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FINAL REPORT

Landfill Bans: Feasibility Research

The environmental, economic and practical impacts of landfill bans or restrictions: research to determine feasibility

Project code: EVA130
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Front cover photography: Picture of leaves

Executive Summary

1.0 Introduction

1.1 Research aims

The aim of this research was to conduct a feasibility study regarding the impacts of introducing landfill bans in England, Scotland, Wales and Northern Ireland. The work seeks to discover whether the costs and benefits of specific landfill bans and restrictions (i.e. measures which do not completely ban waste from landfill) justify their use. Key objectives for the bans / restrictions, shared by Defra and the Devolved Administrations (DAs), were to:

1. Reduce the climate change impacts of managing waste; and
2. Contribute to increases in resource efficiency.

Additional aims of the work included seeking to understand how landfill bans / restrictions could help meet Landfill Directive targets for biodegradable municipal waste (in support of existing policy instruments); increase economic and business opportunities; and increase market certainty regarding the development of collection, reprocessing and treatment infrastructure. Furthermore, the potential health benefits from reduced landfilling were to be explored.

1.2 Update of analysis

This is an update of an earlier version of the report (published in 2010) which reflects changes to the modelling, and additional analysis. An overestimate of the negative externalities associated with landfill was identified in the initial report. This has been corrected. The opportunity was taken to revise the modelling of landfilling to reflect the latest version of MELMod, a model used by Defra / DECC to report emissions from landfill in the UK to the IPCC.[1] The principle effect of this change is, as with the aforementioned modelling error, also to reduce the extent to which landfills are assumed to generate methane. Additional analysis was also undertaken in respect of the cost of household food waste collections to help shed further light on the merits or otherwise of requiring the sorting of food waste under current market conditions. No changes were made to the baselines used in the initial modelling.

The earlier version of the report, concentrated on the analysis of external benefits, and on financial costs as understood using a social metric. Effectively the social metric looks at the cost excluding the effects of a range of policy instruments already in place and designed to balance the effects of environmental externalities. This means the social metric for financial costs looks at the cost to the public purse of bringing in a new policy.

It was felt appropriate in this version of the report, to also give consideration to the costs derived using the private cost metric given that this takes into account existing incentives to avoid landfilling, such as landfill tax and the feed-in tariff. The private cost metric is therefore more representative of what confronts actors in the market place. However, it is important to understand that conventional cost benefit analysis uses the social cost approach, and this is the primary means to assess the desirability of an intervention.

It is sound, methodologically, to then add external costs to the financial costs (in order to arrive at a net social cost), it would not have been sound to add the external costs to the financial costs as estimated using the private metric. Such an approach would incur double counting of some environmental costs since these are reflected both in the externalities, and in the effect of policies implemented to internalise these (however imperfectly).

2.0 Approach to the Work

The following areas of work were undertaken:

3. A literature review of international experience
4. Discussions with regulators regarding existing bans
5. Stakeholder workshops (to discuss both design issues and the possible impacts of a ban)
6. Preliminary environmental modelling
7. A cost / benefit analysis (CBA)

[1] *See Eunomia (2011) Inventory Improvement project – UK Landfill Methane Emissions Model, Final Report to Defra and DECC, January 2011, http://www.decc.gov.uk/assets/decc/research/1213-greenhouse-gas-inventory-improve-project.pdf*

The first four areas of work provided evidence to support the choice of bans to be modelled in the CBA.

Following an initial consideration of implementation options, two types of material-based policy were taken forward for the cost benefit analysis.

- A 'restriction' whereby different types of waste are to be restricted from landfill so that landfilling is avoided as far as is able to be known. In this case, any form of 'sorting' of materials prior to landfilling would be considered sufficient, with carriers required to testify that residual waste destined to landfill had been subjected to a sorting process affecting the restricted material; and
- A 'ban on unsorted waste' whereby different types of waste are to be absolutely diverted from landfill, i.e. none of that type or types of waste are to be landfilled at all. In this case the measure is supported by a defined 'requirement to sort' setting out minimum requirements as to what waste producers, the waste industry and local authorities are required to do to comply with the measure. The 'requirement to sort' would apply irrespective of the destination of residual waste. This was the way in which the ban on 'unsorted waste' has been modelled.

In the latter case, the requirement to sort wastes is seen to play an important complementary role for effective introduction of a ban to divert recyclables from landfill. Many other countries make use of similar measures to the requirement to sort which is elaborated in the Main Report.

3.0 Headline Results

- Climate change benefits and resource efficiency gains are likely to be greatest where landfill bans are coupled with a requirement to sort materials (defined here as a 'ban on unsorted waste');
- If all materials considered in this report are within the scope of a ban on unsorted waste, the median value of the net benefit to society is estimated at £910 million (NPV over 2009 – 2024) and the median quantity of GHG savings achieved over the same period is estimated at 120 million tonnes of CO_2 eq;
- If one considers only those materials for which there are net social benefits (i.e. where the environmental benefits exceed the costs as assessed using the social metric), the median value of GHG savings achieved over the period 2009 to 2024 is estimated at around 73 million tonnes CO_2 eq, and the median value of the net benefit to society from a ban on unsorted waste covering these materials from landfill is estimated at £2.1 billion (NPV over 2009 – 2024). This indicates that banning/restricting some materials to landfill (i.e. those materials for which there is a net social benefit) has a high net cost to society;
- For some materials the analysis shows clear benefits to society from introducing landfill bans. These are metals, paper / card, textiles, wood and glass. For food waste, the outcome in terms of the costs to society varies depending on the technology chosen, though an average of the technologies indicates a net cost to society would be the likely outcome;
- For all of these materials, except textiles, there are savings to business under the private cost metric. The analysis for food is, as with the analysis of benefits to society, sensitive to the choice of treatment (especially use of biogas). The more commonly deployed options generate financial savings under the private cost metric;
- If one considers the analysis using the private cost metric (as opposed to the social cost metric), then for the whole range of materials considered, for each tonne CO_2 eq which is avoided, there is a saving of £0.54. If one considers only those materials which generate net social benefits, there is a saving of £8.72 for each tonne of CO_2 eq using the private cost metric;
- Additional GHG benefits can be secured through a ban on biodegradable waste being sent to landfill, though the magnitude of these depends upon the residual waste treatment utilised; and
- In all cases, the biodegradable waste ban leads to net costs to society. This is due to the increased costs of residual waste treatment options (such as incineration, or mechanical biological treatment) which would be used more widely under such a ban and the fact that the environmental benefits of switching away from landfill are lower than the additional costs of using these treatments.

3.1 Key Impacts of Landfill Bans

3.1.1 Material-based Policies

All results are for the period 2009-2024. Key results concern the private costs of the policies considered and the net benefit to society – the sum of the environmental and financial benefits using central estimates. Table 1 and Table 2 present a summary of the main results of policies with restrictions on landfill and a ban on unsorted waste of key materials.

Table 1 Summary Results for Material Based Restrictions and Unsorted Waste Bans

	Food [1]	**Green - OAW**	**Paper / Card**	**Textiles**	**Wood**
Material / Product Based Restrictions					
Total Waste Diverted (2009-24), Mtonnes	12	2.0	3.0	1.0	3.0
Total CO_2 eq Savings (2009-24), Mt	6.2	0.71	3.9	3.4	3.7
Energy Generated, GWh (2009-24)	3,100	-130	-390	-68	2,500
NPV Financial Savings (Private Metric), £million	-£290 - +£92	£37	£110	-£13	£110
NPV (2009-24) Net Env. Benefits, £million	£300	£40	£110	£140	£82
NPV Financial Savings (Social Metric), £million	-£440	-£43	£17	-£35	-£35
Regulation / Communications Component	-£0.47	-£0.47	-£0.47	-£0.47	-£0.47
Net Benefit to Society (2009-24), £million					
Upper	£100	£11	£200	£130	£90
Median	**£2 - -£230**	**-£3**	**£130**	**£110**	**£48**
Lower	-£350	-£16	£78	£83	£10
Unsorted Waste Bans					
Total Waste Diverted (2009-24), Mtonnes	59	11	24	4.0	5.0
Total CO_2 eq Savings (2009-24), Mt	27	4.3	26	10	5.5
Energy Generated, GWh (2009-24)	13,000	-790	-2,500	-210	3,400
NPV Financial Savings (Private Metric), £million	-£1,300 - +£340	£110	£560	-£100	£96
NPV (2009-24) Net Env. Benefits, £million	£1,300	£240	£750	£430	£130
NPV Financial Savings (Social Metric), £million	-£2,000	-£330	-£24	-£180	-£120
Regulation / Communications Component	-£70	-£70	-£70	-£70	-£70
Net Benefit to Society (2009-24), £million					
Upper	£380	£0	£1,200	£330	£80
Median	**-£57 - -£1,100**	**-£84**	**£720**	**£250**	**£21**
Lower	-£1,500	-£170	£380	£170	-£41

1. *Figures for the private costs for food waste restrictions / bans, and for the net benefit to society are presented as a range for 5 biowaste treatment options modelled in the report. The financial savings under the social metric, and the environmental benefits, relate to an average of the 5 biowaste treatment options modelled in the report.*
2. *The social metric uses a social discount rate to reflect time preference and to value the costs of capital. It excludes the financial effects of policy instruments such as landfill tax, and the Renewables Obligation. Benefits over 15 years (2009-24) have had a discount rate of 3.5% applied in line with guidelines on discounting to net present value in the government's Green Book. Net benefits to society use the social metric as described here and also account for externalities such as the cost of environmental impacts.*

Table 2 Summary Results for Material Based Restrictions and Unsorted Waste Bans

	Glass	Metals	Plastics	WEEE
Material / Product Based Restrictions				
Total Waste Diverted (2009-24), Mtonnes	0.37	0.50	5.2	0.36
Total CO_2 eq Savings (2009-24), Mt	0.16	2.6	6.8	0.04
Energy Generated, GWh (2009-24)	0	0	0	0
NPV Financial Savings (Private Metric), £million	£17	£7	-£330	-£16
NPV (2009-24) Net Env. Benefits, £million	£5	£84	£240	£13
NPV Financial Savings (Social Metric), £million	£5	-£8	-£410	-£33
Regulation / Communications Component	-£0.47	-£0.47	-£0.47	-£0.47
Net Benefit to Society (2009-24), £million				
Upper	£14	£100	-£100	-£14
Median	**£9**	**£75**	**-£170**	**-£20**
Lower	£6	£55	-£240	-£29
Unsorted Waste Bans				
Total Waste Diverted (2009-24), Mtonnes	4.5	7.0	15	2.5
Total CO_2 eq Savings (2009-24), Mt	1.6	30	17	0.21
Energy Generated, GWh (2009-24)	0	0	0	0
NPV Financial Savings (Private Metric), £million	£71	£10	-£850	-£176
NPV (2009-24) Net Env. Benefits, £million	£49	£940	£590	£73
NPV Financial Savings (Social Metric), £million	-£39	-£150	-£1,100	-£270
Regulation / Communications Component	-£70	-£70	-£70	-£70
Net Benefit to Society (2009-24), £million				
Upper	£29	£950	-£310	-£170
Median	**£3**	**£800**	**-£480**	**-£200**
Lower	-£19	£670	-£670	-£230

Food

- The level of financial savings available, as assessed under the private cost metric, is sensitive to the way the biogas is used. Under the landfill restriction, this might result in savings of £92 million or costs of up to £290 million, depending on whether the gas was used for electricity generation, or cleaned for injection into the grid. Under the ban on unsorted waste, the equivalent range is from potential savings of £340 million to a cost of £1.3 billion. It should be noted that the market appears to be responding in a rational manner as the lower cost options are the most common ones; and
- This is a case where it appears that the market is already tipping in favour of a growing uptake of food waste collections. The private costs, therefore, appear to be moving in favour of separate collection, though the cost benefit analysis indicates that costs might exceed benefits where food waste is concerned. Some additional work undertaken in respect of household food waste indicates the potential savings to be derived from food waste collections under the private cost metric, these being significant in some cases where the introduction of food waste collections can be used to improve the efficiency of the existing collection operations. This is can be found in Section 8.1.1 of the Main Report.

Metals

- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for metals could result in net benefits to society of £75 million, and a ban on unsorted waste could increase these benefits to £800 million over the period examined.

Paper and Card

- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for paper and card could result in net benefits to society of £130 million, and a ban on unsorted waste could increase these benefits to £720 million over the period examined.

Textiles

- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for textiles could result in net benefits to society of £110 million, and a ban on unsorted waste could increase these benefits to £250 million over the period examined. For textiles, therefore, although modelling suggests there would be additional private costs associated with the introducing restrictions or bans (in terms of collection and management), the analysis of benefits from the societal perspective suggests that the environmental benefit justifies the additional costs.

Plastics

- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for plastics could result in net costs to society of £170 million, and a ban on unsorted waste could increase these costs to £480 million over the period examined. For plastics, therefore, although the environmental benefits are significant, they do not appear to be justified by the additional costs. It should be considered that this observation applies to additional plastics recycling over and above levels already assumed to occur in the baseline, and does not necessarily imply that existing levels of recycling are not justified.

Wood [2]

- For wood there is a drop in savings under the requirement to sort as it assumed that more of the wood is of lower grade, and costs more to manage through recycling / recovery systems.
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for wood could result in net benefits to society of £48 million, with the equivalent figure under a ban on unsorted waste being £21 million over the period examined.

Green waste

- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that the benefits to society of a landfill restriction for garden waste are close to zero, whilst there may be net costs to society of £84 million under a ban on unsorted waste. Existing market drivers are already strongly influencing the sorting of garden waste, even though the cost benefit analysis might suggest this is not justified. This highlights the fact that excluding the major driver of behaviour regarding garden waste management – the landfill tax – from the financial analysis can lead to conclusions that appear counterintuitive in the current market context.

Glass

- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that the benefits to society of a landfill restriction for glass are around £9 million, whilst under a ban on unsorted waste, the benefits are close to zero (around £3 million). Once again,

[2] Results of the Cost Benefit Analysis for Wood Waste have already been updated and provided in 'Landfill Bans Feasibility Research: Wood Update,' August 2012, published to coincide with Defra's Call for Evidence on Wood Waste Landfill Restrictions in England http://www.wrap.org.uk/content/wood-waste-update-0

this highlights the fact that existing market drivers are already strongly influencing the sorting of materials, in this case, glass.

WEEE

- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for WEEE could result in net costs to society of £20 million, and a ban on unsorted waste could increase these costs to £200 million over the period examined. For WEEE, therefore, although there are environmental benefits, they do not appear to be justified by the additional costs. The costs for collecting additional WEEE are highly uncertain, and heavily dependent upon the pre-existing infrastructure and how easy this is to adapt to collection of, for example, small WEEE items.

It should be noted that the above analysis assumes that all the wastes are diverted from landfill, and that the conclusions in respect of the requirement to sort are likely to change if the model is adapted so that the nature of the residual waste treatment used to deal with unsorted waste reflects the expected mix of treatments which may be in place in future.

3.1.2 Biodegradable Waste Ban

The biodegradable waste ban was considered separately. Summary results are presented in Table 3. The modelling assumed that none of the material based measures were implemented. Hence, the main effect is to shift the majority of waste from landfill into other residual waste management options, of which the Steering Group agreed a small number to be modelled.

- The median net benefit to society is negative in all cases. This means that there are social costs in all cases, and these costs are most pronounced for treatments which include thermal processes (such as incineration and gasification). This reflects the balance of two key factors: the avoided impact associated with not landfilling the waste, and the costs of the switch.
- The option with MBT[3] including stabilisation of waste and output to landfill performs the most favourably, from society's perspective, in this modelling when compared with the four thermal treatments.
- When viewed from the perspective of private costs, the analysis does not change fundamentally. There are still net financial costs, although these are lowest (and relatively small) where the switch is into incineration. The analysis effectively assumes a closed market for residual waste treatment, and no allowance has been made for recent developments in respect of, for example, the export market for RDF.
- A ban on biodegradable waste would be expected to improve investor confidence in the provision of alternatives to landfill, and this effect might be expected to be stronger in the case of the commercial and industrial waste sector, where security of supply of waste into treatment facilities remains a major barrier to securing financial support.

[3] *Mechanical Biological Treatment*

Table 3 Summary Results for Biodegradable Waste Ban

	Incineration (elec)	Incineration (CHP)	MBT: Output to landfill	MBT: SRF to Dedicated	MHT: Output to gasification
Total Waste Diverted (2009-24), Mtonnes	180	180	180	180	180
Total CO_2 eq Savings (2009-24), Mt	39	49	80	37	44
Energy Generated, GWh (2009-24)	110,000	180,000	-10,000	56,000	100,000
NPV Financial Savings (Private Metric), £million	-£360	-£4,000	-£3,100	-£2,900	-£2,500
NPV (2009-24) Net Env. Benefits, £million	-£410	£580	£2,200	-£130	£680
NPV Financial Savings (Social Metric), £million	-£3,500	-£5,500	-£3,700	-£4,600	-£5,900
Regulation / Communications Component	-£0.47	-£0.47	-£0.47	-£0.47	-£0.47
Net Benefit to Society (2009-24), £million					
Upper	-£2,900	-£3,800	-£510	-£3,700	-£4,000
Median	**-£3,900**	**-£4,900**	**-£1,500**	**-£4,700**	**-£5,200**
Lower	-£4,900	-£6,000	-£2,400	-£5,800	-£6,300

3.2 Practical Considerations

- Meaningful enforcement of material based measures would seem to imply a need for lead in times of no less than five to seven years before the introduction of full policy measures. This is likely to be true especially for those wastes, for example, Food, Wood and Garden waste, where reliance upon treatment infrastructure might be expected to be significant (for some other materials, the main change required is in respect of collection, with materials being reprocessed either domestically or overseas).
- For the ban on biodegradable waste, a longer lead-in period of the order 7-10 years seems likely to be warranted partly because of the pressure that would be faced by the planning system as currently configured, and also because the measure would affect a greater quantity of wastes than any of the other measures (in fact, more than ten times as much – see **Table 3**). Timescales at the lower end of this period might be achievable in the DAs, where the measure affects a much smaller absolute quantity of waste.
- Before a ban on biodegradable waste was implemented it would seem to be important to make sure that the levels of recycling have attained something close to what is deemed desirable from the point of view of society. If this was not the case, then climate change and resource efficiency gains may not be fully realised. It is worth noting that many countries with bans / restrictions in place have sought to ensure that instruments designed to encourage recycling and composting / digestion are in place *prior to*, or shortly after, a ban has been announced.
- The quality of the additional materials / products being collected from the waste stream for treatment and reprocessing would need to be considered. A 'requirement to sort' – as the key complementary measure for the ban on unsorted wastes - should seek to strike a balance between ensuring quality of materials on the one hand, whilst not being too prescriptive, in terms of collection system, on the other.
- In the case where a requirement to sort is used, it would seem sensible to extend the 'ban on unsorted waste' to all residual waste treatments so that the requirement to sort is not 'sidestepped' where material is being sent to alternative residual waste management method;
- Restrictions or bans may also (especially as landfill tax rises) see increased incidences of fly-tipping and illegal exports. This is likely to place additional requirements on regulators as they seek to grapple with an already challenging set of circumstances. For this reason, additional resources may be necessary to minimise unintended consequences of restrictions / bans. Equally, if a requirement to sort is specified so that materials collected for recycling are of high quality, this might actually alleviate some existing problems.

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Glossary

AD – Anaerobic Digestion
BMW – Biodegradable Municipal Waste
C&D waste – Construction and Demolition Waste
C&I - Commercial and industrial waste
CV - Calorific Value
CBA – Cost Benefit Analysis
CHP – Combined Heat and Power
DAs – Devolved Administrations
EA – Environment Agency
GHG – Green House Gas e.g. sulphur dioxide
HWRA – Household Waste Recycling Act
HWRC – Household Waste Recycling Centre (sometimes known as civic amenity site)
Known Property (Ban) – describes a physical characteristic of a waste that can, in general, be determined by visual inspection. Examples would be 'combustible' or 'recyclable'
MACCs – Marginal Abatement Cost Curves
Measurable Property (Ban) – refers to a test, which could be a chemical test, a density test or another form of measurement, that determines whether or not the waste is of a particular type, or has a value for that property which is within a certain threshold limit of whatever characteristic the test relates to, be it biodegradability or density, etc
MBT – Mechanical Biological Treatment
MHT – Mechanical Heat Treatment
MRF – Materials recycling facility
MSW – Municipal Solid Waste
NPV – Net present value
OVAM – Public Waste Agency of Flanders
SEPA – Scottish Environmental Protection Agency
SWMPs – Site Waste Management Plans
VFG – Vegetables, Garden and Fruit (waste)
WEEE – Waste Electrical and Electronic Equipment
WTN's – Waste Transfer Note(s)

Acknowledgements

We are grateful to the Steering Group for the original work for their comments throughout the process. We would also like to thank all those who attended the workshops in the course of the original work for their input. We thank the representatives of Defra, Scottish Government, Welsh Government, Northern Ireland DoE and WRAP for comments on this amended version. Finally, we would like to thank Sarah Gray of WRAP for her helpful comments and contributions during her management of the original and revised versions of the study. We would also like to thank Steve Nelson at Defra for his helpful contributions and his thorough comments on our work.

1.0 Background

1.1 Update of analysis

Eunomia Research & Consulting is very pleased to present this Final Report concerning the Environmental, Economic and Practical Impacts of Landfill Bans. This is an update of an earlier version of the report (published in 2010) which reflects two changes to the modelling, and an additional piece of analysis:

1. First, an error in the calculation of the landfill externalities was identified in the initial report. This error led to an overestimate of the negative externalities associated with landfill, and has been corrected;
2. Second, the opportunity was taken to revise the modelling of landfilling to reflect the latest version of MELMod, a model used by Defra / DECC to report emissions from landfill in the UK to the IPCC.[4] The principle effect of this change is, as with the aforementioned modelling error, also to reduce the extent to which landfills are assumed to generate methane; and
3. Third, some additional analysis was undertaken in respect of the cost of household food waste collections to help shed further light on the merits or otherwise of requiring the sorting of food waste under current market conditions.

Other than in these respects, the modelling remains unchanged from the previous version (and much of the text remains as before). In this respect, it is worth of note that at the time of the initial modelling, the landfill tax was set to rise to £72 per tonne, and no higher. This level of tax was used to establish the baseline against which the effects of additional measures were modelled. In this revision to the report, no changes were made to the baselines used in the initial modelling.

1.2 Research aims

The aim of this research was to conduct a feasibility study regarding the impacts of introducing landfill bans (other than those currently in place as a consequence of EU legislation) in England, Scotland, Wales and Northern Ireland. The study sought to discover whether the costs and benefits of different landfill bans or restrictions (i.e. measures to ban or restrict waste from landfill) justify their use and examined issues of feasibility. Key objectives for considering bans and restrictions, shared by Defra and the Devolved Administrations (DAs), were to:

1 Reduce the climate change impacts of managing waste
2 Contribute to increases in resource efficiency

Additional aims of the study included seeking to understand how landfill bans and restrictions could help meet Landfill Directive targets for biodegradable municipal waste; contribute to the generation of renewable energy and heat; increase economic and business opportunities; increase market certainty regarding the development of collection, reprocessing and treatment infrastructure; and explore potential health benefits from reduced landfilling.

1.3 Definition of terms and scope of the report

For clarification, the terms 'landfill ban' (where the intention is that as little as possible of the targeted waste is landfilled at all) and 'landfill restriction' (whereby the policy mechanism is intended to restrict, or significantly reduce waste entering landfills) are both used in this report. We have sought to use one or the other where we are referring to only one of these.

Given the two key objectives for the bans and restrictions (indicated above), the scope of what should be considered as 'a landfill ban or restriction' expanded throughout the course of the study to include measures to encourage recycling or recovery, with some level of check applied at the landfill on the sorting process of

[4] *See Eunomia (2011) Inventory Improvement project – UK Landfill Methane Emissions Model, Final Report to Defra and DECC, January 2011, http://www.decc.gov.uk/assets/decc/research/1213-greenhouse-gas-inventory-improve-project.pdf*

targeted materials / streams which would have the effect of restricting landfill. Consequently, the scope of what is included as a ban or restriction has come to span what one might consider complementary measures, with the check on what is being landfilled becoming somewhat secondary in significance to these complementary measures. This is for the simple reason that the objective of increasing recycling is not, in general, the same as ensuring that it is not landfilled (determining that waste should not be landfilled is not the same as requiring that as much as possible should be recycled).

It was not the aim of this study to carry out assessment of complementary policies beyond those deemed absolutely necessary for the ban or restriction to take effect. Alternative approaches to increasing recycling are not within the scope of this work though we note that there may be alternative means to achieve the objectives set out above than those which are considered in this report.

This report goes someway to presenting the *quantitative* outputs deemed most applicable for representation in a document such as this. It does, however, have to be noted that Defra and the Devolved Administrations (DAs) are being presented with the model developed for the work to enable them to undertake their own additional modelling and analysis of the different policies, sensitivities and variants. As such this report only claims to present the data for some specific scenarios, with the range of these possible scenarios being very much greater (in terms of start date, different baseline assumptions and so forth). The principle intention here is to inform decisions regarding which bans and restrictions show greatest promise in terms of their possible costs and benefits, and to estimate their likely magnitude.

It is also important to note that because of the way in which the model was initially developed (as a model examining the effects of 'stopping material from being landfilled'), the results reflect what would be expected if additional material being recycled would otherwise have been landfilled. In practice, some measures were considered appropriate for examination as the work progressed. This included measures to require some materials to be segregated at source (a 'requirement to sort' a material, or a range of materials). It is clear that the counterfactual fate of the material in that case is not always landfill. As such, a further report will be developed to understand the implications of more realistic assumptions regarding the effect of a requirement to sort. This would divert materials to recycling not just from landfill, but from any residual waste treatment which would otherwise be used to treat the material at the time.

1.4 Structure of the Report

The study included a range of deliverables along the course of the project. This report is structured in the following way:

- Section 2 gives an overview of the methodology.
- Section 3 summarises the material which was used to develop preliminary thoughts concerning a landfill ban.
- Section 4 highlights the restrictions and bans which were chosen for further analysis in the cost-benefit analysis.
- Section 5 considers these restrictions and bans in more detail, giving consideration to how these policies might be designed, and how they might be expected to function.
- Section 6 considers what complementary policies would be necessary, taking into account the discussion in Section 5.
- Section 7 then sets out our approach to the cost-benefit analysis and the assumptions underpinning what we expect to be the effects of the restrictions and bans.
- Section 8 reports the results of the cost-benefit analysis and other modelling outcomes. It includes sensitivity analysis around key parameters.
- Section 9 addresses some other issues likely to arise in the context of the application of the policies under consideration.
- Section 10 contains our conclusions and recommendations.

The Report benefited from a peer review carried out by a team of consultants, led by ERM, at the request of WRAP towards the end of the original study. Eunomia is grateful to the peer review team for the helpful suggestions made in that process, the majority of which are reflected in this Final Report. A separate report was prepared by ERM to accompany the original study. The revised work has also benefited from a thorough peer review of the model undertaken by WRc. We are grateful to WRc for the suggestions made which, again, are reflected in the revised version of this report.

2.0 Research Approach

This section of the report summarises the steps taken to carry out the assessment of landfill bans and restrictions. The Project has been guided by a Steering Group including representatives from:

- Defra;
- Scottish Government;
- Welsh Assembly Government;
- Department of the Environment, Northern Ireland;
- Environment Agency;
- Scottish Environmental Protection Agency (SEPA); and
- WRAP.

The approach to the project was agreed at the start of the project. This included a number of meetings to discuss findings during the course of the research. The outline approach for the study was as follows:

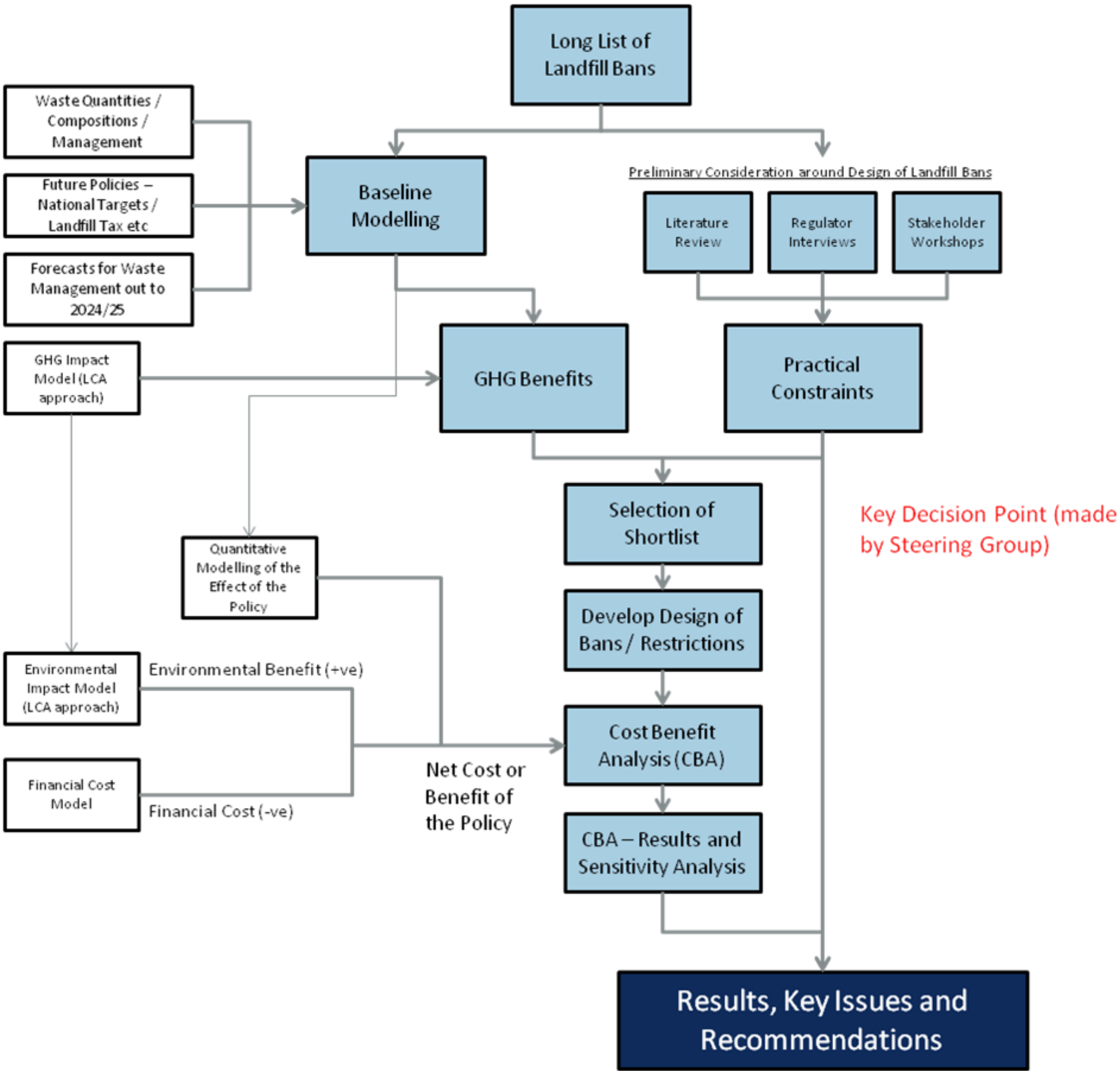
1. Develop a baseline model, including the estimated effects of the landfill tax going forward;
2. Carry out modelling of the climate change impacts of the different ways of managing the specific materials and waste streams of interest, with specific reference to the greenhouse gas impacts of better management of wastes which are currently landfilled;
3. Determine the practical feasibility of a long list of different bans through:
    a. A literature review;
    b. Discussions with representatives of the Environment Agency and SEPA; and
    c. Workshops, with stakeholders, in each of England, Scotland, Wales and Northern Ireland;
4. Propose, and agree, a short list of bans for detailed modelling referring to findings from steps 2 and 3, above;
5. Consider in more depth, the practical design for implementation for each ban to understand its likely impact, and the costs of implementation;
6. Model each of the bans through a Cost Benefit Analysis (CBA) in line with principles set out in HM Treasury Green Book methodology;
7. Consider issues which could arise as a result of implementation of restrictions and bans; and
8. Draw out key conclusions and recommendations.

