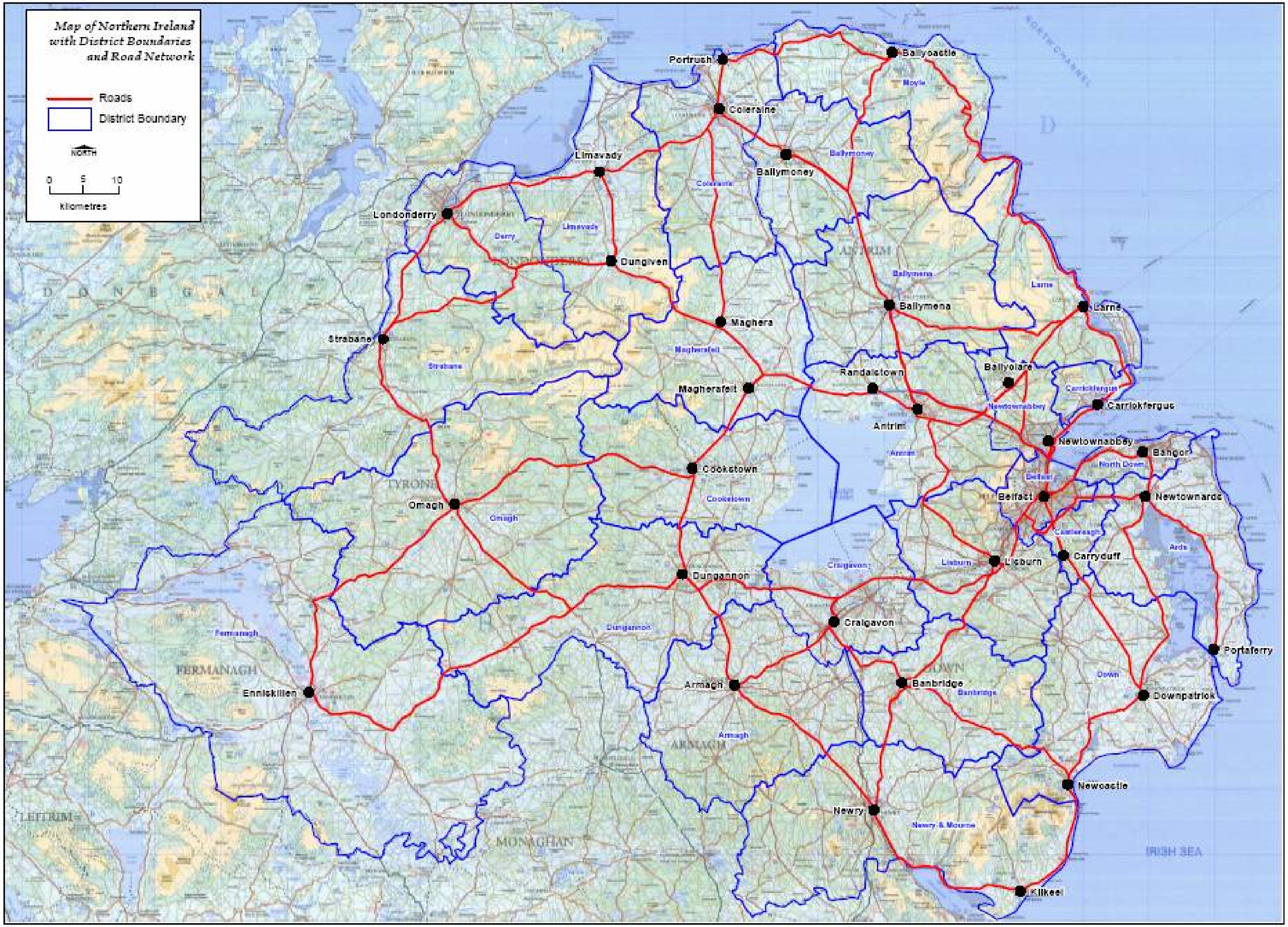


Table F1.1 Optimised Location of Facilities for MSW

Total Number of Plants Required	Priority of Building Plant 1	2	3	4	5	6	7	8
1	Belfast							
2	Belfast	Derry						
3	Belfast	Limavady	Dungannon					
4	Belfast	Omagh	Coleraine	Armagh				
5	Belfast	Strabane	Craigavon	Coleraine	Antrim			
6	Belfast	Derry	Craigavon	Ballymena	Omagh	Portrush		
7	Belfast	Derry	Dungannon	Coleraine	Banbridge	Ballymena	Omagh	
8	Belfast	Derry	Banbridge	Ballymena	Enniskillen	Cookstown	Portrush	Newcastle

Eg: If four plants are required to handle NI's MSW, they should be located in Belfast, Omagh, Coleraine and Armagh, and, if not all built at the same time, constructed in that order

Table F1.2 Thousands of Tonne-Kilometres Associated with Transporting a Total of 100 000 te of MSW to the Above Facilities

Total Number of Plants Required	Priority of Building Plant 1	2	3	4	5	6	7	8
1	5236							
2	5236	3455						
3	5236	3523	2677					
4	5236	3610	2814	2281				
5	5236	3555	2853	2251	1985			
6	5236	3455	2734	2335	1997	1761		
7	5236	3455	2714	2320	1996	1760	1547	
8	5236	3455	2804	2394	2051	1798	1572	1418

Eg: Continuing with the above example, transporting 100 000 te of MSW from across NI to a single plant in Belfast would involve 5 236 000 te-km of transportation. By the time the fourth plant has been built, this falls to 2 281 000 te-km.

Table F1.3 Optimised Location of Facilities for C&I Waste

Total Number of Plants Required	Priority of Building Plant: 1	2	3	4	5	6	7	8	9
1	Belfast								
2	Belfast	Derry							
3	Belfast	Derry	Armagh						
4	Belfast	Derry	Craigavon	Ballymena					
5	Belfast	Derry	Craigavon	Antrim	Omagh				
6	Belfast	Derry	Craigavon	Antrim	Omagh	Coleraine			
7	Belfast	Derry	Craigavon	Antrim	Omagh	Coleraine	Newcastle		
8	Belfast	Derry	Craigavon	Antrim	Omagh	Coleraine	Newcastle	Newtownards	
9	Belfast	Derry	Craigavon	Antrim	Omagh	Coleraine	Newcastle	Newtownards	Magherafelt

Eg: If four plants are required to handle NI's C&I waste, they should be located in Belfast, Derry, Craigavon and Ballymena, and, if not all built at the same time, constructed in that order

Table F1.4 Thousands of Tonne-Kilometres Associated with Transporting a Total of 100 000 te of C&I Waste to the Above Facilities

Total Number of Plants Required	Priority of Building Plant: 1	2	3	4	5	6	7	8	9
1	4463								
2	4463	2834							
3	4463	2834	2169						
4	4463	2834	2191	1810					
5	4463	2834	2191	1825	1544				
6	4463	2834	2191	1825	1544	1325			
7	4463	2834	2191	1825	1544	1325	1149		
8	4463	2834	2191	1825	1544	1325	1149	1048	
9	4463	2834	2191	1825	1544	1325	1149	1048	972

Eg: Continuing with the above example, transporting 100 000 te of C&I waste from across NI to a single plant in Belfast would involve 4 463 000 te-km of transportation. By the time the fourth plant has been built, this falls to 1 810 000 te-km.

