Quantification of the Potential Energy from Residuals (EfR) in the UK

Commissioned by
The Institution of Civil Engineers
The Renewable Power Association

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Summary

This study was commissioned by the Renewable Power Association (RPA) and the Institution of Civil Engineers (ICE). Energy from waste has an important role to play in improving energy security in the UK and, by virtue of its biomass content, it can make a valuable contribution towards our renewable energy targets.

The three primary study objectives were:

- To determine the potential electrical yield from the UK's residual[1] waste up to 2020.
- To determine the potential[2] contribution that energy recovery from residual waste could make to the UK's target under the European Union's Renewables Directive.
- To determine the potential additional contribution to the Renewables Obligation that can be made if eligibility for Renewable Obligation Certificates (ROCs) were extended to encompass all energy recovery techniques[3].

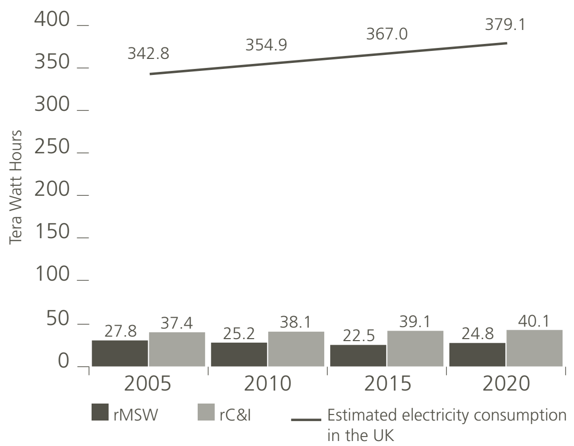
The methodology used within the study involved a detailed analysis of Municipal Solid Waste (MSW) and (due to the incompleteness of base data), a less detailed analysis of Commercial and Industrial (C&I) waste, to establish the projected[4] total waste arisings.

Objective 1:
To determine the potential electrical yield from the UK's residual waste up to 2020.

Figure 1 shows the potential electrical yield from residual MSW (rMSW) and residual C&I waste (rC&I) if it was all sent through the process with the highest yield rate. The analysis shows that:

- potential energy recovery from these residual wastes could account for as much as 17% of total (UK) electricity consumption in 2020.

Figure 1. Potential maximum electrical yield from UK rMSW and rC&I waste 2005 to 2020.



However, the optimum energy recovery process[5] applied is Mechanical and Biological Treatment (MBT) producing Solid Recovered Fuel (SRF) for use as fuel in power stations with a conversion efficiency of 40%. A lack of such end markets for SRF is currently holding back investment in this technology and hence in the short term, energy recovery from residual waste will inevitably fall well short of the potential maximum yields shown in Figure 1.

[1] Residual waste within the context of the study refers to waste remaining after the recycling and composting fraction has been removed, i.e. Total Waste Arisings – Recycling & Composting Fraction= Residual Waste.
[2] "Potential" refers to the absolute maximum electrical yield that can be generated by applying the optimum conversion efficiencies to each waste technology.
[3] At present, mixed wastes can only qualify for the Renewables Obligation if converted to electricity using "advanced technologies" as outlined under Objective 3, over page.
[4] Projected total waste arisings and recycling/composting rates are calculated within the study using targets set by the UK Government and the devolved administrations.
[5] Optimum energy recovery process is not the same as the "environmentally most advantageous" determined by a Life Cycle Analysis, taking account of the environmental cost, e.g. transfer of SRF by road from MBT plant to power station. Similarly, Optimum energy recovery process is not the same as the "economically most advantageous" which would be determined by market testing the different technologies.

Objective 2:

To determine the potential contribution that energy recovery from residual waste could make to the UK's target under the European Union's Renewables Directive.

The EU Renewables Directive[i] sets the UK a 2010 target of sourcing 10% of gross electricity consumption through renewable energy sources. Table 1 shows the potential contribution, i.e. the theoretical absolute maximum, that energy recovery from residual Biodegradable Municipal Waste (rBMW) and residual Biodegradable C&I wastes (rBC&I) can make towards the UK targets if all waste were sent to MBT producing SRF pellets. The analysis shows that:

- potential energy recovery from residual biodegradable waste (rBMW and rBC&I) could exceed the UK 2010 target under the EU Renewables Directive.

Table 1.
The potential contribution to the UK's EU Renewables Directive 2010 target of energy recovery from residual biodegradable waste.

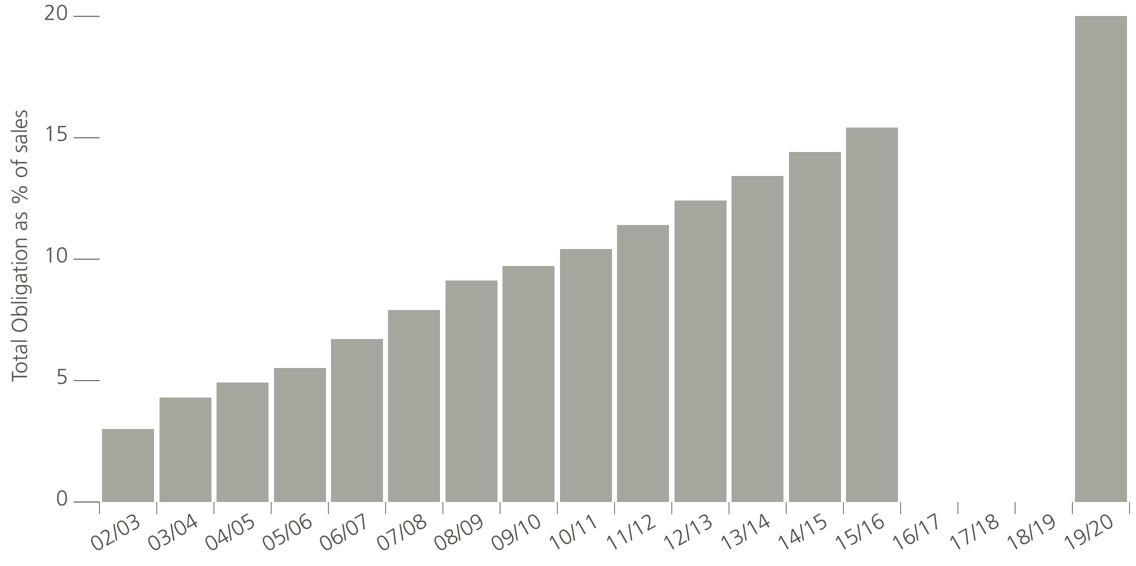
UK Obligation @ 10% of 2010 consumption TWh	**35.5**
Potential electricity generated from biodegradable waste TWh	40.5
Potential electricity generated through rBMW only TWh	15.7
Potential electricity generated through rBC&I only TWh	24.8

Objective 3:

To determine the potential additional contribution to the Renewables Obligation that can be made if eligibility were extended to encompass all energy recovery techniques.

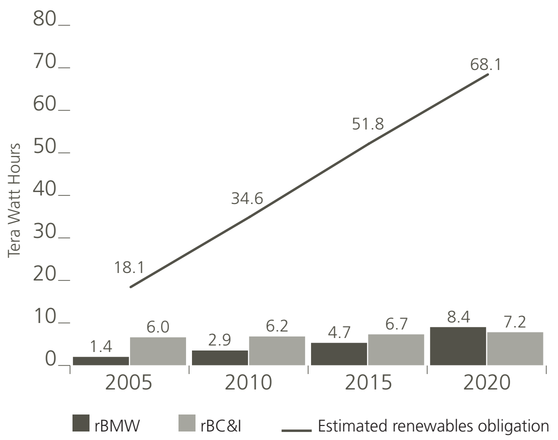
The Renewables Obligation (RO) has been introduced to transpose the requirements of the EU Renewables Directive. This policy requires electricity suppliers to source an increasing percentage of their sales from renewables, Figure 2.

Figure 2. Renewable Obligations 2002 to 2020[ii].



Note: The target of 20% renewables in 2020 is an aspirational goal stated in the Government's Energy White Paper.

Figure 3. Electrical yield from UK rBMW and rBC&I waste using technologies ineligible under the renewables obligation 2005 to 2020.



Based on SU technology market forecasts.

Although counting towards the UK's European renewables targets, electricity generated from mixed waste only counts toward the RO if it is converted through landfill gas or using advanced technologies, i.e. anaerobic digestion, gasification or pyrolysis.

Using MSW technology forecasts published by the Government's Strategy Unit (SU), and using the conversion yield of conventional incineration for C&I waste, Figure 3 shows the potential electrical yield from the biomass fraction of residual waste and the contribution it could make to the RO:

- In 2010 electricity generation from ineligible waste technologies could contribute 26% towards the RO.
- The RO grows more rapidly than the potential increase in electricity generation from residual waste, resulting in the potential contribution dropping to 23% by 2020.

The increase in the contribution of rBMW from 2005 to 2020 results primarily from the diversion of BMW from landfill as a result of the EU Landfill Directive and the Landfill Allowance Trading Scheme (LATS). Targets for the diversion of rBC&I waste from landfill are much less onerous.

The Strategy Unit[III] forecast that novel – eligible – technologies would only account for 4% of total MSW in 2020. This represents an electrical yield of 0.7TWh or a contribution of 1% towards the RO.

Two questions arise from the analysis:

Question 1:

Figure 3 shows the potential electricity generation from techniques which are currently not eligible under the RO to be significant; what is the likelihood of a change to the Renewables Obligation eligibility criteria?

The DTI has committed to examining the role of energy from waste in renewables policy. In the final terms of reference for the 2005-6 Review of the RO, the DTI states that it will review:
"The case for amending Renewable Obligation Certificate (ROC) eligibility rules regarding electricity generated from mixed wastes in ways which are consistent with the goals of supporting technological developments in waste management which offer environmental benefits and which meet the Government's requirements of increasing recycling and reducing the volume of waste sent to landfill" [IV].

To ensure that recycling/composting is not displaced by electricity generation, eligibility criteria can be coupled to local authority Statutory Performance Standards (SPS), i.e. Plant operators processing a local authority's waste only receive ROCs if the authority can demonstrate meeting recycling/composting targets. However, Defra is currently investigating whether these recycling and composting targets should be abolished as their relevance is being challenged by the way in which LATS targets are to be enforced.

Question 2:

Figure 1 shows that as much as 17% of (UK) electricity generation can be satisfied through energy from waste in 2020; what are the main barriers preventing this from happening?

Figure 1 shows that circa 62% of the potential electrical yield derives from rC&I waste. Unlike MSW there are far fewer economic and legislative incentives in place to encourage the diversion of C&I waste from landfill and hence a significant proportion of the potential is likely to be lost to landfill. This is particularly the case with non biodegradable rC&I. For example, in 2020 the maximum potential electrical yield from non biodegradable rC&I waste is circa 14 TWh (4% of UK electricity consumption) but most is likely to be sent to landfill.

- Drivers are being introduced elsewhere in Europe that will help overcome these barriers. The RVF rapport 2004[v] reported that in Sweden, a ban was imposed on landfilling combustible material.
- If the right economic climate and regulatory drivers are created in the UK to divert economically useful (waste) **resources** from landfill, this energy is recoverable for the UK's benefit.

Conclusion:

In seeking to prepare an objective and reasoned study we have made several key assumptions. These have been made transparent in the text but invariably the conclusions are valid only in the context of these assumptions.

The study measures the potential Energy from Residuals (EfR) in the UK. What it shows is that, if the UK chooses to diversify its energy resources, then residual waste could contribute over 15% of the UK's energy demand; 64% being generated from biomass. When taking into consideration the projected technology mix, EfR could still make a contribution of 20% towards the UK's renewable targets and quotas.

Policy tools such as Landfill Tax will encourage the diversion of rC&I waste from landfill. But if the rate of diversion is in line with the Government's diversion target, outlined in Waste Strategy 2000, a significant proportion of the potential EfR is set to be lost to landfill. Closing the landfill option to C&I waste, as is happening elsewhere in Europe and within the UK for BMW would improve the chance of realising this potential.

Glossary of Abbreviations and Definitions

Abbreviations

BC&I	Biodegradable Commercial and Industrial
BMW	Biodegradable Municipal Waste
C&I	Commercial and Industrial
CV	Calorific Value
GJ	Giga Joules
GTV	Gross Thermal Value
EfR	Energy from Residuals
LATS	Landfill Allowance Trading Scheme
MBT	Mechanical and Biological Treatment
MSW	Municipal Solid Waste
MWh	Mega Watt hour
rBC&I	Residual Biodegradable Commercial and Industrial
rBMW	Residual Biodegradable Municipal Waste
RDF	Refuse Derived Fuel
rC&I	Residual Commercial and Industrial
rMSW	Residual Municipal Solid Waste
RO	Renewables Obligation
ROC	Renewables Obligation Certificate
SRF	Solid Recovered Fuel
TWh	Terra Watt hour
TJ	Terra Joules

Definitions

Biodegradable – components that are capable of being degraded in the short to medium term (unlike plastics) and would generate methane in favourable landfill conditions.

The term **residual** is used within this study to refer to the waste fraction remaining if the published Government targets for reuse, recycling and composting are achieved.

Calorific Value – the quantity of energy that can be released by complete combustion of a material typically measured in units of MJ/kg.

Gross Thermal Value – The thermal energy released by complete combustion of a stated mass of material (of stated CV), measured in units of MJ.

Renewables Obligation – The obligation placed on licensed electricity suppliers to deliver a specified amount of their electricity from eligible renewable sources.

Renewables Obligation Certificate (ROC) – Eligible renewable generators receive Renewable Obligation Certificates (ROCs) for each MWh of electricity generated. These certificates can then be sold to suppliers. Suppliers use ROCs as proof of Renewables Obligation compliance.

1. Introduction

The key points in this section are:

- **The UK's EU Renewables Directive target is to source 10% of UK electricity consumption from renewables by 2010.**
- **The UK's Renewable Obligation annual quotas increase to 15.4% of UK electricity sales in 2015.**
- **This study focuses on Municipal Solid Waste (MSW) and Commercial & Industrial (C&I) waste which represents 27% of UK waste arisings.**
- **Not all residual waste is eligible under the EU Renewables Directive eligibility criteria. Only the *Biomass* fraction in mixed waste is eligible.**

1.1 Background

European Directives are currently having a significant impact on both the UK electricity and waste management markets. The European Renewables Directive[VI] requires the UK to source 10% of its electricity from renewable sources by 2010. The UK has transposed the requirements of the Directive into UK law through the Renewables Obligations Orders (RO)[VII, VIII]. The RO have made it a statutory requirement for all licensed suppliers of electricity to source a growing percentage of their total sales from eligible renewable sources, (Figure 2). The European Landfill Directive has imposed limits on the amount of biodegradable waste that can be sent to landfill. Since, in principle, biodegradable waste qualifies under the European Renewables Directive as a renewable resource, the use of biodegradable waste as a feedstock in the generation of renewable electricity contributes towards the objectives of both directives.