This piece of research was complex and challenging. There were many different elements to the study and several key decisions had to be made as the study progressed. Some key decisions in the study were taken by the Steering Group or in close consultation with them.

It is recognised that alternatives exist in any model or study. Where these were considered significant the uncertainties have been highlighted in the report, when appropriate.

To describe the approach clearly, a diagrammatical representation of the study is given in Figure 1 below, followed by sections describing each element.

Figure 1: Schematic of Approach to the Study



2.1 Long List of Landfill Bans and Restrictions

A long list of all the potential types of landfill bans and restrictions was developed. The aim was not to eliminate any possibility without giving it adequate consideration.

The initial long list of potential landfill bans and restrictions covered a wide range of materials and products, streams and 'properties' (see Section 4.0 for details). Throughout the study, and this report, references will be made to the different types of landfill bans and restrictions. A general description of each follows:

- Material / Product based - relate to all, or part, of a certain type of material or product;
- Bans by 'waste stream' - relate to the 'stream' of waste coming from a particular sector, for example, municipal or commercial waste streams. A ban would therefore relate to all waste in either stream;

- Bans by 'known property' - this describes a physical characteristic of a waste that can, in general, be determined by visual inspection. Examples would be 'combustible' or 'recyclable'. The ban would thus relate to any material considered to be defined in this way; and
- Bans by 'measurable property' - refers to a test, which could be a chemical test, a density test or another form of measurement, that determines whether or not the waste is of a particular type, or has a value for that property which is within a certain threshold limit of whatever characteristic the test relates to, be it biodegradability or density, etc.. The ban would apply to waste with a characteristic that falls outside whatever threshold is set.

2.2 Baseline Modelling

In order to understand the effect of bans and restrictions, it was necessary to understand how waste quantities might evolve, and how the management of waste being generated might change, in future years in the absence of any landfill bans or restrictions. This baseline modelling was based around current and emerging strategies in England and the DAs. Representatives for each country were consulted, and have verified, the approach taken to baseline development. Full details of the baseline development, including modelling the effect of the landfill tax, are provided in Appendix 1.

The effect of the bans and restrictions is considered, therefore, against a baseline which reflects not just current, but expected future behaviours. The greater one anticipates the effect of the landfill tax escalator, for example, to be on waste management, the less scope there would be for landfill restrictions and bans to achieve a significant effect over and above that of the tax. This shows that the development of the baseline is a crucial part of the study insofar as it determines the potential magnitude of the effect that landfill bans and restrictions may have. Note that no changes have been made to the baselines as they were agreed in the original work (so they reflect decisions that had been made at that time, and reflect a situation where the landfill tax was due to rise to a maximum level of £72 per tonne in nominal terms).

2.3 Modelling of Climate Change Impacts

In order to inform the short-listing process, a model was developed which was designed to show the GHG impacts of different ways of managing specific materials when they were taken out of landfill and sent to different alternative routes of reprocessing or treatment. This included recycling, composting, anaerobic digestion, incineration (electricity only, CHP and heat only), mechanical biological treatment (MBT) with incineration of SRF, MBT with stabilised output to landfill, and mechanical heat treatment (MHT) with gasification.[5] The literature review gave little reason to believe that a landfill ban would have a strong impact on waste prevention. This was thought especially unlikely in the UK post-2013, at which point the cost of landfilling would be close to the cost of the closest alternatives for residual waste treatment. Prevention effects were not, therefore, included in the modelling (hence why waste prevention was considered in the literature review).

Given that the greenhouse gas (GHG) modelling work was used to form a large part of the cost benefit analysis we do not include an initial section on the development of this model, despite some initial GHG results being presented in Section 4.0 (Selection of Bans for Short List). All the relevant data and modelling assumptions can be found in Appendix 9.

2.4 Preliminary Considerations in the Design of Landfill Bans or Restrictions

These initial stages of the study were designed, primarily, to draw out practical constraints and operational issues with landfill bans. Any relevant data gathered, which related to the rationale for a particular landfill

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[5] It was agreed with the Steering Group not to model a wide array of residual waste treatment options. The view was taken that the aim of the work should not be to 'specify' a preferred form of residual waste treatment, but there was interest in understanding the extent to which the chosen variants (suggested by the Steering Group) gave different outcomes. Generally, landfill bans do not determine 'where the banned material goes'. That is determined by the effect of other existing, or complementary, policy instruments.

ban, was also reported on, where it was felt the issues bore a strong relation to the decisions around how they may be designed. At this stage, the details of the design of a given ban or restriction had not been closely considered as all options were deemed to be 'open'.

2.4.1 Literature Review

A report by Green Alliance, 'Landfill bans and restrictions in the EU and US' was published in August 2009, so the intention of the literature review in this study was to build on this review and provide supplementary information and evidence on the effects of landfill bans elsewhere.[6] The review provided evidence on practical feasibility of different landfill bans from international experience.

A summary of the key issues from the review is given in Section 3.1. The material upon which the identification of these issues was based is provided in Appendix 2.

2.4.2 Discussions with Environment Agency and SEPA Representatives

Prior to the stakeholder workshops (see below), detailed discussions were held with regulators from the Environment Agency (EA) and Scottish Environmental Protection Agency (SEPA) to understand some of the key issues likely to be confronted when considering landfill bans and restrictions, and hence, develop the structure of the debate at the workshops (see Section 3.2). It was felt important to understand the way in which existing bans (on, for example, tyres) had been implemented, and the issues which the regulators had been confronted with.

2.4.3 Stakeholder Workshops

Workshops were run in each of the four nations in the UK. The full agendas for these discussions are in Appendix 3. The workshops covered:

- Lessons from current landfill bans in the UK;
- Ways of implementing landfill bans;
- Streams, wastes, materials or products which might be banned; and
- Lead times and communications mechanisms required for bans.

The workshops were run as discussion groups with relevant stakeholders to draw out some of the practical aspects of landfill ban design. Attendees were limited to regulators and policy makers. Wider public consultations will follow in each country, if the policy is to be taken further.

The workshops were run in the following locations, but in this report shall be referred to by the relevant devolved administration, for consistency. It should be noted that views are not necessarily those of the project steering group nor of the relevant devolved administration for the nation referred to in each case.

- London (England);
- Cardiff (Wales);
- Edinburgh (Scotland); and
- Hillsborough (Northern Ireland).

The workshops were run by Eunomia Research & Consulting. Summaries from each have been provided (see Section 3.3).

The views of relevant stakeholders also helped to highlight key issues relating to the feasibility of different landfill bans. This could then be used to provide evidence as to which should be considered in the CBA.

2.5 Selection of Bans for Shortlist

Bans and restrictions which were either not feasible, or for which some other overriding reason were undesirable in the UK context, were not included in the CBA stage. The *practical constraints* and *GHG*

[6] *Green Alliance (2009) Landfill Bans and Restrictions in the EU and US, Final Report to Defra (ref WR1202) August 2009*

benefits associated with bans and restrictions were the two key factors that provided the rationale behind the short-listing decision (see Section 4.0).

The environmental benefits were given greater weighting by the project steering group, with relatively little weight placed upon the practical constraints related to design and implementation of bans at this stage. This reflects the desired objectives of the policy. It was reasoned that if the GHG benefits were significant, then even if practical constraints appeared to exist, government might be willing to do more to work round these to enable implementation of those restrictions or bans. Note also that because of the study's main subject, the GHG effects were considered, in all cases, from the perspective of the gains which could be made relative to landfilling.

2.6 Develop Design of Each Ban

Once the shortlist of bans had been agreed upon, then in order to understand the costs of implementation and the likely responses, and hence, the overall costs and benefits of their use, a more complete description of the bans and restrictions, and how they would be applied, was required. In developing the design of each of the bans or restrictions, members of the Steering Group including the Environment Agency, Defra and also SEPA and the Scottish Government were consulted (see Section 5.0.

As noted above, this section of work was required as the Steering Group had a focus on ensuring the landfill bans or restrictions would meet the main desired objectives of the policy i.e. climate change mitigation and resource efficiency. Additional consideration as to the design of the policies, above and beyond those investigated in the 'preliminary considerations' stage, was, therefore, required. This led, in turn, to consideration of complementary policies (see Section 6.0).

2.7 Cost Benefit Analysis

Having already established the baseline, the tasks required for the full Cost Benefit Analysis (CBA) stage were:

- Environmental modelling of waste management processes;
- Financial modelling of waste management processes;
- Modelling of changes in mass flows of different materials to different treatments (relative to the baseline);
- Estimation of costs to the regulator and to operators of implementing the ban / restriction;
- Estimation of communication costs; and
- Developing outputs in terms of financial costs, environmental costs, and net costs to society.

Further details regarding the cost benefit analysis are given in Section 7.0 and Appendices 9 to 12.

2.8 Results and Sensitivities

Given the uncertainties in many of the assumptions required to perform a quantitative analysis of this nature, sensitivity analysis is important in order to highlight how sensitive the results are to changes in certain parameters. There was particular interest on whether or not (and under what conditions) the sensitivity analysis would imply a change in the policy recommendation implied by the analysis of costs and benefits. The peer review process usefully pointed out additional sensitivity tests that might be performed following the publication of a draft final report. The results from the CBA stage are given in Section 8.0. Additional discussion about how key variables have affected the results is given in Appendix 13.

2.9 Other Relevant Issues

The implementation of a restriction or ban may give rise to various consequences which, though they might be possible to identify, are rather difficult to quantify (in terms of their effects). Some of these relate to what might be termed the transition from the pre-restriction / ban regime to one where restriction or a ban has been implemented. We seek to identify these in Section 9.0.

2.10 Conclusions and Recommendations

The key conclusions of the research are highlighted along with recommendations for taking forward the landfill restrictions and the ban. These are reported in Section 10.0.

3.0 Preliminary Considerations in the Design of Landfill Bans or Restrictions

This Section summarises the following research areas which formed part of the evidence base used for the selection of bans, which were deemed to be worthy of further consideration at the CBA stage:

- Literature review;
- Regulator interviews; and
- Stakeholder workshops.

This Section has not been changed since the original version.

3.1 Literature Review of Existing Landfill Bans / Restrictions

More detail concerning the nature and implementation of landfill bans in other countries is given in Appendix 2. The key issues are summarised here.

3.1.1 Where Have Landfill Bans Been Applied and Why

All European countries are required to implement bans and restrictions on the landfilling of certain types of waste as a consequence of the Landfill Directive. This outlaws the landfilling of:

- Whole and shredded tyres;
- Liquid wastes;
- Wastes which are explosive, corrosive, oxidising, flammable or infectious; and
- Wastes which have not been pre-treated.

Countries with landfill bans beyond those listed above are shown in **Table 4** below. We also show the other instruments used in the countries concerned to deal with residual waste. Very few countries use *only* bans to influence how residual waste is handled. Germany and Wallonia (in Belgium) are exceptions within Europe. Indeed, given that landfill taxes and landfill bans are instruments which appear to have similar aims, it is interesting to note that countries with landfill bans in place are, in many cases, those with the highest landfill taxes. Should England and the DAs choose to implement landfill bans, therefore, they will be in a similar position to these countries given that the UK landfill tax will, in 2013, be one of the highest landfill taxes in the EU (unless other countries decide to make quite significant increases in their existing taxes).

Green Alliance has conducted interviews with representatives from other countries on landfill bans. They asked respondents why landfill bans had been introduced in their countries to help understand the motivations and drivers behind the decision, and to better understand the corresponding policies used to help achieve the objectives in question. These responses suggested that landfill bans and restrictions have been implemented in other countries for the following main reasons:

1. To promote upstream changes in material use;
2. To move waste management up the hierarchy;
3. To shift waste from landfill into incineration; and
4. To mitigate problematic emissions (such as Greenhouse Gases) that arise from certain materials in landfill.

While not all directly report this to be the case, it seems that in all the European countries examined by Green Alliance, the objective to recover energy from waste has also been a reason for introducing bans. For example, in Flanders, the ban on landfill covers 'waste suitable for incineration', making it implicit that the ban encourages the generation of energy from waste. In Germany, the initial design of the ban would have prevented landfill of materials which had not been incinerated first (because of the standard initially proposed for pre-treatment). Energy from waste has also been a major feature of the Danish system of taxes and bans (not examined in the Green Alliance report). In addition to these objectives, it seems reasonable to suggest that in Germany, the scale of greenhouse gas emissions from landfills also led to a focus on a landfill ban in line with national greenhouse gas reduction plans.

Table 4 Countries Making Use of Landfill Bans, and Accompanying Instruments

Country	Landfill Ban		Landfill Tax		Incineration Tax	
	Date of Announcement / Implementation	Scope of Ban	Date of Implementation	Tax Rate (MSW, €/tonne)	Date of Implementation	Tax Rate (MSW, €/tonne
Austria	2004	Biodegradability and other criteria	1989	(87)/26[7]		7
Belgium-Flanders	1999 2006	Unsorted wastes Sorted and non-sorted wastes for recovery Combustible residual fraction from sorting Wastes suitable for incineration	1987	60		7
Belgium-Wallonia	2004	Various	2004-2010	none		3
Denmark	1997	Combustible waste	1987	50	1993	44
Finland	2005	Biodegradable and compostable waste	1996	30		
Germany	2005	Biodegradability and other criteria				
Italy	2003/2007	Biodegradability and other criteria	1996	26[8]		
The Netherlands	1996	Various, incl. household waste	1996	85		
Norway	From mid-2009	Biodegradable waste	1999	40		Pollutant based
Sweden	2002 2006	Combustible waste Organic waste	2000	43	2006	49
Nova Scotia	1996-2008	Various recyclable fractions				

[7] *The €87 per tonne figure was applied for untreated MSW and the €26 per tonne is for material which has undergone mechanical biological treatment. For MSW to be treated thermally the tax is €7 per tonne which results in a broadly equal position between MBT and incineration when one considers that the tax applies to the landfilled output from the MBT process, not the input. If 25 – 30 % of the plant input is landfilled, then the tax on MBT broadly equates to that on incineration.*

[8] *Highest rate is given. Lowest rate set regionally can be €10.*

Typical targets for landfill bans / restrictions are:

- Combustible wastes / waste suitable for incineration;
- Wastes exceeding a threshold level of biodegradability;
- Materials which have been collected separately for recycling; and
- Organic / compostable wastes.

There are a very small number of cases where specific materials are targeted by a landfill ban or restriction. Where specific materials are listed under the scope of a ban, the mechanism used for implementing the ban rarely focuses upon identifying a material with the objective of banning it. More often, such bans are achieved through other mechanisms, such as requiring collection systems for sorting the targeted materials to be in place.

The Steering Group was particularly interested in material-based approaches, notwithstanding the limited number of cases where such bans had been implemented. There was interest in the approach in Flanders, whereby bans on the landfilling of 'unsorted waste' (and later, on incinerating 'unsorted waste') were implemented. However, the implementation of these bans post-dated the requirement upon local authorities to implement waste collection services of a minimum standard, and the requirement upon commerce and industry to sort specified fractions of waste. In this context, therefore, the bans on landfilling and incinerating unsorted waste, one after the other, appear to have been designed to support the existing 'requirements to sort', rather than being principle drivers themselves to ensure that waste would be 'sorted'. Evidently, a ban on 'unsorted waste' requires that what is implied by 'sorting' is clearly defined.

Green Alliance suggests that the scope of bans tends to be established with reference to: [9]

1. The source of waste;
2. The type of waste, as defined by its recoverability; and
3. Physical characteristics of the waste, such as whether or not it is combustible, or through reference to fermentability, or total organic carbon content.

However, the report highlights that compliance with the terms of the ban is implemented through various means, these relying (to varying degrees) on the landfill operator and the waste holder.

What seems important is that landfill bans, whatever their scope, have to be enforceable in some way. Apparently complex bans, such as that of the Netherlands, which lists more than 30 types of waste, are best suited to a simple implementing mechanism. Hence, in the Netherlands, the rather complex list of materials subjected to a ban is reduced – for the purposes of implementation and enforcement - to a requirement to ensure that all materials falling below a threshold level of density are banned from landfill.

3.1.2 Evidence of Environmental Effects

The consequences of landfill bans are difficult to separate out from the effects of other instruments in place at the same time, including landfill and waste taxes but also other instruments such as producer responsibility and requirements to sort waste. A ban on landfill does not dictate where the material which can no longer be landfilled will be sent. Other policies, and market conditions, will tend to dictate how this material is managed once it can no longer go to landfill. In the case of some bans, the specific design of the ban can influence what is or is not acceptable, but it is unlikely to be able to steer waste into a specified end management route.

In the absence of alternative interventions, the effect of a ban will, most likely, be affected by the costs of the competing options for dealing with a given waste stream. In very basic terms, the ban rules out the option of landfilling for the banned waste stream. A tax might have a similar effect for given materials if it is set at such a rate that under reasonable assumptions regarding how low pre-tax gate fees could fall, landfilling is no longer, from the perspective of costs, an economically viable option.

The Green Alliance report states quite clearly that research highlights the role played by other policies. In four of the cases assessed by Green Alliance – Flanders, Netherlands, Austria and Sweden – the price for residual waste treatments other than landfill is made roughly equal to, or lower than, that of landfill by the taxes in place. From an economic perspective, the effect of a landfill ban is equivalent to setting an infinite tax on landfill (subject to any exemptions applicable). Where landfill taxes already make other residual waste treatments competitive with landfill one might expect the following:

[9] *Green Alliance (2009) Landfill Bans and Restrictions in the EU and US, Final Report to Defra (ref WR1202) August 2009*

- A reduction in landfilling.
- Greater certainty to those seeking to develop alternatives to landfill for residual waste that there will be an increase in the available supply of waste, subject to the ban / restriction being properly enforced.
- Only a very limited impact on recycling or waste prevention. This is because the financial rationale for prevention and recycling will be influenced by the avoided costs of residual waste treatment and disposal. If this barely changes (because of an already high cost of landfill), then any incentive implied by the ban is likely to be weak, with the exception of those materials for which residual waste treatments are especially expensive.

Waste Prevention
As might be expected for policies developed principally to *discourage disposal,* the evidence presented suggests there is minimal effect on waste prevention from landfill bans on their own, and that any preventative effect ought, probably, to be attributed to the combination of policies at work in a specific country, and the general attitude to waste management of the population.

A landfill ban operates like an infinite tax. In doing so, it effectively excludes landfill as an option for managing waste, but it leaves all other options open. In Germany and Wallonia, the absence of waste taxes implies that the ban drives the switch away from landfill, and to alternative forms of management. The ban itself – rather than a tax - generates the most important price effect, which might be expected to give rise to increases in waste prevention activity (at the margin) related to the increased avoided cost of managing residual waste.

Examining variable charging schemes in Germany suggests that the cost differential between landfill and incineration / other pre-treatment anticipated by some local authorities in the years prior to the ban on landfilling being enforced led to them reconfiguring the charging schemes they used to incentivise households to increase recycling and prevent waste.[10] National data for Germany does not give a completely clear view regarding effects on waste prevention. There has been a quite significant drop off in municipal waste in recent years, though the picture is far less clear in respect of production and commercial waste (equivalent to commercial and industrial waste in the UK). This has shown a more volatile trend. The main change in total waste quantities is shown through reductions in construction and demolition waste landfilled, this being affected by different drivers to the landfill ban.

The same financial stimulus to prevention would not be expected in the Netherlands or Flanders, for example, where such a cost differential has been eliminated, or very nearly so, by the existence of landfill levies. Another country in a similar situation is Denmark. The year in which the landfill ban was introduced, 1997, was the same year in which the waste tax was significantly increased. Studies by CESAM suggest the tax, not the ban, has influenced changes in landfilled quantities, but that these effects have been at best limited outside the sphere of construction and demolition waste.[11] One commentator notes:[12]

> *As a conclusion it could be said, that while taxes are very effective in changing the way waste is managed, it seems as if they have no or very little effect on the total amount of waste generated. Denmark has not succeeded in de-linking the growth in waste from the growth in GDP.*

These situations (Netherlands, Flanders and Denmark) are ones which most closely reflect the UK situation as it will be once the landfill tax reaches £72 per tonne, at least in respect of the potential impact of a landfill ban on waste prevention.

Recycling
Recycling rates in most of the countries considered in our review have been increasing. As with waste prevention, however, there is relatively little documented evidence to demonstrate that the introduction of a landfill ban leads directly to an increase in recycling. As with waste prevention, the effects specifically attributable to the ban are confounded by the effects of taxes (as well as a wider array of policy instruments).

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[10] See the case of Landkreis Schweinfurt in D. Hogg (2006) Impact of Unit-based Waste Collection Charges ENV/EPOC/WGWPR(2005)10/FINAL, Paris: OECD and Eunomia (2003) To Charge or Not to Charge? Final report to IWM (EB).

[11] Miljøstyrelsen, Working report no. 18, 1999; and Miljøstyrelsen, Working Report no. 23, 1999.

[12] Suzanne Arup Veltzé (2003) Taxes on Waste, a Steering Instrument – Experience from Denmark, Presentation at ISWA Beacon Conference Seminar, 23-24 October 2003, Malmo, Sweden.

The general impression from the review is that there is rather weak evidence to support the view that landfill bans have had a strong impact upon increasing recycling rates. Some difficulty clearly remains in disentangling the effects of a ban from other policies, though this does constitute evidence that there is no effect from the bans. High landfill taxes are part of the mix of other policy instruments that are often deployed with landfill bans. If existing landfill taxes make landfill more expensive than, or similar in price to, other treatments, any additional effect of a ban *per se* is likely to be weak since the financial attractiveness of alternative options for managing waste (such as incineration, MBT and recycling) will already be established to a considerable degree. As long as one of these is a) available and b) technically appropriate, logic would suggest that a ban might have limited additional effect on recycling. This is because the ban would be doing little to change the costs of residual waste management, and this is a key driver in making the financial case for recycling.

Further details with some specific examples from other countries are explored in more detail in Appendix 2.

Changes in Residual Waste Management

The extent of any reduction in landfilling which can be specifically associated with a ban is also, perhaps surprisingly, difficult to disentangle from the effects of other policies, at least in some countries. There is clearly likely to have been an effect. This effect tends to be easier to observe in the cases – such as in Germany – where the level of tax on landfilling is low, but where the ban has been enacted. Here, one can be fairly confident that, given the much lower cost of landfilling, it is the ban which motivates the movement of residual waste away from landfill and into incineration and MBT treatments. Incineration in Germany has increased from 9.4 million tonnes in 1993 to 17.8 million tonnes in 2007, whilst an estimated 6 million tonnes is now treated through MBT.

In Flanders, by contrast, the decline in landfilling of around 4.5 million tonnes between 1996 and 2005 sees only a relatively small counterpart increase in incineration from around 1.6 million tonnes to just under 3 million tonnes over the same period. The true effect of the policy, in this case, has probably been somewhat obscured by the potential to export waste from Flanders to Germany, but the more telling change over this period has been an increase in recycling which, as discussed above, is very difficult to attribute to the landfill ban alone.

An interesting question relates to the degree to which different countries allow for exemptions from their bans in exceptional circumstances. Those who have introduced the bans with short lead times – the Netherlands and Flanders being the key cases – tend to find that exemptions are more important, but that high landfill taxes are necessary to ensure that these are not taken up over a lengthy period.

3.1.3 Implementation

The implementation of the bans described takes different forms in different countries. The Green Alliance report captures the key issues well. For example, the complexity of the Massachusetts approach partly reflects the fact that the materials subject to the ban cannot, in a meaningful sense, be banned from being landfilled. Few cases exist of nations seeking to ban specific materials from landfills, still less, that they do so as a means to achieve higher rates of recycling of that material.

In Finland, household waste, or similar, where the biodegradable fraction has not been separately collected may not be deposited in a landfill. The pre-treatment requirement effectively requires the waste to be stabilized before landfilling. The instrument does, therefore, afford the municipalities some flexibility giving them the choice to decide whether separate collections or new treatment infrastructure are most viable, but with the same aim of reducing the quantity of BMW landfilled. Anecdotal evidence from waste officers in Finland suggest that the 'ban' in current form is ineffective and unenforceable.[13] The most recent National Waste Plan envisages a revised ban on the basis that the attempt to encourage separate collection of biowaste through the ban, and the ban alone, has proven extremely difficult.[14]

In many countries where landfill bans are in place, there are also requirements to recycle specific materials. As such, the ban on unsorted waste in Flanders can be understood through the existence of legislation, prior to the ban, requiring sorting of waste. The ban becomes 'a backstop' to the policy requiring separation, but brief reflection suggests that such a ban would be incredibly difficult to implement and enforce. How does a landfill (or

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[13] *EEA (2009) Diverting Waste from Landfill: Effectiveness of Waste Management Policies in the European Union, EEA Report No 7.*

[14] *Ministry of the Environment (Finland) (2009) Towards a Recycling Society: The National Waste Plan for 2016, Ministry of the Environment, Helsinki, Finland, April 2009, http://www.environment.fi/download.asp?contentid=102639&lan=EN*

incinerator) operator determine whether waste really has been 'sorted', and how well 'sorted' does waste need to be before it passes the test of having been 'sorted'?

Although the Netherlands system looks rather complex at first sight, the pragmatism shines through in the fact that the ban is not applied to each one of the more than 30 materials / streams banned from landfill, but to wastes below a certain density. In essence, density constitutes an acceptance criterion. Its merit is that it is relatively simple to measure, or at least, to estimate. Its drawback is that it is crude.

3.1.4 Exemptions and Unexpected Consequences

Where bans are introduced with short lead times, there should be an 'outlet' for material which genuinely has nowhere to go. Two ways of dealing with this issue, or at least, making it less problematic, appear to be:

- Allowing waste shipments where waste is destined for recovery (subject to acceptance on the part of the receiving nation);
- Ensuring that the costs of landfilling and the costs of the alternatives are similar, so that the financial motivation is removed from those who would otherwise be motivated to seek exemptions on grounds of cost.

Where lead-times are extended, then the need for exemptions ought to be much reduced, or even eliminated.

If a country keeps its borders closed to export for, for example, energy recovery, then if the ban is of broad scope, and if the exemptions system is tight, treatments other than landfill have to deal with all residual waste. This would demand some over-capacity for such waste within the system. This might have interesting price effects at the margin. If capacity was insufficient in a given year, this might allow landfill operators to charge high gate fees for marginal tonnages. This highlights the fact that, whatever its problems, one merit of landfill is that it is not so sensitive, in terms of cost, to annual throughput.

Conversely, where there is a lack of appropriate treatment capacity, waste storage is required. During the first year of the landfill ban in Austria, the lack of sufficient capacity at treatment plants led to waste being wrapped and stored, often beside landfill sites, in the wait for treatment capacity to become available. 'Waste baling' was a major topic of discussion in Austria in that year.

Some of the landfill bans effectively encourage operators to seek exemptions. One example of this is seen with respect to the ban operating in Flanders. For several years after the introduction of the ban, waste lorries with mixed wastes entered sorting plants and immediately left the plant for landfill with the waste being re-classified as "recycling residues" which attracted a much lower tariff. To avoid this activity, percentages of what was acceptable as 'recycling residue' have been introduced in the legislation. A perverse effect is that now, waste is mixed up until the maximum percentage of recycling residue is obtained, so that it can be landfilled or incinerated, and with diminished levies.

3.1.5 Summary of Key Points from International Experience

Some key points from the review are as follows:

- Most countries with landfill bans in place also make use of landfill taxes;
- The use of relatively high landfill taxes seems to be more important where the lead-time for implementing a ban is short. A high tax can prevent repeated resort to exemptions (which are probably more necessary in cases where lead times are short);
- There is little evidence to suggest that landfill bans / restrictions have had anything other than a very weak effect on waste prevention;
- The effect on recycling is difficult to isolate from the range of other policy instruments implemented before, or alongside, or following implementation of a ban / restriction. However, evidence of an effect on recycling appears to be weak, especially in countries where bans operate alongside relatively high landfill taxes;
- There is a stronger link between bans which target mixed wastes, and diversion to other residual treatments; and
- Most landfill bans have had, as part of their rationale, the switch of waste away from landfill and into other residual waste treatments, notably incineration, but also MBT.

A more complete discussion is to be found in Appendix 2.

3.2 Interviews with Regulators

To provide useful insight and to inform the content and delivery of the workshops that were held in June, interviews were arranged with the regulatory bodies for each nation. Whilst these were undertaken with representatives from the Environment Agency for England and for Wales, and with SEPA, it was not possible to conduct an interview with a representative from the Environment Agency in Northern Ireland prior to the workshops. The Northern Ireland Environment Agency was represented at the subsequent workshop in Hillsborough.

Common themes across all three interviews are summarised below (see Appendix 4 for further information):

- Final responsibility for compliance with a landfill ban currently rests with the landfill operator. Although, ideally, everyone in the chain should have some responsibility, in practice, it is likely to be difficult to implement a landfill ban where the responsibility rests with anyone other than the operator. In the case of restrictions, the nature of the restriction, and the potential for deploying complementary or instruments, were deemed likely to influence the extent to which responsibility can be moved away from the operator.
- To be practicable and unambiguous, a ban or restriction should be specified so that it covers wastes which are readily identifiable, or are highly visible, or can be identified through simple tests.
- Some existing bans suffer from some 'fuzzy edges'. It is not always clear, for example, when liquid wastes should no longer be considered to be 'liquids'.
- Publicity for any potential bans needs to be widespread using a range of existing channels of communication.
- The lead times necessary will be dependent on what materials or streams are being banned, but from four to seven years was the type of period envisaged. Development of related waste management infrastructure is a key point to consider in this context.
- Supporting polices, both upstream and downstream of the landfill, are key to the success of any bans. There was a strong view that policies needed to drive the situation towards one where the targeted wastes were not being landfilled anyway by the time the ban was fully implemented.

3.3 Stakeholder Workshops

As described in the methodology section, four stakeholder workshops were run to elicit the views of relevant stakeholders in each of the four countries. The following sections seek to summarise comments from the workshops. Annotated accounts of each are given at Appendix 5.