Annex G

Application of BPEO Workshop Results to the Final Set of Scenarios

G1 *APPLICATION OF BPEO WORKSHOP RESULTS*

This annex shows how the assessments, provided by the delegates who attended the BPEO workshop, were applied to the second set of scenarios assessed after the workshop.

At the end of the discussion on each criterion, the conclusions are presented that were drawn regarding how the new scenarios should be assessed, based on the scores given during the workshop, using a range from 1 (lowest rated) to 5 (highest).

G1.1 *SOCIAL CRITERIA*

G1.1.1 *Employment*

The delegates were presented with the supporting information reproduced in *Table 2.8*. Despite the apparent range of employment opportunities, particular in unskilled jobs, consensus on employment was very high; the prevailing opinion was that there was little significant difference between the scenarios, so all should be rated equally. However, some tables did express how important employment was, as a consideration in general.

Conclusion

Unless the employment figures present a drastically wider range of possible employment levels, scenarios should be scored equally for employment. In practice, all scenarios were given a score of 3, except *Scenario NS7*, where the multiple new facilities provided significantly higher employment opportunities – this scenario was rated at 3.5 for employment.

G1.1.2 *Public Acceptability*

Views on public acceptability generally put the scenarios into two groups, with the thermal treatment *Scenarios 5a* and *5b* consistently being down-valued versus the three alternatives. Many tables commented that public acceptability, whatever the technology, would need to be addressed by education programmes. No guidance was given on the reasons for the relative scoring of *Scenarios 3, 4* and *7*, though we can infer that *Scenario 3* was down-valued for its reliance on the combustion of RDF.

Conclusion

Scenarios should initially be given a score of 3.5 (only one table gave a maximum score of 5 at the workshop), from which points are deducted as more waste is sent to thermal treatment and, to a lesser extent, MBT with RDF production.

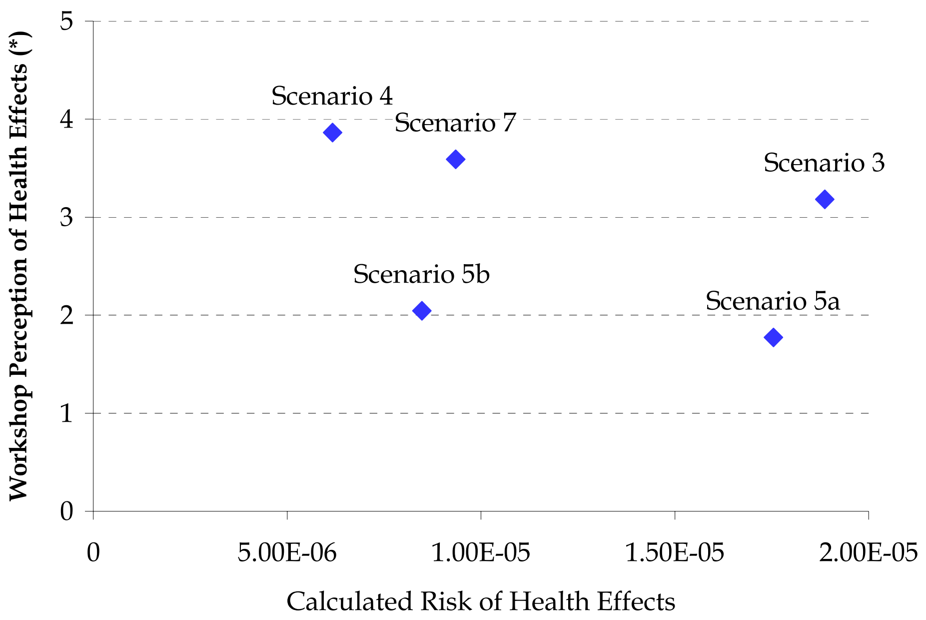
G1.1.3 *Perception of Health Effects*

'Perception of health effects' provided one of the more clear-cut splits between the scenarios. A lot of the tables acknowledged a close link with public acceptability, and several mentioned again the need for education. Representatives were provided with the information in *Table 2.8*. Despite that information (which suggests that *Scenario 3* yields the highest risk of health effects and that *Scenario 5b* is a relatively good performer), the delegates consistently marked down the two scenarios that involved thermal treatment. *Figure G1.1* illustrates that the scores for perception of health effects did reflect the estimated risk of health effects, with the obvious exceptions of the two scenarios involving thermal treatment.

Conclusion

Scenarios with thermal treatment should be down-valued versus the rest, which should be scored according to the risk as calculated.

Figure G1.1 Correlation between Perceived and Calculated Risks of Health Effects



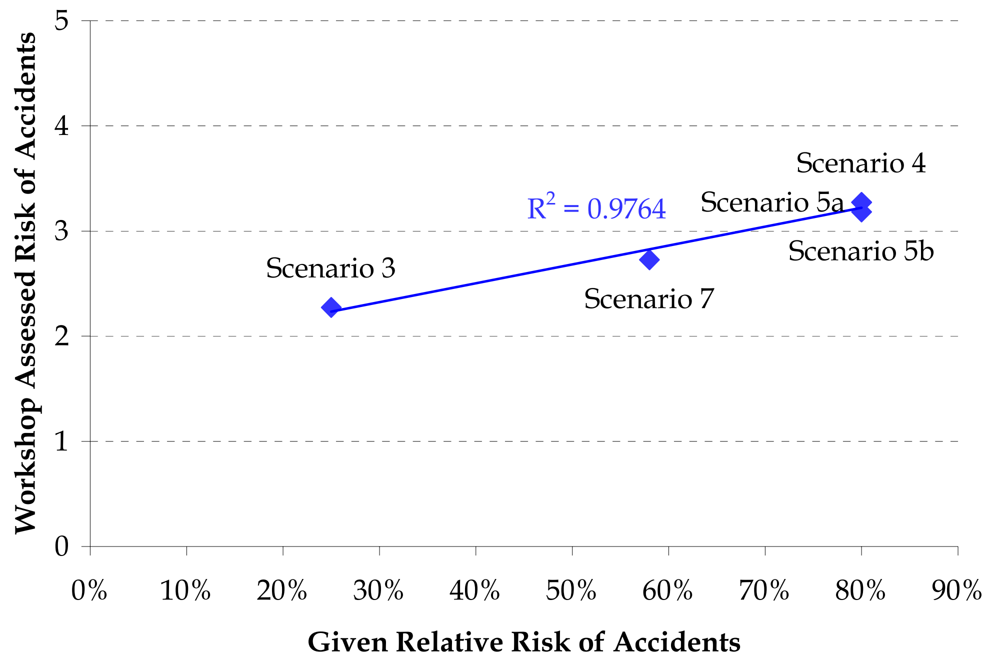
(*) The y-axis plots the workshop's collective perception of the risk of health effects, with high scores representing the (perceived to be) lower risk scenarios

G1.1.4 *Risk of Accidents*

An estimation of the risk of accidents associated with the various scenarios was generated using a methodology that assessed the relative levels of manual handling and mechanical equipment used to handle the waste.