A level of dissimilarity exists in the eligibility criteria for the Renewables Directive and RO. The Renewables Directive reports:
Renewable energy sources shall mean renewable non fossil energy sources (wind, solar, geothermal, wave, tidal, hydropower, biomass[6], landfill gas, sewage treatment plant gas and biogases).

The Directive continues:
Where they use waste as an energy source, Member States must comply with current Community legislation on waste management. The application of this Directive is without prejudice to the definitions set out in Annex 2a and 2b of Council Directive 75/442/EEC of 15 July 1975 on waste. Support for renewable energy sources should be consistent with other Community objectives in particular respect for the waste treatment hierarchy. Therefore the incineration of non-separated municipal waste should not be promoted under a future support system for renewable energy sources, if such promotion were to undermine the hierarchy.

Table 2 shows the position of energy from waste technologies in terms of eligibility under the UK Renewables Obligation (RO). The background to the exclusion of energy from waste is described in the National Audit Office report[IX]:
(The Department of Trade and Industry) decided that, in addition to large-scale hydroelectricity power, another low cost technology, energy from incinerating mixed waste should be excluded from the obligation but its output should continue to count towards the 2010 (EU) target.

Table 2.
The eligibility of energy from waste technologies[X]

Technology	Feedstock	
	Mixed Waste	biomass
Incineration	Ineligible	Eligible*
Pyrolysis, Gasification and Anaerobic Digestion	Only non-fossil derived energy is eligible	Eligible*
Co-Firing biomass with fossil fuel	Ineligible	Eligible until 31 March 2016[7]

Notes: * Subject to a maximum fossil-derived energy content of 2% to allow for accidental contamination.

[6] The EU Renewables Directive defines biomass as: Biomass shall mean the biodegradable fraction of products, wastes and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.
[7] 25% energy crops from 1 April 2009; 50% energy crops from 1 April 2010; 75% energy crops from 2011.

The reasoning was that including it within the RO might inhibit efforts to encourage greater recycling and that some projects were, in any case, commercially viable.

Table 2 shows that energy from mixed wastes can contribute towards the RO targets if it is converted using "advanced technologies", i.e. anaerobic digestion, gasification and pyrolysis.

The purpose of this study is not to question the merits of the eligibility criteria, but to quantify the potential contribution energy recovery (electricity generation) using mixed biodegradable residual waste can make towards both the UK renewable obligations and the EU Renewables Directive.

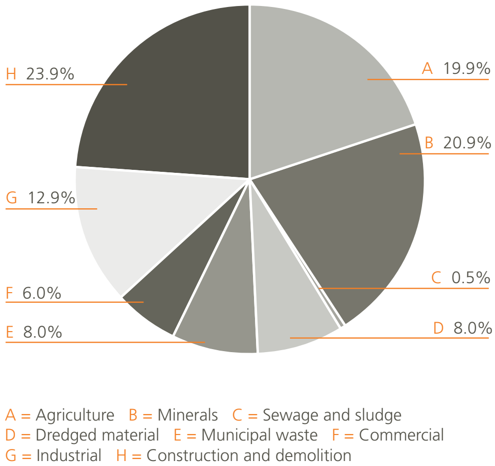
Focus within the study is placed predominantly on Municipal Solid Waste (MSW) since the UK Government has targeted this waste in meeting the EU Landfill Directive. Although recycling and composting rates are set to increase a significant quantity of waste currently landfilled is likely to remain as residual waste and hence an alternative disposal route will be sought. Waste management techniques such as conventional incineration, Mechanical and Biological Treatment (MBT), gasification, pyrolysis and anaerobic digestion can all include energy recovery and hence projecting the likely waste options used will enable the potential renewable electricity generated using residual biodegradable MSW to be determined.

Our study has not ignored biodegradable waste within other waste streams, such as Commercial & Industrial waste. Figure 4 shows the estimated total annual waste arisings by sector in the UK. It is estimated that 434 million tonnes of waste is generated in the UK[XI]. The three main sectors in which mixed biodegradable residual waste is generated are:

- Industrial.
- Commercial.
- Municipal waste.

Collectively these three sectors account for 27% of UK waste. An analysis of Commercial and Industrial (C & I) waste is undertaken within this study to determine the full potential contribution mixed biodegradable residual waste can make towards the renewables obligations.

Figure 4. UK waste arisings in 2002/03.[XII]



1.2 Study Objectives

The three primary study objectives were:

- To determine the potential electrical yield from the UK's residual waste up to 2020.
- To determine the potential contribution that energy recovery from residual waste could make to the UK's target under the European Union's Renewables Directive.
- To determine the potential additional contribution to the Renewables Obligation that can be made if eligibility were extended to encompass all energy recovery techniques.

The DTI will be reviewing the eligibility of energy from waste for the RO during 2005, and therefore there is some brief discussion as to how changes in eligibility may alter this potential contribution.

1.3 Study Methodology

The term ***residual*** is used within this study to refer to the waste fraction remaining if the published targets for reuse, recycling and composting are achieved.

The study only considers solid waste arisings – thus sewage sludge, whilst a waste, is not within the scope of this report as it is generated from aqueous waste arisings.

Although base data is contained in appendices a significant proportion of the analysis of data is contained within the main body of the report. This is due to the critical nature of the analysis in deriving the electrical yields.

To navigate past the detailed analysis the Study Findings and Conclusion (Section 4.) shows the collated results and includes references to the respective sub-sections, Tables and Figures in Section 2. (MSW analysis) and Section 3. (C&I waste analysis).

2. Municipal Solid Waste

The key section findings are:

- **UK Municipal Solid Waste (MSW) arisings will increase from 38.2Mt in 2005 to 51.1Mt in 2020.**
- **UK MSW recycling/composting will increase from 9.3Mt in 2005 to 23.2Mt in 2020 and of the remaining "residual" waste 18.8Mt is estimated to be biomass in 2005 and 17.2Mt in 2020.**
- **The Gross Thermal Value (GTV) of residual MSW (rMSW) is estimated at 304,000TJ in 2005 reducing to 270,000TJ in 2020.**
- **The theoretical absolute maximum electrical yield from rMSW is estimated at 27.8 Terawatt hours (TWh) in 2005 reducing to 24.5TWh in 2020.**
- **The theoretical maximum electrical yield from residual Biodegradable Municipal Waste (rBMW) using energy from waste technologies is estimated at 1.4TWh in 2005 increasing to 9.1TWh in 2020.**

Much of the debate surrounding MSW waste options is polarised, and is characterised as either originating from the "zero waste" or the "incinerate all" camp. The aim of this analysis is to provide an objective evaluation.

Our approach in this section is summarised by the following:

- Calculate total waste arisings in the UK.
- Analyse composition of MSW, determine recycled components now and in the future and, by balance, the expected arisings of rMSW (biodegradable and non-biodegradable).
- Examine the calorific value of the waste streams on the basis of their projected composition, and hence estimate potential for electricity generation from rMSW and biodegradable fractions (rBMW).

2.1 UK Municipal Solid Waste Arisings Targets

The following sub-sections provide a detailed analysis of the expected generation of UK MSW arisings and recycling/composting rates by country taking account of stated waste handling strategies. The information is aggregated in sub-section 2.1.5 to provide an overview of the current and likely future positions with respect to total UK MSW.

2.1.1 England

The Defra Strategy Unit 2002 report "Waste Not, Want Not" reported the Government's aim of reducing the annual growth in municipal waste arisings from 3% to 2% by 2005/06. WRAP (Waste & Resources Action Programme) considers this target core to its 2004 to 2006 business plan as part of its waste minimisation drive. This currently forms the only target in England for reducing the level of municipal waste arisings.

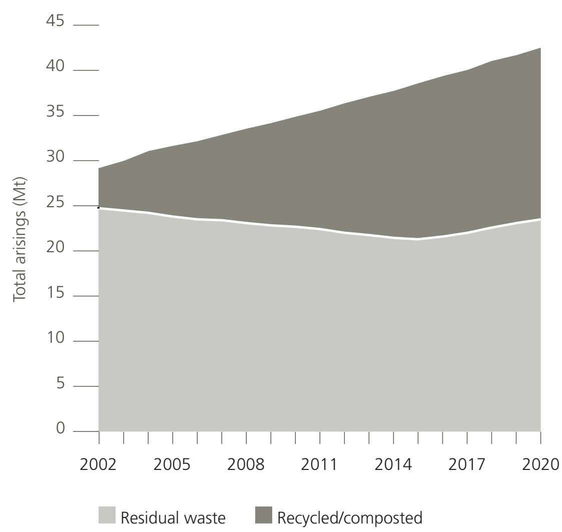
Under the Landfill Directive (1999/31/EC) the UK as a whole is obliged to increase recycling with the following targets:

- To recycle or compost at least 25% of household waste by 2005.
- To recycle or compost at least 30% of household waste by 2010.
- To recycle or compost at least 33% of household waste by 2015.

In addition, the Strategy Unit report details tighter non-statutory recycling targets:

- To recycle or compost at least 35% of household waste by 2010.
- To recycle or compost at least 45% of household waste by 2015.

Figure 5. Municipal waste arisings and recycling in England.



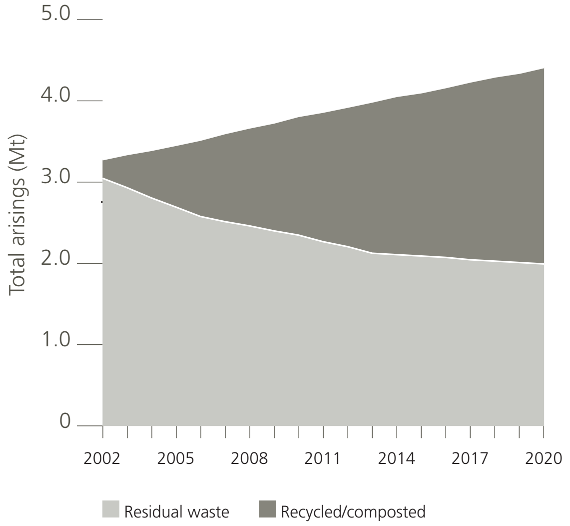
Our projection of the waste arisings in England from 2002 to 2020 is shown in Figure 5. This assumes:

- The Strategy Unit recycling and composting targets in 2010 and 2015 are achieved.
- That the 45% 2015 target will persist between 2015 and 2020.

2.1.2 Scotland

The Scottish Executive National Waste Plan 2003 projects an annual growth in waste of 1.9% between 2002 and 2010 and then 1.5% between 2010 and 2020. Recycling and composting targets follow those set out in the Landfill Directive with the addition of a 55% recycling and composting target in 2020, shown in Figure 6.

Figure 6. Municipal waste arisings and recycling in Scotland.



2.1.3 Wales

The Welsh Assembly's National Waste Strategy "Wise About Waste" sets specific targets for the stabilisation and reduction of household waste:

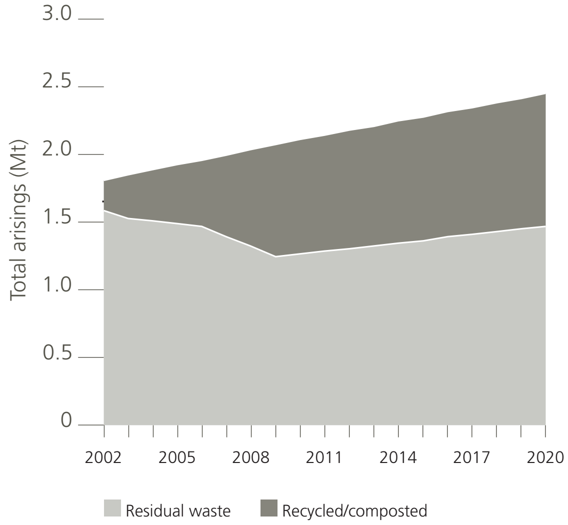
- By 2009/10 (and to apply beyond) waste arisings per household should not exceed 1997/98 levels.
- By 2020 waste arisings per person should be less than 300Kg per annum.

Unfortunately the source of the base data from which these targets were set is not referenced within the strategy. We have therefore been forced to make the following not-unreasonable assumptions regarding the two target years of 2009/10 and 2020:

- The annual growth rate used in Scotland (1.9%) can apply to Wales between 2002 and 2010.
- The annual growth rate used in Scotland (1.5%) can apply to Wales between 2010 and 2020.

The recycling and composting targets follow those outlined in the Landfill Directive with the addition of a 40% recycling and composting target in 2009 and beyond, Figure 7.

Figure 7. Municipal waste arisings and recycling in Wales.



2.1.4 Northern Ireland

The Northern Ireland Department of the Environment and Heritage Services Biodegradable Waste Strategy fixed estimates for future waste arisings are shown in Table 3.

Table 3.
Estimates of future waste arisings in Northern Ireland

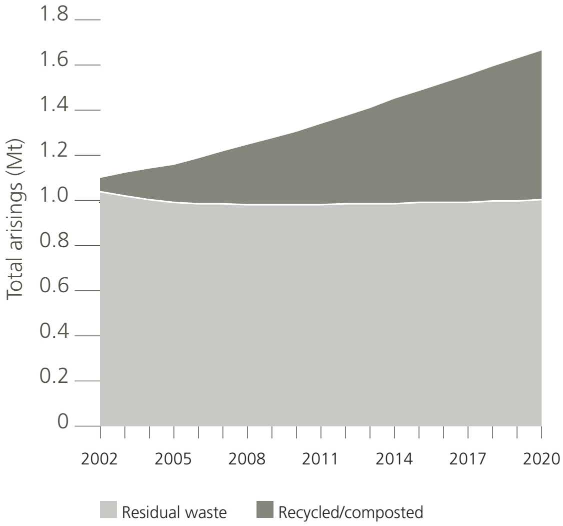
Year	Waste Arisings (Mt)
2005	1.15
2009	1.29
2013	1.398
2020	1.649

In the Northern Ireland waste strategy recycling and composting targets have been set as follows:

- 15% recycling and composting by 2005.
- 25% recycling and composting by 2010.