A common theme to all of the workshops run for this study is that the start of the discussions were dominated by the questions 'what are you trying to achieve from the ban?' and 'what is the rationale?'. The conversations swung very quickly to identifying which other policy instruments or mechanisms would be required to gain the greatest benefit from diverting waste from landfill, and ensuring that it was subsequently treated in the most environmentally sustainable way. These views resonated with the findings of the review, already described in this section.

3.3.1 Past Bans

Key themes of the comments regarding past bans as implemented in the four countries were as follows:

- Bans are easier to implement where the banned waste: a) is readily identifiable (visually); b) is easily described; and c) arises in relatively homogeneous loads (and not as a small part of mixed loads).
- Reflecting this, tyres (visible) and liquids (clearly defined loads) have been relatively easy to ban whilst the ban on gypsum was not straightforward (as it arises as part of a mixed load and tends to crumble in skips, making it difficult to remove it).
- In England and the different DAs, the enforcement of the ban on landfilling of pre-treated waste is approached quite differently. The English approach – itself using a relatively light touch - appears to be rather firmer than is applied elsewhere. In some DAs, it was felt that there was no point in applying regulatory effort when the definition of pre-treatment was so broad that in practice, it would be difficult to demonstrate at the landfill which wastes had not been 'pre-treated'.
- Where it is enforced, the ban on landfill of pre-treated waste is effectively enforced through a paper trail, the operator being required to declare that waste delivered to landfill had been pre-treated.

3.3.2 Moving the Ban Upstream

Some discussion took place as to whether a landfill ban could meaningfully be enforced anywhere other than 'at the landfill'. Key points which arose are described below:

- The effects that would be achieved by moving enforcement of 'bans' upstream (to collectors and producers) might be better achieved through other policies such as producer responsibility, requirements for source segregation, the use of site waste management plans, charging for households, etc.
- Some workshops emphasised the potential role of proper enforcement of the existing system of Duty of Care.

- Proper enforcement of Duty of Care might require the regulatory bodies to be given significant additional resources.

3.3.3 Materials Which Might be Banned from Landfills for Operational Reasons
Both Welsh and Northern Irish workshops regarded mattresses as a problematic stream. They also identified polystyrene as problematic as it occupied considerable volume and simply blew around the site. For the same reason, the Northern Irish workshop identified plastic bags as problematic.

3.3.4 Bans by Waste Stream
- The English workshop explicitly rejected a stream-based approach. Splitting wastes up into streams was felt to be undesirable and an approach best not reinforced by making a part of policy going forward in this way.
- Questions regarding definition were raised in most workshops. If waste from a given stream was put through a basic process, would the output still be regarded as being from that stream, or would it be defined in some other way?
- In most cases, there was a desire to *move away from* a waste stream approach (the focus of existing policy was thought to be too heavily focused on municipal waste). This desire to move away from streaming also found expression in the desire, across all workshops, for the rationale for the ban to be very clear and for it to be clearly justifiable.

3.3.5 Bans by 'Known Property'
In principle, it was felt that bans on the basis of known properties could be implemented. However, it was also felt that the breadth of the definition of 'combustible', or 'recyclable' or 'biodegradable' could lead, implicitly, to a ban on all waste unless a load comprised a stream of material which was, for example, wholly incombustible or wholly comprising non-biodegradable materials. The workshops included some discussion about whether de-minimis allowances could be incorporated, this also being a feature of the discussion around material specific bans.

3.3.6 Bans by 'Measureable Property'
The use of measurable properties was also deemed possible, though there was a clear concern to ensure that whatever the required measurement was, it would not imply excessive costs. Equally, some noted that the costs might not be of such concern since waste acceptance criteria implied the need for some testing anyway.

There was some recognition that if this meant waste had to be routed to facilities prior to landfilling, those facilities could become the locus of any monitoring.

3.3.7 Bans by Material
This was a popular approach from the perspective of the environmental rationale, although bans by material present some practical difficulties which will have to be addressed if they are to be implemented. Food waste was often mentioned as an obvious candidate. However, the key issue raised was how a ban could be made operational. Most felt that a 100% ban was impossible, and that if the intention was to target, for example, food waste specifically, some *de minimis* threshold, or guidance, would need to accompany the ban. Local authority representatives expressed concern that they might be policing such a ban at the household level and were keen to avoid this.

3.3.8 Communications
More widespread communication than has been used with the introduction of previous landfill bans in the UK was considered highly desirable. It was felt that the focus of effort should move upstream to target the producers. The Northern Irish and Scottish workshops were particularly strong in the view that communications packages should be well planned and comprehensive.

3.3.9 Lead Times
Although the desirable characteristics tended towards a discussion which highlighted a long lead time as potentially desirable (to allow infrastructure to be developed), some workshops reached a more nuanced view when discussing the matter in more detail. In the English workshop, for example, it was suggested that long lead times could allow politicians to change their minds, reducing certainty, and undermining the case for investment.

3.3.10 Accompanying Instruments for the Ban
In the English workshop, in particular, but also in other workshops, notably in Northern Ireland, the significance of accompanying instruments and the wider policy framework was highlighted. All workshops wanted to see

waste producers taking more responsibility for their waste, but suggested mechanisms for doing so by means of a ban in and of itself (as opposed to other policy measures) were not especially forthcoming.

3.3.11 What is the Baseline?

In all the workshops, questions were raised amounting to what the ban or restriction was likely to achieve over and above Landfill tax at £72 per tonne as well as existing strategies or those in development. For this study, appropriate baseline estimates for modelling purposes were sought to help take these factors into account.

- In Wales, in particular, a strong view was that landfill was on its way out anyway: the current Draft Strategy was deemed to signal this very strongly. Similar views were expressed, in respect of municipal waste, in Scotland and in Northern Ireland.
- It was generally held that a ban would have its most significant effect on the commercial waste sector, and to a lesser extent, in respect of industrial waste. In the English workshop, waste companies highlighted that in these sectors, the announcement regarding higher tax levels was already driving changes in investments and in collection service offers to customers.
- The issue remains important, therefore, with some attendees at the workshops clearly already seeing a diminishing role for landfill even without the ban, and hence, implicitly, questioning the extent of additional benefits which a ban might deliver over and above the levels of tax already announced.

3.3.12 Desirable Characteristics

The different workshops' were asked their views as to what were desirable characteristics of a landfill ban. Common themes were:

1. Simplicity in design;
2. A clear and supportable rationale;
3. Communications of simple messages to those involved, with increased emphasis on producers as appropriate (not simply expecting operators to pass the message back up the chain via hauliers);
4. A lead time allowing for alternatives for managing the banned wastes to be available (both in the technical sense, and ultimately, in the physical sense); and
5. The need to have accompanying instruments in place, preferably such that:
    a. the desired management approach becomes the least cost approach for banned materials; and
    b. the intended effect of the ban effectively occurs as a matter of course (because incentives drive matters towards this outcome).

4.0 Selection of Bans for Shortlist

The preliminary stages of the study were included to scrutinize all of the different types of landfill bans and restrictions, and come to a conclusion as to which were a) practical and b) would help meet the desired objectives of this type of policy instrument (i.e. climate change and resource efficiency). The areas of work that were completed to arrive at this stage of the project were:

- Development of Waste Management Baseline;
- Initial Greenhouse Gas modelling work;
- Literature review; and
- Regulator / policy maker workshops.

An interim report was prepared presenting the preliminary findings of the research. This was followed by a key meeting with the project steering group, where the initial long list of bans (see **Table 5** and **Table 6** below) was shortened to 11, on the basis of desirability, practicality and likely GHG benefits of not landfilling the material.

This Section has not changed since the original version other than very minor changes to wording.

Table 5 Initial Long List of Material / Product Based Landfill Bans

Material / Product	Sub Categories			
Food	Household food only	Catering waste only	Industrial food	Vegetable oil
Paper and card	Newsprint only	Packaging card		
Glass	Container glass only	Flat glass		
Metals	Ferrous only	Aluminium	Other Non-ferrous	
Wood	C&D wood only	Packaging wood		
Textiles	Clothes only	Industrial textiles		
Batteries	Portable batteries only	Car batteries only		
Plastics	PVC only	C&D PVC	Plastic bottles only	Plastic bags only
WEEE	Large WEEE (fridges / TVs etc)	Small WEEE (mobile phones, stereos etc)		
Furniture	Mattresses only			
ELVs	Automotive shredder residue (ASR)			
Combustion residues	Incinerator bottom ash			

Table 6 Initial Long List of Stream / Property Landfill Bans

Stream	Known / Measurable Property
Municipal waste ('local authority collected')	Biodegradable wastes EITHER all paper, card, food, garden waste, etc. OR Wastes exceeding a threshold level of biodegradability
Commercial waste (commercial, not collected by local authority)	All combustible wastes
Industrial waste	Recyclable wastes
Household waste	Unsorted wastes
C&D Waste (other than inert wastes collected as municipal waste)	Wastes meeting a defined density criterion
Any combination of the above	Wastes meeting a calorific value threshold

The material / product based bans were initially broken down into sub-categories, as some of these may have been easier to ban than others. However, given the lack of data relating to individual components of some waste streams, no GHG modelling work, at this level of detail, was carried out. Only the generic material 'types' (i.e. paper / card) were modelled.

Section 4.1 below describes the first part of evidence used by the steering group to inform their decision to select the 'short list' of bans. Following this, the practical considerations, arising from the preliminary research into the design of landfill bans (Section 3.0), are drawn out. These were also considered by the steering group in their decision. The rationale for selecting the short list of bans is then given in Section 4.3.

4.1 Initial GHG Modelling

The GHG benefits from the landfill bans were highlighted, by the project Steering Group, as a key factor influencing the decision as to which bans to carry forward for closer analysis. After the waste management baseline was constructed (see Appendix 1), an environmental model was developed to assess the greenhouse gas (GHG) impacts of different ways of managing the materials instead of landfilling them, and streams for consideration on the long list. This model was developed to provide some insight (ahead of the full CBA stage) as to where the potential for significant GHG benefits from not landfilling material were greatest. The model was the first stage of the CBA work, and details concerning assumptions which were used in the model can be found in Appendix 9.

As noted above, GHG modelling was not considered for the sub-categories of waste, or in fact, for batteries, automotive-shredder residue, combustion residues, wastes meeting a defined density or wastes meeting a calorific threshold (the complexity of the type of modelling was too great for the scope of the project. Furthermore, the likely relevance to the study was low, given that these types of bans were effectively ruled out in the preliminary research stage – see section below).

Clearly, there are numerous alternative options to landfilling. This element of the study was not intended to provide exhaustive research into all possible options, or show a full range of results and sensitivities. These could be tested in the CBA stage. It was simply to act as a guide as to the where the potential savings might be found.

The GHG benefits of the bans in the 'long list' could be identified in one of two ways, depending on their definition.

- Firstly, where bans sought to address a specific material, such as food waste, the GHG benefits could be determined by modelling a switch of waste out of landfill, into a dedicated recycling / recovery route; and
- Secondly, where a ban effectively required a change in management of the whole residual element, a switch of 'residual' waste from landfill, to alternative processes, was modelled to derive the benefits.

The preferential alternative routes for specific materials were derived from findings in the research on marginal abatement cost curves (MACCs) for the UK's waste sector (this included not only recycling but also recovery options).[15] Where a ban might imply a switch of mixed waste to an alternative residual treatment, a number of processes were modelled to give a range of results (see Section 8.0 for more details). In this initial modelling, all waste - of each type - was switched from landfill. It is recognised that this would not be possible in practice due to constraints on the ability of collection systems to deliver 100% capture for recycling of waste still being landfilled in the Baseline. These factors have, however, been considered for the CBA stage (see Section 7.0 and Appendix 9 for details). The bans in the 'long list' that were modelled using these two approaches are shown below in **Table 7**.

Table 7 Bans Considered in Initial GHG Modelling Phase

Switch of Specific Material to Recycling / Recovery	**Switch of Residual Waste to Alternative Residual Treatment**
All specific materials / products	Biodegradable wastes i.e. wastes exceeding a threshold level of biodegradability
Biodegradable wastes i.e. all paper, card, food, garden waste, etc.	All combustible wastes
Recyclable wastes	Household waste
Unsorted wastes	Commercial waste
	Industrial waste
	C&D waste (other than inert wastes collected as municipal waste)
	All waste

Recognising the limitations of the initial modelling, general conclusions were drawn about bans for specific materials and for whole residual waste streams.

Bans that require a switch of a <u>specific material</u> away from landfill:

- All material based bans can generate a GHG benefit (this does not mean that all are beneficial in terms of the overall balance of costs and benefits – that was a matter for determination by the CBA carried out later in the study);
- For all materials with the exception of wood, the benefits from switching to recycling options (or AD in the case of biowaste) exceeded those from dealing with the material through residual waste treatments other than landfill;
- Where dry recyclables are concerned, a significant proportion of the benefits from switching from landfill and into recycling are, for the biodegradable elements such as paper and card and biodegradable textiles, associated with avoided emissions resulting from taking the material out of landfill;
- For the non-biodegradable elements (such as non-ferrous metals) the benefits in terms of reduced GHG emissions from landfilling are small and the overall benefit from switching away from landfill is dominated by the benefits from recycling itself (through substituting production using primary materials with production using secondary materials);
- Where organic materials such as food and garden waste are concerned, the proportion of the total benefits of any switch from landfill which relate to avoided landfill emissions are dependent on the choice of treatment (AD or composting) for the material, and in the case of AD, on how the biogas is used. In the best situations (AD with biogas used as transport fuel), the total benefit is more or less double the emissions avoided through not landfilling.
- If hurdles to the implementation of these types of ban could be overcome, materials for which the potential gains are greatest would appear to be:
  - Paper and card;
  - Dense plastics;
  - Plastic film;
  - Non-ferrous metals;
  - Textiles;
  - Food waste (sent for anaerobic digestion, especially where the biogas is used for vehicle fuel); and
  - Garden waste.
- If material based bans could be designed (possibly supported by complementary instruments) to focus on larger categories of 'Recyclable Waste' or 'Unsorted Waste', in order to increase source segregation and recycling of a range of materials, significant benefits could be generated; and

[15] *Eunomia (2008)* Development of Marginal Abatement Cost Curves for the Waste Sector*, Report for Committee on Climate Change, Defra and the Environment Agency, December 2008.*

- To the extent that the GHG benefits estimated for recycling assume closed loop recycling, the benefits are only likely to be secured if the additional material being collected is of high quality.

Bans that require a switch of residual waste:

- For the range of waste treatments modelled, GHG benefits could be derived from all processes, indicating that any of the bans which steer residual waste from landfill are beneficial from the perspective of saving GHGs. As with the materials above, this does not imply that benefits necessarily exceed costs;
- If residual waste is being switched from landfill to an alternative form of residual waste treatment, the beneficial impact of the switch is due to a large extent to the avoided landfill emissions (rather than being dominated by major additional benefits from the alternative thermal or non-thermal treatments);
- The magnitude of the potential GHG benefit from bans on specific waste streams closely relates to the quantity of that waste stream which is still being landfilled in the Baseline.

It was clear from this analysis that GHG benefits could be achieved in a sequential manner. For example, potential exists to combine materials based landfill bans, designed to steer specific waste streams into recycling routes, and a landfill ban which seeks to ensure that residual waste can be landfilled only if it has been treated in such a way as to reduce its potential to generate methane, either through thermal or biological means.

The sources of GHG emissions, and savings, are considered in detail in the results of the CBA for all bans and restrictions modelled on the 'short list'.

4.2 Practical Considerations from Preliminary Research

In the Section, information from the literature review covering international experience, discussions with regulators on existing bans, and the views of stakeholders are brought together, alongside general consideration of operational issues. These findings were also appraised by the project Steering Group when making the decision to select the 'short list' of bans and restrictions for modelling in the CBA stage. The evidence is presented below for each type of ban and summarised in the following Table.

Table 8 Summary Feasibility of Landfill Bans

Material / Product	**Stream**	**Known Property**	**Measurable Property**
E.g. Food / Plastics	E.g. Municipal	E.g. Combustible, Unsorted	E.g. Fermentability
■ The most straightforward bans to apply will be for materials which are either large and readily identifiable, or generally arise on the site as single streams of material. Both are likely to diminish as landfill tax increases and other policy measures take effect. ■ If bans are applied to materials which arise as part of mixed waste streams, then in the absence of *de minimis* thresholds, the ban is likely to become a ban on all residual waste. ■ If bans are to be applied to materials and *de minimis* thresholds are to be applied, then materials which, for the most part, only ever arise as small proportions of mixed waste loads would not be appropriate targets. ■ The *de minimis* threshold, even if it could be accurately applied, would not give a good indication of the sorting effort applied to that material prior to its arriving at the landfill. ■ Bans / restrictions could be implemented through the existing Duty of Care system, but the effect might be limited in the absence of supporting instruments.	■ The consensus was that stream based bans should not be considered further. There was no appetite for entrenching separation of streams and there was deemed to be an absence of a clear rationale for doing so.	■ In respect of 'known property' based bans, a ban is extremely difficult to implement in any way other than one which, implicitly, bans all wastes containing materials with that property. ■ Alternatively, supporting instruments are required to define and require 'upstream' behaviour, such as what level of 'sorting' is required. This could allow for a restriction on landfilling of waste to that which had already been 'sorted'.	■ Approaches based on measurable properties are feasible. ■ Density has the merit of simplicity, but in all other respects, it appears to be a rather blunt approach. ■ Using 'calorific value' as the measure would not guarantee positive environmental outcomes. ■ A measure of biodegradability would be preferable and would address problems of landfilling. ■ Any tests, and any testing regime, ought to have due consideration to cost.

In terms of the feasibility of implementing a landfill ban or restriction, the key questions relate to the issue of what can be subjected to a ban / restriction, and how such a ban / restriction could be designed in practice. Two issues appear to be important:

- The list of banned wastes (streams, materials or materials with specific properties); and
- The way in which the ban could actually be implemented, either at the landfill site, or in any other part of the 'waste supply chain'.

Here, we focus initially on the practical implementation and enforcement issues associated with introducing landfill bans, considering, in turn, the issues which could be expected to arise in considering bans by:

- Waste stream;
- Known property;
- Measured property; and
- Material / product.

Further design issues (for example, how the ban is communicated) are considered in Section 5.0.

4.2.1 Bans by Waste Streams

The idea of banning waste from landfill 'by stream' was not wholly supported in the workshops, (see Section 3.3.4) and the reasons appear to be sound ones:

1. The approach would entrench the parcelling up of waste into silos, generally viewed as undesirable;
2. The rationale would be difficult to explain or justify;
3. It is not clear when, for example, household waste would no longer be defined as 'household waste'?
4. A ban might be expected to reduce the number of operational landfills, so the requirement for transfer is likely to increase and mixing of streams to become more, not less, common. This would make distinguishing these streams more difficult. It might be possible to regulate in favour of requiring such streaming, but in practice, this would increase costs without generating any obvious benefit.

The literature review does not offer examples of particular streams where implementation is achieved through policing the materials contained *as* specific streams. Even where bans implemented elsewhere refer to specific streams, therefore, it is not the case that this is regulated as such (the stream itself does not accurately describe what is actually being banned).[16]

For these reasons, it was suggested – and the Steering Group agreed - that stream-based bans should not be considered further. Although these bans could potentially be *made* 'feasible', the reasons for not going forward on this basis seem strong.

4.2.2 Bans by 'Known Property'

The workshops noted two problems with this type of approach (see Section 3.3.5):

1. That of definition. The terms 'combustible', or 'biodegradable', or 'recyclable', could cover a very wide range of materials and products (including parts of products); and
2. The feasibility of eliminating a specific type of waste from a stream. Related to definition, if a ban was specified by known property, then it would effectively imply a ban on all mixed loads of material since most would contain some biodegradable, or some recyclable, or some combustible material. If the intention was to ban all mixed wastes, then it would be preferable to be explicit about this. It might be possible to apply 'threshold limits' in this regard but in practice, these would be incredibly difficult to implement and enforce. A given type of waste may appear in greater or smaller proportions in waste streams depending not only on how intensive the effort to sort those materials has been, but also, depending on how intensive the effort has been to sort *other* materials. Hence, a threshold 'composition' would not necessarily highlight the upstream effort to prevent materials from being landfilled.

In terms of a ban on Unsorted material, if the material constitutes a relatively large proportion of mixed waste (food, paper, etc.), then even if a *de minimis* threshold could be accurately applied, this would not give a good indication of the sorting effort applied to that material <u>prior</u> to its arriving at the landfill. This is because the proportion of a given material in residual waste depends *not only* on the proportion of that material which is captured for recycling, *but also*, on the proportion of *all other* materials with which it is mixed that are captured for recycling / composting / anaerobic digestion.

Although some countries ban wastes by property (see Appendix 2), the reality of most of these bans is that one or other of the following appears to be the case:

- The ban is intended to shift *all* mixed waste, as well as readily identifiable single streams, from landfill. This has been the situation in Flanders, Denmark, Sweden and the Netherlands, which have sought to ensure waste is shifted from landfill to incineration.
- The ban is not really a ban at all, as in, for example, the ban on compostable waste in Finland which has aimed for source separation over landfill. There, difficulties defining the ban have limited its effect.

For these reasons, it was suggested – and the Steering Group agreed - that most bans by 'known property' should not be considered further. In essence, in too many cases, the bans appear to amount to either an ineffectual measure, or, implicitly, a ban on all waste being landfilled. If the intention was to ban all wastes from landfill, it was agreed that this should be made explicit in the design of the ban. Equally, if the intention was to ban 'biodegradable' material, an objective basis for the assessment of biodegradability would be preferable (see below).

[16] *For example, in the Netherlands household and construction & demolition wastes are banned from landfill, but the method for implementing the ban bears no resemblance to tracing the presence or otherwise of that waste stream. In fact the density of each load is calculated as a proxy to combustibility. This shows that the underlying intent of the ban is not what it seems by considering its name.*

4.2.3 Bans by 'Measurable Property'

Whichever wastes bans are designed to cover, the actual way in which they are implemented, at least where they are enforced at landfill sites (or at pre-treatment facilities), often relies on measured characteristics. A minimum specified threshold value for a particular criterion can then be applied.

The comments from the workshops were generally of the view that these restrictions and bans were feasible, but concerns related to the cost of any tests which might be required. Such costs would need to be set against the potential benefits to be gained from such restrictions and bans.

The main criteria used in other countries appear to be:

- total organic carbon;
- a measure of the respirometric activity of the waste (intended to be a proxy for its propensity to produce methane in a landfill);
- the calorific value of the material; and
- the density of the material.

None of these is closely linked to the potential benefits of getting *specific materials* away from landfill. Rather, the emphasis is largely on seeking to address problems with landfilling of materials, or on seeking to shift mixed wastes away from landfill to other treatment routes such as incineration and MBT, or to ensuring that high calorific fractions from MBT processes are used for the purpose of generating energy.

Countries using these approaches tend to rely upon policies other than a landfill ban to reduce waste and increase recycling. The use of the landfill ban is then primarily intended to address the problems of landfilling of untreated waste.

If the characteristic requires waste to be pre-treated to comply with the ban, or if the intention is to move the responsibility 'upstream', the point at which testing occurs could, for wastes which require pre-treatment, be made to be the pre-treatment facilities themselves. This is the approach taken in Austria, where the owner of the waste is required to test the wastes to be landfilled.

In principle, there is no reason why such a ban should not be implemented. Consequently, it was recommended to the Steering Group that these approaches should be considered. The use of density as the measured characteristic might initially seem attractive, but may be a rather blunt approach. A threshold for calorific value might not give positive outcomes as too much depends upon the nature of the material and the alternative treatment to which it would be sent.

Some measure of biodegradability was proposed as the front-running approach (already used in Germany and Austria, and partially in Italy, and recently announced for implementation in Ireland). Any tests, and any testing regime, ought to have due consideration to cost. The expected outcome would be to shift material away from landfill and into alternative residual waste treatments unless additional policies steered waste into alternative management routes (such as composting / anaerobic digestion). The choice of residual waste treatment would be left to the market to determine, subject to the requirement that waste that was landfilled met the biodegradability threshold.

4.2.4 Bans by Material / Product

The workshop participants had varied views as to the practicality of material based bans. For bans already implemented in the UK, it was generally recognised that the easiest bans to implement had been those for which:

1 Materials were readily visible; and
2 Materials arrived at landfill sites in relatively homogeneous loads (and not as one part of a mixed waste stream).

For materials which arose as part of mixed loads, some form of minimum threshold level for the targeted material would need to be established, or the ban would have to be implemented in a softer manner. Neither would be especially easy to achieve and both would potentially lead to a lack of clarity about the purpose of the ban and how it would be implemented.

Very few countries try to implement material based bans. The Green Alliance report highlights the experience of Massachusetts which bans a whole range of materials from landfill. Many of these materials are not 'readily visible' and 'arrive as part of mixed streams'. The way in which the ban is implemented is actually through ensuring that waste facility operators have an approved 'waste ban compliance plan'. The plans provide guidance, recommending visual checks for operators to determine loads with unacceptable quantities of banned materials. Inspections of waste loads suggested include counting bags, estimating load volumes and photographing loads to show contents. Such an approach to implementation for materials that are readily visible in mixed loads is likely to be problematic, and it is likely to be far more so for materials which arise only as small proportions of mixed loads.

In addition, as mentioned above, the reliance upon the proportion of a given material in a mixed load as a basis for understanding how effectively a material has been removed from landfill is fraught with problems. The composition of food waste, as an example, in residual municipal waste can change depending upon how well it is captured, and how well other materials are captured. If other materials are not well targeted, food waste will be proportionately less significant in residual waste even if it is relatively well captured.

Reflecting the above, if material based landfill bans are to be implemented primarily through inspection at the site, the following comments would appear to apply:

- The more straightforward bans to apply will be those for materials which are readily identifiable and easily removed from the site. Otherwise it will be those which arise on the landfill site primarily as single streams of material.

Both types of material are likely to be found in diminishing quantities at landfills as the landfill tax increases;

- If bans are applied to materials which are widely received as part of mixed waste streams, then in the absence of *de minimis* thresholds or an alternative way of implementing the measure as a 'restriction' (rather than outright ban), the measure potentially becomes a ban on a wide range of mixed wastes. If bans are to be applied to materials and *de minimis* thresholds are to apply, then clearly, the material could not be one which is present only in small quantities from the outset (e.g. aluminium cans). The threshold could be applied, however, to a group of materials, of which such a material was one. In that case, however, the targeted material present in such small materials would not be likely to cause the group to exceed the threshold so the problem would remain. Thresholds applied to materials that appear in large quantities such as paper / card, will suffer from the fact that the relative proportion of such materials in residual waste is determined as much by how well other materials are sorted as by the effort to sort the material itself. In short, there is no easy way to overcome the difficulties of implementing bans or restrictions on materials which are widely found in mixed loads other than through accepting paper work as evidence of what had been done.

A ban could be made the responsibility of collectors and reprocessors instead of landfill operators. There are three main mechanisms for achieving this that would bring about more of a reduction in landfilling of the targeted materials than a ban in the strict sense:

1 Via the existing mechanism of Duty of Care, trusting the paper trail.
2 Through the use of complementary instruments alongside a restriction. The aim would be to give greater certainty of outcomes and a stronger effect to the restriction / ban; and
3 Through other policy mechanisms such as producer responsibility, requirements for recycling, site waste management plans, etc.

This research concentrates on the potential use of bans or restrictions and a comprehensive treatment of alternative policy mechanisms is not within its scope. It is possible, however, that if the intention is purely to increase recycling of materials already covered by existing policies, it may be more straightforward to adapt existing ones rather than to introduce new measures targeting the same outcome.

The Steering Group decided to take through, for more detailed analysis, the idea of material based restrictions for a range of materials. The materials which were included for consideration are discussed below.

4.3 Steering Group Decisions for 'Short Listing' Bans and Restrictions

It will be recalled that key objectives were to examine the feasibility of bans and restrictions through assessing the costs and benefits of restrictions and bans designed to reduce GHG emissions and increase resource efficiency.

The above discussion regarding GHG benefits highlighted that benefits were to be gained from recycling of most materials, and through the ban on biodegradable wastes being sent to landfill.

The above discussion regarding practicalities of different bans suggested that stream-based approaches had no special merit and that bans on 'known properties' would in many cases imply a ban on all residual waste to landfill (in which case, this intention should be stated explicitly). The main interest was in material / product based approaches, and in the ban on biodegradable wastes.

The GHG benefits and practicalities of the different types of policy, reported above, were discussed at a project Steering Group meeting. This resulted in the following list of bans being chosen for further consideration, and for more detailed analysis in the CBA phase:

Materials

1. Food
2. Green
3. Paper / card
4. Textiles
5. Wood
6. Glass
7. Metals
8. Plastics

Products

9. WEEE

Property Based

10. Unsorted Waste
11. Biodegradable Waste

Material / product based approaches were included as they were deemed potentially desirable and worthy of further scrutiny on GHG grounds. However, it was accepted that it might be difficult to generate these benefits for the material / product based approaches if they were reliant upon visual inspection and the waste transfer note (Duty of Care) system.

The inclusion of the ban on 'unsorted' wastes was included to allow working up of a 'stronger' policy designed (to be considered) to achieve the key objectives set out by the steering group. This was included in addition to the 9 material / product bans. Policy 10 – the unsorted waste ban – was modelled on a material specific basis (i.e. a Ban on 'Unsorted' Food, Green, Paper / Card etc, would be modelled individually). Further rationale and commentary on these issues are presented in the following Section on the 'Design of Landfill Bans / Restrictions').

At this steering group meeting it was also agreed that materials for which GHG (and possibly other) benefits could be derived should be sorted and sent for recycling / recovery. This intent is quite important since one of the findings from the preliminary research is that for some of the above materials, an outright ban (and communication along these lines) might lead, rather than to waste generators recycling more, to the movement of mixed waste from landfill to other residual waste treatments. This would clearly not deliver the envisaged GHG gains, these being higher (for all materials except wood) for recycling / anaerobic digestion than for other treatments.

The biodegradable waste ban, carried forward to the cost benefit stage, was based on 'measured property' rather than seeking to ban all individual 'biodegradable' materials.[17] This implies that some limit on biodegradability would need to be set, and all waste entering the landfill must fall below this threshold level. Whereas the first 10 policies seek to mitigate climate change and increasing resource efficiency, Policy 11 mainly seeks to address the GHG emissions of landfilling by ensuring that the waste is 'pre-treated' before any landfilling occurs (either through thermal treatments or MBT).

[17] *A restriction on landfilling of, or a ban on landfilling unsorted, biodegradable materials would in any case be readily estimated from the material based approaches.*

5.0 Developing the Designs of the Landfill Bans / Restrictions

Section 3.0 discussed issues around the design and implementation of different 'types' of landfill bans and restrictions. Section 4.0 highlighted the decision making process in determining the preferred 'short list' of bans / restrictions to be carried forward for detailed consideration. This short-listing does not, however, lead directly to a clear and unequivocal description of the nature of the ban / restriction, how it might be implemented / enforced, and the nature of any complementary policies required. This Section gives further consideration to these issues, and describes the nature of the bans / restrictions modelled, how they might function, what complementary policies might be desirable, and in broad terms, what their effects might be.

Further consideration is given to complementary policies in Section 6.0. More details around the assumptions concerning effects are given in Section 7.0. This Section has not changed since the original version of the report.