As *Figure G1.2* shows, the workshop delegates were content to accept this as a guide to assessing the risk of accidents, but the range shows that, despite that, there was little differentiation between the scenarios. Their comments were varied, though a couple noted that, with the level of regulation in the industry, the risk of accidents is likely to be uniformly low.

Figure G1.2 Correlation between Given and Assessed Risks of Accidents



Conclusion

The scenarios should be scored following the developed estimation technique, but the range should be contained within 2¼ to 3¼ of out five.

G1.1.5 Public/Producer Responsibility

Despite equal levels of recycling and composting for *Scenarios 3, 4, 5a and 5b*, the two thermal scenarios were marked lower than the other scenarios. The higher recycling and composting rates of *Scenario 7* made that the highest rated, although all of the scores were close – this was not perceived to be a good differentiating criterion.

Conclusion

All the scenarios should be given roughly the same score. Those with increased recycling and composting should be promoted versus the average, and those with thermal technologies down-valued versus the average.

G1.1.6 Local Amenity

At the BPEO workshop, all scenarios were given a score in the range 2.7-3.2, and four of the eleven tables gave all five scenarios three points, indicating that this was not a significant cause of differentiation between the scenarios. Comments made suggested that local effects from the different technologies should be addressed by a local assessment and the land use planning process would be the appropriate level at which to assess the impacts.

Conclusion

In light of the narrow range of scores assigned to the first set of scenarios at the workshop, each scenario of the second set was given a score of three.

G1.1.7 Social Implications/Equity

All but one of the eleven tables made comments to the effect that none of the scenarios would have an impact on social equity that was significantly different from the other. The remaining table made some comments about the effects of incineration, number of plants and plant location. All but one table rated all five scenarios the same.

Conclusion

At this level, the scenarios' impacts on social equity cannot be differentiated. All scenarios should be given a score of three.

G1.2 FEASIBILITY CRITERIA

G1.2.1 Technical Feasibility

The scores for each of the scenarios showed a wider range of variation for this criterion than for many of the others, indicating that it is an important consideration for differentiating the overall performance of the scenarios. Furthermore, the results were quite consistent, as can be seen in the radar plot, *Figure G1.3*.

The written comments from the representatives convey a good knowledge of waste management techniques, and a strong preference for proven technologies. *Scenarios 3, 4* and *7*, relying on MBT, AD and a combination of the two, respectively, scored very similarly.

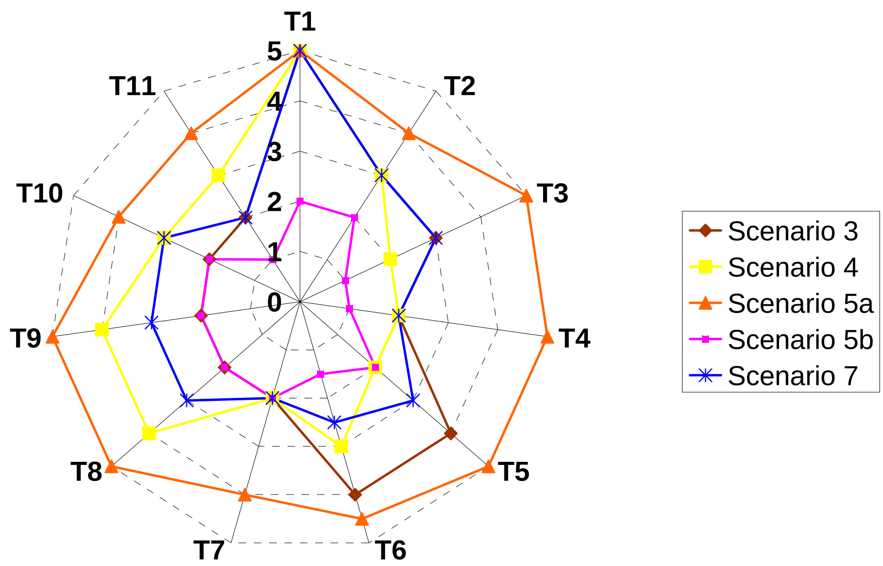
Conclusion

With gasification not included in any of the new scenarios, the assessment at the workshop leads to the conclusion that thermal treatment is rated (for technical feasibility) above any of the other technologies, which are ranked equally.

G1.2.2 Practical Feasibility

The written comments suggest that the tables took some different views on what was important under this criterion. Two tables thought all scenarios were the same, while others took into account, variously, what the public would accept, the technical feasibility of the scenarios, transport issues and the relative merits of MBT. However, discounting gasification, all scenarios were rated very similarly (2.8, 2.9, 3.0 and 3.0), suggesting that practical feasibility is not a good means of differentiating the scenarios.

Figure G1.3 Radar Plot (†) Representation of the Technical Feasibility Assessment



(†) Each of the 'spokes' on the radar plot gives the results from one table. The further the point is from the centre, the higher that scenario is rated by that table. It is clear from the plot that the pink series – for scenario 5b – and the orange series – for scenario 5a – are rated differently from the rest, with the former scoring poorly and the latter highly.

Conclusion

The hybrid scenarios are much more similar than the original scenarios, so it can be expected that they would score similarly. It was decided to score all of them at 3, apart from NS3, which, as a virtual single-technology solution, was given a score of 2.

G1.2.3 Flexibility

Like technical feasibility, flexibility also produced a clear preference, this time for scenario 7, with its mix of technologies, while the other scenarios scored very evenly (see *Figure G1.4*).

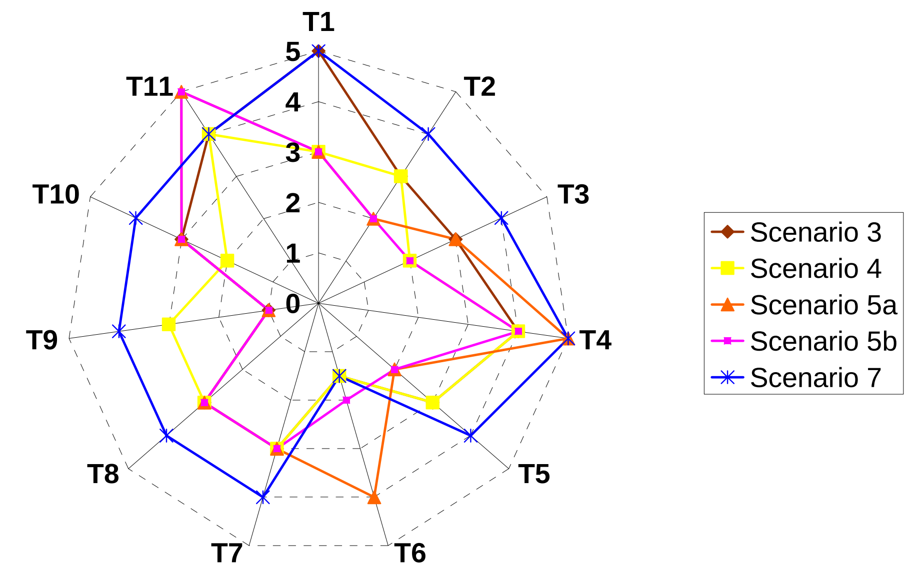
Conclusion

Given these findings, it seems appropriate to rate the hybrid scenarios for flexibility on the basis of the number of different technologies that are used, and to take into account the degree to which they rely on each other for feedstocks.