Figure 8 shows the projected waste arisings in Northern Ireland between 2002 and 2020. It has been assumed that recycling and composting will account for 40% of waste in 2020.

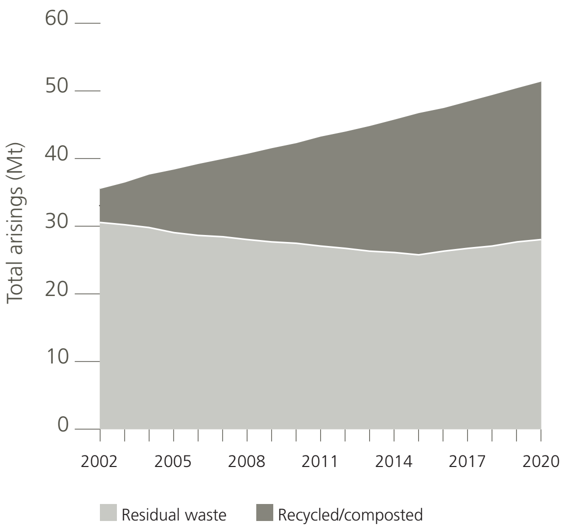
Figure 8. Municipal waste arisings and recycling in Northern Ireland.



2.1.5 Summary: United Kingdom aggregate arisings

Figure 9 shows the total projected municipal waste arisings in the UK based on the analysis undertaken within the four individual countries. The base data used to create the previous figures can be found in Appendix 1. The analysis shows that the level of residual waste remains nearly constant throughout the period with the growth in waste arisings being taken up by the expansion in recycling and composting.

Figure 9. Municipal waste arisings and recycling in UK.



2.2 Composition of UK municipal solid waste

In this section we review the composition of MSW across the UK now and in the future. The impact of varying composition is two-fold:

- It impacts on the recyclable fraction and hence the residual MSW.
- Consequently, the MSW composition will alter the GTV, and hence the Electrical Yield obtained, for a given conversion efficiency

2.2.1 Composition of total UK MSW

Table 4 shows the composition of MSW in the four UK countries. The net fraction of biodegradable waste depends on the surveyed waste composition in each region. Putrescible waste is much higher in England/Wales and Northern Ireland, but this probably reflects an increase in the quantity of garden waste being collected as a means of meeting recycling and composting targets.

A major uncertainty is how the composition will change between 2002 and 2020. Over the past 20 years the growth in the ready meals market, wine drinking at home, etc have no doubt resulted in significant changes in household waste composition. However, no reference of future compositional changes could be found in any waste strategy documents within the four UK countries. Without such data it was considered appropriate to use existing compositional data and make no provision for possible changes in composition since such provision would be speculative. We have therefore assumed a constant composition over the period.

Table 5 shows the composition and volumes (kt) of MSW generated within the UK. This data was calculated using the composition (Table 4) and annual total waste arisings data for the individual countries (Appendix 1).

Given this basis for the arisings, it is now necessary to determine how much of each of the components will be recycled, reused or composted, and thus removed from the waste stream to be treated.

Table 4.
Composition of Waste (%).

Waste type	England and Wales[XIII]	Scotland[XIV]	Northern Ireland[XV]
Paper/card	19	26	17
Putrescible	42	16	44
Textiles	3	4	1
Fines	3	7	9
Misc. combustible	8	17	8
Misc. non-combustible	4	2	3
Metals	7	7	4
Glass	7	9	7
Plastics	7	12	8
% Biodegradable	**68**	**60**	**70**

2.2.2 Composition of the recycled fraction

Our approach to estimating the composition of the recycled fraction through the period 2002 to 2020 is as follows:

- Determine the composition of the current recycling fraction in 2002.
- Estimate a probable composition of the recycled fraction in 2020. We will assume that the Government's target recycling/composting rate of 45% is achieved.
- Interpolate between the two for intervening years.

Current Waste Composition

The composition of the recycled fraction of MSW within the UK in 2002/03 was unavailable and we were forced to rely on the analysed composition of the recycled fraction in England alone. In practice, this represents 87% of the MSW recycled in the UK in 2002/03, is likely to remain a dominant component and hence is considered representative of the total stream.

The Municipal Waste Survey 2002/03 lists the composition of the household waste recycled in England in 2002/03 and reports that 4.577 million tonnes of MSW were recycled/composted in England, 15.6% of MSW. Assuming the non-household waste element recycled was of the same composition as that of the household element – which when combined makes up MSW – the composition of the MSW recycled is as shown in Table 6.

Table 6.
Composition of MSW recycled in England in 2002/03

Waste type	Total Recycled (tonnes)	% of total MSW
Paper/card	1,560,814	5.3%
Putrescible	1,646,832	5.6%
Textiles	74,919	0.26%
Fines	0	0
Misc. combustible	0	0
Misc. non-combustible	0	0
Metals	622,938	2.1%
Glass	653,461	2.2%
Plastics	18,036	0.06%
Total	**4,577,000**	**15.6%**

Table 5.
Tonnage Breakdown of UK MSW (kt) 2002 to 2020.

Waste type	2002	2005	2010	2015	2020
Paper/card	6,929	7,465	8,240	9,071	9,976
Putrescible	14,058	15,172	16,753	18,479	20,369
Textiles	1,077	1,161	1,282	1,410	1,551
Fines	1,254	1,348	1,489	1,639	1,802
Misc. combustible	3,124	3,362	3,711	4,081	4,482
Misc. non-combustible	1,342	1,449	1,599	1,763	1,943
Metals	2,442	2,634	2,907	3,201	3,522
Glass	2,539	2,735	3,020	3,325	3,657
Plastics	2,655	2,859	3,156	3,473	3,818
Total	**35,420**	**38,185**	**42,156**	**46,442**	**51,119**

Future Waste Composition

Two projections of the composition of the recycled fraction at a 40% recycling/composting rate have been undertaken. We have used these as an intermediate step to estimating the waste composition at the Government's 45% recycling target. One projection is by CTech, as part of a Biffaward study, and the other is outlined in the National Waste Strategy for Wales (Wise About Waste).

To examine the merits of the two projections, the composition of the MSW used within each of the two studies was compared to the current composition of the UK MSW calculated in Section 2.2.1. Table 7 shows that, in terms of the compositional change in MSW composition, the Welsh data is a less radical departure. We deduce that the projection of recycled fraction composition is therefore a safer extrapolation from the current recycling position.

Note that in Table 7, we are not predicting recyclate composition, merely ensuring that the prediction bases are similar. We have then used the Welsh data of recyclate composition superimposed on the overall UK MSW arisings in the next step.

Table 8 shows the proportion of each material that will be recycled/composted in 2002 (using the base data from England) and in 2013, when it is projected that the recycling rate in the UK will reach 40% (using the base data from Wales).

Table 8.
Proportion of waste types to be recycled/composted.

Waste type	2002 @ 15.6% Overall recycling	2013 @ 40% Overall recycling
Paper/card	27.2%	46.6%
Putrescible	14.1%	54.7%
Textiles	1.4%	58.0%
Fines	0.0%	0.0%
Misc. combustible	0.0%	14.5%
Misc. non-combustible	0.0%	11.4%
Metals	30.8%	38.3%
Glass	31.1%	58.0%
Plastics	0.8%	38.6%

Appendix 2 shows in greater detail the projected proportion of each waste type that will be recycled or composted in the UK between 2002 and 2020. Table 9 shows the quantities of each waste type that will be recycled or composted in selected years between 2002 and 2020.

Table 7.
A Comparison of the Base MSW Composition Data.

	Current 15.6% r/c	Future 40% r/c	
Waste type	UK MSW	Biffaward	Wales – Waste Strategy
Paper/card	19.6	27.4	25.6
Putrescible	39.7	21.7	29.0
Textiles	3.0	1.9	2.2
Fines	3.5	6.8	3.7
Misc. combustible	8.8	10.3	12.1
Misc. non-combustible	3.8	4.6	5.1
Metals	6.9	7.8	8.4
Glass	7.2	9.7	6.2
Plastics	7.5	9.8	7.2

2.2.3 Composition of residual MSW

rMSW is simply calculated as:

{Total MSW} – {recycled or composted MSW}

In terms of the component waste types, this is derived by subtracting the recycled or composted data (Table 9) from the total MSW (Table 5). The result of this is shown in Table 10.

2.3 Thermal and Electrical Value of MSW

2.3.1 Gross thermal value of UK residual MSW

The calorific value (CV) was calculated using the detailed compositional analysis undertaken by Julian Parfitt for the Strategy Unit[XVII] and the calorific values of each element shown in CTech's Biffaward study[XVIII]. Table 11 summarises the calorific value and biodegradability of each of the waste streams. The values for the biodegradability of each waste stream were also taken from Julian Parfitt's study.

Table 9.

Quantities of each waste type to be recycled or composted in the UK (kt).

Waste type	2002	2005	2010	2015	2020
Paper/card	1,759	2,519	3,251	4,299	4,800
Putrescible	1,856	4,033	7,177	10,273	11,496
Textiles	14	211	558	831	927
Fines	0	0	0	0	0
Misc. combustible	0	144	394	601	670
Misc. non-combustible	0	48	133	204	228
Metals	70	893	989	1,246	1,391
Glass	736	1,092	1,464	1,958	2,187
Plastics	20	345	899	1,364	1,522
Total	**5,088**	**9,289**	**14,855**	**20,775**	**23,219**

Table 10.

Quantities of rMSW in the UK (kt).

Waste type	2002	2005	2010	2015	2020
Paper/card	5,170	4,946	4,989	4,772	5,177
Putrescible	12,202	11,138	9,577	8,205	8,873
Textiles	1,063	950	733	580	624
Fines	1,254	1,348	1,489	1,639	1,802
Misc. combustible	3,124	3,218	3,317	3,480	3,811
Misc. non-combustible	1,342	1,400	1,466	1,560	1,715
Metals	1,740	1,740	1,917	1,955	2,131
Glass	1,802	1,643	1,555	1,366	1,471
Plastics	2,635	2,512	2,260	2,109	2,296
Total	**30,332**	**28,896**	**27,300**	**25,666**	**27,899**

Table 11.
Calorific value and biodegradability of each MSW waste stream.

Waste type	Calorific Value (MJ/kg)	% Biodegradable
Paper/card	17.23	100
Putrescible	6.55	100
Textiles	16.12	50
Fines	7.39	50
Misc. combustible	9.25	50
Misc. non-combustible	0	0
Metals	0	0
Glass	0	0
Plastics	34.51	0

Appendix 3 shows the GTV (in GJ) for each of the waste types and for each waste stream (total residual waste, the biodegradable fraction of residual waste and the recycled or composted fraction). Figure 10 summarises the data in Appendix 3 and shows that the GTV within the recycled fraction increases considerably over the 18 years, whilst the other two waste streams show a steady reduction between 2002 and 2015, before a slight increase in 2020 (resulting from the recycling rate remaining at 45% between 2015 and 2020, but with waste arisings still increasing).

It is important to note that the calorific values of waste presented in the previous figure are true weighted composites. That is, they take into account the varying composition and component waste flows in calculating calorific value. A second simplification is that, for materials for which there is a fractional recovery, there is no discrimination in the ultimate fate of a waste material. That is for textiles (50% biodegradable material) the streams sent to landfill, incineration…., all have a 50% biodegradable content.

2.3.2 Potential Electrical Yield from UK residual MSW

To determine the potential amount of electricity that could be generated from residual MSW feedstock the energy efficiencies of the various conversion processes are required. Conversion efficiencies are technology-dependent, and must be applied to the GTVs of their particular feedstocks to obtain net Electrical Yield. (In addition, some pre-treatment technologies – such as MBT – will absorb some Electrical Yield in the sorting and conditioning of the feedstock, and this should be factored in.)

Firstly, we examine historic values of yield quoted in previous studies:

- The CTech Biffaward Study reports that the energy efficiency of a mass burn (conventional) incinerator is 25.4% equating to an electricity yield of 650 kWh/T.
- Defra reports the electricity yields of various waste management techniques, Table 12[xix]. At 581 kWh/T, the Defra analysis shows some discrepancy with the CTech value for incineration.

In review we have found the CTech figure of 25.4% to be a fair representation of the current efficiency of a high-performing mass burn incinerator. We believe it is justified to use this figure in subsequent analysis on the expectation that, with advances in technology, this performance will come to represent a mid-range, or typical, plant efficiency.

There is clearly some discrepancy between the reported CVs of MSW. Calculating the CV of our predicted MSW stream, based on Parfitt's basic material CVs, and 25.4% thermal conversion, the calculated electricity yield in this analysis is 714 kWh/T. We rationalise the difference within the three studies as a result of the following factors:

- The **composition** of the waste being analysed. The Defra figure refers to **total MSW** whereas the two other figures refer to **residual MSW**, with differing compositions.
- The **energy efficiency** taken as representative of each waste technology.

For the purposes of this study, we will use our calculated value of 714 kWh/T for Electricial Yield based on conventional technology. A sensitivity check reveals that the CV for the residual MSW does not differ significantly from the biodegradable-only component of the MSW, nor significantly over time with changing composition. A fixed value of 714 kWh/T for the net Electrical Equivalent of residual MSW will therefore be used.

The Government projects a scenario in which a multitude of energy-yielding waste treatment options are used. Historic reports from Defra have quoted Electrical Equivalents for such technologies (including the 581 kWh/T figure referred to above). These are presented for comparison in Table 12. We will assume that these numbers are correct relative to each other with respect to Electrical Equivalent of MSW for the composition used by Defra. The numbers will be scaled, using conventional incineration technology as a basis, relative to our new figure of 714 kWh/T. These factors are also shown in the table.

The Defra study did not disclose the Electrical Yield from Mechanical and Biological Treatment (MBT). Its omission was however explained thus:

"Both MBT and the manufacturing of refuse derived fuels (RDF) are processes for promoting higher thermal efficiency in energy recovery by raising the calorific value of the fuel input. As such, these processes are not energy conversion technologies per se but rather pre-treatment methods. For this reason they have been excluded from the analysis."