It is important also to note that from this point forth, the distinction between a 'ban' and a 'restriction' becomes somewhat important. The term restriction effectively implies that one accepts that what the measure will achieve is not an outright ban on a given material, but rather, a restriction on the quantity being landfilled.

Initial Considerations

In discussions, at the workshops and with members of the Steering Group, about implementing bans or restrictions 'upstream', additional complementary policies were generally felt necessary. Otherwise it was felt that the restrictions / bans would need to be enforced at the site itself.[18]

There are clearly implications for any 'at the site' enforcement for the behaviour of actors upstream. If a landfill ban or restriction is to be worthy of the name, enforcement has to take place, at least in some form, at the site itself. There are effectively three methods for enforcing bans or restrictions at the site:

- By visual inspection (materials / characteristics);
- Through checking that the paper trail was in order (i.e. waste transfer notes indicated that the waste arriving at the landfill was not of a type which could not be landfilled); and
- Through reference to a measured property (a form of waste acceptance criterion).

These measures are not mutually exclusive. In all cases where a landfill ban is implemented, it would be expected that the operator would a) check waste transfer notes, and b) ensure that when visually inspected, the waste did not contain material that was banned from landfill. It is not always practical for these visual inspections to include an investigation of each load / sack etc., let alone a thorough inspection.

It should be noted that we have deliberately sought to ensure that the approach to modelling a landfill ban / restriction on materials and products is somewhat differently specified to the ban / restriction on unsorted waste. The differences between the two, in terms of how we have envisaged they would be applied, and the effects that they might have, are deserving of some explanation. Again, it is important to note that bans / restrictions on specific materials were modelled, notwithstanding the findings from the preliminary research, to a) further draw out the limitations with this approach and b) implicitly provide a greater range of policy scenarios for consideration. The design of the policies are described in the Sections below and summarised by the following points (note the explicit definitions of 'ban' or 'restriction' – the paragraphs on 'Communication' regarding each of the approaches provides some further comment):

- **Material / Product Restrictions –** visual inspection of the waste at the landfill backed up by requirement to check on waste transfer notes. This could only meaningfully imply a restriction on what is landfilled, not a ban;
- **Unsorted Waste Ban –** as material / product restrictions, but with a supporting policy to define what is meant by 'sorting', this being defined with consideration given to materials quality. Since the policy would <u>require</u> the sorting to take place, the aim, in this case, is to *<u>ban</u>* material which has not been subject to the required sorting; and

[18] Although other approaches have been mentioned in the course of this study, such as banning waste from specific landfills, or from sections of landfills, or ensuring the waste is landfilled in mono-fills, these were not considered to be especially relevant to the objectives for the bans / restrictions, and thus have not been included in the subsequent discussions.

- **Biodegradable Waste Ban –** measures on the biodegradability of waste will be taken, and any waste not meeting specified thresholds would be banned.

5.1 Material / Product Restrictions

In the scenario analysis which forms part of the cost benefit stage we model the following policy options:

Material / Product Restrictions

1. Food
2. Green
3. Paper / card
4. Textiles
5. Wood
6. Glass
7. Metals
8. Plastics
9. WEEE

Policy Design

A measured criterion is not, generally, an applicable approach for implementing the material or product specific bans being considered here.[19] Hence, in principle, the ways to implement these bans would appear to be by means of visual inspection, and through ensuring that upstream, producers / carriers/ managers had exercised their Duty of Care in line with legislation. An interesting facet of the German approach is that responsibility moves right to the producer.[20] This was discussed in the Scottish workshop, less so in the others.

In the first and most obvious approach, the carrier would have to declare that the banned waste was not present at all in the waste being delivered to the site. This approach would essentially amount to a ban on many mixed loads, for reasons already discussed in Section 4.2.4 above (because the materials being investigated are present in many mixed loads of material, and often, in small quantities dispersed throughout the load). Only relatively homogeneous loads (on visual inspection) of materials that were not banned, or wastes which originated from sources where it was reasonable to expect that the banned waste would not be present, would be expected to be allowed into landfills. For these reasons, therefore, none of the material based bans / restrictions have been modelled in this way (i.e. by assuming a ban on all mixed waste). In other words, and this is an important point from the perspective of how the measures are communicated (see below), none of the material based approaches amounts to a *ban per se*. All of the material based bans are, therefore, 'restrictions'.

Secondly, the implementation of a ban through the Duty of Care system is based upon landfill operators inspecting waste transfer notes to check that the waste being delivered to the site has met the criteria for acceptability at the landfill.[21] In this case, carriers would be expected to testify, on waste transfer notes, to the fact that:

1. the waste being delivered to landfill was waste collected from premises where measures had been taken to ensure that some of the targeted materials had been separated out from the mixed stream; or
2. that the waste being delivered to landfill was waste which had originated from a facility which was designed to sort the targeted materials from the rest of the waste.[22]

Operators would not accept waste for landfilling where no such declaration had been made.

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[19] *Though in principle, some materials or products might be detectable only through testing, in which case, the ban would fall into the category of 'property-based' bans as defined here.*

[20] *The German approach is electronically based and places responsibility upon the producers of waste. Interestingly, a trial for electronic waste tracking is underway in South-East England. In principle, this might make pave the way for individual companies to submit their own waste transfer notes in due course.*

[21] *It is noteworthy that even though waste which has not been 'pre-treated' is currently banned, waste transfer notes have not been required to make provision for the carrier to state that the waste has indeed been pre-treated. As such, even enforcing the pre-treatment requirement as it currently stands through checking the paper trail might not always have been exactly straightforward.*

[22] *Typically, appropriate for mixed skips from construction and demolition wastes.*

In principle, therefore, it would seem that a restriction on materials being sent to landfill could be implemented through the waste transfer note system in a manner akin to the existing requirement to pre-treat waste prior to landfilling. There are good reasons to question how effective this might be, especially considered against a baseline in which the landfill tax has risen to £72 per tonne (see Section 6.3.2). Using these existing mechanisms, this measure might not have sufficient teeth to ensure that considerable additional quantities of material were recycled beyond levels achieved in the Baseline. A major overhaul of the existing Duty of Care system was felt by some stakeholders to be needed to make it a potentially effective way to implement restrictions.

A key point associated with this approach is that it would make no clear definition as to what was required by the term in terms of the efforts made to sort waste. As a consequence, carriers who had reason to believe that waste had been subject to *any* form of sorting of the material from waste would, presumably, be in compliance. This situation can be contrasted with that set out for the ban on unsorted waste referred to below.

The key elements to the design of material / product restrictions are:

- Loads are visually inspected by landfill operators and would notify the carriers / regulators when the material / product subject to the restriction had obviously not been subjected to any form of sorting at all. Most mixed loads would have some quantities of some or all of the materials / products listed above. Landfill operators would be expected to allow the waste to be landfilled, rather than remove the 'banned' waste, or be forced to reject the load, as long as paperwork was in order;
- Landfill operators are expected to cross check visual inspections with some data requirement on Waste Transfer Notes (WTNs) stating that the 'restricted' waste has been removed, by sorting, upstream. No additional strengthening of this duty of care system, in terms of regulation, is expected. Waste producers would not know what level of sorting was required to comply with the restriction. It is expected that most would consider themselves to be compliant with minimal change from the *status quo,* though commercial collectors and some local authorities not collecting the targeted materials / products might be expected to seek some expansion of their activities.

Definition and Communication Issues

It is important to note, in this context, that communicating this type of measure as 'a ban' might not have the desired effect (i.e. of increasing recycling). A possible impact would be that the communication leads to collectors, who would assume 100% removal of the material is required and clearly not be able to guarantee it, seeking instead other forms of residual waste treatment.[23] If this was the case, then these bans would have effects similar to that of the biodegradable waste ban described in more detail in Section 5.3.

Hence, although some have suggested, in both workshops and in the Steering Group, that this type of measure could have value as a communications tool (which we agree it does), we are inclined towards the view that communicating a measure as 'a ban' when there was clearly no intention to implement the measure as a ban could lead to frustration among the affected parts of industry. In such situations, various actors in the market might feel persuaded by such communications to undertake actions / investments which they subsequently find they either did not need to take, or which, in the case of investments, proved worthless (because the 'ban' being *communicated* was not *implemented* as such). This type of ambiguity is exactly what many operators suggested they would like to see eliminated from any measure being proposed. We would strongly suggest, therefore, that only bans which it is intended to implement as such are communicated as bans.

5.2 Unsorted Waste Bans

Given the potential significance of the unsorted waste restriction in terms of meeting the key objectives for the restrictions / bans, and the potential need to include complementary policy measures, considerable effort has been taken to describe this particular policy, and how it has been modelled in the CBA stage. For reasons highlighted previously in Section 5.1, a restriction on 'unsorted wastes' would be difficult to implement through a combination of visual inspection and the Duty of Care alone, and would leave the question as to what was implied by 'sorting' open to interpretation. This ban therefore necessarily requires some complementary measure before it

[23] *Note that de minimis thresholds for the types of materials considered in this study were not deemed practical in the preliminary research stage. The main point being that they are all very common materials, and will be present in some form in most loads. Visually inspecting the loads to determine whether the threshold was met, or not, would be impractical and lead to many ambiguities.*

can be effectively enforced. A 'requirement to sort' waste was therefore considered as a means by which the restriction could effectively be imposed ensuring that waste had been sorted prior to disposal. It was assumed that this would make the policy both easier to enforce in practice and stronger in effect.

Unsorted Waste Bans

10. Ban on Unsorted Waste by Material / Product
    a. Food
    b. Green
    c. Paper / card
    d. Textiles
    e. Wood
    f. Glass
    g. Metals
    h. Plastics
    i. WEEE

Policy Design
This approach effectively seeks to increase the effectiveness of the material / product based restrictions described above. Essentially, the aim is to ensure that:

1 The targeted materials are moved into recycling routes (not residual waste treatment); and
2 The quantities affected are larger than the simple requirement to apply any form of sorting, as described above.

If the policy is restricting 'unsorted' waste from landfilling, then the landfill operators, carriers and waste producers need to know what 'unsorted waste' means, or equivalently, what they need to do to comply with a requirement to ensure their waste is 'sorted'. In the absence of such a definition, waste producers and carriers might tend to assume that any form of sorting constitutes compliance with the ban, and the ban would resemble the weaker restriction described above.

It would appear that a key complementary policy, therefore, is a policy that defines 'sorting', and requires waste producers to ensure the sorting of waste to a certain standard is required prior to landfilling. Carefully specified, the *'requirement to sort'* could be specified such that it became highly likely that capture rates of the targeted material(s) for recycling were significantly increased above baseline levels. This policy is considered more closely in Section 6.2, where it is also made clear that this type of policy is widely used, though with differing scope, in other countries.

Within the design on the 'unsorted waste restriction', carriers would be expected to declare that:

1 the waste being delivered to landfill was waste collected from premises where collection systems of a required standard were in place, and where measures had been taken to sort the materials;[24] or
2 the waste being delivered to landfill was the residue from sorting processes which achieved particular standards for sorting of the materials routed via their facilities. This would be expected to be applicable only for those materials where it was deemed that sorting on site was particularly difficult (this could include small construction projects).

One of the aims of the feasibility study was to ensure that GHG benefits would be secured and that resource efficiency would be improved. A 'requirement to sort' could be applied in at least two ways:

- A requirement to sort to a specific standard if the material is destined to be landfilled; and
- A requirement to sort irrespective of the destination of the residual waste.

Evidently, the former is consistent with a 'landfill ban'. It would, however, be possible for producers and waste carriers to sidestep the requirement to sort if they simply sent the waste they produced to an alternative residual waste treatment facility (i.e. something other than a landfill). The analysis of GHG benefits suggested that the shifting of materials from recycling to incineration or MBT would, in the vast majority of cases, be detrimental

[24] *Typically appropriate for municipal and commercial wastes.*

(one exception was the case of wood).[25] In order to ensure that the gains GHG and resource efficiency gains were more likely to arise from the policy, it would seem necessary to apply the 'requirement to sort' not only to wastes being sent to landfills, but to all wastes irrespective of how they are subsequently treated (even for wood, the sorting prior to incineration would seem to be desirable). Another complementary policy, therefore, would be that the same checks applied at landfills (described below) would need to be applied to other residual waste treatments. This is discussed in Section 6.4.

Enforcing a requirement to sort would – whether it was regulated directly, or through Duty of Care – necessarily require checks that premises from which waste was being sent to landfill did indeed have in place the required sorting system. Indeed, to the extent that premises were inspected to check that the required sorting systems were in place, it seems likely that one possible means of checking would be through checking that waste transfer notes were in line with expectations, this being supported through a check to see that provision was made at the premises concerned to enable the designated materials to be sorted in the desired manner. It would not seem appropriate for waste carriers to be tasked with this enforcement. Hence, this should be a task either for the Environment Agency or, possibly more appropriately, local authorities given their existing roles in enforcing legislation at the local level (and that they also play a role in enforcing the Duty of Care and, in England, the Site Waste Management Plan Regulations).

A final approach might be to effect the change through requirements in landfill operator's environmental permits. The permits could be worded in such a way as to require operators to ensure that all material entering the landfill had been subjected to some sorting process. This would, however, put considerable onus on the operators and would probably be appropriate only where the intention was to implement an outright ban. This might be an appropriate approach for implementing the biodegradable waste ban described below.

The key elements to the design of unsorted waste restrictions are:

- A requirement to sort waste is clearly specified. This would be enforced at the producer level to ensure that those covered were doing what was expected of them;
- Loads would be visually inspected by landfill operators and operators of other residual waste facilities who notify the carriers / regulators when the material / product subject to the ban had obviously not been sorted in the required manner. Most mixed loads would have some quantities of some or all of the materials / products listed above. Landfill operators would be expected to allow the waste to be landfilled, rather than remove the 'banned' waste, or be forced to reject the load, as long as paperwork was in order; and
- Landfill operators and operators of other residual waste facilities would be expected to cross check visual inspections with the information on Waste Transfer Notes (WTNs) stating that the 'banned' waste has been removed, by sorting, upstream. It would be expected that the WTN would need to be clearly worded such that those delivering waste to the site could confirm that the waste delivered to the facility was derived only from producers who had complied with their requirement to sort. The emphasis would be on producers (and those collecting directly from producers) to make the relevant on the WTN, and hence, the enforcement would be most appropriate at the point where 'waste' was first generated.

Definition and Communication Issues

In terms of communication of this type of approach, the potential for communicating the message would also be more straightforward if it applied to all businesses and local authorities. It would also be possible to communicate this message in a more positive manner than in the case of the more weakly applied restriction highlighted above. Local authorities and businesses would be informed that they would be expected to avail themselves of sorting systems as required, so that the banned materials were no longer discarded in the residual waste stream, or that in the case of some C&D wastes, a given waste stream was sent for sorting at a suitably accredited facility.

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[25] *It is worth noting, however, that some countries such as Denmark and Finland require sorting of treated waste wood specifically to ensure that elevated emissions of arsenic (associated with chromated copper arsenate preservative) from municipal incinerators do not occur (see, for example, L. M. Oottosen, I. V. Kristensen, A. J. Pedersen and H. K. Hansen (2004) Handling of Impregnated Wood and Characterisation of Ash Residues After Combustion of the Wood, http://www.cepis.ops-oms.org/bvsacd/arsenico/Arsenic2004/theme2/paper2.8.pdf).*

It remains likely that there would still be some quantity of the 'banned' materials in residual waste as collection systems would not be expected to capture 100% of the material. The intention would be, however, to move as close to this position as was possible given the constraints of human behaviour, the quality of collection systems, and the quality of sorting systems.

5.3 Biodegradable Waste Ban

A ban on biodegradable waste could be implemented through use of a measured criterion. Evidence from Europe strongly suggests that this is entirely feasible. Whilst, in principle, visually inspecting a load to see if it included any biodegradable waste could be part of the approach, in practice, to model the ban on biodegradable waste in this way would be equivalent to the aggregated effects of banning each of the biodegradable materials identified for consideration under either the restriction, or the unsorted waste ban.

In this case, therefore, the expectation would be that any waste with biodegradable material within it would have to be either biologically pre-treated to reduce its biodegradability, or treated through other means such as incineration. As such, measurement of biodegradability would be required. This could occur at treatment facilities rather than the landfill itself, with landfill operators encouraged to accept wastes from sources other than appropriately accredited treatment facilities only where the wastes were obviously not biodegradable, or where testing demonstrated their biodegradability to fall below the threshold set. Hence, the requirement to test for biodegradability could be shifted more towards treatment facilities, with less frequent tests at landfill sites.

There are a number of tests which could be used for the assessment of biodegradability. These are discussed in Appendix 6. We have based our modelling on the view that the test would be a fermentability test designed to ensure that biodegradability fell below a threshold of 10mg O_2/g dry matter.

Definition and Communication Issues

The intent of this particular ban is to ensure all waste whose fermentability lies above a certain threshold is banned from landfill. If it does, the waste must be pre-treated before landfilling through either (typically) biological or thermal treatments to reduce its biodegradability. This ban should be communicated clearly as a ban, alluding to the fact that unless there is good reason to believe that the waste being sent to landfill has characteristics that lead one to believe it has a biodegradability below the threshold level, then the expectation should be that pre-treatment is required.

6.0 Key Complementary Policies

In the material based restrictions, which seek to encourage recycling, we have suggested that a restriction on its own would have a limited effect. On the other hand, we have suggested that the unsorted waste ban, complemented by a requirement to sort materials, and the extension of the ban to other residual waste treatments, could have a much stronger effect in encouraging recycling of materials. Indeed, it may be that the requirement to sort becomes the principle driver of change, not the ban at the landfill itself. Given, however, that the purpose of this research is to consider the potential for landfill bans and restrictions, then the requirement to sort clearly appears an important complementary measure to the ban. This is in line with other country experience where bans on 'unsorted materials' have been implemented.

In the case of the landfill ban, proposed on biodegradable waste, the instrument could also be supported by other measures. These might also give an incentive to meet the requirements of the ban. One of these could be the landfill tax, as suggested in the international review. It is not within the scope of this research to consider changes to the landfill tax, however, since this is a reserved matter for HM Treasury.

It is important to note that the outcomes of the restrictions, in terms of recycling, might equally be met through the application of, or adaptation of (where they already exist) measures such as producer responsibility initiatives. We have not been asked to review the potential for these instruments to deliver the same objectives as are being sought here, though we note in passing that the use of new, or the adaptation of existing, instruments could also be considered as alternative means to deliver similar outcomes to those which the restrictions and bans are estimated to achieve.

With one's focus clearly on landfill bans and restrictions, and accepting that the landfill tax is a reserved matter for HM Treasury, this Section examines the key complementary measures that might be considered for the restrictions and bans being examined in the cost benefit analysis phase.

This Section has not changed since the original version of the report.

6.1 Complementary Policies for Material / Product Based Restrictions and Bans

If the intention is to ensure that the material is sent to a specific management route, then a ban will be insufficient on its own; landfill bans on their own only seek to ensure that material does not go to landfill. They say little or nothing about the end destination of the banned material.

In the report for Defra by Green Alliance, considerable weight is placed upon the use of 'supporting instruments', but the report makes clear that in some countries (it cites Austria and Sweden, but Denmark would be another good example), the principle beneficiary of landfill bans has been incineration. The report also suggests that:[26]

> *'Flanders is an impressive example of a country that has used phased landfill and incineration bans to achieve nearly 70 per cent recycling, reuse and composting, while decreasing its dependence on incineration. Any diversion from landfill towards energy-from-waste should be the result of a clear policy, not a default result of a landfill ban or restriction. Government should explore the use of policy instruments to discourage the incineration of recyclable or compostable materials, to ensure that they are treated as high up the waste hierarchy as possible.'*

The authors of this report would dispute the fact that the landfill and incineration bans (the two are hardly comparable in Flanders – the ban on landfill is intended to ensure, quite clearly, that all residual waste suitable for combustion is incinerated) have been strong factors in driving recycling in Flanders. An array of other policy instruments drives recycling, and in Flanders, as with Austria, Sweden and Denmark, the principle effect of landfill bans has been to encourage incineration, albeit that some waste that falls under the scope of the ban is still landfilled in the country concerned. Our view is that the range of instruments in place in Flanders would have delivered similar recycling rates without the bans.

The Flemish 'dependence on incineration' (referred to in the above quotation) was not based upon domestic incineration capacity. Following the announcement of the restriction on landfilling in Germany, landfill operators

[26] *Green Alliance (2009) Landfill Bans and Restrictions in the EU and US: A Green Alliance Project for Defra (ref WR1202): Summary Evidence Review, August 2009.*

dropped prices, so attracting more waste into their facilities. This led, in turn, to the freeing up of capacity at German incinerators, with Flemish waste being exported to these facilities.

We believe these points are important precisely because they suggest that there is little evidence of landfill bans (as typically configured) bringing about major changes in recycling, especially in those countries – like Flanders – where landfill and incineration taxes more-or-less equalize the costs of landfilling and the costs of incineration.

Probably the only possible exception to this has been in Germany, where the absence of landfill taxes has implied that the introduction of restrictions on landfilling increased the avoided cost of dealing with residual waste, and this is a key financial parameter affecting the economics of recycling. Even here, however, such a response is difficult to attribute to the landfill restrictions to a significant degree, not least because of the existence of a range of other instruments deployed to increase recycling. Indeed, the much more significant change has been the development of alternative residual waste treatment capacity, mainly incineration, but also MBT.

If the intention is to move materials further up the waste hierarchy and into recycling / composting / digestion, it is likely that other instruments will be required to drive this. In discussing how this might be achieved, we have suggested that an appropriate measure would be a 'requirement to sort' in support of a ban on unsorted wastes from landfill and other residual waste treatments. The 'requirement to sort', and the extension of such a requirement beyond waste that is destined for landfill only, are the measures which we concentrate upon here (though as hinted at above, other instruments could also be considered appropriate for the purpose). Other instruments might be, for example, a requirement upon collectors to offer a particular standard of service to commercial and industrial waste producers. However, we are not persuaded that this would have a significant impact. Whereas a requirement to sort specific materials requires companies to behave in that way, simply offering them the service manifestly does not. Indeed, recycling services for paper and card are effectively on offer for all companies already. That does not, however, mean that every company sorts all paper and card for recycling (and the same could be said for a range of other materials).

6.2 Obligations to Recycle in Other Countries

Many countries that make use of landfill bans do so having established rules regarding which materials households and industry must recycle. More detail on this is provided in Appendix 7, and here, we present a very brief summary.

6.2.1 Household Waste

The European countries that use a minimum recycling standard for the household waste stream include Austria, Belgium (particularly Flanders and Wallonia), the Czech Republic, Denmark, England and Wales (through the Household Waste Recycling Act), Finland, Germany, Hungary, Italy, the Netherlands, Portugal, Slovenia, Sweden and Switzerland. In addition, both South Korea and Taiwan have also implemented minimum recycling standards in recent years, and several locations within the US also have a minimum recycling standard for their household waste, including the city of Portland, and the state of New Jersey. These minimum standards vary in the types and number of materials that must be source-separated, the way in which the materials must be collected and the way that they are funded.

Table 9 summarises the key materials that must be collected separately in those countries that implement recycling obligations. The main driver behind the majority of regulations appears to be the implementation of laws on packaging and associated producer responsibility measures, which have driven the separate collection of most materials except for food and garden waste. The separate collection of food/garden waste is mainly linked to the enactment of Ordinances and the development of compost standards which, in many cases, exclude the products of biologically treating 'mixed waste' from consideration as 'compost'. Further detail on each country is given in Appendix 7.

6.2.2 Commerce and Industry

The countries that currently use a minimum recycling standard for the C&I sector include Austria, Denmark, Finland, Germany, the Netherlands, Poland, Portugal, Slovenia and Switzerland. In addition, the city of Portland and the state of New Jersey also require a minimum recycling standard from their businesses. California (USA) is also looking to implement a mandatory commercial recycling programme. The minimum standards for C&I waste sorting vary in the types and number of materials that must be source-separated, the way in which the materials must be collected and in the way that they are funded.

Table 9 Materials Requiring Separate Collection According to Country

Country	Biowaste	Glass	Plastics	Paper / card	Alu.	Steel/ tin	Beverage Composites	Textiles	Wood
AT	✓	✓	✓	✓	✓	✓	✓		
BE	VFG and all food	✓	Plastic bottles	✓	✓	✓	✓	✓	
CH	✓	✓	PET	✓	✓	Tin	✓		
CZ		✓	✓	✓			✓		
DE	✓	✓	✓	✓	✓	tinplate	✓		
DK		✓		✓					
England& Wales	Any two recyclables								
FI		✓	✓	✓	✓	✓	✓		
NL	✓	✓		✓				✓	
PT		✓	✓	✓	✓	✓			✓
SI	Garden and vegetable		✓	✓	✓	✓			
SE			✓	✓	✓	✓	✓		✓
South Korea	✓	✓	✓	✓	✓	✓	✓	✓	
Taiwan	✓	✓	✓	✓	✓	✓	✓	✓	
USA (New Jersey)		✓		✓	✓	✓			

**separate collection specified as requirement for Waste Management Regional Plans, with targets in place for the various materials, but does not directly state that source-separation is mandatory.*

Source: Table compiled from a variety of sources including the Federal Office for the Environment (2008), the European Topic Centre on Resource and Waste Management, Fogarty et al. (2008), the Ministry of the Environment of the Czech Republic, ECOTEC Research and Consulting Limited (2000), Taiwan Government Information Office, and OECD (2006).

6.2.3 Construction and Demolition Wastes

The countries that currently use a mandatory minimum recycling standard for the C&D sector include Austria, Belgium, Denmark, Finland, Germany, Slovenia, the Netherlands, USA and Japan. They adopt different approaches, based upon a range of threshold requirements, and sometimes backed with a financial incentive.

6.3 Suggested Approach

A suggested approach to implementing a requirement to sort is set out the sections which follow. This effectively constitutes the case we have modelled in the cost benefit analysis in Section 7.0. It should be noted, however, that there are a number of potential variants to this approach. For example, it might be decided that some commercial enterprises should be targeted for some materials earlier than others (e.g. restaurants and cafes could be targeted for food waste collection before other premises). At construction and demolition sites, there could also be a phased implementation, or the requirement to sort could be considered in different ways to accommodate sites where on-site segregation is relatively difficult because of spatial constraints. Hence, the following is a suggestion only, and a full specification of a requirement for sort would merit further consideration to ensure its broad applicability.

6.3.1 Household Waste

Compared with some countries, the UK has been relatively tentative in its use of regulatory approaches to require the sorting of specific wastes. The Household Waste Recycling Act (HWRA) is relatively weak, and applies only to two materials, and only in England and Wales. The proposed Welsh Strategy sets out recycling targets which imply a requirement to collect food waste separately.

It seems clear that where household waste is concerned, most countries which have made use of this type of approach have done so through a combination of:

1 Ordinances (typically for biowaste);
2 Requirements within producer responsibility legislation (sometimes upon householders, sometimes upon obligated entities / producer responsibility organisations); and
3 Requirements (upon municipalities) to provide for the collection of specific materials.

If such measures are to achieve considerable captures of the targeted materials, however, and if the capture of those materials is to be of a high quality, then as well as specifying the materials to be sorted, it would seem to be desirable to consider specifying a level of service to the household which makes it as convenient as reasonably possible for the householder to engage with the service provided.

Such an approach has been taken in Flanders. There, minimum standards are set for municipalities. These are shown in Table 10. The minimum frequencies and collection methods for different household waste fractions are **absolute minimum requirements**. Municipalities and the intermunicipal partnerships (collaborating municipalities) are responsible for implementation of these requirements. Some deviation is allowed, for example, in the case of packaging, in the context of an innovative pilot project initiated by FOST Plus (the producer responsibility organization which deals with packaging in Belgium), or in the case of other materials, where OVAM (the Public Waste Agency of Flanders) grants its approval.

Table 10: Approach to Separate Collection in Flanders

Fraction	**Minimum collection method**	**Collection modality**	**Recommended minimum frequency**
Household waste	Door-to-door collection	Household waste container **or** household garbage bag	Bi-weekly except for city centres and tourist areas of coastal municipalities
Bulky waste	HWRC **and** door- to-door collection **Or** door-to-door collection	Container(s)	2x a year via door-to-door collection on demand, 4x a year on demand (3) as of 2010 6x a year via door-to-door collection or on demand
VFT-waste(VGT-regions)	Door-to-door collection	VFG containers **or** approved compostable bags(1)	Bi-weekly
Paper and cardboard waste	Door-to-door collection (mixed fraction) **and** collection at the HWRC	Container	Monthly
Glass waste (glass cullet)	Bottle bank - two-colour separations **or** door-to-door collection (in combination with the collection at the HWRC)	At least 1 bottle bank per 1000 residents (district by district and at **or** near the HWRC)	Monthly
PMD-waste (plastic bottles and flasks, metal packaging and drink cartons)	Door-to-door collection (possibly in combination with the collection at the HWRC) **or** HWRC (2)	Collection receptacle	2 x month (2)
Textile waste	HWRC and door-to-door collection **or** HWRC and separately placed containers	Containers 1/1000 residents	4 x a year via door –to-door collection
Construction and demolition waste containing asbestos	HWRC	Container	
Stone debris – inert	HWRC	Container	
Prunings (green regions) (VFG regions)	Door-to-door collection **and** HWRC HWRC		4 x a year via door–to-door collection in green regions, on demand
Fine garden waste and grass	HWRC	Container	
Metals mixed (= discarded iron)	HWRC	Container	
Wood waste	HWRC	Container	
Tree trunks	Composting facility **or** HWRC		
Small hazardous waste (all	HWRC	Small hazardous waste –safe	4 x a year

Fraction	Minimum collection method	Collection modality	Recommended minimum frequency
fractions) + injection needles	**or** door- to-door collection or district collection	**or** comparable space Collection receptacle	
Old and expired medications/ drugs	Pharmacist		
Waste electrical and electronic equipment(WEEE)	HWRC **and** re-use centres	Conform to acceptance requirement	Conform to acceptance requirement
Re-usable goods	Door-to-door collection **and** carrying to re-use centre (possibly to HWRC)		On-going, on demand

Source: OVAM (2008) Implementation Plan for Environmentally Responsible Household Waste Management
Notes:
(1) Compostable bags only in existing collection projects and in city centres with a population density exceeding 1,000 residents per km^2.
(2) A lesser frequency is allowed when the objectives of the Interregional partnership agreement on the prevention and management of packaging waste 30.05.1996 are achieved following the positive evaluation of an innovative trial project (conforming to the accreditation by Fost Plus).
(3) following the positive evaluation of this collection method of bulky waste.

As well as minimum service standards, OVAM seeks to improve the quality of collected materials. It has established the following targets to ensure waste fractions qualifying for recycling should contain as few pollutants as possible. These are:

- a maximum 3% for VFG waste, green waste and paper and cardboard waste,
- a maximum 5% for wood and glass waste,
- a maximum 15% for construction and demolition waste, and
- a maximum 5 to 15% for textile waste.

In principle, we believe this type of approach is sound. Requirements to sort should be based around minimum standards for services which should make high captures of material for recycling highly likely, whilst not being prescriptive. Targets for impurities also seem to be sensible so that a landfill restriction on unsorted waste is not undermined by large quantities of MRF residue resulting from waste collected with high contamination rates. The service specification should, therefore, seek to:

- Ensure high captures of material; and
- Ensure quality of the captured materials; whilst
- Allowing for innovation through not being too prescriptive in terms of collection method used.