G1.2.4 Existing Facilities

Eight of the eleven tables ranked all five scenarios equally for existing facilities, arguing that all would require new facilities to be built on a much larger scale than to date (the others all gave a slight higher score to scenario 7). Furthermore, four of the eleven tables downgraded their scores across the board, such that the overall average score for this criterion was 2½.

Figure G1.4 Radar Plot Representation of the Flexibility Assessment



Conclusion

Overall, this was neither seen as a particularly important criterion, nor as a differentiating one, so the new scenarios were all given 2 points.

G1.2.5 Compliance with Policy

All the new scenarios were fully compliant with policy, so there was little to distinguish between them. It was decided to rate them the same as the original *Scenario 5b* or *7*, depending on which they most resembled.

The above assessments led to the scoring presented in *Table G1.1*.

Table G1.1 Assessment of New MSW Scenarios against Social and Feasibility Criteria

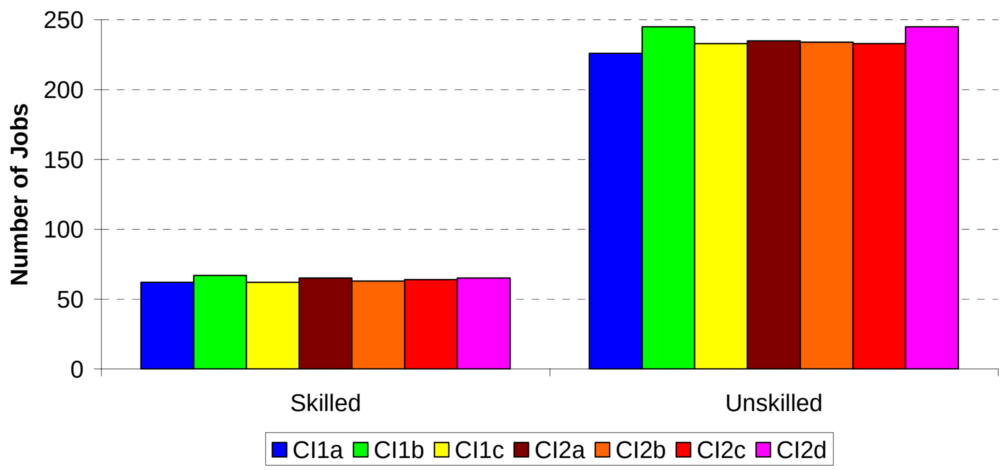
	Decision Criteria	NS1	NS2	NS3	NS4	NS5	NS6	NS7	NS8
Social Criteria	Employment	3.0	3.0	3.0	3.0	3.0	3.0	3.5	3.0
	Public Acceptability	1.7	2.5	1.0	3.5	3.5	2.6	2.3	1.5
	Perception of Health Effects	2.0	3.0	1.0	4.0	3.9	2.7	2.3	1.4
	Risk of Accidents	3.3	3.1	3.2	2.9	3.0	3.0	2.3	2.7
	Public / Producer Responsibility	2.6	3.3	2.5	3.5	3.0	2.8	2.8	2.6
	Local Amenity	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Social Implications / Equity	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Total	**18.7**	**20.9**	**16.7**	**22.9**	**22.3**	**20.1**	**19.1**	**17.1**
	Normalised	*0.31*	*0.67*	*0.00*	*1.00*	*0.90*	*0.55*	*0.38*	*0.06*
Feasibility Criteria	Technical Feasibility	4.6	4.6	4.6	2.9	2.9	4.6	4.6	4.6
	Practical Feasibility	3.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0
	Flexibility	3.0	3.0	2.0	4.0	4.0	4.0	3.0	3.0
	Existing Facilities	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Compliance with Policy	4.2	4.2	4.2	4.4	4.4	4.2	4.2	4.2
	Total	**16.8**	**16.8**	**14.8**	**16.2**	**16.2**	**17.8**	**16.8**	**16.8**
	Normalised	*0.67*	*0.67*	*0.00*	*0.47*	*0.47*	*1.00*	*0.67*	*0.67*

The same general conclusions that were drawn for the MSW BPEO were also applied to the C&I waste BPEO. The results are discussed below.

G2.1.1 *Social Criteria*

For employment, the conclusion was that, unless the employment figures present a drastically wider range of possible employment levels, scenarios should be scored equally for employment. The skilled and unskilled employment opportunities for the revised C&I waste scenarios are plotted in *Figure G2.1*. It is clear that none of the scenarios out-performs the rest, so all were rated at 3.

Figure G2.1 Levels of Employment Generated by Revised C&I Waste Scenarios



The scoring of the remaining social criteria is presented in *Table G2.1*.

Table G2.1 Assessment of New C&I Waste Scenarios against Social Criteria

Criterion	Summary of Assessment
Public Acceptability	Scenarios were initially given a score of 3.5, from which points were deducted as more waste would be sent to thermal treatment and, to a lesser extent, MBT with RDF production.
Health Effects	The perception of health effects was that thermal processes were less favourable than the others, and the scenarios were scored according to this rule, in the range of 1-4 points.
Risk of Accidents	The scenarios were scored following the developed estimation technique, but the range was contained within 2¼ to 3¼ out of five.
Public/Producer Responsibility	Scenarios with increased recycling and composting were promoted versus the average, and those with thermal technologies down-valued versus the average.
Local Amenity	Little differentiation in this criterion, so all scenarios were given a score of three.
Social Equity	At this level, the scenarios' impacts on social equity cannot be differentiated. All scenarios were given a score of three.

G2.1.2 Feasibility Criteria

The scoring of the feasibility criteria is presented in *Table G2.2*.

Table G2.2 Assessment of New C&I Waste Scenarios against Social Criteria

Criterion	Summary of Assessment
Technical Feasibility	Scenarios were rated according to the scores given for the two lead options at the BPEO workshop – 5a and 7 – depending on whether or not thermal treatment was included.
Practical Feasibility	Workshop scenarios were generally rated very similarly, suggesting that practical feasibility is not a good means of differentiating the scenarios. All were therefore scored 3.
Flexibility	All scenarios were rated at 3 except scenario CI2a, whose strong balance of different technologies made it the most flexible (4 points).
Existing Facilities	All scenarios will need significant new infrastructure, so this was seen neither as particular important nor differentiating. All scenarios were scored 2 points.
Compliance with Policy	All the new scenarios were fully compliant with policy, so there was little to distinguish between them. It was decided to rate them the same as the original Scenario 5b or 7, depending on which they most resembled.