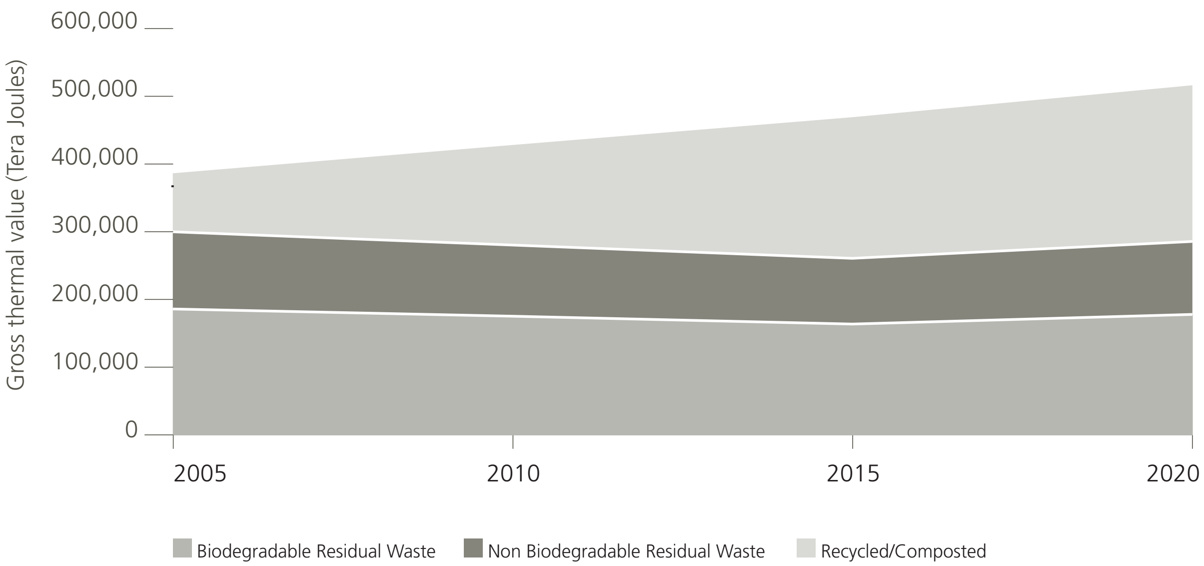
It is, however, important for this study to include MBT within the analysis. Using data reported primarily within the Herhof data sheet on MBT it is possible to determine the relative performance of MBT. The data used was:

Table 12.
Electricity yields from MSW management options.

Waste management Option	Electrical Equivalent (Defra)	Relative Performance	Electrical Equivalent (New)
Anaerobic digestion	331 kWh/T	0.57	407 kWh/T
Pyrolysis/gasification	642 kWh/T	1.10	789 kWh/T
Incineration	581 kWh/T	1.00	714 kWh/T
Landfill (where electricity generated)	203 kWh/T	0.35	249 kWh/T
MBT-derived SRF		1.30	928 kWh/T

Note: See explanation below for MBT figure derivation

Figure 10. Gross Thermal Value of MSW 2005 to 2020.

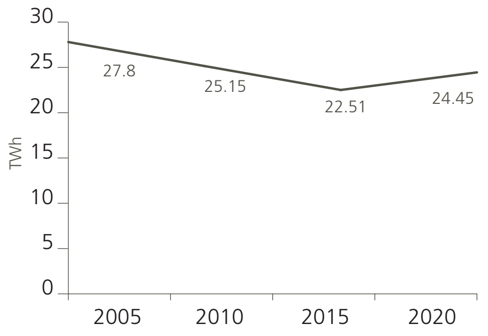


- Herhof report that solid recovered fuel (SRF) accounts for 50% of the process output. However, in Austria and Belgium the rate of Refuse Derived Fuel (RDF) production from MSW varies from 23% to 50% by weight of waste processed[xx]. In terms of the biodegradable fraction 30% by mass is removed at the drying stage. Within this analysis, to take into consideration the losses during the drying process and other losses it is assumed that 50% by mass of the biodegradable fraction processed is converted to SRF.
- The calorific value of SRF is 15 to 18 MJ/kg. Fichtner[xxi] report a range of 11 to 17 MJ/kg for RDF from MBT (non technology specific). Since the objective of the analysis is to determine the "potential" yield, a figure of 16.5 MJ/kg is used.

Although markets for SRF are currently limited, analysis of its potential was undertaken based on the above data and using 40%[xxii] as the electricity yield of the fossil fuel electricity generating plant in which the pellets may be burnt as fuel. It is estimated that the electricity yield from MBT is 1.3 times that of incineration: Appendix 4 shows how this figure was derived. This does not take into consideration the energy required to generate SRF within the MBT process but represents the total (external) potential from SRF pellets.

Independent enquiries within the waste management sector suggest that the processing cost (energy) of the mechanical pre-treatment stages is around 30 kWh/T of input material when considering integrated treatment and incineration plant. We have not taken this offset into account, since we are here considering stand-alone generation potential. Nor are we accounting for the other resources required to remove non-burnable wastes and water nor additional transport fuels compared to conventional EfW techniques.

Figure 11. Maximum Electrical Yield that can be generated from rMSW.



Subject to these constraints, the analysis shows that MBT has the highest electricity yield of the waste management options assessed. Hence the maximum potential generation of electricity from waste would require all the waste to be sent to MBT. Figure 11 shows the maximum Electrical Yield from all rMSW if processed through MBT, i.e. the biodegradable and non biodegradable fractions. This information will be used in Section 4 to determine the potential electrical yield from the UK's residual waste up to 2020, i.e. Objective 1.

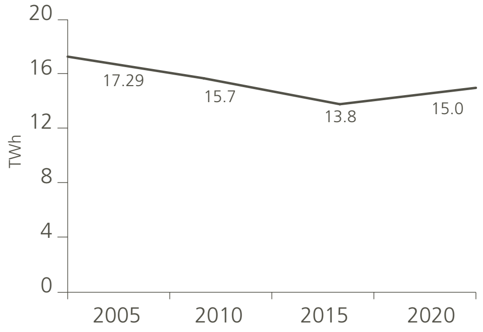


Figure 12. Maximum Electrical Yield that can be generated from rBMW.

Figure 12 shows the maximum total Electrical Yield 2005 to 2020 from the biodegradable fraction of rMSW. This information can be used to determine the theoretical absolute maximum contribution that can be made to both the EU Renewables Directive and the Renewables Obligations from rBMW, i.e. Objectives 2 and 3 of this study.

This analysis is purely hypothetical since it would be a major shift for all rMSW to be sent to MBT. In the next section a moderated and realistic assessment of the potential contribution to the renewables targets will be made based on the projected quantities of waste sent to each waste management option.

2.3.3 Projected Electrical Yield from rBMW

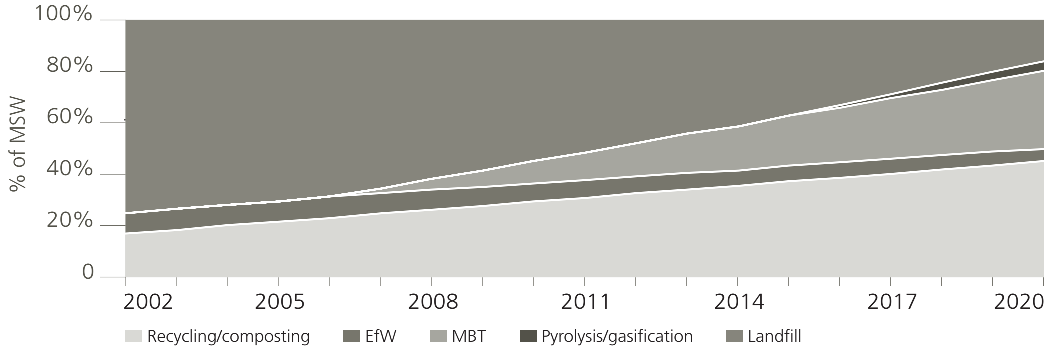
In 2002 the Strategy Unit undertook a study in which it attempted to forecast management options for MSW in 2020. The base case for the modelling assumed:[xxiii]

- New technologies such as gasification and pyrolysis will come on stream in 2016 and account for 4% of total MSW in 2020.
- Mechanical and Biological Treatment will come on stream in 2008 and account for 30% of total MSW by 2020.
- The maximum incinerator capacity would be reached in 2006 at 4 million tonnes when all build capacity in the system, at that time, was realised and no new incinerators would be built thereafter.
- Recycling and composting will account for 45% of MSW in 2020.
- Landfill will account for 16% of MSW in 2020.

The analysis shows that MBT was considered the most prominent means of managing the residual waste diverted from landfill accounting for 30% of MSW in 2020. In Figure 13 we summarise graphically the outputs of this modelling exercise.

We can combine the mix of disposal options analysis shown in Figure 13 with the Electrical Equivalents of the disposal routes from Table 12 to calculate the Electrical Yield generated from rBMW. This assumes that the proportion of waste going to each waste management option follows that of the total residual waste. That is, in 2020: 30% to MBT, 16% to landfill, 5% to EfW and 4% to new technologies. Table 13 indicates the potential Electrical Yield generated in selected years from 2005 to 2020 for the energy from waste technologies using:

Figure 13. Results of Strategy Unit waste management option modelling.



- MBT with all SRF used as fuel in power stations with a conversion efficiency of 40%.
- Conventional Incineration with a conversion efficiency of 25.4%.

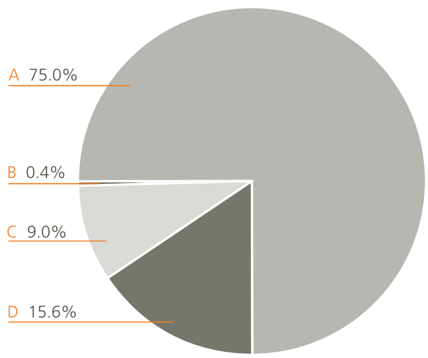
The need to fulfil the requirements of the Landfill Directive means the waste industry is in transition and hence it is possible that MSW and the way it is managed has changed since the Strategy Unit forecasts were made. As a means of verification, assumptions made within the strategy unit study were analysed. Two key assumptions made are:
- Landfill will account for only 16% of total MSW in 2020.
- Of the 35% of total MSW accounted for by MBT and EfW, MBT will account for 30% and EfW only 5%.

The implications and sensitivities of these two assumptions are explored further in the sections below.

2.3.4 Exploring Assumption 1: Landfill will account for only 16% of total MSW in 2020.

Figure 14 shows the waste management options used for MSW in England in 2002/03. At 75% landfill is clearly the most prominent waste disposal route. However, the future use of landfill as an option for managing rBMW is constrained by the EU Landfill Directive's targets. The Directive has been transposed into UK law through the Waste and Emissions Trading Act, which provides the framework for the Landfill Allowance Trading Scheme (LATS), setting increasingly tighter restrictions on the level of biodegradable MSW that can be landfilled.

Figure 14. Total MSW in England in 2002/03.[xxiv]



A = Landfill B = Other C = Incinerated with energy recovery
D = Recycled/composted

Table 14 shows the impact LATS is likely to have on the quantity of residual biodegradable MSW sent to landfill. The analysis shows that by 2020 a maximum of 40% of biodegradable residual MSW can be sent to landfill. Appendix 1 shows that 51.12Mt of MSW is estimated for 2020 and hence the 6.39Mt to be landfilled in 2020 represents 12.5% of total MSW. The value of 16% (total MSW to be landfilled in 2020) used within the Strategy Unit study is therefore in the same ballpark.

Table 13.
Potential electrical yield from rBMW feedstock using energy from waste technologies (Terawatt Hours) based on Strategy Unit model.

	2005	2010	2015	2020
Total Electrical Yield from MBT @ 928 kWh/T	0	1.912	4.150	7.904
Total Electrical Yield from EfW @ 714 kWh/T	1.395	1.230	1.014	1.014
Total Electrical Yield from new technologies @ 598 kWh/T *	0	0	0	0.689
Total Electrical Yield of biodegradable residual MSW	1.395	3.142	5.164	9.607

*The electricity yield figure is calculated using the assumption that half the new technology capacity will be anaerobic digestion and half gasification/pyrolysis.

Table 14.
The potential impact of the UK LATS allowance (Kt).

	2005	2010	2015	2020
Total rBMW	19,137	17,335	15,826	17,168
UK LATS Allowance	18,705	13,700	8,216	6,390
By difference… **rBMW to be managed through an alternative means to landfill**	**433**	**3,635**	**7,610**	**10,778**

2.3.5 Exploring Assumption 2: Of the 35% of total MSW accounted for by MBT and EfW in 2020, MBT will account for 30% and EfW only 5%.

This assumption was made on the basis that no further EfW capacity will come on stream after the capacity in the pipeline in 2002 was realised. It was forecast that the proportion of MSW sent to EfW would peak in 2006 at 4 million tonnes. However, since 2002 difficulties have been experienced in developing end market capacity for SRF. The Environmental Services Association (ESA) project that incineration capacity will reach 4.6Mt in 2006, Table 15.

Table 15.
Incineration capacity 2001 to 2006 (Mt)[xxvi].

Year	Incineration Capacity Mt
2001	2.79
2002	3.01
2003	3.01
2004	3.23
2005	3.99
2006	4.62

Fichtner[xxvii] base the modelling within their study on RDF opportunities on the assumption that there will be 6Mt capacity of EfW in 2010 increasing to 8Mt in 2020. This would result in EfW accounting for 15.6% of total MSW in 2020 as opposed to 5% in the Strategy Unit model (Figure 13).

One difficulty in forecasting the likely capacity of EfW to come on stream is that it is reliant on the decisions made by each individual Waste Disposal Authority (WDA). In turn, this is dependent on their individual circumstances. Some indication of trends can be inferred when waste contracts are renewed. Listed below are the WDAs in England where it is known that waste contracts are due for renewal in the next three years (2005 to 2007):

- Greater Manchester
- Norfolk
- Southwark (LBC) – London Borough
- Wakefield
- Cambridgeshire
- Dorset
- Derbyshire
- Essex
- West Yorkshire
- Kirklees
- Bradford
- Bedfordshire
- Central Berkshire
- West Berkshire
- Cornwall
- Nottinghamshire
- Shropshire
- Gloucestershire
- North Yorkshire
- Cheshire
- Merseyside

A watch on the contracts selected by these organisations through tendering processes over the coming years will be instructive.