For the materials under consideration, we would propose the following:

1 **Food** waste – to be collected from the kerbside at least weekly. The rationale for this relates to the information available concerning food waste captures from existing schemes. Households should be provided with caddies for the kitchen. The approach to the provision of liners (for the caddy) is worthy of further discussion. In principle, captures will be highest where residual waste is collected no more frequently than fortnightly in wheeled bins, unless the bins are 140l or less in size (and with no side waste, and flat lid policies in place), or weekly in the case of sack-based collections. We have assumed that one or other would apply;

2 **Garden** waste – where garden waste is concerned, the nature of service specification should consider, and seek to constrain, the potential for free garden waste collections to increase waste arisings. For this reason, *minimum* service requirements ought to be set to allow for services to be designed with this in mind. We suggest, therefore, that the minimum requirement might be:

   - a kerbside garden waste collection on a fortnightly basis on which a charge is levied; or
   - a periodic free garden waste collection at a frequency of at least once every two months in the months from March to October (note that this is akin to the Flemish approach for prunings – see above);

   In all cases, provision for garden waste collection would be expected at all HWRCs. This specification should allow for collection of most of the 'garden clear-outs' without necessarily undermining the potential for home composting, or stimulating 'over-delivery' of garden waste. Equally, if local authorities wished to collect garden waste free of charge from residents, this would not be ruled out, although the costs of such a service are likely to be high (particularly if, at the same time, a requirement for weekly food waste collection was implemented);

3 **Paper and card** should be collected at least fortnightly. The benefits from recycling card appear to outweigh any benefits from composting / digesting the material, but consideration should be given to encouraging the collection of contaminated (e.g. pizza boxes) card for biowaste treatment;

4 **Textiles** should be collected at least once every 6 weeks with provision also made at HWRCs for separate collection of textiles and carpets. Bulky waste collections should also ensure that where textiles are collected, the first consideration is for their re-use or recycling;

5 **Metals** clearly arise in a variety of forms in the household waste stream:
- Cans and foils should be collected at least fortnightly;
- Scrap metals should be collected at all HWRCs.

6 **Glass** arises both as packaging and in the form of flat glass.
- Packaging glass should be collected either
  a) at least fortnightly from the kerbside; or
  b) using bring schemes of a specified minimum density (for example, three – one for each of the main 'colours' – banks for every 1,500 inhabitants);
- Flat glass should be separately collected at all civic amenity sites.

There are issues to be considered regarding the best way in which to ensure that the types of benefit considered in the analysis in this report. These are secured only in the case of glass cullet being used in closed loop processes. Hence, to the extent that quality is deemed important, then collecting and sorting glass should be oriented towards achieving glass of a sufficient quality for use in the remelt industry. It might be prudent, therefore, to require the collection service to demonstrate that this would indeed be likely to be the outcome;

7 **Wood** tends to arise either as small off-cuts, or in the form of larger items such as doors, floorboards, skirtings, etc. It seems questionable that the small quantities arising as offcuts would justify a kerbside collection, and certainly not on a frequent basis (given the likely sporadic nature of arisings). Recent work by Resource Futures suggests that of all wood waste arisings collected by local authorities, only 15% or so were collected at kerbside, with just under 80% collected at HWRCs.[27] Therefore, it seems sensible to require wood to be sorted at all HWRCs. It may be worth considering requiring separate skips for contaminated grades and for cleaner grades of wood, though these will occupy considerable space;

8 **Plastics** arise in the form of bottles, other dense plastic packaging, and as films, as well as being part of a range of products, including WEEE. Interestingly, the Flemish system does not target a wide range of plastics, this decision having been taken in the past on the basis of an analysis of costs and benefits. Plastic bottles should be collected at least fortnightly. The question as to whether a wider range of plastics should be targeted ought to be considered in the context of knowledge of costs and benefits, and indeed, this report might be considered part of that process. We assume here that a wide range of materials are collected at kerbside and at HWRCs (though we note that recent evidence suggests that the vast majority of plastic in waste collected by local authorities – just under 80% - is collected either at kerbside or through bring recycling schemes).[28] The case for requiring collection of films from household waste would, for example, appear to be weak;

9 **WEEE** potentially presents the most awkward situation. Around 30% of WEEE is estimated to arise in kerbside collections, with just under 50% arising at HWRCs. The Flemish approach also focuses upon re-use centres, which were set up by OVAM. The case for universal provision of kerbside collections of WEEE has not obviously been made, but it might be for some materials unless alternative mechanisms enforce a much more widespread implementation of take-back schemes. WEEE also arises as part of bulky waste, and clearly, such materials should be recycled as far as possible. It could be considered, for example, that WEEE could be collected at kerbside on a relatively infrequent basis, thereby seeking to improve the collection logistics of materials which are unlikely to be set out in large quantities if the collections are made on a frequent basis.

In addition to the above, the available evidence suggests that captures of material are likely to be higher where there are 'constraints' placed upon residual waste quantities. It would be worth considering, as a means of enhancing captures, requiring that residual waste should be collected no more frequently than fortnightly in

[27] *Resource Futures (2010) Municipal Waste Composition: Review of Municipal Waste Component Analyses, Report to Defra, WR0119, http://randd.defra.gov.uk/Document.aspx?Document=WR0119_8662_FRP.pdf*

[28] *Resource Futures (2010) Municipal Waste Composition: Review of Municipal Waste Component Analyses, Report to Defra, WR0119, http://randd.defra.gov.uk/Document.aspx?Document=WR0119_8662_FRP.pdf*

wheeled bins, unless the bins are 140l or less in size (and with no side waste, and flat lid policies in place), or weekly in the case of sack-based collections. This might be especially worthwhile considering if food waste is included in the list of materials to be targeted, and if the above suggestion for collecting food waste is accepted since this would make improve the acceptability of less frequent refuse collections on the part of households. It would also reduce costs.

It is important to note that this approach does not seek to specify one way of delivering collections. Rather, the aim is to constrain that choice through requiring certain minimum requirements to be achieved.

Consideration could be given to establishing minimum densities of HWRCs (e.g. one per 20,000 households, perhaps moving towards one per 15,000 households) so that opportunities for delivering this material were made more easily available to households.[29]

Consideration could also be given to the provision of 'on the go' recycling facilities. Standards for this aspect of service provision are less well developed or understood.

It may be tempting to exempt some more rural areas on grounds of cost, but our experience suggests that if sparsely populated areas are already in receipt of refuse collections, the incremental cost of service provision over and above the costs of refuse collection can be kept rather similar to the increases in more densely populated areas. Various factors come into play, but with careful system design, the argument against doing this on grounds of cost appear relatively weak. Some dispensations could be given where the system being provided obviously demonstrated the capability to deliver high captures of the targeted materials.

As with the Flemish approach, it would seem desirable to allow for some deviations from these rules for specific materials where a strong case is made for this. The Flemish approach also suggests that in order to avoid facilities side-stepping the requirements by routing waste through 'sorting facilities' at which no sorting takes place, there may be merit in specifying maximum residue levels for sorting facilities.

Finally, it should be noted that the above proposal is less well adapted to multi-occupancy residences. Just as Flanders differentiates between regions defined as 'green' or 'VFG' (effectively, without and with, respectively, the ability to treat meat excluded food waste), so it may be sensible to establish specific service standards tailored towards multi-occupancy residences. These standards could be based upon, for example, a minimum density of bulk collection bins for the specified materials.

6.3.2 Commercial Waste

There is no obligation to sort materials placed upon actors in the commercial and industrial waste in the UK other than those that are implied by existing landfill bans (for example, gypsum, or tyres). The extent to which commercial and industrial waste producers engage in sorting of different materials is not at all clear at present. There is some information which has come from industry surveys, as well as surveys conducted by, or on behalf of, local authorities. All are interesting from the perspective of understanding who currently recycles what (though none gives a complete picture) whilst the various pieces of the jigsaw make it possible to draw some conclusions (albeit somewhat speculatively) regarding barriers to recycling, and hence, what might help improve performance in this regard.

Around the time when the Pre-treatment Regulations entered into force, a survey was carried out by YouGov for Taylors. This suggested that whilst the majority of companies have paper and card collected for recycling, most other materials were not being collected for recycling by the majority of companies (see Table 11). The Table shows that 'corporates' performed significantly better than SMEs in this regard. It suggests, however, that only 15% of SME respondents and 6% of Corporate respondents were in receipt of no service at all. It seems quite possible that this figure understates the true number, possibly reflecting both an unwillingness to self-declare as non-recyclers, as well as a certain degree of 'self-selection' in the respondents. In addition, the inclusion of companies recording collections for 'metals' and for wood suggests that the survey covered enterprises of a more industrial nature.

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[29] We estimate the current density to be of the order 1 per 24,000 households (based upon just over 1,100 sites and around 25 million households).

Table 11: Businesses Recycling Different Non-hazardous Products

Material	SMEs	Corporates
Paper	71%	90%
Cardboard	60%	75%
Cans	39%	61%
Glass	37%	54%
Plastic	39%	52%
Metal	20%	44%
Scrap metal	15%	41%
Wood	18%	32%
Food	12%	25%
Tetra pak cartons	12%	19%
None	15%	6%

Source: YouGov (2007) Recycling in the UK Plc: A State of the Workplace Report, Commissioned by Taylor Intelligence, October 2007.

The suspected overstatement of performance in respect of SMEs is supported by a number of more recent surveys:

- In work undertaken in Cambridge and Peterborough, of 194 SMEs surveyed, 61% were not recycling any material, and of those who did, 19% were recycling one material only, whilst 9% of businesses take their waste and recycling home or to a Household Waste Recycling Centre (HWRC);[30]
- A survey in Nottingham found that 65% of businesses do not separate materials on site for recycling. The most often recycled materials were paper and card;[31]
- A survey in Oxfordshire found that 58% of businesses were not recycling;[32]
- A survey of 638 SMEs in West Sussex found that around 50% of companies either 'do not recycle' or offered no reply to the question. The material recycled by most companies was paper, with around 30% recycling this material;[33]
- In Yorkshire and Humber, a survey of 190 businesses found that 64% were not recycling;[34]
- A survey of 294 businesses in South Hams suggested that 54% of businesses were separating material on-site for recycling;[35] and
- A survey of 398 businesses in Wokingham, Reading and Bracknell Forest found that 80% of the 398 respondents were recycling.[36]

The suggestion is that large numbers of SMEs do not recycle. Interestingly, of those that do, a significant proportion often do so by taking waste either to their home, or to HWRCs and bring sites.

The numbers recycling different types of material, however, broadly reflect the Taylors survey. The West Sussex survey shows that as with the Taylors survey, paper and card are the most widely recycled materials, with glass, plastic bottles and cans close behind. It seems reasonable to suggest that these are the materials for which recycling services are most readily available. The information is also interesting in that it suggests the nature of systems being used by businesses. Evidently, many businesses have collections of paper, or paper and card, and

[30] *Resource Saver (2008) Waste Practices Survey – An analysis in relation to recycling trends and compliance issues, report to RECAP (Cambridgeshire County Council), 11 March 2008*

[31] *MEL (2007) Nottingham City Regional Trade Waste Compositional Analysis, Report for Nottingham City Council, January 2007.*

[32] *Environmental Information Exchange at Oxford Brookes University (2008) EiE Waste Audit Report for Oxfordshire County Council Audits for April 2007 to March 2008, Report for Oxfordshire County Council – April 2007 to March 2008.*

[33] *West Sussex (2007) Recycling Business Waste in West Sussex Analysis of Questionnaire Results, November 2007.*

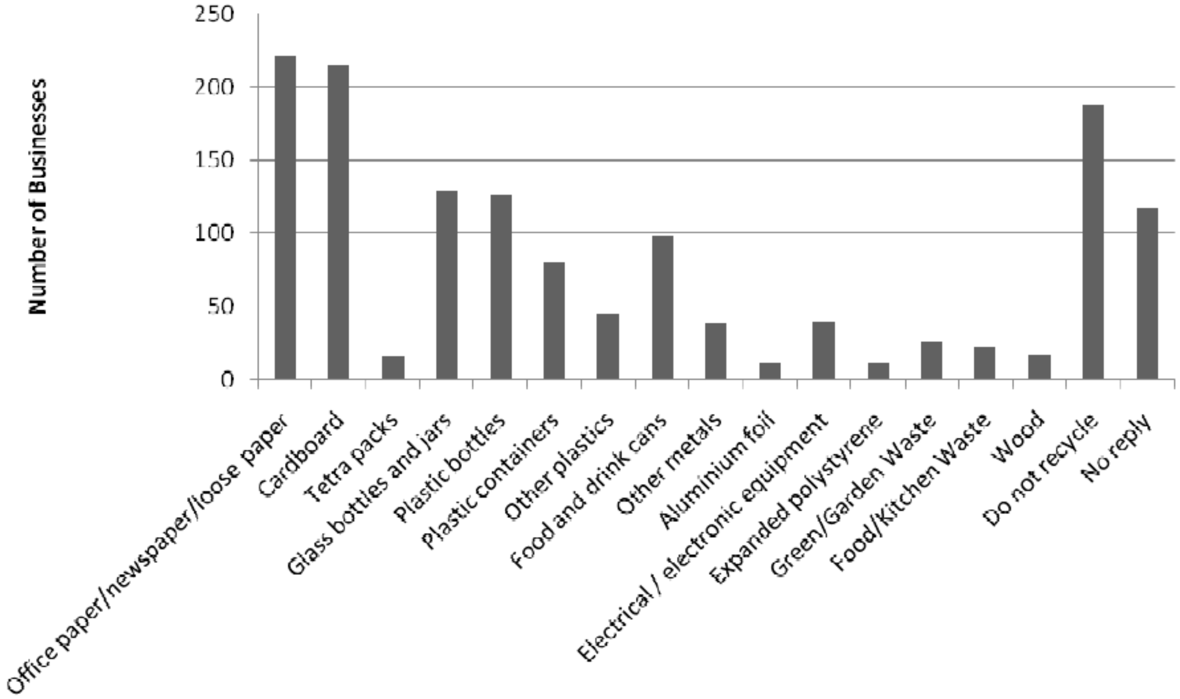
[34] *MEL Research (2006) Yorkshire and Humber Regional Trade Waste Compositional Analysis, Report to Government Office for Yorkshire and the Humber, March 2006.*

[35] *MEL Research (2006) South Hams Trade Waste Analysis August 2005 to January 2006, Report to South Hams Council.*

[36] *Scott Wilson (2008) Research and Design of a Joint Business Waste Management Strategy and Action Plan: Business Waste Survey, Report for Wokingham, Bracknell Forest and Reading Borough Councils (re3 Partnership) & Business Link, November 2008.*

it would seem that many have services which only collect these materials. On the other hand, a similar number of businesses have services which collect each of plastic, glass and cans. Many businesses probably use services which target plastic and cans together, sometimes with glass. Because the sorting of metals from plastics is a relatively simple process, and because there is limited impact on the quality of one from the other, the suggestion would be that few businesses would have collections of plastic without also having a collection of metal cans. Separate glass collections are now widespread in the hospitality sector, so the figures may reflect the prevalence of these, with many receiving collections for plastics and cans. Finally, relatively few businesses have a collection of food waste, and fewer have collections for Tetra pak cartons.

Figure 2: Materials Recycled by Businesses in West Sussex



Source: West Sussex (2007) Recycling Business Waste in West Sussex Analysis of Questionnaire Results, November 2007.

Summarising various surveys, the BREW Centre for Local Authorities notes the following (amongst other points):[37]

- The majority of SMEs have no objections to recycling schemes becoming compulsory if services are available;
- Large businesses are more likely to have an arrangement with a private contractor than SMEs;
- SMEs often admit that they do not have a waste recycling service provider, citing small volumes of waste as the main reason. Many use household waste services;
- The majority of businesses would like recycling to be collected once a week; and
- The majority of SMEs would not be willing to separate organic waste for recycling/composting.

The most frequently quoted barriers to recycling commercial waste were:

- Lack of collection and/or bring facilities (preferred collection on a weekly basis);
- Cost (many expect services to be free); and
- Lack of time.

Perhaps significantly, in the majority of the surveys consulted, the BREW Centre for Local Authorities notes that businesses do not quote 'space to separate and store materials for recycling' as a barrier.

In this context, and recognising that commercial and industrial waste producers have differing requirements in terms of the desired frequency of collections, we would propose that the requirement to sort requires that businesses arrange for the separate collection, and provide facilities at their premises for separation, of:

[37] *BREW Centre for Local Authorities (2008) Highlights of Local Authority Trade Waste and Recycling Reports 2007/8.*

1 **Paper and card** – this is likely to be straightforward and is widely practiced at present;
2 **Plastics** - this is likely to be straightforward and is relatively widely practiced at present;
3 **Metals** - this is likely to be straightforward and is relatively widely practiced at present;
4 **Glass** - this is likely to be straightforward and is relatively widely practiced at present; and
5 **Food waste** – this is becoming more widely practiced and requirements to sort are likely to increase the prevalence of this type of collection. However, the surveys referred to above suggest this will not be so straightforward to achieve on a widespread basis, and indeed, communications with existing operators suggests that it will be important for service providers to work with the users in the early days of service provision; and
6 **WEEE** – evidently, business-to-business schemes already exist and could be used on a more widespread basis than would currently seem to be the case (see, for example, Figure 2).[38] Having said this, although official statistics seem to suggest low quantities of WEEE collected from businesses, there is general agreement that this under-reports the current level of collection activity.

The other materials being investigated by this study are likely to arise in sporadic, sometimes large (office refurbishment etc., some specific industries) quantities. For these materials, the required frequency of collection service is likely to be lower. For these materials, there may be merit in considering how HWRCs could be used by businesses, on payment of relevant fees, to allow for the separate collection of materials arising in considerable quantities. These materials would be:

1 **Textiles** - this is not widely practiced in commercial companies and with the exception of small quantities of rags for cleaning, such materials are likely to arise only periodically in many businesses. Some carpet suppliers are already operating take-back schemes, and this market is a developing one;
2 **Wood** – in commercial companies such materials are likely to arise in small quantities and only periodically. In industrial contexts, wood may arise in larger quantities and a key issue may be to sort contaminated / impregnated wood from 'clean' materials. Alternatively, such material will be graded by reprocessors;
3 **Garden waste** - this is likely to arise in limited quantities. It should be possible for food waste collections to accommodate small quantities and softer materials (such as cut flowers, or the occasional potted plant). For the more sporadic quantities, either professional gardeners may deal with the material, but the alternative of using HWRCs could be a valuable one.

It is not so straightforward to approach the commercial and industrial sector from the perspective of a defined 'customer experience' because the heterogeneity of the customers leads to a correspondingly wide range of requirements in terms of service provision. In addition, the collection market is itself more 'locally fragmented' by competition than is the case in household waste collections. The specification needs, therefore, to be somewhat looser than it can be in the household sector.[39] On the other hand, it might be appropriate to specify certain rules which would be designed to ensure that collection systems still retain a focus on the quality of the collected material.

6.3.3 Construction and Demolition Wastes

As with construction and demolition wastes, there are no requirements for sorting, although several companies have committed to halving waste sent to landfill by 2012,[40] and the landfill tax provides a significant incentive to increase separation of wastes (if for no other reason, to segregate wastes qualifying for lower rate tax from those qualifying for the standard rate). This separation may take place on-site (where space is not a constraint), or off-

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[38] *Although this work has been asked not to investigate the potential for existing policy instruments to achieve the objectives being set for the landfill ban, it might be difficult to avoid close consideration of how a requirement to sort would influence the market as currently constituted.*

[39] *There is a much wider debate to be had here regarding the structure of the market for the collection of C&I waste. It is generally accepted that there are benefits to be gained from operating with one service provider in the household sector (for example, so called economies of density in collection) (see, for example, OECD (2000) Competition in Local Services: Solid Waste Management, DAFFE/CLP(2000)13; M. Warner (2008) Reversing privatization, rebalancing government reform: Markets, deliberation and planning, Policy and Society 27, pp 163–174; The Competition Authority (Ireland) (2005) Decision of The Competition Authority (Case COM/108/02) concerning Alleged Excessive Pricing by Greenstar Holdings in the Provision of Household Waste Collection Services in Northeast Wicklow, 30th August 2005, available at: http://tca.ie/search.aspx?SearchTerm=e/05/002). This thinking is less commonly extrapolated to the commercial (and industrial) waste sector, though there may be arguments in support of this view.*

[40] *See http://www.wrap.org.uk/construction/halving_waste_to_landfill/*

site at sorting facilities in cases where space is more of a constraining factor. Some such material may still be landfilled but the rationale for even basic sorting of materials is strengthened as the differential in landfill tax rates increases, with landfill operators also engaged in sorting activities at the front of sites. Sorting facilities are becoming more complex, replicating developments in countries such as the Netherlands and Germany, where sorting of the non-inert fraction of C&D waste has progressed significantly.

In England, Site Waste Management Plans (SWMPs) have been mandatory since 6th April 2008.[41] They have been implemented under the Clean Neighbourhoods & Environment Act 2005 in line with the Code for Sustainable Homes (which is voluntary) and Planning Regulations. They are also an extension of Duty of Care which is contained in the Environmental Protection Act 1990 and the Environmental Protection (Duty of Care) Regulations 1991. Some of the DAs, for example, Wales, are considering their own approaches to dealing with C&D wastes, based, in part, around the SWMPs concept.

A review of the approach of other countries suggests that requirements to sort sometimes attach to the value of projects, but in others, they relate either to the quantity of waste being handled or to the area of the development. The approach adopted in Austria appears to have much to recommend it. There, the distinction is made between companies that are obliged to separate their own waste and have it collected, and those who agree to commit their waste to special commercial waste sorting facilities.

We suggest, therefore, that for this waste stream, the requirement to sort is specific as follows. All operators should sort the following materials:

- Gypsum (the existing ban);
- Plastic;
- Metals;
- Glass;
- Cabling / wiring;
- Wood;
- Garden waste; and
- Concrete, rubble and other masonry material.

They should do so either through on-site sorting, or by sending mixed materials to an approved sorting facility. Such facilities would need to be accredited for the purpose, and as in Austria, accreditation should be based upon an assessment of their likelihood of achieving recycling rates of the order 85% and above.

From the perspective of the landfill operator, matters should be relatively straightforward in the case of materials being sent from accredited facilities. Matters might not be so clear cut in the case of sorting facilities which are not accredited, but which are receiving mixed waste which results from the sorting of other materials. Evidently, the paper trail still becomes important in this case.

In principle, this requirement to sort could be given additional impetus through mechanisms such as refunded compliance bonds. These are effectively bonds put up at the start of a project which commit a company to a given recycling rate (say 90%) of all waste, with the bond being refunded in full where the commitment is met. Used alongside SWMPs and a process of accreditation for sorting facilities, such a scheme would be more straightforward to audit, and would help drive performance to high levels.

6.3.4 Enforcing a Requirement to Sort

Enforcing a requirement to sort will not necessarily be straightforward. As was discussed above, this could take place through 'Duty of Care' reaching upstream, but in practice, the desired effect would be the same as if a regulator was enforcing the requirement to sort directly. Hence, we have given consideration to the level of resourcing which this might require below (see Appendix 14). In principle, this regulatory task might be best placed with the local authorities since they already play a role in enforcing the Duty of Care and the implementation, in England, of SWMPs, whilst local authority regulation costs may be lower, at the local level, than the costs that might be incurred via centralised regulation by the Environment Agency.

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[41] *HM Government & Strategic Forum for Construction (2008)* Strategy for Sustainable Construction, http://www.berr.gov.uk/files/file46535.pdf

6.4 Ban on Sending Unsorted Wastes to Residual Waste Facilities

If the intention of a landfill ban (and complementary measures) is to increase recycling of materials which are currently not captured from the waste stream, then it makes sense to apply any 'requirement to sort' across the board rather than simply to material that would otherwise have been landfilled. For example, if, in an area where incinerators already deal with the majority of residual household waste, there is little by way of glass recycling, then a ban on *landfilling* unsorted waste will change nothing (because the unsorted waste is not being landfilled). We are also aware of some two-tier areas in England where Districts' wishes to collect food waste separately are effectively constrained by the existing residual waste treatment contract. As the proportion of residual waste being sent to landfill declines, the potency of a measure aimed at ensuring that material is sorted for recycling or composting / digestion prior to landfilling is significantly diminished (since a growing proportion of residual waste will not be destined for landfill anyway).

Consequently, all facilities intending to deal with 'residual waste' should be treated in the same way as landfills for the purpose of the measure where the express intention is to encourage recycling of materials. In essence, therefore, the ban on unsorted waste would amount to a requirement to sort the designated materials and products irrespective of the choice of residual waste treatment. As such, a logical counterpart to the 'requirement to sort' is the extension of the measure to all other residual waste treatment facilities (such as incineration, MBT, MHT, autoclaving, pyrolysis / gasification, etc.).

There are other reasons why it may be more beneficial and more productive to apply the requirement to sort to all businesses. The requirement to sort, particularly in the case of commercial wastes, should help to increase 'economies of density' in collection, whilst the approach would give greater certainty to the market in terms of collection (the certainty would be reduced if, for example, requirements to sort could be side-stepped through switching residual waste from landfill to an alternative residual waste treatment).

6.5 Summary

This Section has sought to outline complementary policies which would support the effects of the restrictions and bans under examination. The main points are summarised here:

- Where material based restrictions are concerned, a requirement to sort waste – with a minimum service standard – would help to increase recycling and may also help maintain the quality of collected material;
- This requirement would be specified differently for household, commercial and industrial waste, and construction and demolition waste;
- There would need to be an accreditation system for sorting facilities in place, notably for facilities receiving mixed construction and demolition wastes from operators facing spatial constraints on the sites where they are working;
- The requirement to sort would need to be enforced directly;
- If the intention is to encourage recycling of specific materials irrespective of the destination of residual waste (as the environmental analysis suggests it should be), then the restriction on *landfilling* of unsorted waste logically needs to be extended to a restriction on sending unsorted wastes to *any form of residual waste treatment*.

Where the material based restrictions are concerned, there are a range of other instruments which could be considered either alone, or in combination, for achieving the desired effects of the proposed restrictions and bans. It is worth noting that in the case of the material based restrictions and the ban on unsorted wastes, in principle, the requirement to sort could be replaced by another measure, or combination of measures.

7.0 Modelling the Costs and Benefits of the Restrictions and Bans

The modelling of costs and benefits on the restrictions and bans is central to this report. In this Section, we describe how this analysis of costs and benefits is built up, and provide some of the underlying assumptions regarding the effects of the restrictions and bans. This Section is little changed from the original, other than through updating of the 'unit impacts' Tables contained within it.

7.1 Model Overview

Figure 3 provides a basic schematic of what the model actually does. It shows how the model is built upon a combination of 'Unit Modelling' and 'Mass flow Modelling'. The former is based upon a model of the financial costs of the different waste management options and a model of the environmental costs of the different options.

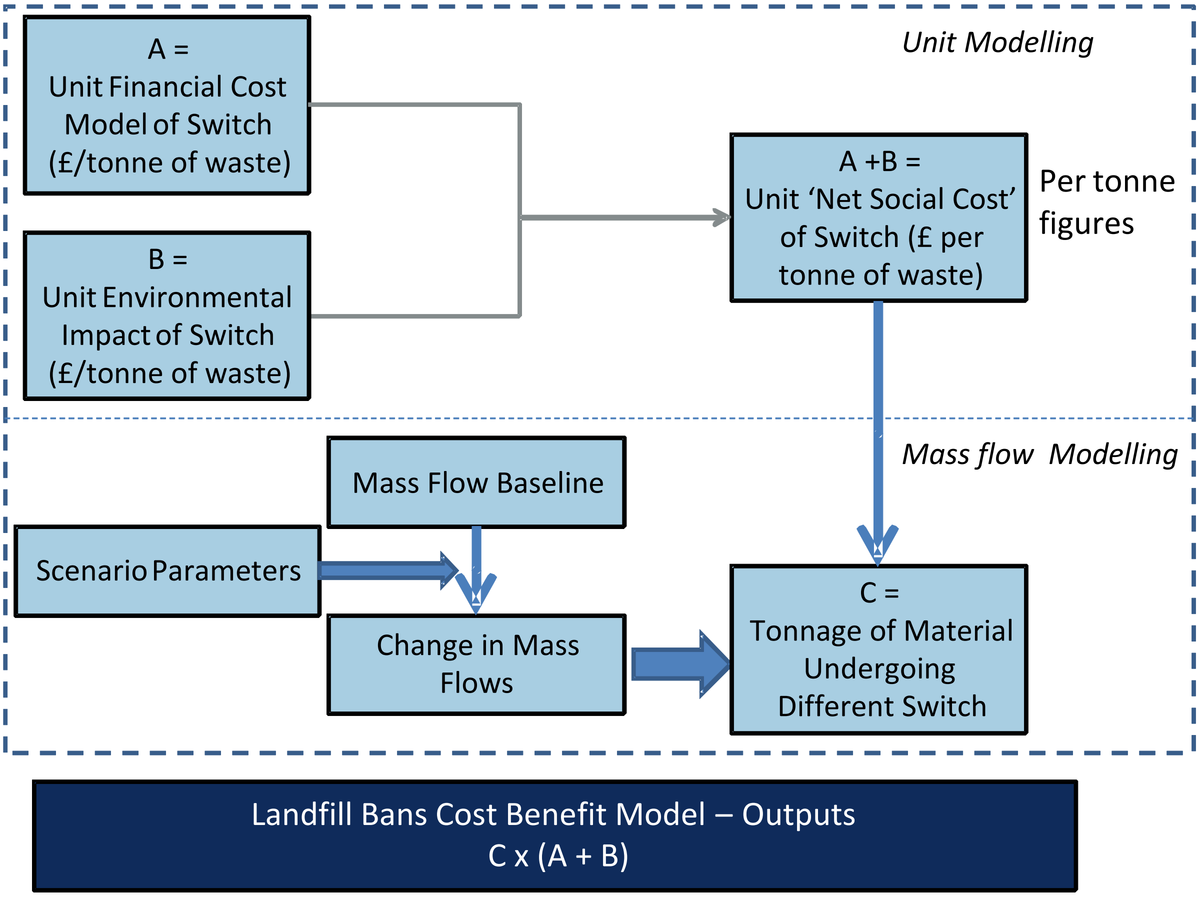
When the model is examining, for example, the switch of paper from landfill to recycling, it considers the unit financial cost of the switch from landfill to recycling (A) as well as the unit environmental cost of the same switch (B).

These are then added together to give a unit 'net social cost' for the same switch (A + B). The net social cost is the sum of the financial and the environmental costs, and represents the net costs to society of the change being examined.

The mass flow model, on the other hand, concentrates on calculating how much waste is subjected to a given switch. So, for example, if the model is examining the restriction on paper being sent to landfill, it draws upon the parameters used to describe that scenario to calculate the quantity of paper likely to undergo the switch from landfill to recycling (C).

The key results from the analysis of costs and benefits are derived from multiplying the quantities of material undergoing a given switch (here, the quantity of paper moving from landfill to recycling) by the unit impacts. The net social cost of the whole Scenario, therefore, is given by C x (A + B).