The above assessments led to the scoring presented in *Table G2.3*.

Table G2.3 Assessment of New Scenarios against Social and Feasibility Criteria

	Decision Criteria	CI1a	CI1b	CI1c	CI2a	CI2b	CI2c	CI2d
Social Criteria	Employment	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Public Acceptability	3.0	2.8	3.5	2.0	2.8	1.0	1.8
	Perception of Health Effects	2.9	2.4	4.0	1.9	3.3	1.0	2.0
	Risk of Accidents	3.0	2.8	2.8	3.2	2.9	3.3	2.9
	Public / Producer Responsibility	3.2	3.2	3.5	2.8	3.2	2.5	2.9
	Local Amenity	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Social Implications / Equity	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Total	**21.1**	**20.2**	**22.8**	**18.9**	**21.2**	**16.8**	**18.5**
	Normalised	***73%***	***57%***	***100%***	***36%***	***74%***	***0%***	***30%***
Feasibility Criteria	Technical Feasibility	2.9	2.9	2.9	4.6	4.6	4.6	4.6
	Practical Feasibility	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	Flexibility	3.0	3.0	3.0	4.0	3.0	3.0	3.0
	Existing Facilities	2.0	2.0	2.0	2.0	2.0	2.0	2.0
	Compliance with Policy	4.4	4.4	4.4	4.2	4.2	4.2	4.2
	Total	**15.2**	**15.2**	**15.2**	**17.8**	**16.8**	**16.8**	**16.8**
	Normalised	***0%***	***0%***	***0%***	***100%***	***61%***	***61%***	***61%***

Annex H

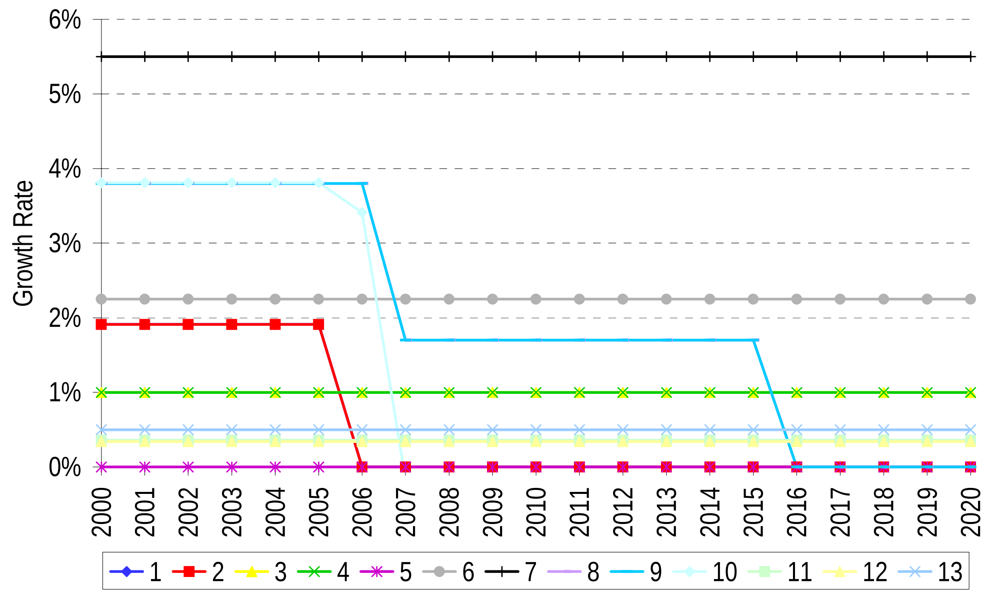
Commercial and Industrial Waste Arisings Growth

H1 COMMERCIAL AND INDUSTRIAL WASTE ARISINGS GROWTH

This annex describes the process used to determine plausible waste growth rates for commercial and industrial waste in Northern Ireland.

13 waste strategies were reviewed for local authorities and district councils in Northern Ireland, England and Wales. In general, there was no clear consensus on strategies for growth in C&I waste for the regions assessed. It was generally stated that it was difficult to predict trends in C&I waste arisings based on data available from existing UK surveys. *Figure H1.1* summaries the growth rates in C&I waste, plotting annual growth rate by year. The rates range from 5.5% growth per annum to 0% growth per annum.

Figure H1.1 Projected C&I Growth Rates

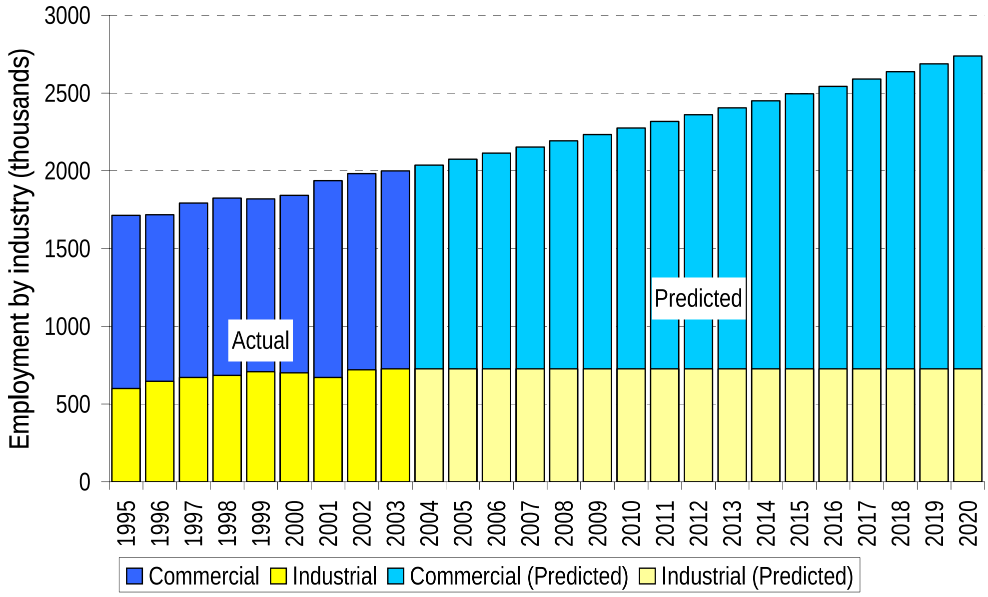


Numbers in the key cross-reference the left-hand column of *Table H1.1*.

In general, it was considered that growth in C&I waste arisings are linked to growth in GDP or regional growth in employment. However, it was recognised that a lack of accurate data makes these relationships difficult to establish. It was also anticipated that the quantities of C&I waste could decline due to current and emerging European and national policy and legislation, and due to more efficient production processes. Some projections therefore anticipated a growth in C&I waste to 2020, but at a declining rate.