Table 16 lists the WDAs in England generating the most MSW. These 26 WDAs account for 52% of MSW arisings and 52% of the BMW that needs to be diverted from landfill in England in 2020. Analysing how these 26 WDAs intend diverting the waste from landfill will be a clear indication of the contributions EfW and MBT will make.

Table 17 shows that if EfW were to account for 15% of MSW in 2015 to 2020 with MBT making a smaller contribution, then the electricity yield will only drop marginally, see Table 13 for comparison. This information will be used.

Table 16.
The WDAs in England with the highest MSW arisings.

Waste Disposal Authority	Residual MSW in 2001	BMW Landfilled in 2001	LATS Allowance 2020	BMW landfilled in 2001 minus LATS in 2020[8]
Greater Manchester WDA	1,341,159	847,951	259,075	588,876
North London Waste Authority	863,217	308,863	168,064	140,799
West London Waste Authority	768,771	526,732	154,231	372,501
Merseyside WDA	732,266	510,051	145,523	364,528
Kent County Council	595,441	428,967	135,884	293,083
Essex County Council	558,003	387,635	131,971	255,664
East London Waste Authority	517,577	309,885	99,150	210,735
Birmingham City Council MBC	510,252	134,144	97,908	36,236
Lancashire County Council	521,670	385,367	121,079	264,288
Hampshire County Council	524,459	373,467	126,484	246,983
Western Riverside Waste Authority	473,996	325,922	93,018	232,904
Hertfordshire County Council	479,958	296,974	101,905	195,069
Surrey County Council	471,240	315,614	104,422	211,192
Nottinghamshire County Council	396,653	227,711	85,017	142,694
West Sussex County Council	391,318	265,267	83,784	181,483
Staffordshire County Council	381,541	191,606	86,301	105,305
Cheshire County Council	367,247	241,988	78,750	163,238
Norfolk County Council	361,366	245,369	77,422	167,947
Leeds City Council MBC	343,444	247,443	70,779	176,664
Derbyshire County Council	344,307	241,981	72,381	169,600
North Yorkshire County Council	320,820	227,801	67,296	160,505
Northamptonshire County Council	322,439	217,085	71,444	145,641
Devon County Council	314,742	224,668	73,349	151,319
Suffolk County Council	310,056	204,802	68,521	136,281
Lincolnshire County Council	293,760	201,776	61,504	140,272
Durham County Council	287,529	207,702	58,252	149,450
Total	**12,793,231**	**8,096,771**	**2,693,514**	**5,403,257**

Table 17.
Electricity yield from rBMW using energy from waste technologies (Terawatt Hours) based on higher projected EfW capacity.

	2005	2010	2015	2020
Total Electrical Yield from MBT @ 928 KWh/t	0	0.887	2.124	5.189
Total Electrical Yield from EfW @ 714 KWh/t	1.395	2.019	2.572	3.173
Total Electrical Yield from new technologies @ 598 KWh/t*	0	0	0	0.689
Total Electrical Yield in Biodegradable residual MSW	**1.395**	**2.906**	**4.696**	**9.051**

* The electricity yield figure is calculated using the assumption that half the new technology capacity will be anaerobic digestion and half gasification/pyrolysis.

[8] The analysis assumes, based on the previous analysis undertaken within this study, that the annual growth in MSW between 2001 and 2020 will be comparative to the increase in recycling/composting and hence residual waste will remain constant over the period. This enables the diversion rates for 2020 to be calculated using 2001 base data.

3. Commercial and Industrial Waste

The key section findings are:

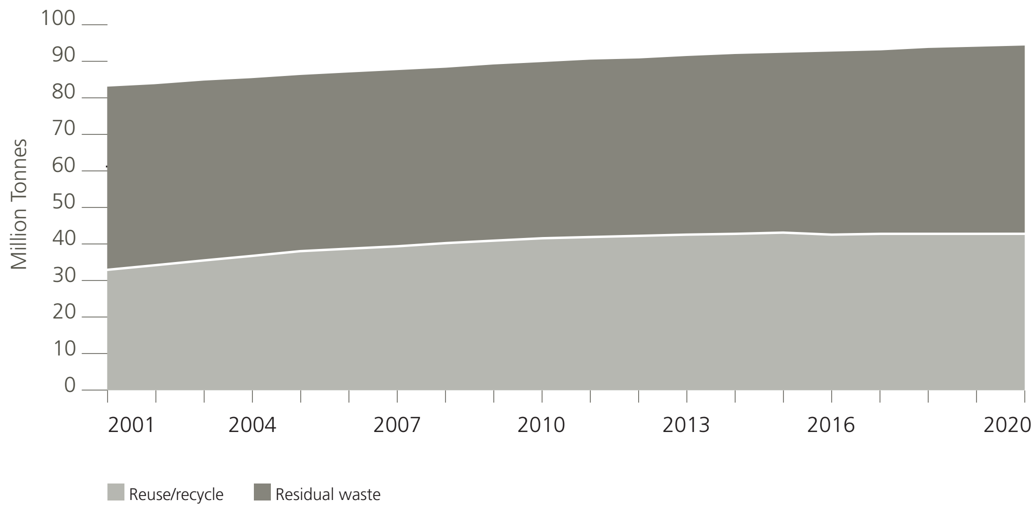
- **UK Commercial and Industrial (C&I) waste arisings are estimated at 86.2Mt in 2005 increasing to 94.2Mt in 2020.**
- **UK C&I recycling/composting is estimated at 37.9Mt in 2005 increasing to 42.9Mt in 2020 and of the remaining "residual" waste 24.2Mt is estimated to be biomass in 2005 increasing to 25.7Mt in 2020.**
- **The Gross Thermal Value (GTV) of residual commercial and industrial waste (rC&I) is estimated at 407,800TJ in 2005 increasing to 437,100TJ in 2020.**
- **The theoretical absolute maximum electrical yield from rC&I will increase from 37.4TWh in 2005 to 40.1TWh in 2020.**
- **The theoretical maximum electrical yield from residual biodegradable commercial and industrial waste (rBC&I) using energy from waste technologies will increase from 5.96TWh in 2005 to 7.2TWh in 2020.**

3.1 UK C&I Waste Arisings

Data on Commercial and Industrial (C&I) waste arisings are not as complete as that for the municipal sector. The Environment Agency's national (England and Wales) waste survey (October 1998 and April 1999) was the last detailed survey undertaken. However, although non-statutory in nature, four regional assemblies in England have produced detailed projections of the growth in C&I waste and recycling/reuse targets. Collectively these four regions accounted for nearly 40% of the UK C&I waste in 2001. Appendix 5 contains the base data from the four regions and the projected UK totals from 2001 to 2020.

Based on the data projections from the regional assemblies recycling/reuse are forecast to increase from 39% in 2001 to 46% in 2020, Figure 15. This leaves annual residual waste arisings from the sector at just below 50 million tonnes throughout the time period.

Figure 15. UK C&I Waste arisings 2001 to 2020.



3.2 Composition of UK C&I Waste

Appendix 6 shows the projected composition of C&I waste and Appendix 7 the proportion of each waste type recycled or reused between 2001 and 2020. The rate of growth in recycling or reuse of each waste type has been given an equal weighting using the 1998 Environment Agency national survey as base data. This information enables residual C&I waste arisings to be calculated.

Table 18 shows the biodegradability of each of the waste types. When combined with the projected waste arisings data (which assumes the composition of C&I waste remains constant), the quantity of biodegradable residual waste can be calculated, Table 19. The mixed waste streams of general commercial, general industrial and other general and biodegradable are outstandingly high. This could be because sorting and collection of these wastes for recycling is less practised, being highly resource intensive and hence costly.

Table 18.

The assumed biodegradability of C&I waste.

Waste	Assumed biodegradability[xxix]
Paper and card	100%
Food	100%
General commercial	80%
General industrial	50%
Other general and biodegradable	60%

3.3 Total Electrical Yield in UK Residual C&I Waste

Table 20 shows the analysis of Gross Thermal Value and maximum potential electrical yield within the rC&I if all rC&I waste is sent to MBT with SRF used as fuel in a 40% conversion efficient power station. This information will be used in Section 4 to satisfy study objective 1.

Table 19.

UK C&I Biodegradable residual waste (kt).

Waste type	2002	2005	2010	2015	2020
Paper/card	293	302	314	323	340
Food	919	730	546	535	573
General commercial	14,695	14,958	15,399	15,840	16,214
General industrial	5,489	5,622	5,823	5,995	6,139
Other general and biodegradable	2,812	2,558	2,329	2,355	2,450
Total	**24,210**	**24,172**	**24,413**	**25,049**	**25,717**

These stream values will be combined with CV data to yield Thermal Values and Electrical Yields.

Table 20.

GTV and electrical yield from rC&I.

	2005	2010	2015	2020
Paper and Card @ 16.5GJ/T				
Arisings (T)	302,000	314,000	323,000	340,000
GTV (TJ)	4,983	5,181	5,330	5,610
Maximum potential electrical yield (TWh)	0.46	0.48	0.49	0.51
Food @ 6.5GJ/T				
Arisings (T)	730,000	546,000	535,000	573,000
GTV (TJ)	4,745	3,549	3,477.5	3,724.5
Maximum potential electrical yield (TWh)	0.44	0.33	0.32	0.34
General commercial @ 9.5GJ/T				
Arisings (T)	18,698,000	19,249,000	19,800,000	20,268,000
GTV (TJ)	177,631	182,865.5	188,100	192,546
Maximum potential electrical yield (TWh)	16.29	16.77	17.25	17.66
General Industrial @ 16GJ/T				
Arisings (T)	11,245,000	11,647,000	11,989,000	12,279,000
GTV (TJ)	179,920	186352	191,824	196,464
Maximum potential electrical yield (TWh)	16.50	17.09	17.59	18.02
Other general and biodegradable @ 9.5GJ/T				
Arisings (T)	4,265,000	3,882,000	3,927,000	4,083,000
GTV (TJ)	40,517.5	36,879	37,306.5	38,788.5
Maximum potential electrical yield (TWh)	3.72	3.38	3.42	3.56
Total				
Arisings (T)	35,240,000	35,638,000	36,574,000	37,543,000
GTV (TJ)	407,797	414,827	426,038	437,133
Maximum potential electrical yield (TWh)	37.40	38.05	39.08	40.09

Sources of estimated average gross calorific values are the DTI[XXX] and CTech.[XXXI]

3.3.1 Maximum Potential: All residual waste to energy

Table 21 shows the maximum potential electrical yield from rBC&I based on the same MBT/SRF route as above. This shows that rBC&I waste accounts for circa 65% of the potential electrical yield from rC&I (Table 20). This information can be used to determine the theoretical absolute maximum contribution to the renewables targets that can be made from rBC&I waste.

3.3.2 Realistic Potential: Landfill allowance is utilised, remaining waste to energy

Table 21 represents the hypothetical maximum, but in reality landfill is likely to remain a significant disposal route. The Waste Strategy 2000 for England and Wales sets a target of reducing the amount of industrial and commercial waste sent to landfill to 85% of 1998 landfill levels by 2005[xxxii]. It is estimated, using the Environment Agency national waste survey data, that 19.4 million tonnes of the UK's residual biodegradable C&I waste went to landfill in 1998 and hence to meet the 85% target a maximum of 16.5 million tonnes would be landfilled from 2005 onwards.

Table 21.
Maximum electrical yield from rBC&I waste

	2005	2010	2015	2020
Paper and Card @ 16.5GJ/T				
Arisings (T)	302,000	314,000	323,000	340,000
GTV (TJ)	4,983	5,181	5,330	5,610
Maximum potential electrical yield (TWh)	0.46	0.48	0.49	0.51
Food @ 6.5GJ/T				
Arisings (T)	730,000	546,000	535,000	573,000
GTV (TJ)	4,745	3,549	3,477.5	3,724.5
Maximum potential electrical yield (TWh)	0.44	0.33	0.32	0.34
General commercial @ 9.5GJ/T				
Arisings (T)	14,958,000	15,399,000	15,840,000	16,214,000
GTV (TJ)	142,101	146,290.5	150,480	154,033
Maximum potential electrical yield (TWh)	13.03	13.42	13.80	14.13
General Industrial @ 16GJ/T				
Arisings (T)	5,622,000	5,823,000	5,995,000	6,139,000
GTV (TJ)	89,952	93,168	95,920	98,224
Maximum potential electrical yield (TWh)	8.25	8.55	8.80	9.01
Other general and biodegradable @ 9.5GJ/T				
Arisings (T)	2,558,000	2,329,000	2,355,000	2,450,000
GTV (TJ)	24,301	22,125.5	22,372.5	23,275
Maximum potential electrical yield (TWh)	2.23	2.03	2.05	2.13
Total				
Arisings (T)	24,170,000	24,411,000	25,048,000	25,716,000
GTV (TJ)	266,082	270,314	277,580	284,867
Maximum potential electrical yield (TWh)	24.41	24.79	25.46	26.13

Table 22 shows the impact this would have with the quantity of non landfilled biodegradable residual waste increasing from 7.7Mt in 2005 to 9.2Mt in 2020. No forecasts on how this material is likely to be handled was found during the study and hence an arbitrary mean electricity yield figure equivalent to that of conventional incineration was used to derive the total Electrical Yield generated from the non landfilled biodegradable residual waste. Table 23 shows the estimated total Electrical Yield using these assumptions. This information will be used in Section 4.4 for to meet study objectives 2 and 3 referring to the renewables targets.

Table 22.
The impact Landfilling has on the projected waste options (Mt).

	2005	2010	2015	2020
Total rBC&I	24.172	24.413	25.049	25.717
Waste strategy landfill target	16.500	16.500	16.500	16.500
By difference… rBC&I to be managed through an alternative means to landfill	**7.672**	**7.913**	**8.549**	**9.217**

Table 23.
The Total Electrical Yield (Terawatt Hours) using energy from waste in rBC&I waste.