Figure 3 Cost Benefit Model Process Diagram



Some further explanation of some of the key principles is given below. Full details are given in Appendices 9 to 12.
The treatment processes that were modelled in the CBA stage related to the preferred switches of material. The preferences related to climate change and resource efficiency. The processes that relate to all the restrictions / bans are as follows:

- Food – diverted to the following biowaste treatment options:[42]
    - Anaerobic Digestion with onsite generation of electricity
    - Anaerobic Digestion with onsite generation of electricity and heat
    - Anaerobic Digestion with the biogas compressed and used as a vehicle fuel
    - Anaerobic Digestion with the biogas compressed and injected into the national grid
    - In-vessel Composting (IVC)
- Green – garden waste diverted to open-air windrow (OAW) facilities;
- Paper / card – recycling;
- Textiles – recycling;
- Wood – recycling and energy recovery;
- Glass – recycling;
- Metals – recycling;
- Plastics – recycling;
- WEEE – recycling;
- Biodegradable Waste – residual waste diverted to one of the following treatment processes:[43]
    - Incineration (electricity generation only)
    - Incineration (CHP mode)
    - MBT with output to landfill
    - MBT with SRF to a dedicated combustion Facility
    - MHT (autoclave) with output to gasification

7.2 Financial Costs

Details of the economic and cost modelling are given in Appendices 10 to 12. These Appendices describe what may be termed the central assumptions for the analysis. In Section 8.0, we carry out sensitivity analysis around these financial costs.

The modelling of financial costs was carried out using two different metrics:

- The **social metric,** which makes use of the standard Green Book approach, using a social discount rate to reflect social time preference, which takes into account impatience, catastrophic risk and marginal utility of income. Under this metric, the effects of taxes and subsidies are stripped out; and
- The **private metric** which applies a private Weighted Average Cost of Capital (WACC) valuing the opportunity cost of capital investments – either the cost of capital charges, or the opportunity cost of not reinvesting capital in an alternative project. This metric includes the effects of taxes and subsidies that private agents face that are excluded in the social metric.

[42] *A number of treatments were considered to give a range of results.*

[43] *A number of treatments were considered to give a range of results.*

The different cost metrics are summarised in **Table 12**.

Table 12 Different Cost Metrics

Metric	Discount Rate / Cost of Capital	Resource cost v. retail price?
Pure Social metric (Conventional NPV approach)	NPV using Green Book[44] social time preference discount rate (3.5% for first 30 years, 3% for 31-75 years etc.) of inter-temporal comparisons. Capital costs annualised at 3.5%	Value resource cost only, i.e. effects of taxes or subsidies stripped out
Pure Private metric (private agents' perspective)	NPV using Green Book[45] social time preference discount rate (3.5% for first 30 years, 3% for 31-75 years etc.) of inter-temporal comparisons. Capital costs annualised at estimated weighted average cost of capital (WACC) assumed to range from 10-15% for this study.	Value costs as retail prices including effects of landfill tax, ROCs etc.

Results in Section 8.0 are given both for the social and private cost metrics. Only in the case of the social cost metric, however, are the financial costs and environmental costs added together to arrive at a figure for the net social costs. It is standard practice, in this type of analysis, to strip out the effects of taxes and subsidies from the financial costs to ensure (amongst other things) that in cases where policies seek to 'internalise' environmental costs and benefits, these are not 'double counted' when the environmental costs are added in. Hence, in the cost benefit analysis, whilst we have calculated the financial costs under the private metric, we do not use these as the basis for the summation of costs and benefits. The private costs are shown principally to indicate what costs actors in the market place are likely to be confronted by when the policies are introduced. These private costs likely to be more familiar to those affected by the measures examined precisely because they do account for the effects of landfill tax and other extant policy instruments.

The costs do not necessarily represent the average costs of recycling the materials today. At the margin (over and above the Baseline, with the landfill tax having risen to £72 per tonne) the types of materials left in the residual waste stream, in the commercial and industrial sectors, were considered to be relatively similar. Therefore, the nature of collection rounds and the associated costs have been taken to be the same for both commercial and industrial sectors. Furthermore, in interpreting the financial costs of the switch from landfill, it has to be considered that the costs of landfilling are calculated before the application of landfill tax in the social metric.

The costs are presented in real 2009 sterling terms. Where estimates are based on figures from earlier years, these have been inflated by the relevant GDP deflator.

7.3 Environmental Costs

Details of the environmental modelling can be found at Appendix 9. The Appendix highlights the central estimates used in the environmental modelling. In Section 8.0, we carry out sensitivity analysis around these central assumptions.

The environmental modelling of the facilities proceeds using a model of the impacts of:

1. Transport;
2. Process energy use;
3. Process emissions;
4. Avoided emissions (associated with materials recycling, or energy generation); and
5. Other benefits (for example, with respect to reduced water use associated with compost applications)

The effects of the emissions and the estimated offsets (the 'avoided emissions') are then calculated using estimates of the environmental or social costs of different emissions. For GHGs, Defra Guidance suggests different values for different emissions, depending upon the nature of the source (or the displaced source).[46] For

[44] *http://greenbook.treasury.gov.uk/chapter05.htm#discounting*

[45] *http://greenbook.treasury.gov.uk/chapter05.htm#discounting*

[46] *DECC (2009) Carbon Valuation in UK Policy Appraisal: A Revised Approach. Climate Change Economics, Department of Energy and Climate Change, July 2009.*

particulate matter (PM_{10}), oxides of nitrogen (NO_x), sulphur dioxide (SO_2) and ammonia (NH_3) we have used the UK Government's Interdepartmental Group on Costs & Benefits (IGCB) Guidance on Air Quality Damage Costs. [47]

Several impacts have not been amenable to any monetisation of their damages, whilst others, such as disamenity, have not been included as the effects are not well characterised across all relevant facility types. The impacts which are not captured, therefore, include:

1 Disamenity (including odour, nuisance);
2 Bioaerosols;
3 Emissions to land;
4 Emissions to water;
5 Water use at facilities; and
6 Household time.[48]

7.4 Unit Environmental, Financial and Net Social Benefits

In order to improve understanding of the way in which the net social benefits are built up, we have provided figures from the modelling of these below. We have shown these as environmental benefits (a positive figure represents environmental gain), financial benefits (or savings – a positive figure represents a saving, a negative figure represents a cost) and the net social benefits (a positive figure represents a benefit, a negative figure represents a cost).

Table 13 shows the figures for biodegradable wastes. The greenhouse gas related benefits from switching out of landfill are heavily affected by the extent to which the landfill is assumed to capture the methane it generates over the period the waste biodegrades. We give, in the Table, figures for two cases, showing the extent of variation when the gas capture is 75% and 30%. The figures highlight the fact that at 75% landfill gas capture, the environmental benefits of switching out of landfill are considerably lower than where the capture is assumed to be 30%. In some cases, for example, for Green waste, and for food waste sent to IVC, this is decisive in the analysis of whether the costs of the switch, as examined under the social metric, are justified by the benefits.

The upper level of gas capture reflects the assumptions used by Defra / DECC in reporting to the UNFCC. The lower level is somewhat higher than the default level proposed by the IPCC, and is similar to the levels reported by many other EU Member States.[49] It should be noted that the change in costs – because these reflect the social cost metric – effectively assume landfill costs before the application of any landfill tax.

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[47] *Defra (2008) Damage Cost Guidance, November 2008. Available at http://www.defra.gov.uk/environment/airquality/panels/igcb/pdf/damage-cost-calculator-guidancepaper.pdf (accessed September 2009)*

[48] *For a discussion of this issue, see D. Hogg (2006). Impact of Unit-based Waste Collection Charges. Report for the OECD Environment Directorate, Working Group on Waste Prevention and recycling, May 2006.*

[49] *European Environment Agency (2011) Annual European Union Greenhouse Gas Inventory 1990-2009 and Inventory Report 2011, Technical Report No. 2/2011*

Table 13 Environmental Benefits, Financial Savings and Net Social Benefits of Switching Biodegradable Waste from Landfill

		Biodegradable Wastes										
		Food										
		AD: on-site biogas use (elec)	AD: on-site biogas use + CHP	AD: compressed biogas used in vehicles	AD: biogas injected to gas grid	IVC	Green	Paper / Card	Card	Textiles	Wood - Recycling	Wood - Combustion
Environmental Benefits	Total GHG - 75% Gas Capture	£9	£11	£13	£14	£8	£9	£30	£30	£143	£13	£29
	Total GHG - 30% Gas Capture	£30	£31	£34	£34	£28	£31	£70	£70	£159	£43	£60
	Air Quality	£0	£0	£1	£1	£1	-£1	£1	£1	£71	-£1	-£0
	Other	£11	£11	£11	£11	£16	£16	£0	£0	£0	£0	£0
Financial Savings (Social)	Municipal (75%)	-£48	-£58	-£60	-£62	-£36	-£40	-£35	-£35	-£43	£11	-£6
	C&I / C&D (75%)	-£50	-£60	-£62	-£64	-£38	-£39	£31	£31	-£52	£10	-£14
	Municipal (30%)	-£44	-£54	-£57	-£58	-£33	-£36	-£28	-£28	-£40	£16	-£1
	C&I / C&D (30%)	-£46	-£56	-£59	-£60	-£35	-£35	£38	£38	-£49	£16	-£9
Net Social Benefit	Municipal (75%)	-£27	-£35	-£34	-£36	-£12	-£16	-£3	-£3	£171	£23	£23
	C&I / C&D (75%)	-£29	-£37	-£36	-£38	-£14	-£15	£62	£62	£162	£23	£15
	Municipal (30%)	-£3	-£11	-£10	-£12	£13	£10	£43	£43	£190	£59	£59
	C&I / C&D (30%)	-£5	-£13	-£12	-£14	£11	£11	£109	£109	£181	£59	£51

Table 14 shows the same results but for the non-biodegradable materials, the outcomes for which are unaffected by landfill gas captures. These highlight the range of different outcomes for different materials. They suggest that the case for additional recycling of some materials, notably ferrous and non-ferrous metals, is much stronger than for others when viewed from the perspective of the net social benefit being generated.

Table 14 Environmental Benefits, Financial Savings and Net Social Benefits of Switching Non-biodegradable Waste from Landfill

		Non-Biodegradable Wastes					
		Glass	Ferrous metal	Non-ferrous metal	Dense plastics	Film plastics	WEEE
Environmental Benefits	Total GHG	£14	£64	£443	£67	£70	£53
	Air Quality	£3	£19	£78	£18	£18	-£2
Financial Savings (Social)	Municipal	-£23	-£23	-£23	-£127	-£92	-£168
	C&I / C&D	£34	-£2	-£36	-£90	-£101	-£92
Net Social Benefit	Municipal	-£5	£60	£498	-£42	-£4	-£117
	C&I / C&D	£52	£81	£485	-£5	-£13	-£40

Table 15 shows the same results for residual waste. For these wastes, the magnitude of the net social benefit is affected by landfill gas captures, but the net social benefits are always negative.

Table 15 Environmental Benefits, Financial Savings and Net Social Benefits of Switching Residual Waste from Landfill

		Incineration Elec	Incineration CHP	MBT: Stabilisation, output to landfill	MBT: SRF to EfW	MHT: gasification
Environmental Benefits	Total GHG - 75% Gas Capture	-£7	-£0	£11	-£7	-£2
	Total GHG - 30% Gas Capture	£6	£12	£24	£6	£11
	Air Quality	-£2	-£2	-£0	-£1	£1
Financial Savings (Social)	All Sectors (75%)	-£43	-£27	-£29	-£36	-£46
	All Sectors (30%)	-£40	-£24	-£28	-£34	-£44
Net Social Benefit	All Sectors (75%)	-£52	-£30	-£18	-£44	-£47
	All Sectors (30%)	-£36	-£14	-£4	-£29	-£33

7.5 Mass Flow Effects of the Different Restrictions and Bans

In this Section, we give some further information regarding how the Baseline was constructed. We also briefly discuss how the effects of the different restrictions and bans have been modelled. Details concerning the construction of the Baseline can be found in Appendix 1, and a more complete description of the rationale underpinning the assumptions driving the changes in mass flows is to be found at Appendix 8.

7.5.1 Baseline

In order to understand the effects of bans / restrictions which might be implemented in future, clearly, one needs to understand how the world might look in future without the policy in place. Where the issue is that of waste, this is a major challenge. Data on the current situation is relatively poor for commercial and industrial waste. The basis for projections is almost wholly absent because of the lack of data points showing how quantities have changed over time. Given that one wishes to understand not only quantities, but also, management routes, and that this needs to be extrapolated, the heroic nature of some of the assumptions required becomes quite clear.

The approach taken was as follows:

- For municipal waste, total arisings and quantities recycled were taken from the latest WasteDataFlow figures. At the time the baseline was developed the latest figures were for 2007/08. The most relevant compositional data was then used for England and each of the DAs. Going forward the waste strategies for England and each of the DAs were used to provide targets for recycling and other treatments. Recycling rates were then interpolated using time profile developed to reflect the rate of uptake of recycling for the different materials. The remaining residual waste was then apportioned to different residual treatments depending upon the relevant strategies;
- For commercial and industrial wastes, the approach differed across the countries. For Wales the C&I waste survey, published in 2009, was used for part of the composition and the proportions of material recycled. Due to the large 'mixed commercial waste' category in the survey (>50%) the survey on its own was not suitable, so the composition for the municipal sector was applied to this fraction. For the other countries, the latest arisings data was used along with a composition from the ERM Carbon Balances report.[50] A basic model was developed to estimate the effect of the landfill tax on the quantity of waste landfilled from the C&I sectors (see Section 6 of Appendix 1). From this, overall recycling, and residual treatment, rates out to 2013 were calculated. The tax was considered to be the primary (additional) driver on these sectors so no change was modelled past 2013 (this is described in Appendix 1). Again material specific recycling and treatment rates were assigned to each material (based on an understanding of performance in high-performing systems in the UK and the EU) so that the overall change was consistent with the modelled effect of the tax.
- For construction and demolition wastes, latest arisings figures were used for England and each of the DAs. The composition from the 2005/06 Welsh C&D survey was used to calculate the quantities of each material. The proportions of each material recycled were then used for all countries. Recycling rates for each material in 2024 were then estimated, and interpolated linearly.

It should be noted that our model anticipates that the landfill tax will generate greater changes for the C&I sector than has been assumed in previous government modelling. Because there is less waste landfilled in the baseline as a result, the potential for change in the situation where the restrictions and the bans are applied is somewhat diminished. To the extent that one recognises the uncertainties which surround our estimates, it could be argued that if we have been 'optimistic' regarding the effectiveness of the tax, then the effects of the restrictions and the ban (i.e. the magnitude of the changes set in train) are effectively, other things being equal, conservatively estimated in our modelling.

Table 16 Estimated Quantity of Waste Landfilled in UK, 2008/09 and 2024/25

	Landfilled 2008/09					**Landfilled 2024/25**			
	MSW	**Com.**	**Ind.**	**C&D**		**MSW**	**Com.**	**Ind.**	**C&D**
Food	4,733	6,258	563			1,105	4,336	306	
Green	797	717	193	492		173	425	86	54
Paper / card	2,914	2,442	479	376		643	876	239	28
Textiles	628	199	55			150	100	39	
Wood	344	203	171	512		66	66	72	102
Glass	612	492	68	44		101	320	36	17
Ferrous metal	437	257	231	164		90	182	86	64
Non-ferrous metal	90	231	181	41		21	102	135	16
Dense plastics	1,212	611	108	721		283	434	73	300
Plastic film	967	1,012	142			277	753	101	
WEEE	404	528	68			85	420	37	

7.5.2 Assumptions Regarding Timing

The actual dates of announcement and implementation of any restriction or ban will be a matter for Defra and the DAs, and is likely to be determined following consultation and publication of this report. For the purposes of this study, the following assumptions were made regarding timing of implementation:

[50] *ERM (2006) Carbon Balances and Energy Impacts of UK Wastes, Defra R&D Project WRT 237, Final Report*

- The year of announcement of the each of the restrictions and bans modelled for this report was 2010.
- A nominal lead in time of 5 years was used for the material based restrictions and bans on unsorted material.
- The lead-in time for the biodegradable waste ban was set at 8 years, recognising:
    - the longer lead times likely to be required for residual waste treatment infrastructure; and
    - the desirability of having this ban enter into force after measures have been implemented to increase recycling / composting / digestion.
- The date of implementation was therefore 2015 for the material-based measures, and 2018 for the biodegradable waste ban.

7.5.3 Effects of the Bans and the Restrictions

This Section sets out the assumptions made regarding the effect of the restrictions and bans that have been modelled. All of the restrictions and bans modelled have effects which are measured relative to a defined Baseline. Consequently, the modelling should be understood as an attempt to understand the effects of policy relative to a future scenario which is, itself, subject to some uncertainty. We have sought to make the estimates as best we can, and on the basis of transparent assumptions.

For the material and product based restriction and bans, the effects of policies were modelled by considering the change in recycling rates for the specific material expected in 2015 (the year in which the restriction / ban was assumed to be implemented). This was considered relative to Baseline levels.

Recycling rates achieved in the case of the material and product-based **restriction only** were estimated based upon the following considerations:

- Knowledge of how many local authorities are collecting which materials now, and estimates of how many are likely to be collecting the specified material at some point in the future. The principle effect of the restriction was expected to come through local authorities who were not already collecting these materials introducing new collections for them, though doing so with no specific standard for the collection in mind. The assumed quality of these collections was, therefore, assumed to be low;
- Estimates of which materials are likely to be being collected from commercial and industrial enterprises once landfill tax reaches £72 per tonne and the extent to which the announcement of the restriction would be likely to generate additional uptake of recycling by companies not in receipt of services. The principle stimulus to additional uptake is expected to come from marketing, by collection companies, of their services. The absence of a 'requirement to sort', and the weak enforcement of the Duty of Care at present, gives little reason to expect that the additional uptake will be highly significant, over and above levels expected as a consequence of the tax (i.e. the Baseline). Studies highlight that even recent surveys show large numbers of SMEs not recycling anything at all, and a significant number of those that do recycle, recycling only one material. Similarly, in respect of Duty of Care, studies show that many SMEs are not aware of their obligations to pre-treat waste and many also are not aware of their obligations under Duty of Care. [51] [52] The suggestion is, therefore, that the marketing effects of collection companies certainly did not reach all companies, particularly SMEs. There seems little reason to believe that the Duty of Care can be relied upon to propel significant increases in recycling beyond those already occurring as a result of the landfill tax. The exception may be cases where specific materials are barely recycled, despite tax at £72 per tonne; and
- Estimates of which materials are likely to be being sorted from construction and demolition wastes once the landfill tax reaches £72 per tonne, and the extent to which the announcement of the restriction would be likely to generate additional recycling by waste producers / sorting companies.

These effects can only be estimates. The effects of material-based, **restriction only** policies are uncertain because there are many factors that come into play, including the effect of marketing by collection companies of their services, and other behavioural changes that are difficult to quantify. There are no scientific studies that show what the effect of material based restrictions might be. Estimating the effect of the policy is therefore of

[51] University of Southampton, the Federation of Small Businesses and the Hampshire and Isle of Wight Sustainable Business Partnership (2008) Sustainable Waste Management: Implementing Sustainable Waste Management Within Micro and Small to Medium Sized Enterprises, September 2008.

[52] Resource Saver (2008) Waste Practices Survey – An analysis in relation to recycling trends and compliance issues, report to RECAP (Cambridgeshire County Council), 11 March 2008.

necessity, based upon judgement, taking into consideration factors such as how strongly the policy is likely to be enforced, and the effect of existing drivers such as landfill tax.

By contrast, recycling rates modelled in the case of the '**ban on unsorted wastes'** are modelled as delivering high rates of recycling by international standards. Clearly, achievement of these depends much upon the nature of the specification of the requirement (see Section 6.3). We have modelled the effect based upon best practice data regarding collection systems in countries which have a policy akin to a sorting requirement or minimum service specification. Given that most of this data is from countries which have *also* implemented some type of landfill ban and, in most cases, a landfill tax, this seems a reasonable approach.

The **biodegradable waste ban** was modelled by a rate of diversion of waste from landfill to other residual treatments. The model can fairly straightforwardly switch from one form of treatment to another for residual waste. 90% of residual waste is assumed to be switched from landfill in the case of MSW and the case of commercial and industrial waste (allowing for some inert materials to be sent to landfill still). Lower switch rates are used for construction and demolition waste as we estimate that some of these wastes which are being sent to landfill will not be biodegradable in nature.

In the case of the biodegradable waste ban, we expect limited effects on recycling over and above Baseline levels which include the landfill tax at £72 per tonne. Given median landfill gate fees of £20.50 per tonne in early 2009, the real price of landfilling is expected to be of the order £85 per tonne in 2013. The provision of recycling services, and the level of recycling, are likely to increase as the avoided cost of disposal rises. If other residual waste management methods are broadly similar in cost at this time, then the avoided cost of dealing with residual waste will barely change. As this seems likely in many cases, so that this measure would give no obvious additional stimulus to recycle (as all 'cost effective recycling' will already have been implemented), the principle effect of the biodegradable waste ban will be to switch residual out of landfill and into alternatives. In practice, it may be that some additional recycling is stimulated by the change, but it was deemed sensible to concentrate on the outcomes of what is expected to be the principle effect of the ban (i.e. a shift in residual waste away from landfill).

7.6 Summary Recycling Rates Achieved

The Tables below summarise the effects of the restrictions and bans in terms of the changes in mass flow related to increases in recycling or recovery rates. Tables showing the absolute tonnages of material switched are given in Appendix 8.

Table 17 Food Recycling Rates Achieved

		Restriction Only				Unsorted Waste Ban			
		MSW	Comm.	Ind.	C&D	MSW	Comm.	Ind.	C&D
Food	Baseline Recycling Rate (2008)	7%	9%	66%	-	7%	9%	66%	-
	Baseline Recycling Rate (2015)	21%	17%	73%	-	21%	17%	73%	-
	Resulting Recycling Rate (2015)	26%	28%	77%	-	54%	66%	89%	-

Table 18 Green Recycling Rates Achieved

		Restriction Only				Unsorted Waste Ban			
		MSW	Comm.	Ind.	C&D	MSW	Comm.	Ind.	C&D
Green	Baseline Recycling Rate (2008)	77%	68%	70%	60%	77%	68%	70%	60%
	Baseline Recycling Rate (2015)	76%	72%	76%	75%	76%	72%	76%	75%
	Resulting Recycling Rate (2015)	76%	74%	77%	80%	83%	87%	90%	95%

Table 19 Paper / Card Recycling Rates Achieved

		Restriction Only				Unsorted Waste Ban			
		MSW	**Comm.**	**Ind.**	**C&D**	**MSW**	**Comm.**	**Ind.**	**C&D**
Paper / Card	Baseline Recycling Rate (2008)	50%	75%	80%	40%	50%	75%	80%	40%
	Baseline Recycling Rate (2015)	70%	80%	85%	64%	70%	80%	85%	64%
	Resulting Recycling Rate (2015)	72%	82%	86%	71%	82%	92%	93%	95%

Table 20 Textiles Recycling Rates Achieved

		Restriction Only				Unsorted Waste Ban			
		MSW	**Comm.**	**Ind.**	**C&D**	**MSW**	**Comm.**	**Ind.**	**C&D**
Textiles	Baseline Recycling Rate (2008)	17%	49%	40%	-	17%	49%	40%	-
	Baseline Recycling Rate (2015)	25%	55%	45%	-	25%	55%	45%	-
	Resulting Recycling Rate (2015)	36%	56%	47%	-	50%	81%	82%	-

Table 21 Wood Recycling Rates Achieved

		Restriction Only				Unsorted Waste Ban			
		MSW	**Comm.**	**Ind.**	**C&D**	**MSW**	**Comm.**	**Ind.**	**C&D**
Wood	Baseline Recycling Rate (2008)	64%	50%	64%	78%	64%	50%	64%	78%
	Baseline Recycling Rate (2015)	73%	59%	68%	85%	73%	59%	68%	85%
	Resulting Recycling Rate (2015)	73%	60%	69%	86%	74%	63%	70%	88%
	% Diversion to Combustion	50%	50%	50%	50%	70%	70%	70%	70%

Note: Wood does not include furniture.

Table 22 Glass Recycling Rates Achieved

		Restriction Only				Unsorted Waste Ban			
		MSW	**Comm.**	**Ind.**	**C&D**	**MSW**	**Comm.**	**Ind.**	**C&D**
Glass	Baseline Recycling Rate (2008)	65%	78%	80%	54%	65%	78%	80%	54%
	Baseline Recycling Rate (2015)	80%	82%	84%	65%	80%	82%	84%	65%
	Resulting Recycling Rate (2015)	81%	82%	85%	70%	88%	90%	90%	90%

Table 23 Metals Recycling Rates Achieved

		Restriction Only				Unsorted Waste Ban			
		MSW	**Comm.**	**Ind.**	**C&D**	**MSW**	**Comm.**	**Ind.**	**C&D**
Metals	Baseline Recycling Rate (2008)	56%	66%	80%	89%	56%	66%	80%	89%
	Baseline Recycling Rate (2015)	65%	72%	82%	91%	65%	72%	82%	91%
	Resulting Recycling Rate (2015)	66%	74%	83%	92%	75%	91%	92%	95%

Table 24 Recycling Rates Achieved Under Restriction Only on Plastics

Restriction Only		**MSW**		**Comm.**		**Ind.**		**C&D**
Plastics		MSW - Dense	MSW – Film	Com. - Dense	Com. - Film	Ind. – Dense	Ind. - Film	C&D - Dense
	Baseline Recycling Rate (2008)	19%	2%	41%	31%	61%	52%	35%
	Baseline Recycling Rate (2015)	24%	3%	45%	35%	63%	53%	50%
	Resulting Recycling Rate (2015)	33%	14%	51%	39%	69%	59%	55%

Table 25 Recycling Rates Achieved Under Ban on Unsorted Plastics

Restriction Only + Requirement to Sort		**MSW**		**Comm.**		**Ind.**		**C&D**
Plastics		MSW – Dense	MSW - Film	Com. – Dense	Com. - Film	Ind. – Dense	Ind. - Film	C&D - Dense
	Baseline Recycling Rate (2008)	19%	2%	41%	31%	61%	52%	35%
	Baseline Recycling Rate (2015)	24%	3%	45%	35%	63%	53%	50%
	Resulting Recycling Rate (2015)	47%	13%	67%	57%	78%	78%	75%

Table 26 WEEE Recycling Rates Achieved

		Restriction Only				**Unsorted Waste Ban**			
		MSW	**Comm.**	**Ind.**	**C&D**	**MSW**	**Comm.**	**Ind.**	**C&D**
WEEE	Baseline Recycling Rate (2008)	29%	36%	60%	-	29%	36%	60%	-
	Baseline Recycling Rate (2015)	45%	40%	69%	-	45%	40%	69%	-
	Resulting Recycling Rate (2015)	46%	43%	70%	-	58%	56%	77%	-

8.0 Key Results from the Analysis

This Section presents the results of the cost benefit analysis for landfilling of different waste streams. The analysis is, it will be appreciated from preceding discussions, developed on the basis of a complex model which incorporates a number of subsidiary calculations and various additional assumptions.

There are a number of variables in the modelling that would be expected, therefore, to affect the final results of the cost benefit analysis. Each of these variables carries with it a varying degree of both uncertainty, and level of influence on the results.

A detailed list and discussion around all these uncertainties is given in Appendix 13. The description of the modelling in the Appendices presents our central assumptions for key parameters and variables. However, in seeking to present the results of the modelling exercise, and particularly in seeking to understand the net cost to society (which provides an indication as to whether the policy is economically justified or not), it was considered that point (i.e. single) estimates of the possible outcome were insufficient to convey the potential variation in the outcome of the analysis as the value of key variables is flexed (for purposes of sensitivity analysis).

Therefore, we have used a technique called Monte Carlo simulation to vary the most significant input parameters to the cost benefit model in order to calculate probability distributions for the key results. This allows us to a) present ranges for the final figures in a mathematically structured way (a key factor highlighted by the peer review team in their report) and b) highlight which of the model inputs are the most important in driving the model outcomes (in particular, in determining the net cost to society of the policy under examination).

Monte Carlo simulation is, in essence, a computer based mathematical modelling tool. It is often used for calculating risk in the business environment. The software used allows the user to assign ranges, and probability distributions, to input variables and record the statistical distribution of whatever numerical outputs are required. This allows the user to calculate the median value, and a range around this value with specified confidence limits. The median value and the 10% and 90% confidence limits are shown in the results. This effectively shows the reader that the actual result is 80% likely to fall between these upper and lower bounds; a useful indication of uncertainty and risk for the policy maker.

As mentioned above all of the uncertainties in the modelling are set out and discussed in Appendix 13. It is relevant to model some of these in Monte Carlo simulation, but not all. For example, where distinct sets of input variables can be chosen (i.e. different datasets of environmental damage costs, or different landfill gas generation models), the sensitivity of results to these changes are shown in isolation at the end of this Section.[53]

The key input parameters that are varied in the cost benefit model are as follows:

- **General (i.e. applied uniformly across all policies):**
  - Landfill Gas Capture Rate (30% to 75%);
  - Baseline C&I Waste Arisings (+/- 5%);
  - MSW Growth Rates (+/- 1%); and
  - C&I Growth Rates (+/- 0.5%).
- **Material Specific (i.e. affecting specific material-based policies):**
  - Recycling Benefits (see Appendix 9 – Table 72);
  - Financial Costs of Collection (+/- 15%);
  - Financial Disposal / Treatment Costs (+/- 15%);
  - MSW Capture Rates in 2024 (by material / country);
  - Baseline C&I Capture Rates in 2013/14 (by material); and
  - Effects of Policies (change in tonnages).

[53] *It would, in our view, be incorrect to allow damage costs of air pollutants to be allowed to vary, simultaneously, between upper and lower bounds given that underpinning each of these would be an implied value of life-year, or value of statistical life. To allow all damage costs to vary simultaneously would be akin to making a different assumption to calculate the damages for each of the pollutants under consideration.*

These variables relate to different parts of the calculation of the net cost to society. As **Figure 3** shows, there are unit financial and environmental impacts, and tonnage changes. Changing the variables gives rise to a range of potential impacts. So as to avoid complexity in presenting the results, we only show median (most likely) values in the Main Report, the exception being the values of the net benefit to society, where we present upper and lower bounds within 80% confidence limits. Full results for each output parameter, including the probability distributions, are given in Appendix 14.

In this Section the results for each of the modelled restrictions / bans are presented in the following manner:

- A section for each material / product, with the effects of the Restriction Only **and** the Ban on Unsorted Waste (for that material / product) presented together;
- Biodegradable Waste Ban;
- Criticality analysis by ban, where appropriate (this type of analysis changes one key variable until the tipping point for the policy recommendation is reached, and shows what risk there is to the policy decision);
- Scenario considering combination of most beneficial bans from the societal perspective; and
- Specific Sensitivities around general variables not changed in the Monte Carlo simulations.

The breakdown in results is presented in the order in which they are calculated. This approach should guide the reader to how the final net cost to society is derived.