Discussions with the Steering Group suggested that the growth rates in the separate categories of commercial and industrial wastes might be quite different, though few of the other studies adopt this approach. As a rough means of estimating the state of the two business sectors, employment statistics were examined, as shown in *Figure H1.2*. The trends seem to be that industrial employment is basically flat, while commercial employment is continuing to grow, at a rate of 1.87%.

Figure H1.2 Northern Ireland Employment by Business Category (Actual and Predicted)



Data Sources: Predicted: Extrapolation
Actual: *Northern Ireland Labour Force Survey*: Historical Supplement Spring 1984 to Winter 2003/04, NISRA and DETI, 30 June 2004

Based on the above, it was decided that the growth rate for industrial waste should be 0% for the whole period, reflecting little growth in this business sector and a heightened sense of waste management costs. For commercial waste, an initial growth rate was adopted in line with the employment growth rate, at 1.9%, halving in 2012, as continuing legislation reins in the rate of waste production.

Table H1.1 Growth Rate of Commercial & Industrial (C&I) Waste in Northern Ireland

Graph Legend	Authority/Company	Growth Rate	Comment	Reference
1	Southern Waste Management Partnership	1.91% pa growth to 2005	A projected growth rate of 1.91% has been used to assess future C&I waste generation. This is consistent with the rate identified in the Waste Management Strategy for Northern Ireland for household wastes, and, in the absence of other more reliable data, is considered appropriate, based on the assumption that the majority of C&I wastes landfilled in the sub region are municipal type wastes, as evidenced by the quantities collected and landfilled by the Councils.	Kirk McClure Morton, (2001). *SOUTHERN WASTE MANAGEMENT PARTNERSHIP- WASTE MANAGEMENT PLAN*. Internet document (accessed 12 July 2004, 10.16am) http://www.swampni.org.uk/downloads/5193.00%20SWaMP%20WMP%20-%20Complete.pdf
2	North West Region Waste Management Group	1.91% pa growth to 2005	Only those targets arising within the five-year period will be considered in the Plan. The estimated cumulative waste for landfilling was based on household waste increasing by 1.91% per year on the 1999/2000 figure of 152 431 tonnes per annum and C&I increasing by 1.91% per year on the 1999/2000 figure of 75 000 tonnes.	Kirk McClure Morton, (2003). *NORTH WEST REGION WASTE MANAGEMENT GROUP - Waste Management Plan*. Internet document (accessed 12 July 2004, 10.42am) http://www.northwestwasteplan.org.uk/downloads/5253.00%20NW%20WMP%20Complete.pdf
3	Eastern Region Waste Management Group	1.0% pa growth to 2020	Historically, quality of data on C&I waste across the UK has been poor. As a result it is difficult to estimate the trends in C&I waste arisings in the same way as it is for the MSW. For waste planning purposes it is practical and prudent to assume total waste generation will not reduce but the rate of growth will reduce. A range of growth rates were modelled between 0.5% and 1.6% per annum.	Enviros, (2003). arc21 Eastern Region Waste Management Group. Sub-region Waste Management Plan. Internet document (accessed 12 July 2004, 11.12am) http://cobweb.businesscollaborator.com/arc21/cwmpframe.htm

Graph Legend	Authority/Company	Growth Rate	Comment	Reference
4	Environment & Heritage Service	1.0% pa growth to 2020	Trends in C&I waste arisings are difficult to establish from existing data surveys. Between the 1999/2000 and 2001 surveys, no significant increase was detected, but it is acknowledged that the statistical reliability of the current data is uncertain. A working assumption of 1% was used for the arc21 Plan, and this is considered reasonable. Future surveys of C&I waste arisings, to be carried out on a regular basis, will be used to refine these projections.	EHS, (2003). *Biodegradable Waste Strategy for Northern Ireland: DRAFT. May 2003*. Department of the Environment: Environment & Heritage Service. Internet document (accessed 12 July 2004, 10.50am) http://www.ehsni.gov.uk/pubs/publications/draftBiodegradableWasteStrategy.pdf
5	East of England Regional Waste Management Strategy	0% to 2020	The increase in the amount of C&I waste during the 1990s was considerably less than that of MSW and appeared to have stabilised. For the purposes of the Strategy it has been assumed that the quantity of these waste arisings will remain at the level of 2000. These assumptions will need to be monitored to ensure that they form an appropriate basis for waste management and planning	East of England Region, (2003). *EAST OF ENGLAND REGIONAL WASTE MANAGEMENT STRATEGY 2002: EAST OF ENGLAND REGION WASTE TECHNICAL ADVISORY BODY*. Internet document (accessed 19 July 2004, 16.11) www.eelgc.gov.uk/eelgcDocs/RWMS16-3.pdf
6	Riverside Resource Recovery Facility	2.25% pa growth to 2020	Several scenarios are proposed for all categories of waste arisings in the catchment area. The 'most likely' option was selected. *Low diversion* – increase in 3% pa *Most likely* – increase in 2.25% pa *Ambitious* - increase in 2.25% pa *High Diversion* - increase in 2.25% pa	David Davies Associates, (2003). *PROOF OF EVIDENCE. Electricity Act 1989: Section 36. Riverside Resource Recovery Facility: VOLUME I Summary*. Internet document (accessed 19 July 2004, 17.07) www.rrrl.co.uk/news/poe02.doc
7	London Remade	5.5% pa growth to 2020	Growth in commercial and industrial waste arisings is likely to be closely linked to changes in Gross Domestic Product. Projections have therefore been made on this basis. Three scenarios are considered: • Waste grows in line with GDP @ 5.5% • Waste growth 2.5% less than GDP due to waste minimisation • Waste growth 3.5% less than GDP due to waste minimisation	Enviros, (2000). *LONDON REMADE DEVELOPING MARKETS FOR RECYCLABLE MATERIALS IN LONDON: DRAFT PRIORITISATION STUDY*. Enviros RIS, London. Internet document (accessed 21 July 2004, 16.21) www.londonremade.com/download_files/mpstudy.pdf