	2005	2010	2015	2020
Total Electrical Yield (@ conversion efficiency of 25.4%)	5.96	6.18	6.68	7.2

4. Study Findings and Conclusion

The key section findings are:

- **The Gross Thermal Value (GTV) of residual waste is estimated at 708,000TJ in 2005 increasing slightly to 722,000TJ in 2020.**
- **Using the theoretical absolute maximum electrical yield, residual waste could account for as much as 17% of total UK electricity consumption in 2020.**
- **Based on the theoretical maximum electrical yield, energy from waste could make a contribution of 26% towards the EU Renewables Directive 2010 UK target.**
- **The potential electrical yield from energy from waste technologies currently not eligible under the Renewables Obligation could make a contribution to:**
  - **the Renewables Obligation of 22% in 2015;**
  - **the Government's aspirational 20% renewables target for 2020 of 23%.**

4.1. The Accuracy of Estimates

The accuracy of the outputs from this study is dependent on the following:

- The UK will meet its EU Landfill Directive targets and non statutory national targets (growth rates in waste arisings, landfill diversion of C&I waste).
- The composition of waste (MSW and C&I) will remain constant throughout the time period.
- The accuracy of the source data used (current waste composition, conversion efficiencies, projected materials recycled, projected waste management technologies to be used).

The composition of the waste is the least predictable element. Table 4 shows a significant compositional variation across UK countries with putrescible waste being a case in point, varying from 16% of MSW in Scotland to 44% of MSW in Northern Ireland. The Parfitt study for the Strategy Unit revealed some major shortcomings in previous compositional studies which poses the question whether the variation across countries is due to true variation or whether it signifies inaccuracies.

Making compositional forecasts up to 2020 is also difficult. The analysis within the study is undertaken at a time when demand for heavy waste fractions to meet recycling targets have led to more garden wastes entering the MSW waste stream, but a change in Government policy could reverse this. The recycled material balance would have a consequent impact on the composition of the rMSW.

Changing consumption patterns will also have an impact on MSW composition. The last 20 years have seen a growth in the amount of packaged goods consumed and new social trends causing an increase in the number of single occupancy households. WRAP is targeting supermarkets as part of its waste minimisation strategy, and the impact this will have on waste composition could be significant.

The composition of C&I waste is likely to see even greater changes driven by new patterns of consumption and sourcing manufactured products off-shore. This trend is likely to see the composition of C&I waste moving closer to the composition of MSW. The Environment Agency will shortly (2005 or 2006) produce the second National Survey on C&I waste arisings which will enable the first comparative study to be undertaken showing the changes that have occurred since the first study in 1998.

This study embodies a long-term forecast. Inevitably the time period over which the forecast is undertaken can influence the accuracy of the results. However, the method of analysis used throughout this study is of sufficient transparency to enable the results to be regularly reviewed in light of revised or updated base data.

Figure 16. Gross Thermal Value of UK MSW 2002 to 2020.

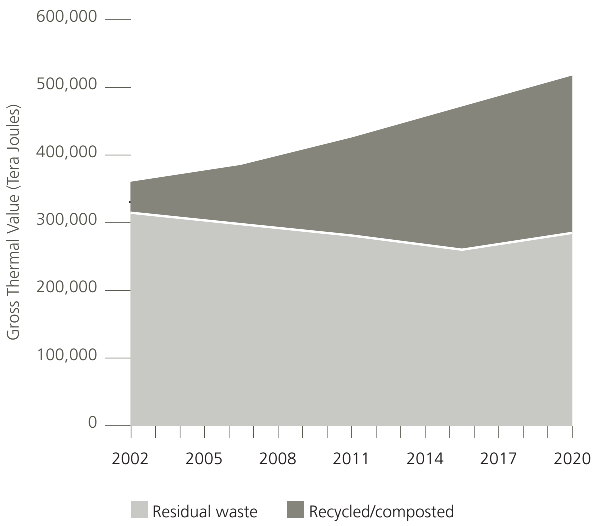
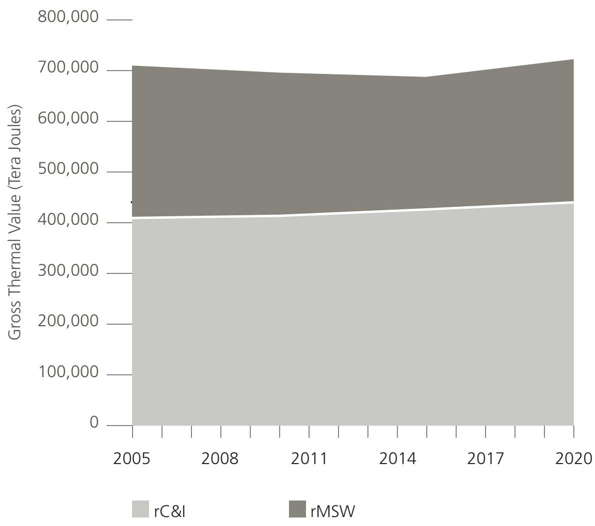


Figure 17. Gross Thermal Value of UK residual MSW and C&I waste 2005 to 2020.



4.2. Gross Thermal Value (GTV)

Figure 16 summarises the data from Appendix 3 and sub-section 2.3. It shows that the GTV in total MSW is set to increase from 359,000 Tera Joules in 2002 to 517,000 Tera Joules in 2020. Since the composition was not changed over the time period this increase is directly associated with the growth in overall waste arisings, which is projected to grow from 35.42Mt in 2002 to 51.12Mt in 2020 (Appendix 1). This growth does not however result in a growth in the GTV of rMSW that can be exploited by waste management techniques incorporating energy recovery. Instead a greater proportion of the GTV in MSW is set to be within the recycled/composted fraction, i.e. in 2002 87% of the GTV of total MSW was in the residual fraction whereas in 2020 it is estimated that just over half (52%) will be within the residual fraction. Recycling and composting is set to grow from 5.1Mt or 14% of MSW in 2002 to 23.2Mt or 45% of MSW in 2020 (Appendix 1 and Figure 9) which is clearly the reason for this shift.

In absolute terms the GTV in residual MSW is also set to decrease from 315,000 Tera Joules in 2002 to 285,000 Tera Joules in 2020 (Appendix 3).

Figure 17 shows the GTV for both residual MSW and C&I waste (Table 19). The analysis shows that the GTV of rC&I waste is set to increase from 2005 to 2020 from 408,000 TJ to 437,000 TJ. This trend is due to the growth rate of C&I waste arisings exceeding that of the increase in recycling/composting, i.e. Appendix 5 shows a projected increase in waste arisings of 8Mt and only a 5Mt increase in recycling/composting.

Figure 17 shows that overall the GTV of residual MSW and C&I waste is unlikely to change significantly from 2005 to 2020 with a growth in the GTV of rC&I waste compensating for a reduction in rMSW.

4.3. The Potential Electrical Yield from Residual Waste

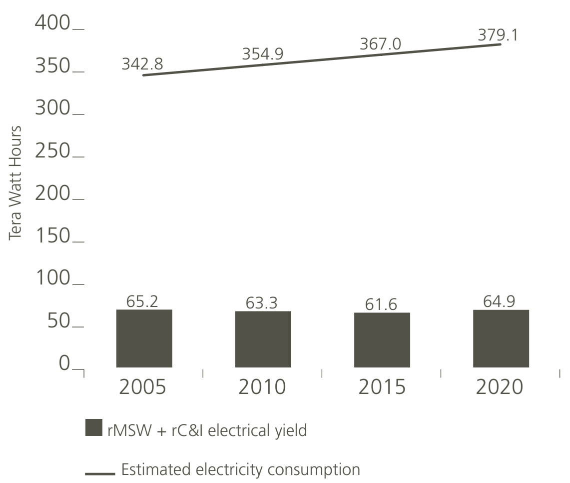
Table 24 shows the projected electricity consumption and sales in the UK from 2005 to 2020. The electricity consumption has been projected using the DTI – Digest of UK Energy Statistics (DUKES) 2000 to 2003 consumption figures. The electricity sales refer to the DTI's[xxxiii] projected sales by licensed suppliers in Great Britain from 2005 to 2010. The sales from 2010 to 2020 have been projected based on the 2005 to 2010 DTI figures. The DTI – Renewables Obligation preliminary consultation reported that Northern Ireland represents 2.5% of available electricity in the UK and this figure was used to derive projected sales for the UK.

Table 24.
Estimated sales by licensed electricity suppliers in UK.

Period	Estimated consumption in the UK (TWh)	Estimated sales by licensed suppliers in GB (TWh)	Estimated sales in the UK (TWh)
2005/06	342.8	320.6	328.6
2006/07	345.2	321.4	329.4
2007/08	347.6	322.2	330.3
2008/09	350.1	323.0	331.1
2009/10	352.5	323.8	331.9
2010/11	354.9	324.3	332.4
2011/12	357.3	325.2	333.3
2012/13	359.8	326.0	334.2
2013/14	362.2	326.7	334.9
2014/15	364.6	327.5	335.7
2015/16	367.0	328.2	336.4
2016/17	369.4	329.0	337.2
2017/18	371.9	329.7	337.9
2018/19	374.3	330.5	338.8
2019/20	376.7	331.3	339.6
2020/21	379.1	332.0	340.3

Figure 18 shows the potential contribution electricity generated from waste could make if all rMSW (sub-section 2.3.2) and rC&I waste (sub section 3.3) was processed through the MBT/SRF route. This analysis is undertaken to satisfy Objective 1. The analysis shows that in 2020 as much as 17% of total UK electricity could be sourced through this route.

Figure 18. Potential maximum electrical yield from UK rMSW and rC&I waste 2005 to 2020.



However, two significant barriers currently prevent this from being realised:

- Use of alternative waste disposal routes.
- Lack of end markets for SRF.

The analysis has shown that although the proportion of waste disposed through landfill will reduce significantly from 2005 to 2020 it is still likely to be widely used. Although LATS will restrict the amount of BMW sent to landfill (Table 14) the Strategy Unit estimates that 16% of MSW will still be sent to landfill in 2020 (Figure 13), which with recycling/composting at 45% (Appendix 1) represents nearly one third of rMSW. In addition, with fewer legislative rules in place the diversion from landfill of C&I waste is likely to be far less significant than that of MSW. Table 21 shows that 16.5Mt of rBC&I will be sent to landfill in 2020 accounting for 64% of rBC&I. In addition, non biodegradable rC&I waste has a potential electricity yield of 14 TWh in 2020 (Tables 20 and 21) or 4% of total UK electricity consumption much of which is likely to be landfilled with zero electrical yield.

In terms of turning potential into reality, a significant barrier is establishing an outlet for SRF from the MBT process. Table 17 shows that by 2020 this process could potentially generate 51% of the electrical yield from rBMW. Fichtner[xxxiv] analysed possible markets for SRF (RDF) and concludes:

Coal fired power stations;
there is almost no prospect of a UK coal fired power station using RDF as a substitute fuel until 2016, when any plants remaining in operation would have to be capable of achieving the co-incineration emission limits for NOx (as specified in the Waste Incineration Directive (WID)).

The cement industry;
The cement industry, which enjoys a concession under WID enabling it to accept a wide variety of waste derived fuels, would place RDF relatively low in its suitability ranking.

Dedicated RDF fired power stations;
If dedicated RDF fired power stations are contemplated, the paper industry may represent an opportunity, with the possibility of co-incinerating the high CV RDF with the very low CV de-inking sludge from paper recycling.

This indicates that the full potential electrical yield will not be realised in the next five years at least and such issues surrounding SRF need to be addressed if the potential in the latter years is to be realised.

4.4 The Potential Contribution to Renewables Targets and Quotas

The key years in terms of renewables targets and quotas are:

- 2010 for the EU Renewables Directive, which requires the UK to source 10% of electricity consumption from renewables.
- Under the Renewables Obligation the UK have set annual quotas up to 2015, Figure 2.
- In the UK Government's Energy White Paper an aspirational figure of sourcing 20% of electricity sales from renewable sources.

4.4.1 Potential contribution to the UK's EU Renewables Directive target

Table 24 shows that the projected electricity consumption in 2010 is 354.9TWh and hence the EU Renewables Directive target of 10% in 2010 would require the UK to generate 35.5TWh of renewable electricity. Table 25 shows that if all rBMW and rBC&I was processed through MBT with SRF used as power station fuel the UK could more than meet the target through energy from waste.

Table 25.

The potential contribution to the UK's EU Renewables Directive 2010 target of energy recovery from residual biodegradable waste.

UK Obligation @ 10% of 2010 consumption TWh	35.5
Potential electricity generated from biodegradable waste TWh	40.5
Potential electricity generated through rBMW TWh	15.7
Potential electricity generated through rBC&I TWh	24.8

Source: Figure 12 and Table 21.

Table 25 shows the absolute theoretical maximum if all waste were sent through the process generating the highest electrical yield. Table 26 takes into consideration the projected waste technology forecasts from the Strategy Unit (Figure 13), i.e. the projected disposal routes used to handle waste. The analysis shows that even when applying the current best case conversion efficiencies for each technology only 9.1TWh of the 40.5TWh can be realised. However, in terms of the EU Renewable Directive target and Objective 2 of this study this still represents a potential contribution of 26%.

Table 26.

The potential contribution to the UK's EU Renewables Directive 2010 target of energy recovery from residual biodegradable waste using the Strategy Unit technology forecasts.

UK Obligation @ 10% of 2010 consumption TWh	35.5
Potential electricity generated from biodegradable waste TWh	9.1
Potential electricity generated through rBMW TWh	2.9
Potential electricity generated through rBC&I TWh	6.2

Source: Figure 17 and Table 23.

4.4.2 Potential contribution to the UK's Renewables Obligation

Table 27 shows the contribution energy from waste technologies could make towards the Renewables Obligation and the 2020 aspirational figure of 20% if all were eligible. In terms of MSW only the contribution of new technologies is currently eligible under the Renewables Obligation eligibility criteria. Based on the Strategy Unit forecasts this is set to account for 4% of the MSW which Table 27 shows to equate to 0.7TWh or 7.6% of the potential electrical yield from energy from waste.

Assuming, based on the analysis of MSW, that the total electrical yield from rBC&I shown in Table 27 will come from currently ineligible technologies, Figure 19 shows the potential contribution the electrical yields from ineligible energy from waste technologies could make to the Renewables Obligation – Objective 3 of this study[9].

The analysis shows that the potential electrical yield from ineligible technologies represents 41% of the Renewables Obligation in 2005 dropping to 23% in 2020. The reason for this drop is the steep increase in the Obligation, although a contribution of 23% is still significant.

4.4.3 Realising the potential

The issues surrounding end markets for SRF and the diversion of waste to technologies with lower energy conversion efficiencies have been discussed. However, Figure 19 shows that the potential contribution of ineligible technologies is significant and hence the question arises as to how this can be realised.