For each of the bans the following data are presented:

- **Total GHG Impacts, by carbon accounting category, Million Tonnes CO_2 eq**
  - Traded CO_2 eq (emission that fall within the EU ETS);
  - Non-Traded CO_2 eq (emission that do not fall within the EU ETS); and
  - International / Overseas CO_2 eq (emissions occurring not within the UK).
- **Net Energy Generation**
  - Net Electrical Energy Generated (MWh in the year 2024);
  - Net Heat Energy Generated (MWh generated in 2024); and
  - Net Transport Fuel Equivalent Generated (fuel energy in 2024 in MWh)[54].
- **Monetised Environmental Benefits, Net Present Value (NPV) 2009-2024 £million**
  - GHG emissions (total GHG impacts given above x relevant cost of carbon);
  - Air Quality Impacts (equivalent to the *health benefits* from the policy); and
  - Other (includes benefits from use of fertiliser etc).
- **Financial Costs, (NPV) 2009-2024 £million**
  - Total Financial Costs under Social Cost Metric (figures used to calculate Net Cost to Society);
  - Total Financial Costs under Private Metric (these costs more closely resemble those seen by the waste management industry); and
  - Communications / Regulations Element (to show where this may be significant in terms of the Net Cost to Society). Details of the modelling of this are given in Appendix 14.
- **Net Benefit to Society (financial costs + environmental Benefits), (NPV) 2009-2024 £million**
- **Tornado Diagram showing the most important parameters driving the results**
  In these diagrams a variable with a negative (-ve) impact (i.e. a bar to the left) represents an input variable that has a strong influence on <u>reducing</u> the net benefit to society as it increases; conversely (+ve) bars on the chart show variables that <u>increase</u> the net social benefit as their value increases.

[54] *The conversion of fuel to MWh is to enable some form of comparison to be made. It should also be noted that care needs to be taken in simply 'adding' these forms of energy together just because they are expressed in the same units. The nature and quality of electrical energy, heat energy and transport fuel are quite different – one is not really adding 'like to like'.*

8.1 Food Waste Restriction / Ban (Policy Scenarios 1 and 10a.)

When a measure is implemented that seeks to divert food waste from landfill, the nature of the biowaste treatment utilised to manage the waste has a significant bearing on the environmental benefits achieved. Hence it is important to show a range of results for different treatment options in the results. The environmental performance and financial costs for the following biowaste treatments were modelled (all relevant assumptions around these treatment facilities can be found in Appendix 9):

- Anaerobic Digestion: on-site biogas use (with electricity generation only);
- Anaerobic Digestion: on-site biogas use (operating in CHP mode);
- Anaerobic Digestion: with compressed biogas used as a vehicle fuel;
- Anaerobic Digestion: with compressed biogas injected to national gas grid system; and
- In-Vessel Composting.

Greenhouse Gases
The greenhouse gas performance of the systems, and also of the landfill, will have a significant impact on the net benefit to society for a restriction / ban on food waste. The following table shows the median GHG impacts from the two policy scenarios:

Table 27 Cumulative GHG Emissions (2009-2024) from Food Waste Restrictions / Bans, million tonnes CO_2 eq

	Restriction					Unsorted Ban				
	AD: (elec)	AD: CHP	AD: vehicles	AD: grid	IVC	AD: (elec)	AD: CHP	AD: vehicles	AD: grid	IVC
Traded CO_2 eq	-0.9	-0.9	0.4	0.4	0.6	-3.7	-3.7	1.6	1.6	2.4
Non-Traded CO_2 eq	-5.3	-5.6	-6.9	-6.9	-5.9	-23	-24	-29	-30	-25
International CO_2 eq	n/a					n/a				
Total CO_2 eq (excluding biogenic)	-6.2	-6.5	-6.5	-6.6	-5.4	-26	-28	-28	-28	-23

Note: -ve figures indicate a net GHG saving

The main points to note about the emission of GHGs are:

- Under all biowaste treatment scenarios there is a net reduction in GHG emissions;
- The unsorted ban with a sorting requirement generates more than four times the savings as the restriction only; and
- There are emissions reductions from the 'Traded' sector for biowaste treatments that generate electricity. For those that do not generate electricity, there are increases in emissions of GHGs in the traded sector associated with a reduction in renewable energy generation from landfill gas.

Energy
In four out of the five cases when the biowaste is being treated energy is being generated, either through electricity, heat or compressed biogas. **Table 28** shows the net increase or reduction in energy generated.[55]

[55] *It should be noted that it is entirely possible to capture heat from compost processes. This was not modelled in this study but evidently, the environmental performance would be anticipated to be slightly higher than that of the IVC option.*

Table 28 Net Change in Energy Generation from Food Waste Restrictions / Bans (2009-2024), GWh

	Restriction					Unsorted Ban				
	AD: (elec)	AD: CHP	AD: vehicles	AD: grid	IVC	AD: (elec)	AD: CHP	AD: vehicles	AD: grid	IVC
Electricity (Total)	2,200	2,200	-1,000	-1,000	-1,000	9,600	9,600	-4,100	-4,100	-4,100
Heat (Total)		1,200		7,100			5,000		30,000	
Transport Fuel (Total)			5,400					23,000		

Note: -ve figures indicate a net reduction in energy generated

The main points to note about the energy generation are:

- Where the process does not generate any electrical energy there is a net reduction in electricity generated. This relates to the reduction in generation from landfilled food waste;
- Significant quantities of heat can be generated if the gas can be successfully injected in the grid system. This is a technically challenging option;
- Large quantities of energy can also be generated by compressing the biogas and using it as a vehicle fuel. These types of systems are currently operational in several European Member States;
- In-Vessel Composting is the only case where there is a net reduction in energy generated (though in principle, heat could be recovered);
- All of the energy generated by these processes is renewable; and
- The net quantities of energy generated are around four times greater under the Unsorted Waste Ban, with sorting requirement, scenario.

Environmental Benefits

Table 29 shows the expected environmental benefits. Key points are as follows:

- One of the most significant contributors to the environmental benefits from this policy is from a reduction in GHG emissions. **Table 29** shows the greatest level of emissions occurs in the UK and outside the EU ETS. These emissions effectively relate to the savings of methane from not landfilling the food waste (as opposed to a saving from the treatment itself;
- Other emissions savings, from the use of compost and digestate off setting fertilizer etc, make the second largest contribution to the GHG benefits; and
- The smallest contribution by far comes from the air quality / health benefits.

Table 29 Net Present Value (NPV) of Environmental Benefits from Food Waste Restrictions / Bans, £ million

	Restriction					Unsorted Ban				
	AD: (elec)	AD: CHP	AD: vehicles	AD: grid	IVC	AD: (elec)	AD: CHP	AD: vehicles	AD: grid	IVC
GHGs	£160	£180	£210	£210	£170	£710	£760	£890	£890	£710
Air Quality	£3	£3	£11	£9	£7	£12	£15	£49	£37	£30
Other	£97	£97	£97	£97	£140	£420	£420	£420	£420	£600
Net Environmental Benefits	£260	£280	£310	£310	£310	£1,100	£1,200	£1,400	£1,300	£1,300

Note: +ve figures indicate a net environmental benefit

Financial Savings

The financial savings are shown in **Table 30.** The key points are:

- Under the Social cost metric all treatments incur a financial penalty, notwithstanding the use of the social discount rate to value the capital costs;
- The most expensive option under the social cost metric is AD with biogas used as a vehicle fuel. From the private perspective this now switches to the process where biogas is injected into the grid. This is because the capital costs are high and there is no additional saving on fuel duty, as is the case when vehicle fuel is offset;
- Again the relative pattern of costs or benefits are repeated, but magnified where the Unsorted Ban with Sorting Requirement is considered;
- The communications / regulation element is minor compared to the total financial costs for all food waste scenarios (except, perhaps, if considered from the private perspective);
- When considering the private cost metric, use of some technologies leads to financial savings. In this metric, the landfill tax is included in the figures. Furthermore renewable energy incentives (Feed-in Tariffs) are included with electricity generation. In the CHP case, the additional costs of infrastructure exceeds the additional sales revenue (note, we have not included support from the forthcoming renewable heat incentives). There are clear financial savings for implementation of food waste collections where the food waste is processed in an anaerobic digester generating electricity; and
- IVC is higher in cost than AD facilities generating energy on-site as we have factored in an additional cost in the process for managing the green waste needed as structural material. The additional cost is included as this material could be treated in (generally) less costly non-ABPR compliant open-air windrow facilities.

Table 30 Net Present Value (NPV) of Financial Savings from Food Waste Restrictions / Bans, £ million

	Restriction					**Unsorted Ban**				
	AD: (elec)	AD: CHP	AD: vehicles	AD: grid	IVC	AD: (elec)	AD: CHP	AD: vehicles	AD: grid	IVC
Financial Savings (Social Metric)	-£480	-£510	-£530	-£380	-£310	-£2,100	-£2,300	-£2,300	-£1,800	-£1,400
Financial Savings (Private Metric)	£92	£20	-£170	-£290	-£32	£340	£34	-£770	-£1,300	-£190
Comms / Regulation Element	-£0.47	-£0.47	-£0.47	-£0.47	-£0.47	-£70	-£70	-£70	-£70	-£70

Note: -ve figures indicate a net financial cost

Net Benefit to Society

When the environmental benefits and financial savings under the social metric are combined the net benefit to society can be calculated. All the variables in the model were run with the Monte Carlo simulation to generate statistical distributions for the net cost. The median (most likely) values, along with 10% and 90% intervals, are given in the Table below. The upper and lower intervals show that there is an 80% probability that the actual value will lie between the values quoted.

It can be seen that in nearly all cases, both the restriction and the food waste ban imply net costs to society. Whilst the benefits range from +£100 million to -£350 million for the restriction, the unsorted food waste ban generates benefits ranging from +£380 million to -£1,500 million. Since the negative figures imply costs, then it can be seen that the changes typically imply net costs to society since the costs of the change outweigh the environmental benefits. The exceptions are where food waste is sent either to IVC or to AD where the gas is injected into the gas network. In these cases, the sensitivity analysis indicates the possibility that there will be net benefits to society in each case.

Table 31 Net Present Value (NPV) of Net Benefit to Society from Food Waste Restrictions / Bans, £ million

	Restriction					Unsorted Ban				
	AD: (elec)	AD: CHP	AD: vehicle	AD: grid	IVC	AD: (elec)	AD: CHP	AD: vehicle	AD: grid	IVC
Net Environmental Benefits	£260	£280	£310	£310	£310	£1,100	£1,200	£1,400	£1,400	£1,300
Financial Saving (Social Metric)	-£480	-£510	-£530	-£380	-£310	-£2,100	-£2,300	-£2,300	-£1,800	-£1,400
Upper (90% Interval)	-£110	-£130	-£110	£37	£100	-£480	-£610	-£520	£33	£380
Net Benefit to Society (median value)	**-£210**	**-£230**	**-£210**	**-£63**	**£2**	**-£940**	**-£1,100**	**-£980**	**-£410**	**-£57**
Lower (10% Interval)	-£320	-£350	-£330	-£170	-£100	-£1,400	-£1,500	-£1,500	-£860	-£490

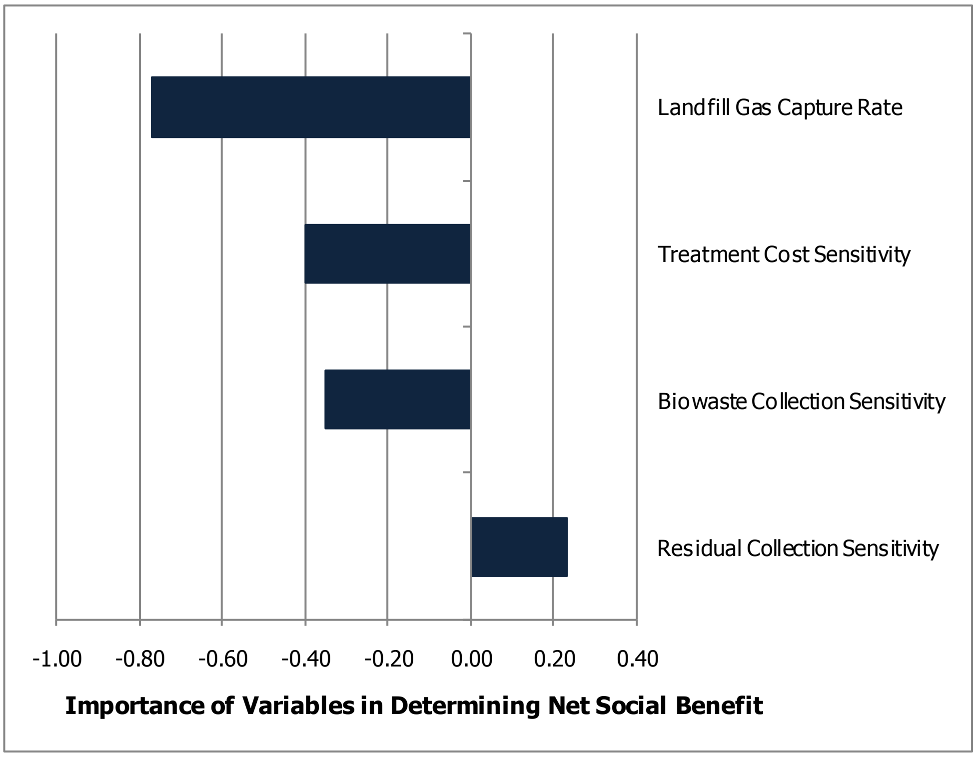
Note: +ve figures indicate a net benefit to society

Key Parameters

Key sensitivities to the results are highlighted in **Figure 4**:

- The most significant variable that affects the modelling of net benefit to society for the ban on food waste is landfill gas capture. The greater the estimated gas capture rate the lower the benefit to society, as less carbon is considered to be emitted to atmosphere from the landfill, so that the environmental benefits of the change are diminished;
- The 'treatment cost sensitivity' varies the cost of biowaste treatment by +/- 15%. As the cost of treatment goes up, the financial savings decline, as does the net benefit to society;
- The net benefit to society is also sensitive to the costs of collection. If food waste collection costs go up then financial costs increase, but vice versa, if refuse collection costs go up there are greater avoided savings;
- As the quantity of uncollected food waste in the commercial sector is high in the Baseline, and the growth in waste arisings for this stream may also be high, the estimated rate of growth is also a sensitive variable; and
- All other parameters modelled have marginal influence on the net benefit to society.

Figure 4 Key Variables Driving the Net Benefit to Society from Food Waste Restriction / Ban on Unsorted Food Waste



Notes: The most sensitive input variables are at the top of the chart. Where the variable has most bearing in _reducing_ *the net benefit to society, the horizontal bar is to the left of the median (zero value). When the impact is positive, the bar is to the right.The example used shows a ban on unsorted food waste, with biowaste being diverted to AD: biogas used as vehicle fuel.*

No sensitivities specific to food waste, outside the Monte Carlo simulation, were carried out.

Key Messages from Restriction on Food Waste / Ban on Unsorted Food Waste:

- The model suggests that for food, there would be net greenhouse gas savings of around 6.2 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 27 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £300 million and £1.3 billion, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is sensitive to the way the biogas is used. Under the landfill restriction, this might result in savings of £92 million or costs of up to £290 million, depending on whether the gas was used for electricity generation, or cleaned for injection into the grid. Under the ban on unsorted waste, the equivalent range is from potential savings of £340 million to a cost of £1.3 billion. It should be noted that the market appears to be responding in a rational manner as the lower cost options are the most common ones; and
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a food waste to landfill restriction could results in net costs to society of £230 million or net benefits of £2 million, depending on the technology used. Under the ban on unsorted waste, the range increases from a net cost of £57 million to a net cost of £1.1 billion;
- There is a greater than 80% certainty that the financial costs outweigh the environmental benefits for all biowaste treatment options other than IVC and AD with gas to grid. This is true when all key variables are modelled within realistic ranges. For both IVC and AD with gas to grid, under the most favourable assumptions, there may be net benefits to society; and

- The most significant variable in the determination of the results is the assumed landfill gas capture rate. This is in line with what one would expect. If this is at the upper limit (75%), the benefits to society fall significantly. As the gas capture rate falls, the benefits increase.

8.1.1 Further Analysis of Food Waste Restriction / Ban

The results from the modelling above are based upon an analysis using a high-level top-down modelling approach designed in the first instance with the intention of modelling the environmental (and more specifically, the GHG-related) impact of a wide range of measures affecting a range of materials. The approach to modelling of costs is relatively simplistic: where measures such as food waste collection are introduced, then capturing the more complex system-wide changes associated with the change in the collection system is rather difficult using such a simple approach.

In updating this report, some further analysis was undertaken to consider the costs and benefits of changes in collection systems related to a requirement to sort food waste. Essentially, the costs and benefits of switching from systems without weekly food waste collection to systems with weekly food waste collection were considered. Systems were examined in which the dry recycling services were either weekly kerbside sort systems, or fortnightly comingled systems. In addition, systems were examined in which the frequency of refuse collection was either weekly or fortnightly in the baseline system, but when the food waste collection was introduced, in all systems, it was considered to be a weekly service, with the refuse being collected fortnightly. The systems modelled are shown in **Table 32**. The containment systems assumed are shown in **Table 33** and the vehicles which were assumed to be used are shown in **Table 34**.

Table 32 Key Options to be Modelled

Option	**Residual Frequency**	**Dry Recycling**	**Food Waste**
1	Fortnightly	Weekly Kerbside Sort or Fortnightly Single-Stream Comingled	None
2	Weekly	Same as Above	None
3	Fortnightly	Same as Above	Weekly

Table 33 Containment Provision

Service		**Option 1**	**Option 2**	**Option 3**
Residual		240 L wheeled bin		
Dry Recycling	Kerbside Sort	2 x 55 L boxes 1 x 47 L reusable sack		
	Comingled	240 L wheeled bin		
Food Waste		None	None	Kitchen and Kerbside Caddies

Table 34 Vehicles Used

Service		**Option 1**	**Option 2**	**Option 3**
Residual		RCV with bin lifts	RCV with bin lifts	RCV with bin lifts + food pod
Dry Recycling	Kerbside Sort	Modern High Volume Stillage	Modern High Volume Stillage	Modern High Volume Stillage
	Comingled	RCV with bin lifts	RCV with bin lifts	RCV with bin lifts + food pod
Food Waste	Kerbside Sort	None	None	On Stillage
	Comingled			Alternating in Pods on Dry and Residual

Clearly, the systems described do not represent all possible changes in system, but they are intended to give a broadly representative picture of what happens when a system without food waste collection is adapted and re-optimised to include food waste. The capture of the different materials by system type are shown in **Table 35** to **Table 38**. Some issues are of note:

- Comingled recycling captures of 225kg/hhld for weekly residual waste collections and 255 kg/hhld for fortnightly residual collections in rural authorities based on national data;[56]

[56] *Upper quartile in Tables 23 and 24 of Resource Futures (2010)* Analysis of kerbside dry recycling performance in the UK 2008/09*, Report for WRAP, September 2010*

- Kerbside sort captures are assumed to be 10% less than the commingled captures above for the same range of materials, based on an analysis of the same data set for WAG,[57] but include additional captures of textiles; and
- Recycling captures for urban authorities are based on the same capture rates derived for the above (rural) kg captured, but an assumed lower level of participation (see **Table 39**) results in a reduced capture per household.

Table 35 Materials Captured for Urban Authority with Kerbside Sort Recycling (kg/hhld)

	Option 1	**Option 2**	**Option 3**
Dry Recycling	209	184	209
Food Waste	0	0	78
Residual	571	676	492
Total	780	860	780
Recycling/Composting Rate	27%	21%	37%

Table 36 Materials Captured for Urban Authority with Comingled Recycling (kg/hhld)

	Option 1	**Option 2**	**Option 3**
Dry Recycling	221	196	221
Food Waste	0	0	78
Residual	559	664	481
Total	780	860	780
Recycling/Composting Rate	28%	23%	38%

Table 37 Materials Captured for Rural Authority with Kerbside Sort Dry Recycling (kg/hhld)

	Option 1	**Option 2**	**Option 3**
Dry Recycling	242	212	242
Food Waste	0	0	90
Residual	558	668	468
Total	800	880	800
Recycling/Composting Rate	30%	24%	41%

Table 38 kg per Household Captured for Rural Authority with Comingled Dry Recycling

	Option 1	**Option 2**	**Option 3**
Dry Recycling	255	225	255
Food Waste	0	0	90
Residual	545	655	455
Total	800	880	800
Recycling/Composting Rate	32%	26%	43%

Table 39 Participation Assumptions

Dry System	**Authority Type**	**Option 1**	**Option 2**	**Option 3**
Kerbside Sort and Comingled	Urban	80%	72%	80% (70% food)
	Rural	90%	81%	90% (75% food)

Bespoke modelling of the costs of collection and of the costs of treatment was carried out on the systems above. The aim was to understand what would be the change in costs implied by introducing weekly food waste collections where no such collection existed, and also to estimate, using results from the modelling work undertaken in the main landfill bans study, the environmental costs and benefits of the switch being made. It should be noted that these costs and benefits represent detailed system-wide modelling of the effects that could

[57] *Eunomia Research & Consulting, Resource Futures, and HCW Consultants (2010)* Kerbside Collections Options: Wales*, Report for WRAP, January 2011*

be expected in real world service changes. Note that this modelling was undertaken assuming landfill tax was being applied at £80 per tonne.

The main results are shown in **Table 40**. This shows how the costs and benefits change when a weekly food waste collection is introduced depending upon the starting point (i.e. the collection system) from which the switch is made.

Table 40 Outputs from Modelling (all costs are costs per household)

Starting Point	(1) Change in Financial Cost	(2) Change in Environmental Cost	(3) Net Change, Financial and Environmental	(4) Break Even Level of Food Waste Prevention	(5) Break Even Level of Food Waste Prevention (financial only)
U KS, weekly	-£21.96	-£7.19	-£29.15	n/a	n/a
U KS, fortnightly	£0.75	-£2.50	-£1.75	n/a	1.08%
U Co, weekly	-£16.94	-£6.87	-£23.81	n/a	n/a
U Co, fortnightly	£2.95	-£2.50	£0.45	0.93%	4.27%
R KS, weekly	-£21.59	-£7.99	-£29.57	n/a	n/a
R KS, fortnightly	£1.96	-£2.83	-£0.87	n/a	2.84%
R Co, weekly	-£12.72	-£7.63	-£20.35	n/a	n/a
R Co, fortnightly	£8.98	-£2.83	£6.14	12.61%	12.99%

Note on abbreviation: U = Urban, R = Rural, KS = Kerbside, Co = Co-mingled.

The key points to be drawn from the Table are as follows (we use the numbered column headers for ease of reference):

1. In respect of the financial costs, the financial costs (Column (1)) are negative for all systems where the starting point is a weekly refuse collection service. In other words, for all these systems, there is a net saving, the variation being from £13-£22 per household;
2. Evidently, the introduction of a food waste collection is more costly where the existing system is already based around a fortnightly refuse collection service. In this case, the scope for further cost savings is significantly reduced, and in all cases, the financial costs are positive (Column (1)). In other words, for all these systems, there is a net financial outlay, the costs for three of these being relatively small (between £1 and £3 per household), but slightly higher for the rural comingled service. It should be noted that although the scope for cost reduction is limited in these cases, on the other hand, for such systems, the level of resident satisfaction in the absence of a weekly food waste collection may be lower. In these cases, the introduction of a weekly food waste collection might be deemed to enhance the acceptability of the overall service offering. It should be noted, by way of comparison, that switching from the fortnightly refuse service to a weekly refuse service incurs far greater costs (of the order £20 per household in all cases), and leads to a reduction in environmental benefits rather than an improvement;
3. In all cases, there is a reduction in the environmental costs of the service, or an environmental benefit (see Column (2)). The environmental benefit of the switch is highest for those systems switching from the weekly refuse collection service. This is because the quantity of refuse declines, and as well as leading to the separate collection of food waste, the capture of dry recyclables also improves under this switch. Where refuse is already collected fortnightly, there is not the same uplift in capture of the dry recyclables;
4. The net effect is that in all cases where refuse is currently collected weekly in the baseline, and in two cases where refuse is collected fortnightly in the baseline, the balance of costs and benefits (Column (3)) is negative. The net level of benefits varies from £20-£30 per household for situations where the refuse collection is moved from weekly to fortnightly. Note that strictly speaking, it is not methodologically sound to add the environmental and financial costs together where the financial costs include taxes and transfers, especially given the aim of landfill tax to internalise landfill-related externalities (amongst other things) (see below);

5. For one of the two cases in which refuse is currently collected weekly, the net cost is small (£0.45 per hhld). The worst case is the switch from the rural comingled service with fortnightly refuse in the baseline, for which the balance of costs and benefits is just over £6 per household;
6. Some evidence has suggested that food waste collections might help sensitise households to the amount of food they throw away (see also Section 9.6.7). The modelling has not accounted for this possibility. To the extent that this effect is observed empirically, then for those cases where the costs exceed the benefits (in Column (3)), we have estimated, in Column (4), the extent of any food waste prevention effect which would be necessary to reduce the net costs to zero. The analysis indicates that for one of the systems, if the food waste collections cause a reduction in the amount of food waste thrown away of 1%, then the environmental benefits alone (i.e. not including any savings on disposal costs) would balance the additional financial costs. In the rural comingled case, the prevention effect needs to be stronger (a 13% reduction would need to be observed) for the financial costs to be offset by the environmental benefits of the prevention effect. None of these figures is excessive by the standards of the anecdotal evidence being reported; and
7. There are methodological issues associated with the addition of financial and environmental costs where costs are calculated under the private metric. Column (5) indicates the level of the prevention effect which would be required in order that the reduced disposal costs and the reduced impact associated with the generation of food waste offset any increase in the financial costs implied by the new service. This shows that the rural comingled service would need to demonstrate a 13% reduction in order that the additional financial costs were offset by environmental benefits associated with prevention, and the avoided disposal costs. Otherwise, the prevention effects necessary vary between 1% and 4% of total food waste generated.

Where authorities are moving from a situation of weekly food waste collection, there will be considerable benefits from introducing weekly food waste collection and reducing the refuse collection frequency to fortnightly. If the starting point is fortnightly residual waste collection, then there may be net costs, though this assumes no effect on the prevention of food waste. For the majority of cases, a small effect, in terms of sensitising citizens, will lead to net benefits being derived. Furthermore, for citizens, the changed service is likely to be more acceptable since there will be weekly collections of the most fermentable waste fraction.

8.2 Green Waste Restriction / Ban (Policy Scenarios 2 and 10b.)

In this policy scenario we have modelled additional green waste being diverted to open air windrow (OAW) composting plants, as a result of the restriction / ban (all relevant assumptions around this treatment facility can be found in Appendix 9). The levels of composting are high in the Baseline, but there is still some impact from the policies as considered here.

Greenhouse Gases
As garden waste is a biodegradable material, with a propensity to degrade in landfills, the savings of GHG emissions from the switch are important. These are shown below in **Table 41**.

Table 41 Cumulative GHG Emissions (2009-2024) from Green Waste Restrictions / Bans, million tonnes CO_2 eq

	Restriction	Unsorted Ban
Traded CO_2 eq	0.05	0.30
Non-Traded CO_2 eq	-0.76	-4.7
International CO_2 eq	n/a	n/a
Total CO_2 eq (excluding biogenic)	-0.71	-4.3

Note: -ve figures indicate a net GHG saving

Key points are as follows:
- The switch of green waste to an OAW composting facility provides a net GHG saving;
- The net increase in emissions from the 'Traded' sector (i.e. emissions that fall within the EU ETS) is due to the loss of methane captured to generate electricity at landfills;
- The most significant saving is from avoided fugitive methane from landfilling; and
- GHG reductions from the unsorted waste ban are more than 6 times those of the restriction only.

Energy
OAW processes do not generate any energy (though they can be configured to recover heat). The configuration modelled here is a net user of energy during its operation. With the reduction of energy generation from less landfill gas capture (as described above) there is a net decrease in renewable energy generation from these policy scenarios. Under the 'restriction only' a median reduction of energy generated of around 130 GWh electricity is calculated in the model from 2009 to 2024. With the stronger effect of the Unsorted Ban, more waste is diverted and thus just over 790 GWh of renewable electricity production is lost over the same period.

Environmental Benefits
The environmental benefits are presented in **Table 42**. One can note the following:

- The most significant elements of the net environmental benefit from these policies are related to reducing GHG emissions and offsetting fertilizer production; and
- Air quality is impacted upon negatively, reflecting the emissions of ammonia and other compounds from the open air composting process. These are, however, minor contributors to the overall figure.

Table 42 Net Present Value (NPV) of Environmental Benefits from Green Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
GHGs	£23	£140
Air Quality	-£1	-£5
Other	£18	£110
Net Environmental Benefits	£40	£240

Note: +ve figures indicate a net environmental benefit

Financial Savings
The financial savings from the two policies are shown in **Table 43**. One can see that:

- Under the social cost metric there are net financial costs for both policy options.
- Under the private metric, financial savings result from the restriction and the unsorted ban, mainly due to the inclusion of the landfill tax in this metric, and hence, the cost savings from avoiding the payment of the tax.

Table 43 Net Present Value (NPV) of Financial Savings from Green Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
Financial Saving (Social Metric)	-£43	-£330
Financial Saving (Private Metric)	£37	£110
Of which, Comms / Regulation Element	-£0.47	-£70

Note: -ve figures indicate a net financial cost

Net Benefit to Society
The figures for the net benefit to society are shown in **Table 44.** These indicate that:

- When the median figures are considered, both policy options result in a net cost to society;
- The costs are more significant in the case of the unsorted garden waste ban as compared with the restriction only; and
- In the case of the restriction only, the net costs are marginal, and the 80% confidence interval spans figures that suggest the possibility of net savings to society.