Graph Legend	Authority/Company	Growth Rate	Comment	Reference
8	North Wales Region	Industrial: 3.8% pa growth to 2006 1.7% pa growth to 2015 0% pa growth to 2021 Commercial: 3.8% pa growth to 2006 1.7% pa growth to 2015 0% pa growth to 2021	There remains uncertainty over forecasting C&I waste growth for future years. Forecasting of commercial and industrial waste growth has been considered separately. Commercial waste is assumed to follow the same growth as MSW. Commercial *High Growth* - 3.8% pa growth to 2021 *Medium Growth* - 3.8% pa growth to 2006 1.7% pa growth to 2015 0% pa growth to 2021 *Low Growth* - 1% pa growth to 2021 *Waste Strategy Scenario* – 1.9% decline to 2021 Industrial: *High Growth* - 2.0% pa growth to 2021 *Declining Growth* - 3.8% pa growth to 2006 1.7% pa growth to 2015 0% pa growth to 2021 *Towards Zero Waste* - 0.9% pa growth	SLR Consulting Ltd, (2003). *Developing a regional waste plan for the North Wales region: Strategic assessment report*. Internet document (accessed 21 July 2004, 15.40) http://www.walesregionalwasteplans.gov.uk/pdfs/stageone_pdfs/northfullreportstageone.pdf
9	Regional Waste Management Strategy for the East Midlands	As above line for North Wales Region.	Predicted growth of C&I waste is often linked to GDP. However, a lack of accurate data makes this relationship difficult to prove conclusively. Other comments as above line for North Wales Region.	SLR Consulting Ltd, (2003). *DEVELOPMENT OF A REGIONAL WASTE STRATEGY FOR THE EAST MIDLANDS FINAL TECHNICAL REPORT*. Internet document (accessed 19 July 2004, 16.28) www.emra.gov.uk/publications/documents/waste_tech_reportJan03.pdf
10	Worcestershire and Herefordshire	3.81% pa growth to 2005 3.41% pa growth to 2006 and has continuous decline of 0.2% pa to 2020 (ie 3.21% in 2007, 3.01% in 2008, etc)	The modelling of C&I growth has been based on the average economic growth, from the National Statistics Online. The growth rate for Worcestershire was 5.09% and 2.54% for Herefordshire. The average of 3.81% was used for C&I projections. Waste growth will be continuous until 2004/05, after which the rate is presumed gradually to decrease due to legislative pressure. Growth is assumed to decrease by 0.4% for 2005/06, after which there is a continuous annual 0.2% decrease.	*Managing waste for a brighter future. A joint municipal waste strategy for Hereford and Worcester 2004 to 2034: Draft consultation*. Internet document (accessed 21 July 2004, 17.16) www.worcestershire.gov.uk/home/cs-env-fulldoc.pdf

Graph Legend	Authority/Company	Growth Rate	Comment	Reference
11	South West Regional Assembly	Commercial 1.9% pa growth to 2020 Industrial 0.9% pa decline to 2020 (Equivalent to 0.36% growth pa for total C&I)	There is inherent uncertainty about the robustness of future waste projections, particularly as far ahead as the year 2020. For the purposes of this assessment, however, they were considered sufficient to enable a range of options to be assessed. Based on data presented, commercial waste represents 45% (and industrial 55%) of the total C&I waste stream. This equates to an equivalent growth of 0.36% for the total stream.	SLR Consulting Ltd, (2003). *DEVELOPING A REGIONAL WASTE MANAGEMENT STRATEGY FOR THE SOUTH WEST REGIONAL ASSEMBLY REVISED EXECUTIVE SUMMARY* (as at 9th June 2003). Internet document (accessed 12 July 2004, 12.08pm) http://www.southwest-ra.gov.uk/swra/downloads/ourwork/waste/downloads/BEPO/ExecSummary.pdf
12	West of England and the Regional Waste Strategy	0.34% pa growth to 2020 (equivalent)	C&I represents the largest proportion of waste arising in the West of England. Comprehensive data on C&I waste production is limited, so it is difficult to predict changes over time. The area manages more C&I waste than arises within the area, principally due to specialised treatment and reprocessing facilities in Bristol. The Regional Waste Strategy predicts a very small increase (about 7%) in total waste arising over the period to 2020. This is equivalent to 0.34% pa growth to 2020	JSPTU, (2004). *AGENDA ITEM 13: JOINT COMMITTEE FOR STRATEGIC PLANNING AND TRANSPORTATION 8 JULY 2004. WASTE PLANNING: A SUB-REGIONAL RESPONSE TO THE REGIONAL WASTE STRATEGY AND WASTE PLANNING GUIDANCE FOR THE WEST OF ENGLAND*. Internet document (accessed 12 July 2004, 14.08pm) http://www.jsptu-avon.gov.uk/committee/jul04reports/regwastestrat.pdf
13	The Joint Committee (Bath and North East Somerset, Bristol City, North Somerset and South Gloucestershire)	0.5% pa growth to 2011 (equivalent)	Preliminary forecasts of employment growth have been used in an attempt to predict future change in waste arisings. The majority of employment growth for B&NES Bath & North East Somerset is likely to be within the commercial sector. Overall employment growth may be in the order of 15%, it is considered that the major waste generating employment sectors may account for some 10% of growth to 2011. This is equivalent to approximately 0.5% pa growth to 2011.	Entec UK, (2003). Joint Strategic Planning and Transportation Unit Sub Regional Study of Waste: Final Report. Internet document (accessed 12 July 2004, 14.55pm) http://www.jsptu-avon.gov.uk/publications/documents/wastemainreport.pdf

Annex I

CD&E Waste Arisings Growth Rate

I1 CD&E WASTE ARISINGS GROWTH RATE

In the light of the difficulty in estimating the possible growth rate for construction, demolition and excavation (CD&E) wastes in Northern Ireland, it was decided to take advice from waste strategies already completed in the UK. In total, 13 waste strategies were reviewed, for local authorities and district councils in Northern Ireland, England and Wales. In general, it was stated that no reliable data was available for projected growth rates in CD&E waste. *Table I1.1* summaries the growth rates in CD&E waste that were used in the strategies. *Table I1.2* provides the details for each strategy.

Table I1.1 Projected C&D Growth Rates in the UK

Projected C&I Growth Rate	Number of Waste Strategies Supporting this Growth Rate
0% pa	Eleven strategies
2% pa to 2006 1% pa to 2015 0% pa to 2021	One strategy
5% pa	One strategy

In general, it was anticipated that the quantities of CD&E waste produced would increase as the economy grows. However, it was also expressed that other influencing factors, such as landfill tax, the Landfill Directive and aggregates tax would counteract the trend of increasing CD&E waste growth, driven by continuing economic development.

It could be argued that these data support the adoption of a 0% growth rate in CD&E waste in Northern Ireland to 2020. However, given that the recent NI Investment Strategy has estimated a capital expenditure programme of £16 billion over the period 2005 to 2015, mainly on infrastructure projects such as roads, water treatment, schools, hospitals and housing, it would be unrealistic to assume a zero growth rate in CD&E waste arisings.

For this study, the growth rate has been set at 1%, on the basis that significant improvements in waste prevention and on-site reuse will go some way to minimising the waste growth resulting from this massive infrastructure programme.