The issue over the outlets for SRF means that changing the eligibility rules on SRF is unlikely to have any immediate impact on the renewables obligation whereas conventional incineration capacity is already in place and could contribute to the Obligations almost immediately.

Figure 19. Potential contribution of ineligible energy from waste technologies from UK rMSW and rC&I waste 2005 to 2020.

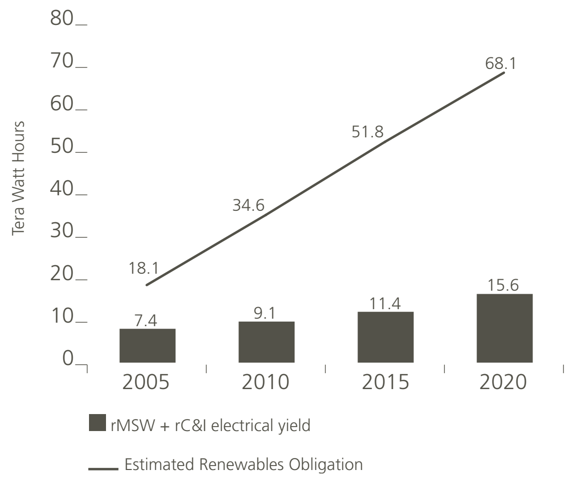
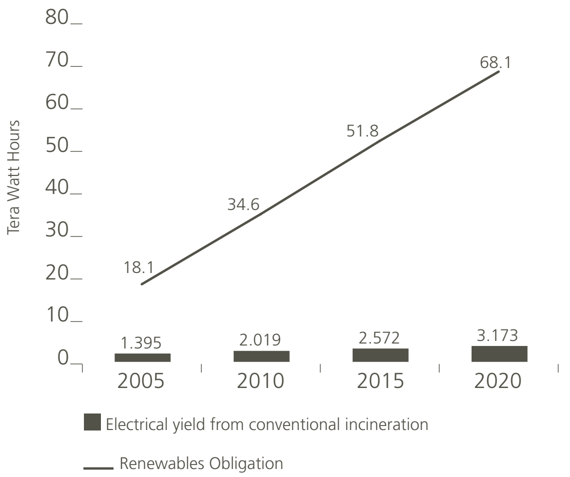


Figure 20 shows the contribution that could be made from the conventional incineration of rBMW, which equates to 7.9% in 2005 and due to the steep increase in the Obligation 4.8% in 2020.

A key issue with the inclusion of conventional incineration into the Renewables Obligation is how to prevent waste being diverted from recycling or composting and hence having an impact from a waste hierarchy perspective. One possible solution is to link the eligibility criteria in with the Statutory Performance Standards, i.e. Waste Disposal Authorities are only eligible if they can demonstrate that they have met recycling and composting targets. However, the Government is currently undertaking a review of the Standards and changes could alter the suitability of this solution.

[9] The 2020 figure represents the aspirational target as outlined in the Government's Energy White Paper.

Figure 20. Potential electrical yield from conventional incineration of rBMW 2005 to 2020.



4.5. Conclusion

The analysis within this study has shown that energy from waste could account for almost one-fifth (17%) of the electricity generated in the UK and make a significant contribution to both the EU Renewables Directive (26%) and the Renewables Obligation (22% in 2015). However, barriers are currently in place restricting the contribution energy from waste can make.

Policy tools such as Landfill Tax will encourage the diversion of rC&I waste from landfill. But if the rate of diversion is in line with the Government's diversion target, outlined in Waste Strategy 2000 of reducing the amount of C&I waste being landfilled to 85% of 1998 landfill levels by 2005, a significant proportion of the potential EfR is set to be lost to landfill. Closing the landfill option to C&I waste, as is happening elsewhere in Europe and within the UK for BMW would improve the chance of realising this potential.

Table 27.
Potential Electricity yield from rBMW and rBC&I using energy from waste technologies (Terawatt Hours).

	2005	2010	2015	2020
TMSW – Total Electrical Yield from MBT @ 928 KWh/t	0	0.887	2.124	5.189
MSW – Total Electrical Yield from EfW @ 714 KWh/t	1.395	2.019	2.572	3.173
MSW – Total Electrical Yield from new technologies @ 598 KWh/t*	0	0	0	0.689
Total Electrical Yield in rBMW	**1.395**	**2.906**	**4.696**	**9.051**
C&I – Total Electrical Yield (@ conversion efficiency of 25.4%)	5.96	6.18	6.68	7.2
Total Electrical Yield in rBC&I	**5.96**	**6.18**	**6.68**	**7.2**
Total Electrical yield rBMW and rBC&I	7.36	9.09	11.38	16.25

* The electricity yield figure is calculated using the assumption that half the new technology capacity will be anaerobic digestion and half gasification/pyrolysis.
Source: Table 17 and Table 23.

Appendices

Appendix 1
UK MUNICIPAL WASTE 2002 – 2020

	England		Wales		Scotland		Northern Ireland		UK Total	
	Total MSW (Mt)	Recycled/ composted	Total MSW (Mt)	Recycled/ composted	Total MSW (Mt)	Recycled/ composted	Total MSW (Mt)	Recycled/ composted	Total MSW (Mt)	Recycled/ composted
2002	29.31	4.58	1.79	0.23	3.23	0.22	1.09	0.07	35.42	5.09
2003	30.19	5.69	1.83	0.32	3.29	0.40	1.11	0.10	36.42	6.51
2004	31.09	6.81	1.87	0.37	3.36	0.58	1.13	0.14	37.44	7.90
2005	31.72	7.93	1.90	0.43	3.42	0.76	1.15	0.17	38.18	9.29
2006	32.35	8.79	1.94	0.48	3.48	0.94	1.18	0.20	38.94	10.42
2007	33.00	9.66	1.97	0.60	3.55	1.07	1.21	0.23	39.73	11.55
2008	33.66	10.52	2.01	0.71	3.62	1.19	1.23	0.26	40.52	12.69
2009	34.33	11.39	2.05	0.82	3.69	1.32	1.26	0.29	41.33	13.82
2010	35.02	12.26	2.09	0.84	3.76	1.44	1.29	0.32	42.15	14.85
2011	35.72	13.28	2.12	0.85	3.82	1.57	1.33	0.36	42.98	16.06
2012	36.43	14.31	2.15	0.86	3.88	1.71	1.36	0.39	43.82	17.27
2013	37.16	15.34	2.18	0.87	3.94	1.84	1.40	0.42	44.68	18.48
2014	37.90	16.37	2.21	0.89	4.00	1.92	1.43	0.46	45.55	19.63
2015	38.66	17.40	2.25	0.90	4.06	2.00	1.47	0.49	46.44	20.79
2016	39.43	17.75	2.28	0.91	4.12	2.08	1.51	0.52	47.34	21.26
2017	40.22	18.10	2.32	0.93	4.18	2.15	1.54	0.56	48.26	21.74
2018	41.03	18.46	2.35	0.94	4.24	2.23	1.58	0.59	49.20	22.23
2019	41.85	18.83	2.39	0.96	4.30	2.31	1.61	0.63	50.15	22.72
2020	42.69	19.21	2.42	0.97	4.36	2.39	1.65	0.66	51.12	23.23

Appendix 2
Projected proportions of MSW to be recycled or composted in the UK between 2002 and 2020

Waste type	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Paper/card	27.2	28.9	30.6	32.3	34.0	35.6	37.3	39.0	40.7	42.4	44.1	46.6	48.9	51.2	51.2	51.2	51.2	51.2	51.2
Putrescible	14.1	17.9	21.7	25.4	29.2	32.9	36.7	40.4	44.2	48.0	51.7	54.7	57.4	60.0	60.0	60.0	60.0	60.0	60.0
Textiles	1.4	6.8	12.1	17.4	22.8	28.1	33.4	38.8	44.1	49.5	54.8	58.0	60.8	63.6	63.6	63.6	63.6	63.6	63.6
Fines	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Misc. combustible	0.0	1.4	2.7	4.1	5.5	6.8	8.2	9.6	11.0	12.3	13.7	14.5	15.2	15.9	15.9	15.9	15.9	15.9	15.9
Misc. non combustible	0.0	1.1	2.1	3.2	4.3	5.4	6.4	7.5	8.6	9.7	10.7	11.4	11.9	12.5	12.5	12.5	12.5	12.5	12.5
Metals	30.8	31.3	31.9	32.4	33.0	33.5	34.0	34.6	35.1	35.7	36.2	38.3	40.2	42.0	42.0	4.20	42.0	42.0	42.0
Glass	31.1	33.4	35.8	38.2	40.6	42.9	45.3	47.7	50.1	52.4	54.8	58.0	60.8	63.6	63.6	63.6	63.6	63.6	63.6
Plastics	0.8	4.4	8.0	11.5	15.1	18.7	22.2	25.8	29.4	33.0	36.5	38.6	40.5	42.4	42.4	42.4	42.4	42.4	42.4

Appendix 3

Material	2005		2010		2015		2020	
	Weight (Kg)	Calorific value (MJ)	Weight (Kg)	Calorific value (MJ)	Weight (Kg)	Calorific value (MJ)	Weight (Kg)	Calorific value (MJ)
Paper/card								
Recycled	2,519,450,213	43,410,127,170	3,250,877,905	56,012,626,307	4,299,172,811	74,074,747,535	4,799,645,742	82,697,896,134
Residual	4,945,889,234	85,217,671,510	4,989,429,569	85,967,871,478	4,771,912,994	82,220,060,890	5,176,589,681	89,192,640,200
Residual of which biodegradable	4,945,889,234	85,217,671,510	4,989,429,569	85,967,871,478	4,771,912,994	82,220,060,890	5,176,589,681	89,192,640,200
Putrescible								
Recycled	4,033,454,477	26,419,126,825	7,176,564,225	47,006,495,673	10,273,655,216	67,292,441,664	11,495,618,483	75,296,301,064
Residual	11,138,064,302	72,954,321,176	9,576,531,245	62,726,279,655	8,205,002,429	53,742,765,909	8,872,968,767	58,117,945,425
Residual of which biodegradable	11,138,064,302	72,954,321,176	9,576,531,245	62,726,279,655	8,205,002,429	53,742,765,909	8,872,968,767	58,117,945,425
Textiles								
Recycled	211,761,225	3,413,590,943	547,912,649	8,832,351,906	830,633,274	13,389,808,372	927,159,508	14,945,811,273
Residual	949,518,688	15,306,241,251	733,682,741	11,826,965,792	579,655,823	9,344,051,873	623,571,295	10,051,969,281
Residual of which biodegradable	474,759,344	7,653,120,625	366,841,371	5,913,482,896	289,827,912	4,672,025,937	311,785,648	5,025,984,641
Fines								
Recycled	0	0	0	0	0	0	0	0
Residual	1,347,754,913	9,959,908,805	1,488,565,391	11,000,498,237	1,639,378,240	12,115,005,193	1,801,907,804	13,316,098,669
Residual of which biodegradable	673,877,456	4,979,954,403	744,282,695	5,500,249,119	819,689,120	6,057,502,597	900,953,902	6,658,049,334
Misc. combustible								
Recycled	144,529,792	1,336,900,577	394,049,312	3,644,956,132	600,842,212	5,557,790,463	669,887,434	6,196,458,764
Residual	3,217,724,975	29,763,956,021	3,316,711,730	30,679,583,506	3,479,769,856	32,187,871,169	3,811,885,376	35,259,939,724
Residual of which biodegradable	1,608,862,488	14,881,978,011	1,658,355,865	15,339,791,753	1,739,884,928	16,093,935,585	1,905,942,688	17,629,969,862
Misc. non-combustible								
Recycled	48,842,333	0	133,212,774	0	203,629,471	0	227,748,082	0
Residual	1,399,797,551	0	1,466,157,747	0	1,559,549,134	0	1,714,897,323	0
Residual of which biodegradable	0	0	0	0	0	0	0	0
Metals								
Recycled	892,981,647	0	989,246,814	0	1,245,502,654	0	1,391,244,771	0
Residual	1,740,763,149	0	1,917,709,098	0	1,955,337,620	0	2,130,890,438	0
Residual of which biodegradable	0	0	0	0	0	0	0	0
Glass								
Recycled	1,092,770,153	0	1,464,477,008	0	1,958,165,480	0	2,186,564,385	0
Residual	1,642,674,644	0	1,555,088,903	0	1,366,496,508	0	1,470,591,823	0
Residual of which biodegradable	0	0	0	0	0	0	0	0
Plastics								
Recycled	344,856,366	11,900,993,206	898,611,730	31,011,090,816	1,363,651,442	47,059,611,265	1,521,670,519	52,512,849,628
Residual	2,513,813,430	86,751,701,469	2,256,974,181	77,888,178,995	2,109,265,404	72,790,749,075	2,295,967,689	79,233,844,943
Residual of which biodegradable	0	0	0	0	0	0	0	0
Total								
Recycled	9,288,646,206	86,480,738,721	14,854,952,417	146,507,520,834	20,775,252,560	207,374,399,298	23,219,538,924	231,649,316,863
Residual	28,896,000,886	299,953,800,231	27,300,850,607	280,089,377,664	25,666,368,009	262,400,504,109	27,899,270,195	285,172,438,243
Residual of which biodegradable	18,841,452,824	185,687,045,724	17,335,440,746	175,447,674,901	15,826,317,383	162,786,290,916	17,168,240,685	176,624,589,462

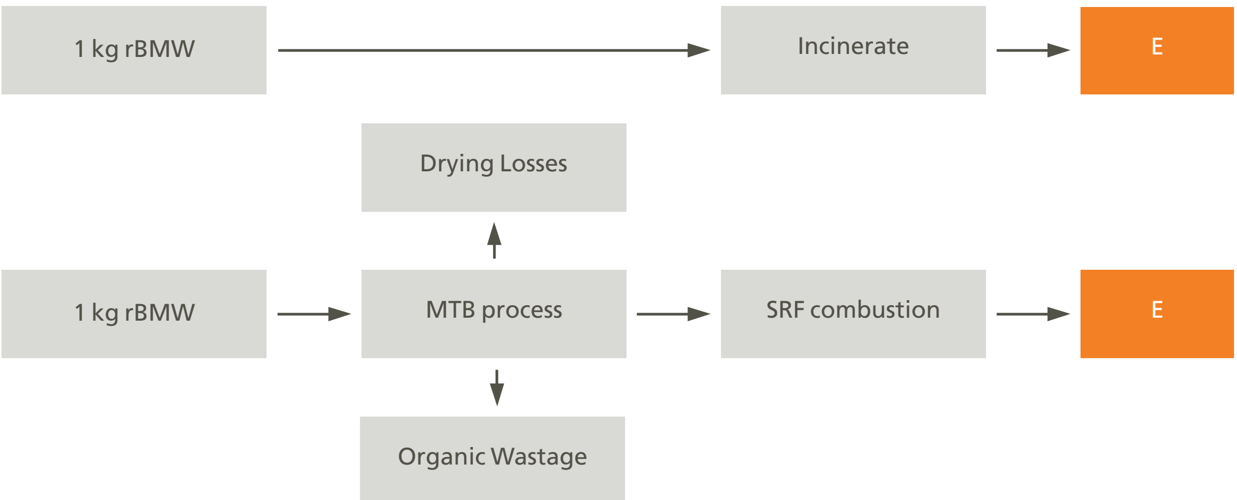
Calculating the relative performance of MBT

The purpose of this section is to demonstrate the derivation of the factor for the relative electrical generation performance of MBT against standard incineration.

The basis of all work is that potentials are compared per kg of residual BMW (rBMW). Complication arises because of the intermediate treatment of the MBT process which results in:

- some inefficiency due to loss of organic material from the input stream
- some inefficiency due to energy absorbed by waste drying
- improved calorific value of dried residual waste in pellets.

These transformations are illustrated by the following diagram, and the factors described in the subsequent table.



Using the Appendix 3, 2010 rBMW data:

	Input rBMW CV	Treatment efficiency	MBT Pellet CV	Thermal Efficiency
Incineration	10 MJ/kg	n/a	n/a	25.4%
MBT		50%	16.5 MJ/kg	40%

The yield of Incinerated waste is therefore:
$Y_{Incin} = 10 \text{ x } 25.4\% = 2.54^{MJ}/_{kg}$

and the yield of MBT-treated waste is:
$Y_{MBT} = 50\% \text{ x } 16.5 \text{ x } 40\% = 3.30^{MJ}/_{kg}$

The relative performance is the ratio of the two:

Relative Performance
$= \frac{Y_{MBT}}{Y_{Incin}} = \frac{3.30}{2.54} = 1.3$

Appendix 5

UK Commercial and Industrial Waste Arisings 2001–2020 (tonnes)

Year	Base Data from Regional Assembly Strategy Reports								UK Projected Arisings	
	East Midlands[xxxv]		East of England[xxxvi]		South East[xxxvii]		North West[xxxviii]			
	Region total	Reuse/ recycle	Region total	Reuse/ recycle	Region total	Reuse/ recycle	Region total	Reuse/ recycle	Total	Reuse/ recycle
2001	7,718,784	3,177,127	5,854,000	2,910,400	8,315,566	2,906,813	9,576,600	3,430,909	83,000,000	32,776,014
2002	7,729,037	3,256,502	5,854,000	3,148,800	8,587,485	3,004,866	9,577,200	3,504,545	83,745,912	34,067,152
2003	7,742,301	3,335,878	5,854,000	3,387,200	8,868,295	3,102,919	9,577,800	3,578,182	84,523,219	35,358,290
2004	7,758,656	3,415,253	5,854,000	3,625,600	9,158,289	3,200,972	9,578,400	3,651,818	85,332,906	36,649,428
2005	7,778,186	3,494,629	5,854,000	3,864,000	9,457,765	3,299,025	9,579,000	3,725,455	86,175,981	37,940,566
2006	7,800,978	3,497,581	5,854,000	3,969,400	9,694,209	3,385,729	9,582,000	3,799,091	86,867,722	38,649,336
2007	7,818,991	3,500,532	5,854,000	4,074,800	9,936,564	3,472,433	9,585,000	3,872,727	87,562,449	39,358,106
2008	7,831,320	3,503,484	5,854,000	4,180,200	10,184,978	3,559,136	9,588,000	3,946,364	88,258,165	40,066,876
2009	7,837,660	3,506,435	5,854,000	4,285,600	10,439,603	3,645,840	9,591,000	4,020,000	88,954,466	40,775,646
2010	7,837,201	3,509,387	5,854,000	4,391,000	10,700,593	3,732,544	9,594,000	4,093,636	89,649,623	41,484,417
2011	7,829,377	3,485,116	5,854,000	4,391,000	10,914,605	3,808,698	9,599,400	4,167,273	90,207,762	41,815,517
2012	7,813,692	3,460,845	5,854,000	4,391,000	11,132,897	3,884,851	9,604,800	4,240,909	90,756,454	42,146,618
2013	7,789,729	3,436,573	5,854,000	4,391,000	11,355,555	3,961,005	9,610,200	4,314,545	91,294,827	42,477,718
2014	7,757,159	3,412,302	5,854,000	4,391,000	11,582,666	4,034,952	9,615,600	4,388,182	91,822,243	42,802,997
2015	7,715,745	3,388,031	5,854,000	4,391,000	11,814,319	4,108,898	9,621,000	4,461,818	92,338,310	43,128,276
2016	7,665,347	3,023,941	5,854,000	4,391,000	11,991,534	4,182,845	9,629,200	4,535,455	92,694,466	42,557,162
2017	7,615,453	2,925,047	5,854,000	4,391,000	12,171,407	4,247,014	9,637,400	4,609,091	93,058,962	42,659,805
2018	7,566,058	2,822,955	5,854,000	4,391,000	12,353,978	4,311,183	9,645,600	4,682,727	93,431,891	42,754,010
2019	7,517,157	2,710,393	5,854,000	4,391,000	12,539,288	4,375,351	9,653,800	4,756,364	93,813,349	42,820,597
2020	7,468,745	2,589,082	5,854,000	4,391,000	12,727,377	4,439,520	9,662,000	4,830,000	94,203,427	42,864,106

Appendix 6

Projected composition of C&I waste 2002 to 2020

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Industry										
Inert/C&D	2,433	2,456	2,479	2,504	2,524	2,544	2,564	2,585	2,605	2,621
Paper and card	3,068	3,096	3,126	3,157	3,182	3,208	3,233	3,259	3,284	3,305
Food	2,444	2,467	2,490	2,515	2,535	2,555	2,576	2,596	2,616	2,632
General industrial & commercial	11,460	11,566	11,677	11,792	11,887	11,982	12,077	12,172	12,267	12,344
Other general & biodegradable	7,685	7,756	7,831	7,908	7,972	8,035	8,099	8,163	8,227	8,278
Metals & scrap equipment	4,757	4,801	4,847	4,895	4,934	4,973	5,013	5,052	5,092	5,124
Contaminated general	3,665	3,699	3,735	3,772	3,802	3,832	3,863	3,893	3,924	3,948
Mineral wastes & residues	14,296	14,429	14,567	14,711	14,829	14,947	15,066	15,185	15,304	15,399
Chemical & other	6,204	6,262	6,322	6,384	6,436	6,487	6,539	6,590	6,642	6,683
Total	**56,012**	**56,532**	**57,073**	**57,637**	**58,100**	**58,565**	**59,030**	**59,496**	**59,961**	**60,334**
Commerce	–	–	–	–	–	–	–	–	–	–
Inert/C&D	227	229	232	234	236	238	240	241	243	245
Paper and card	2,797	2,823	2,850	2,879	2,902	2,925	2,948	2,971	2,995	3,013
Food	452	456	460	465	468	472	476	480	483	486
General commercial	20,245	20,433	20,628	20,832	21,000	21,167	21,336	21,504	21,672	21,807
Other general & biodegradable	2,137	2,157	2,178	2,199	2,217	2,235	2,252	2,270	2,288	2,302
Metals & scrap equipment	600	606	611	617	622	627	632	637	642	646
Contaminated general	821	828	836	844	851	858	865	872	879	884
Mineral wastes & residues	22	22	22	22	22	23	23	23	23	23
Chemical & other	433	438	442	446	450	453	457	460	464	467
Total	**27,734**	**27,991**	**28,260**	**28,539**	**28,768**	**28,998**	**29,228**	**29,459**	**29,689**	**29,874**

Appendix 6 (continued)

Projected composition of C&I waste 2002 to 2020

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Industry									
Inert/C&D	2,637	2,653	2,668	2,683	2,693	2,704	2,715	2,726	2,737
Paper and card	3,325	3,345	3,364	3,383	3,396	3,409	3,423	3,437	3,451
Food	2,648	2,664	2,680	2,695	2,705	2,716	2,726	2,738	2,749
General industrial & commercial	12,419	12,493	12,565	12,635	12,684	12,734	12,785	12,837	12,891
Other general & biodegradable	8,328	8,378	8,426	8,474	8,506	8,540	8,574	8,609	8,645
Metals & scrap equipment	5,155	5,185	5,215	5,245	5,265	5,286	5,307	5,328	5,351
Contaminated general	3,972	3,996	4,019	4,041	4,057	4,073	4,089	4,106	4,123
Mineral wastes & residues	15,493	15,585	15,675	15,763	15,824	15,886	15,949	16,015	16,081
Chemical & other	6,724	6,764	6,803	6,841	6,867	6,894	6,922	6,950	6,979
Total	**60,701**	**61,061**	**61,414**	**61,759**	**61,997**	**62,241**	**62,490**	**62,745**	**63,006**
Commerce	–	–	–	–	–	–	–	–	–
Inert/C&D	246	248	249	251	252	253	254	255	256
Paper and card	3,032	3,050	3,067	3,084	3,096	3,108	3,121	3,134	3,147
Food	489	492	495	498	500	502	504	506	508
General commercial	21,940	22,070	22,197	22,322	22,408	22,496	22,586	22,679	22,773
Other general & biodegradable	2,316	2,330	2,343	2,356	2,366	2,375	2,384	2,394	2,404
Metals & scrap equipment	650	654	658	662	664	667	669	672	675
Contaminated general	889	895	900	905	908	912	916	919	923
Mineral wastes & residues	23	24	24	24	24	24	24	24	24
Chemical & other	470	473	475	478	480	482	484	486	488
Total	**30,056**	**30,234**	**30,409**	**30,579**	**30,697**	**30,818**	**30,942**	**31,068**	**31,197**

Appendix 7

Projected percentage of C&I wastes recycled or reused 2001 to 2020

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Industry											
Inert/C&D	34	36	37	39	40	41	41	42	42	43	43
Paper and card	95	95	95	95	95	95	95	95	95	95	95
Food	66	70	72	75	77	80	80	82	82	84	84
General industrial & commercial	4	4	4	5	5	5	5	5	5	5	5
Other general & biodegradable	48	51	52	55	56	58	58	60	60	61	61
Metals & scrap equipment	95	95	95	95	95	95	95	95	95	95	95
Contaminated general	32	34	35	36	37	39	39	40	40	41	41
Mineral wastes & residues	65	69	70	74	76	79	79	81	81	83	83
Chemical & other	21	22	22	24	24	25	25	26	26	26	26
Total Industry	**46**	**49**	**50**	**53**	**54**	**56**	**56**	**58**	**58**	**59**	**59**
Commerce											
Inert/C&D	25	26	27	28	29	30	30	31	31	32	32
Paper and card	95	95	95	95	95	95	95	95	95	95	95
Food	56	60	61	64	66	68	68	70	70	72	72
General commercial	9	9	9	10	10	11	11	11	11	11	11
Other general & biodegradable	54	57	59	62	63	65	65	67	67	69	69
Metals & scrap equipment	95	95	95	95	95	95	95	95	95	95	95
Contaminated general	42	44	46	48	49	51	51	52	52	54	54
Mineral wastes & residues	47	50	51	54	55	58	57	59	59	61	61
Chemical & other	21	22	23	24	25	25	25	26	26	27	27
Total Commerce	25	26	27	27	28	28	29	29	29	30	30
Total C&I	**39**	**41**	**42**	**43**	**44**	**44**	**45**	**45**	**46**	**46**	**46**

Appendix 7 *(continued)*

Projected percentage of C&I wastes recycled or reused 2001 to 2020

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020
Industry									
Inert/C&D	43	43	44	44	43	43	43	43	43
Paper and card	95	95	95	95	95	95	95	95	95
Food	85	85	85	85	85	85	85	85	85
General industrial & commercial	5	5	5	5	5	5	5	5	5
Other general & biodegradable	62	62	62	62	62	62	62	62	62
Metals & scrap equipment	95	95	95	95	95	95	95	95	95
Contaminated general	41	41	41	41	41	40	40	40	40
Mineral wastes & residues	83	83	84	84	83	81	81	81	81
Chemical & other	27	27	27	27	27	26	25	25	25
Total Industry	**59**	**59**	**60**	**60**	**59**	**58**	**85**	**58**	**58**
Commerce									
Inert/C&D	32	32	32	32	32	31	30	30	30
Paper and card	95	95	95	95	95	95	95	95	95
Food	72	72	73	73	72	70	70	70	70
General commercial	11	11	11	11	11	11	11	11	11
Other general & biodegradable	69	69	70	70	69	67	67	67	67
Metals & scrap equipment	95	95	95	95	95	95	95	95	95
Contaminated general	54	54	54	54	54	52	52	52	52
Mineral wastes & residues	61	61	61	61	61	59	58	58	58
Chemical & other	27	27	27	27	27	26	26	26	26
Total Commerce	**30**	**30**	**30**	**30**	**29**	**29**	**29**	**29**	**29**
Total C&I	**46**	**47**	**47**	**47**	**46**	**46**	**46**	**46**	**46**

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The RPA is a trade association with over 200 members, whose activities span the entire range of the renewable energy industry. RPA members account for the lion's share of renewable electricity generation and the Association has played an active part in the development of the Renewables Obligation. The RPA commissioned this report to gain greater understanding of the potential for renewable electricity generation from mixed wastes, in the context of the Government's consideration of eligibility of waste in the current review of the Renewables Obligation.

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Oakdene Hollins was established in 1994 by David Fitzsimons and Nicholas Morley. Our area of consultancy is in the sustainable use of resources at strategic, research and implementation levels. Our activities range across: The management of government programmes related to resource, reuse and sustainability issues; Investigation of environmental economics on behalf of private and public sector organisations; Publicly supported research into, for example, uptake of new technologies; Direct in-company intervention in Lean Manufacturing and Resource Efficiency programmes; Independent evaluation of the potential of novel technologies and business models to effect more sustainable consumption or production.

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