Table I1.2 Growth Rates of Construction, Demolition and Excavation (CD&E) Waste in Sampled Waste Strategies

Authority / Company	Growth Rate	Comment	Reference
Southern Waste Management Partnership	0% pa	No reliable data for projected growth. Assumed that C&D waste generation in the sector will remain constant and that government initiatives such as the Aggregates Tax will counteract the trend of increasing waste growth driven by continuing economic development.	Kirk McClure Morton, (2001). *SOUTHERN WASTE MANAGEMENT PARTNERSHIP- WASTE MANAGEMENT PLAN*. Internet document (accessed 12 July 2004, 10.16am) http://www.swampni.org.uk/downloads/5193.00%20SWaMP%20WMP%20-%20Complete.pdf
North West Region Waste Management Group	0% pa	No reliable data for projected growth. Assumed that C&D waste generation in the sector will remain constant and that government initiatives such as the Aggregates Tax will counteract the trend of increasing waste growth driven by continuing economic development.	Kirk McClure Morton, (2003). *NORTH WEST REGION WASTE MANAGEMENT GROUP - Waste Management Plan*. Internet document (accessed 12 July 2004, 10.42am) http://www.northwestwasteplan.org.uk/downloads/5253.00%20NW%20WMP%20Complete.pdf
Eastern Region Waste Management Group	0% pa	It is unlikely that the quantity of construction and demolition waste requiring disposal to landfill will increase in the future as greater emphasis is being placed on the reuse and recycling of this waste stream. Monitoring of this waste stream is essential to enable more accurate predictions for forward planning during the Plan period.	Enviros, (2003). arc21 Eastern Region Waste Management Group. Sub-region Waste Management Plan. Internet document (accessed 12 July 2004, 11.12am) http://cobweb.businesscollaborator.com/arc21/cwmpframe.htm
Environment & Heritage Service	0% pa	The quantities of C&D wastes produced are related primarily to the economy, and the associated activity within the construction industry. Whilst it may be anticipated that the quantities of wastes produced would increase as the economy grows, there will be other influencing factors, such as Landfill Tax, and the Landfill Directive, with the categorisation of sites as inert, non-hazardous or hazardous. These factors may balance each other out. In the absence of established trends therefore, it is assumed that C&D waste production will be constant.	EHS, (2003). *Biodegradable Waste Strategy for Northern Ireland: DRAFT. May 2003*. Department of the Environment: Environment & Heritage Service. Internet document (accessed 12 July 2004, 10.50am) http://www.ehsni.gov.uk/pubs/publications/draftBiodegradableWasteStrategy.pdf

Authority / Company	Growth Rate	Comment	Reference
North Wales Regional Waste Plan Forum	0% pa	-	North Wales Regional Waste Plan Forum, (2002). Strategic Assessment Report: 4B/533/001. November 2002. Internet document (accessed 12 July 2004, 12.08pm) http://www.walesregionalwasteplans.gov.uk/pdfs/stageone_pdfs/northexecutivesummarystageone.pdf
South West Regional Assembly	0% pa	-	SLR Consulting Ltd, (2003). *DEVELOPING A REGIONAL WASTE MANAGEMENT STRATEGY FOR THE SOUTH WEST REGIONAL ASSEMBLY REVISED EXECUTIVE SUMMARY* (as at 9th June 2003). Internet document (accessed 12 July 2004, 12.08pm) http://www.southwest-ra.gov.uk/swra/downloads/ourwork/waste/downloads/BEPO/ExecSummary.pdf
East Midlands Regional Technical Advisory Body	2% pa to 2006 1% pa to 2015 0% pa to 2021	It would appear that the target set in Mineral Planning Guidance No. 6 will probably be met without significant change in current C&D management practices; however, the Landfill Directive and Aggregates Levy are likely to see a continuation of diversion away from landfilling of a waste.	SLR Consulting Ltd, (2003). *DEVELOPMENT OF A REGIONAL WASTE STRATEGY FOR THE EAST MIDLANDS FINAL TECHNICAL REPORT*. Internet document (accessed 12 July 2004, 12.08pm) www.emra.gov.uk/publications/documents/waste_tech_reportJan03.pdf
West of England and the Regional Waste Strategy	0% pa	It is predicted that the amount of inert and construction & demolition waste will remain fairly constant over the period to 2020, and that the proportions managed by recycling and landfill will remain unchanged. This prediction is based on material passing through licensed waste management sites and does not include material that is utilised in construction projects without passing through licensed facilities. There are no government targets that would significantly change the waste stream composition and disposal route.	JSPTU, (2004). *AGENDA ITEM 13: JOINT COMMITTEE FOR STRATEGIC PLANNING AND TRANSPORTATION 8 JULY 2004. WASTE PLANNING: A SUB-REGIONAL RESPONSE TO THE REGIONAL WASTE STRATEGY AND WASTE PLANNING GUIDANCE FOR THE WEST OF ENGLAND*. Internet document (accessed 12 July 2004, 14.08pm) http://www.jsptu-avon.gov.uk/committee/jul04reports/regwastestrat.pdf
Bath & North East Somerset Local Plan	5% pa to 2011	Anticipated that 75 tonnes of C&D waste will be generated per new housebuild in the region (approx 400 houses to be built). There are additional construction plans for traffic management, highway improvements/maintenance, water drainage and commercial redevelopment.	B&NES, (2003). *Bath & North East Somerset Local Plan Revised Deposit 2003*. Internet document (accessed 12 July 2004, 14.14pm) http://www.bathnes.gov.uk/localplans/banes2003/b8.htm

Authority / Company	Growth Rate	Comment	Reference
North Wales Regional Waste Plan	0% pa to 2021	Three scenarios were proposed: • 'High Growth' scenario of 1% pa, assuming a significant and continuing upturn in construction activity. • 'No Growth' scenario represented by zero growth, assuming that construction activity remains constant at current levels. • A 'Towards Zero' scenario of minus 2% pa assuming that construction activity will continue to decline and that levels of waste are suppressed by changes in the nature of that activity.	Wales Regional Waste Plan, (2002). North Wales Regional Waste Plan Forum: Strategic Assessment Report November 2002. Internet document (accessed 12 July 2004, 14.14pm) http://www.walesregionalwasteplans.gov.uk/pdfs/stageone_pdfs/northmaintextstageone.pdf
South West Wales Regional Waste Plan	0% pa to 2021	Three scenarios were proposed as for North Wales Regional Waste Plan (see above).	Wales Regional Waste Plan, (2004). South West Wales Regional Waste Plan Forum: Strategic Assessment Report. Internet document (accessed 12 July 2004, 14.30pm) www.walesregionalwasteplans.gov.uk/pdfs/sw_pdf/swexecutivesummarystageone.pdf
Cornwall Waste Local Plan	0% pa to 2011	-	Cornwall CC, (2003). *Appendix 9: Technical Paper on current and predicted trends in Waste Arisings and Disposals in Cornwall*. Internet document (accessed 12 July 2004, 14.45pm) http://www.cornwall.gov.uk/Environment/waste/apend09.htm
The Joint Committee (Bath and North East Somerset, Bristol City, North Somerset and South Gloucestershire)	0%	For C&D wastes, a neutral growth in arisings has been assumed. It is considered that the amount of waste being recycled and reused will continue at its current high level and that landfill tax will ensure that the amount disposed of to landfill will continue to be low. This assumption may need to be revised as further work clarifies the true level of C&D arisings.	Entec UK, (2003). Joint Strategic Planning and Transportation Unit Sub Regional Study of Waste: Final Report. Internet document (accessed 12 July 2004, 14.55pm) http://www.jsptu-avon.gov.uk/publications/documents/wastemainreport.pdf

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ERM's Oxford Office

Eaton House
Walbrook Court
North Hinksey Lane
Oxford OX2 0QS
UK
T: +44 1865 384 800
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