Table 44 Net Present Value (NPV) of Net Benefit to Society from Green Waste Restrictions / Bans

	Restriction	**Unsorted Ban**
Net Environmental Benefits	£40	£240
Financial Saving (Social Metric)	-£43	-£330
Upper (90% Interval)	£11	£0
Net Benefit to Society (median value)	**-£3**	**-£84**
Lower (10% Interval)	-£16	-£170

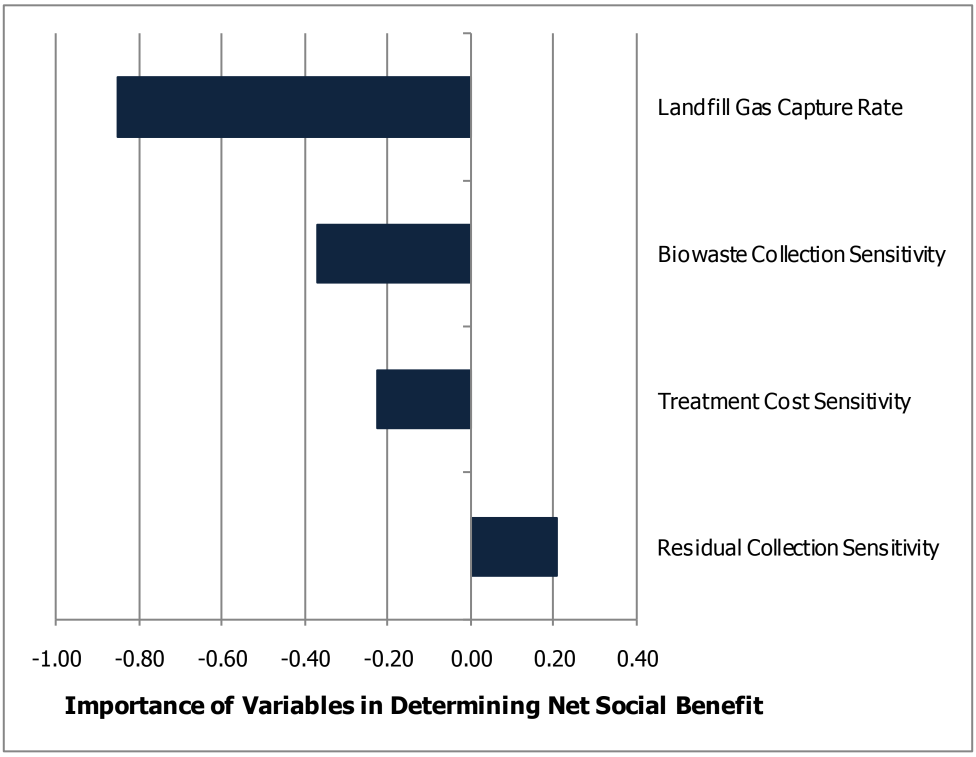
Note: +ve figures indicate a net financial benefit

Key Parameters

Key drivers of the variation in values are as follows:

- As with food waste (and all biodegradable materials) the most sensitive factor in the calculation of net social benefits, from restrictions / bans on green waste, is landfill gas capture. This is shown clearly by the tornado diagram below (see **Figure 5**), which shows the most sensitive variables, in descending order; and
- Assumptions relating to the costs of biowaste and refuse collection, and treatment costs, are also shown to be the most influential with respect to the net social benefits.

Figure 5 Key Variables Driving the Net Benefit to Society from Green Waste Restriction / Ban on Unsorted Green Waste



Notes: The most sensitive input variables are at the top of the chart. Where the variable has most bearing in reducing the net benefit to society, the horizontal bar is to the left of the median (zero value). When the impact is positive, the bar is to the right.

Key Messages from Restriction / Ban on Unsorted Green Waste:
The key messages in respect of the policies affecting green waste are as follows:

- The model suggests that for green waste, there would be net greenhouse gas savings of around 0.71 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 4.3 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £40 million and £240 million, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is £37 million under the landfill restriction, and £110 million under the ban on unsorted waste;
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that the benefits to society of a landfill restriction for garden waste are close to zero, whilst there may be net costs to society of £84 million under a ban on unsorted waste; and
- There is a greater than 80% certainty that the financial costs outweigh the environmental benefits for the ban, but the picture is more finely balanced in the case of the restriction only. The most significant factor affecting the net cost to society is the landfill gas capture rate.

8.3 Paper / Card Waste Restriction / Ban (Policy Scenarios 3 and 10c.)

In this policy scenario we have modelled additional Paper / Card waste being diverted to overseas recycling facilities (all relevant assumptions around the collection and reprocessing of this material can be found in Appendix 9). The levels of recycling are high in the Baseline, however, there is still a significant impact from the policies, at the margin, as paper and card forms a significant proportion of the overall waste stream.

Greenhouse Gases

As paper and card are biodegradable wastes, they tend to degrade in landfills. The savings of GHG emissions from the switch are therefore important. A separate sensitivity around the recycling offset assumed for paper / card is given at the end on this Section. The GHG savings are shown below in **Table 45**.

Table 45 Cumulative GHG Emissions (2009-2024) from Paper / Card Waste Restrictions / Bans, million tonnes CO_2 eq

	Restriction	Unsorted Ban
Traded CO_2 eq	0.15	1.0
Non-Traded CO_2 eq	-2.4	-16
International CO_2 eq	-1.5	-9.9
Total CO_2 eq (excluding biogenic)	-3.9	-26

Note: -ve figures indicate a net GHG saving

The key observations are:

- The switch of Paper / Card waste to recycling provides a net saving of Greenhouse gases. This is significant in the case of the ban on unsorted waste, these being almost seven times the size of the benefits generated under the restriction only;
- The net increase in emissions from the 'Traded' sector (i.e. emissions that fall within the EU ETS) is due to the loss of electricity generated at landfills (assumed to avoid, at the margin, generation from fossil sources);
- The most significant savings are from avoided fugitive methane (from landfilling); and
- International savings are also considerable (these being assumed to be the benefits from the recycling activity itself).

Energy

The recycling of paper / card produces no energy although GHG savings relate to 'embodied energy' in the material. Furthermore, with the reduction of energy generation, from less landfill gas capture, there is a net fall in energy generation from these policy scenarios. Under the 'restriction only' a median reduction of energy generated of around 390 GWh electricity is calculated in the model over the period 2009 to 2024. With the stronger effect of the Unsorted Ban, more waste is diverted, and thus a net reduction of 2,500 GWh of electricity occurs.

Environmental Benefits
The environmental benefits of the policies are shown in **Table 46**. The Table shows that:

- Once again, the most significant element of the net environmental benefit from these policies is associated with GHG savings; and
- Air quality impacts are small by comparison. It is reasonable to assume that these would change if the accounting methodology for damage costs were changed to use a dataset that related specifically to countries where recycling was likely to occur.

Table 46 Net Present Value (NPV) of Environmental Benefits from Paper / Card Waste Restrictions / Bans, £ million

	Restriction	**Unsorted Ban**
GHGs	£110	£730
Air Quality	£3	£17
Net Environmental Benefits	£110	£750

Note: +ve figures indicate a net environmental benefit

Financial Savings
The financial savings from recycling of paper and card are shown in **Table 48**. These highlight that:

- Under the social cost metric there is a net financial benefit for the restriction only, but a net cost for the ban on unsorted waste, though these are relatively small (especially in comparison to the benefits just described);
- Under the private metric financial savings would be expected under both policy scenarios. It is generally accepted that recycling of paper and card does, other than under exceptional conditions, 'pay for itself' in market terms; and
- If the ban on unsorted waste was introduced for paper and card alone, the estimated financial costs of communication and regulation do have some impact on the overall financial savings. If these were spread over a number of material based bans, the financial savings associated with the ban on unsorted paper and card, specifically, would increase.

Table 47 Net Present Value (NPV) of Financial Costs from Paper / Card Waste Restrictions / Bans, £ million

	Restriction	**Unsorted Ban**
Financial Saving (Social Metric)	£17	-£24
Financial Saving (Private Metric)	£110	£560
Comms / Regulation Element	-£0.47	-£70

Note: -ve figures indicate a net financial cost

Net Benefit to Society
The figures for the net benefits to society are shown in **Table 48**:

- The key determinant of the net benefit to society, for these policies, is the level of benefits arising from GHG savings;

- A significant benefit to society is predicted in both cases. The net benefit to society is, however, far greater for the ban on unsorted paper, being around five and a half times that of the simple restriction; and
- The simulations indicate that one could be confident that the policies would deliver net benefits to society.

Table 48 Net Present Value (NPV) of Net Benefit to Society from Paper / Card Waste Restrictions / Bans, £ million

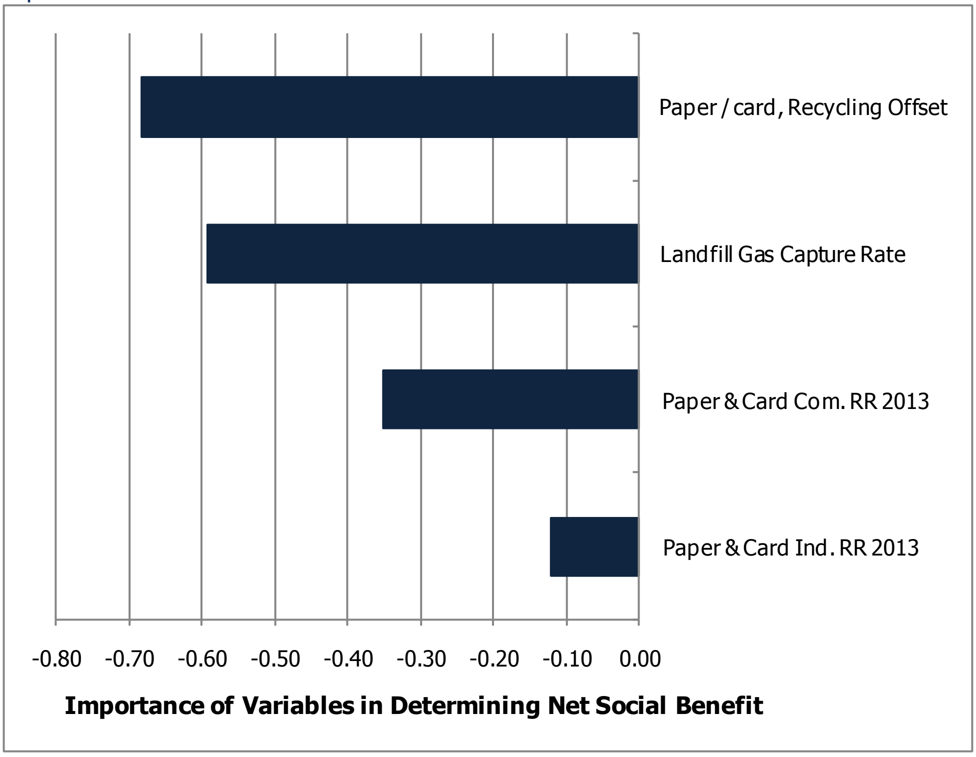
	Restriction	**Unsorted Ban**
Net Environmental Benefits	£110	£750
Financial Saving (Social Metric)	£17	-£24
Upper (90% Interval)	£200	£1,200
Net Benefit to Society (median value)	**£130**	**£720**
Lower (10% Interval)	£78	£380

Note: +ve figures indicate a net financial benefit

Key Parameters

The significance of variables in terms of their influence on the net social benefits is shown in the tornado diagram (**Figure 6**).

Figure 6 Key Variables Driving the Net Benefit to Society from Paper & Card Waste Restriction / Ban on Unsorted Paper & Card Waste



Notes: The most sensitive input variables are at the top of the chart. Where the variable has most bearing in <u>*reducing*</u> *the net benefit to society, the horizontal bar is to the left of the median (zero value). When the impact is positive, the bar is to the right.*

Key observations are as follows:

- The Paper / Card recycling offset is a very important determinant of the outcome. The basis for our assumption is given in Appendix 9. However, there is a range of values from different studies indicating that the potential benefit from recycling Paper/ Card could be quite varied. Clearly the greater the unit benefit of recycling, the greater the net benefit to society. This sensitivity is explored further below;
- As with food waste (and all biodegradable materials) one of the most sensitive factors in the calculation of net social benefits, from restrictions / bans on Paper / Card waste, is landfill gas capture;
- The Baseline Recycling rates also influence the net social cost - the greater these are, the less the material which remains to be captured, and hence the lower the net GHG savings and environmental benefits;

Recycling Offset Sensitivity

In the discussion around the choice of recycling offset for Paper / Card in Appendix 9, we note the existence of a range of values in the literature, and highlight the uncertainties in the data. The central figure we use is 0.28 tonnes CO_2 eq saved per tonne of paper / card recycled. In the Monte Carlo simulations we use a range from 0 to around 3.0 tonnes CO_2 eq saved per tonne of paper / card recycled (this takes into account the increase in sequestration effect from offsetting virgin plant based material).

When we rerun the simulation using the lowest value (0 tonnes CO_2 eq saved per tonne of waste recycled), <u>and</u> to show a 'worst case' scenario, we use 75% landfill gas capture, the net benefits to society still never fall to zero (see **Table 49**).

We believe that the low benefit from recycling paper and card is unlikely as long as the material being recycled is of reasonable quality. It should be noted that in the literature, the high end value is driven mainly by modelling suggesting a sequestration effect when the forest stock is left standing (as opposed to being harvested). Since the majority of studies never consider this possibility, it may well be the case that even where all other conditions are unfavourable (from the perspective of assigning net benefits – for example, the nature of energy sources used in primary and secondary paper production), the sequestration effect remains. If such a view was confirmed, then even our central case would significantly under-represent the net benefits from the policies under consideration.

Table 49 Net Present Value (NPV) of Net Benefit to Society from Paper / Card Waste Restrictions / Bans, £ million

	Unsorted Ban (median values)	Unsorted Ban ('worst case' sensitivity)
Upper (90% Interval)	£1,200	£290
Net Benefit to Society (median value)	**£720**	**£140**
Lower (10% Interval)	£380	£50

Note: +ve figures indicate a net financial benefit

Key Messages from Restriction / Ban on Unsorted Paper / Card Waste:

- The model suggests that for paper and card, there would be net greenhouse gas savings of around 3.9 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 26 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £110 million and £750 million, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is £110 million under the landfill restriction, and £560 million under the ban on unsorted waste;
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for paper and card could result in net benefits to society of

£130 million, and a ban on unsorted waste could increase these benefits to £720 million over the period examined;

- The most significant factors affecting the net benefit to society are the GHG benefits attributed to recycling of paper and card, and the landfill gas capture rate; and
- Under all the sensitivity tests run, there is a high level of certainty that the environmental benefits will outweigh the financial costs for these policies, especially under the requirement to sort. Even under the least favourable assumptions, the net benefit to society of the ban on unsorted waste remains positive.

8.4 Textiles Waste Restriction / Ban (Policy Scenarios 4 and 10d.)

In this policy scenario we have modelled additional Textiles waste being diverted to overseas recycling facilities (all relevant assumptions around the collection and reprocessing of this material can be found in Appendix 9). The levels of recycling are not high in the baseline relative to other materials, such as Paper / Card. Therefore, potential exists for diverting significant additional quantities of waste from landfill.

Greenhouse Gases

Textiles are often categorised as 50% biodegradable and 50% polymer based materials. Hence the GHG savings can accrue in various ways. Either though avoided emissions from landfilling, or from the offsetting off virgin materials, such as fossil-derived energy. The GHG benefits from the diversion of textiles waste into recycling are shown below in **Table 50**.

Table 50 Cumulative GHG Emissions (2009-2024) from Textiles Waste Restrictions / Bans, million tonnes CO_2 eq

	Restriction	**Unsorted Ban**
Traded CO_2 eq	0.03	0.08
Non-Traded CO_2 eq	-0.42	-1.3
International CO_2 eq	-3.0	-9.2
Total CO_2 eq (excluding biogenic)	-3.4	-10

Note: -ve figures indicate a net GHG saving

Key observations are:

- The switch of textiles into recycling provides a net GHG reduction. This is three times higher in the case of the ban on unsorted waste than in the case of the restriction;
- The most significant savings are from avoided emissions resulting from recycling textiles abroad (the international savings);[58] and
- A smaller contribution to emissions reduction arises from avoided fugitive methane (from not landfilling the biodegradable element of textiles).

Energy

The recycling of Textiles produces no energy. Furthermore, there is a net decrease in energy generation from these policy scenarios (due to reduced landfill gas capture and combustion in gas engines). Under the 'restriction only' a median reduction of energy generated of around 68 GWh electricity is calculated over the period 2009 to 2024. Half of this is assumed to derive from biomass sources. With the stronger effect of the ban on unsorted textiles, more waste is diverted, and thus a net reduction of around 210 GWh of electricity is obtained over the same period. Again, half of this is assumed to be from biomass (this quantification relates to renewable energy targets).

Environmental Benefits

The environmental benefits are shown in **Table 51.** Key observations are as follows:

[58] *Whether the GHG benefits from recycling specific materials arise domestically or overseas is complex. As more textiles are recycled, it is possible that more of this becomes of a nature that is reprocessed domestically rather than abroad. The assumption regarding the location of the benefits may be too simplistic in this case.*

- The majority of the benefit arises from GHG savings;
- The benefits are roughly three times higher for the ban on unsorted textiles than on the restriction; and
- The contribution from air quality emissions is, in relative terms, higher than has been the case in the restrictions and bans previously discussed.

Table 51 Net Present Value (NPV) of Environmental Benefits from Textiles Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
GHGs	£87	£260
Air Quality	£57	£170
Net Environmental Benefits	£140	£430

Note: +ve figures indicate a net environmental benefit

Financial Savings

The financial savings are displayed in **Table 52**. One can see from this that:

- Under both the social and private cost metrics, there are net financial costs associated with introducing both policy options. These are smaller under the private metric owing to the significance of landfill tax in the calculation;
- The communications and regulation element is around half of these costs in the case of the ban on unsorted waste. As mentioned previously, these costs would be spread across a range of materials if a ban covering a number of unsorted materials was to be introduced.

Table 52 Net Present Value (NPV) of Financial Costs from Textiles Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
Financial Saving (Social Metric)	-£35	-£180
Financial Saving (Private Metric)	-£13	-£100
Comms / Regulation Element	-£0.47	-£70

Note: -ve figures indicate a net financial cost

Net Benefit to Society

The figures for the net benefit to society from the restriction and the ban on unsorted textiles are shown in **Table 53**. They show that:

- The most influential factor in determining the net benefit to society, for policies directed at banning textiles waste from landfill, is GHG savings; and
- A significant net benefit to society is anticipated under each of the policies. The simulations show that, within the bounds set for the input variables, there is a greater than 80% confidence level in the likelihood of net benefits being derived in excess of £83 million in the case of the restriction, and £170 million in the ban on unsorted textiles.

Table 53 Net Present Value (NPV) of Net Benefit to Society from Textiles Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
Net Environmental Benefits	£140	£430
Financial Saving (Social Metric)	-£30	-£180
Upper (90% Interval)	£130	£330
Net Benefit to Society (median value)	**£110**	**£250**
Lower (10% Interval)	£83	£170

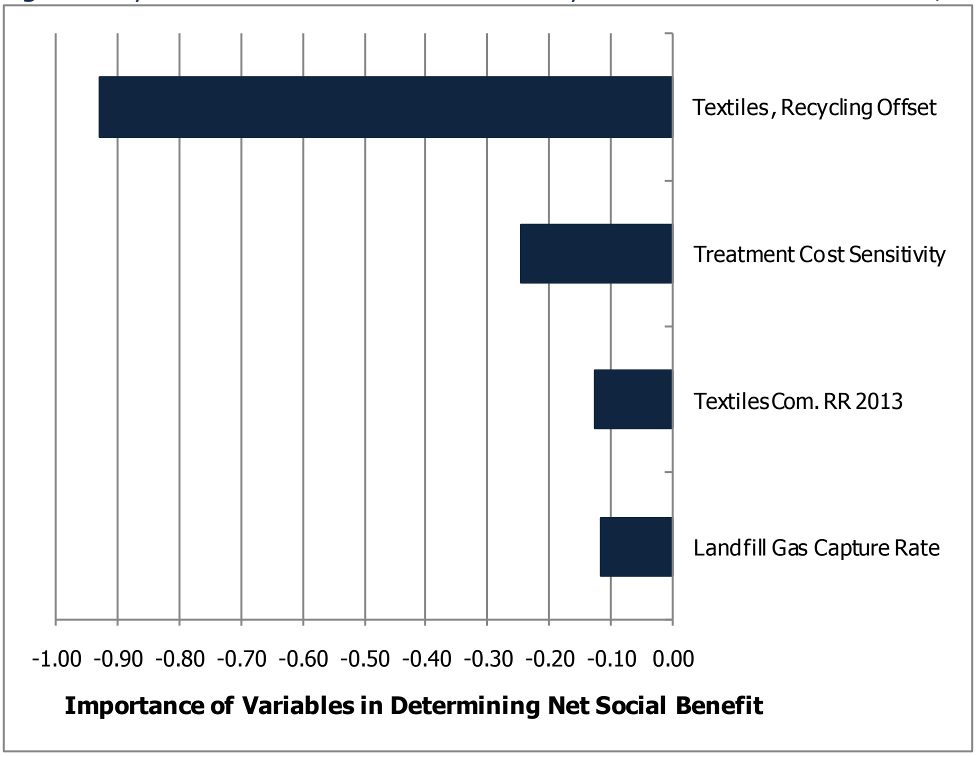
Note: +ve figures indicate a net financial benefit

Key Parameters

The tornado diagram (**Figure 7**) indicates the following:

- That the magnitude of the GHG savings attributed to recycling textiles is the key driver of variation in the size of the net social benefits;
- That the treatment (or recycling) cost for textiles also has a fairly strong influence on the net benefit figures;
- That the policies are also sensitive to:
    - Assumptions regarding the effect of policy on the capture of textiles for recycling from commercial waste streams; and
    - The landfill gas capture rate.

Figure 7 Key Sensitivities in the Net Benefit to Society from Textiles Waste Restrictions / Bans



Notes: The most sensitive input variables are at the top of the chart. Where the variable has most bearing in reducing the net benefit to society, the horizontal bar is to the left of the median (zero value). When the impact is positive, the bar is to the right.

Key Messages from Restriction / Ban on Unsorted Textiles Waste:

- The model suggests that for textiles, there would be net greenhouse gas savings of around 3.4 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 10 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £140 million and £430 million, respectively, under the two policies;
- Under the private cost metric, the costs of the landfill restriction appear to be around £13 million, the figure rising to £100 million under the ban on unsorted waste;
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for textiles could result in net benefits to society of £110 million, and a ban on unsorted waste could increase these benefits to £250 million over the period examined. For textiles, therefore, although modelling suggests there would be additional private costs associated with introducing restrictions or bans (in terms of collection and management), the environmental benefit appears to justify the additional costs;
- The most significant factor affecting the net benefit to society is the level of GHG benefit attributed to the recycling of textiles; and
- Under all the sensitivity tests run, there is a high degree of certainty that the environmental benefits will outweigh the financial costs for these policies, especially under the requirement to sort.

8.5 Wood Waste Restriction / Ban (Policy Scenarios 5 and 10e.)

In the case of wood, we have modelled a small quantity of additional wood waste being diverted to recycling facilities in the UK, with the more significant fraction of what is being collected being combusted in a dedicated facility (all relevant assumptions around the collection and reprocessing of this material can be found in Appendix 9).

Greenhouse Gases

Wood contains a large quantity of lignin so it degrades more slowly in a landfill than, for example, food waste. The GHG savings can accrue in various ways under the policies for wood. It could be either a) though avoided emissions from landfilling, b) from the reduction in demand for virgin wood (or other materials) through recycling, or c) though the generation of energy, which offsets the marginal source of electricity (in our modelling this is from Combined Cycle Gas Turbines).

The GHG benefits from the diversion of wood waste into recycling and recovery under the two policies are shown below in **Table 54**. The main points are as follows:

- The switch of Wood waste to recycling or energy recovery provides a net saving of greenhouse gases;
- The most significant saving is from avoided landfill emissions;
- Other emissions are also avoided through the recycling of wood and though energy recovery, where the energy offsets the marginal source of electricity; and
- The GHG savings from the ban on unsorted wood are around one and half times the savings from the restriction.

Table 54 Cumulative GHG Emissions (2009-2024) from Wood Waste Restrictions / Bans, million tonnes CO2 eq

	Restriction	Unsorted Ban
Traded CO_2 eq	-1.0	-1.3
Non-Traded CO_2 eq	-2.7	-4.2
International CO_2 eq	0.0	0.0
Total CO_2 eq (excluding biogenic)	-3.7	-5.5

Note: -ve figures indicate a net GHG saving

Energy
The quantitative effects of the policies are described in Appendix 6. At the margin, it is expected that a high proportion of waste wood, diverted from landfill, will be sought out by operators of combustion facilities. Under the restriction only, a median increase in energy generated, of around 2,500 GWh electricity, is calculated for the period 2009 to 2024.[59] With the stronger effect of the Unsorted Ban, more waste is diverted, and this figure increases to around 3,400 GWh in the same year.

Environmental Benefits
The environmental benefits for the policies on wood are shown in **Table 55**. Key observations are that:

- The most significant part of the net environmental benefit from each of the policies is from reduced GHG emissions;
- The costs related to air emissions (mainly associated with combustion) are small by comparison; and
- As with the GHG benefits, the ban on unsorted wood gives environmental benefits around one and a half times those expected from the restriction only.

Table 55: Net Present Value (NPV) of Environmental Benefits from Wood Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
GHGs	£82	£130
Air Quality	-£0.29	-£0.54
Net Environmental Benefits	£82	£130

Note: +ve figures indicate a net environmental benefit

Financial Savings

The financial savings associated with the two policies are shown in **Table 56** below.

Table 56: Net Present Value (NPV) of Financial Savings from Wood Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
Financial Saving (Social Metric)	-£35	-£120
Financial Saving (Private Metric)	£110	£96
Comms / Regulation Element	-£0.47	-£70

Note: -ve figures indicate a net financial cost

Key observations are:

- Under the social cost metric there are net financial costs for both policy options;
- When considering the costs under the private metric, there are financial savings under the restriction only but these turn to costs when considering the unsorted ban; and
- The communications and regulation element comprises a significant proportion of the costs under the ban on unsorted waste option. These costs (or the element attributable to wood alone) could be reduced if a number of materials were targeted at the same time. The effect of such a reduction in cost would be to move the median case under the ban on unsorted wood waste much closer to zero under the social metric.

[59] *Note the dedicated combustion facility modelled in this study generates electricity only. It is recognised that CHP facilities will provide different environmental benefits. However, these are not expected to be significant, or change the policy recommendation for wood waste restrictions / bans.*

Net Benefit to Society

The figures for the net benefit to society are shown in **Table 57**. These show that:

- The most influential factor in determining the net benefit to society, for policies directed at banning Wood waste from landfill, is the level of GHG savings achieved;
- A benefit to society is likely under both policies, but the sensitivity analysis suggests that under less favourable assumptions, net costs might be imposed on society in the case of the ban on unsorted waste; and
- The overall situation could be improved if communication costs were shared across a range of materials all being restricted. The effect of such an approach would be to improve the likelihood that a financial saving would result, irrespective of the assumptions made (i.e. even at the less favourable end of the 80% confidence interval).

Table 57: Net Present Value (NPV) of Net Benefit to Society from Wood Waste Restrictions / Bans, £ million

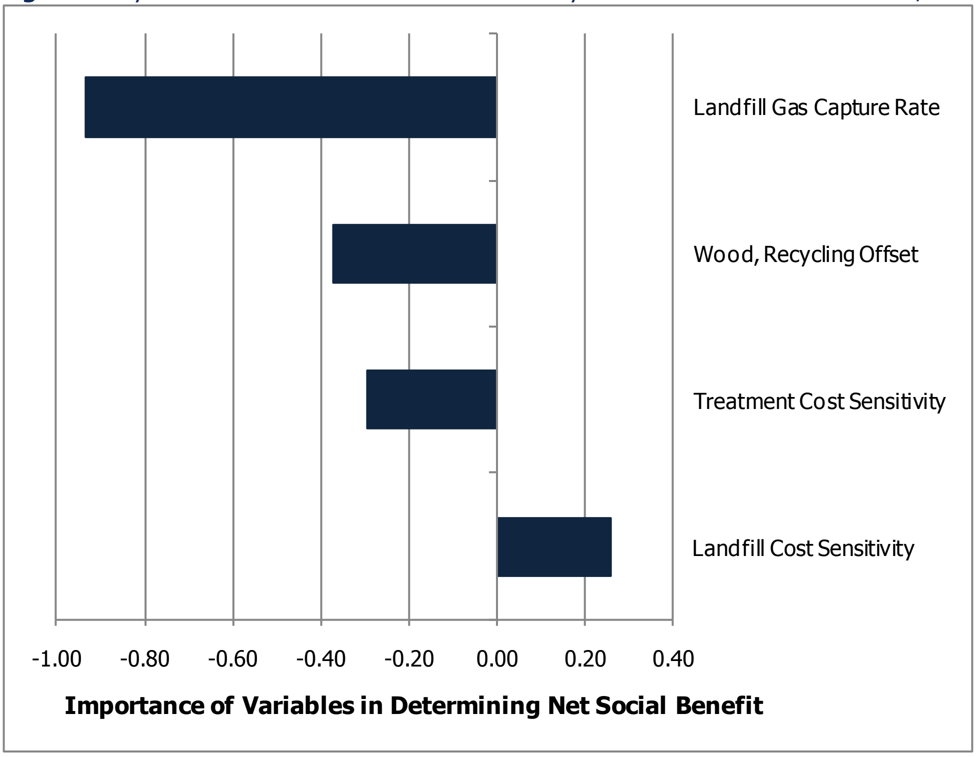
	Restriction	**Unsorted Ban**
Net Environmental Benefits	£82	£130
Financial Saving (Social Metric)	-£35	-£120
Upper (90% Interval)	£90	£80
Net Benefit to Society (median value)	**£48**	**£21**
Lower (10% Interval)	£10	-£41

Note: +ve figures indicate a net financial benefit

Key Parameters

As for the other biodegradable materials reported above, the most significant variable that affects the net benefit to society is the landfill gas capture rate, but the magnitude of the GHG savings associated with wood recycling, and the collection and treatment costs, are also influential factors (see **Figure 8**, below).

Figure 8 Key Sensitivities in the Net Benefit to Society from Wood Waste Restrictions / Bans



Key Messages from Restriction / Ban on Unsorted Wood Waste:

- The model suggests that for wood, there would be net greenhouse gas savings of around 3.7 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 5.5 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £82 million and £130 million, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is £110 million under the landfill restriction, and £96 million under the ban on unsorted waste. Note that there is a drop in savings under the requirement to sort as it assumed that more of the wood is of lower grade, and costs more to manage through recycling / recovery systems;
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for wood could result in net benefits to society of £48 million, with the equivalent figure under a ban on unsorted waste being £21 million over the period examined. The outcome for society would appear to be positive in the main, but if regulation and communication costs are high then there may be net costs. If these can be spread over a number of materials, it becomes more likely that net benefits will arise; and
- The most significant factor affecting the net effects on society is the landfill gas capture rate.

8.6 Glass Waste Restriction / Ban (Policy Scenarios 6 and 10f.)

In this policy scenario we have modelled additional Glass waste being diverted to recycling facilities. All the relevant assumptions around the collection and reprocessing of this material can be found in Appendix 9. The levels of recycling are relatively high in the Baseline. However, some material still remains un-captured, at the margin.

Greenhouse Gases

Glass waste is not biodegradable so no 'biogenic' emissions arise from a change in management of this material. Nor are there relevant changes in emissions valued in the 'Traded' sector. This is because there is no reduction in landfill gas captured, and no energy is generated / avoided. The main source of the GHG savings will be, therefore, from the diversion of Glass waste into recycling. The changes in emissions are shown below in **Table 58**.

Table 58 Cumulative GHG Emissions (2009-2024) from Glass Waste Restrictions / Bans, million tonnes CO_2 eq

	Restriction	**Unsorted Ban**
Non-Traded CO_2 eq	0.00	0.05
International CO_2 eq	-0.16	-1.7
Total CO_2 eq (excluding biogenic)	-0.16	-1.6

Note: -ve figures indicate a net GHG saving

Key observations are as follows:

- The switch of Glass waste to recycling provides a net saving of Greenhouse gases. The most significant saving results from the recycling process itself;
- Evidently, the assumptions used to calculate the unit benefits from recycling will have a strong influence on the total GHG savings. This is discussed further below;
- A small increase in non-traded GHG emissions occurs through the transport of materials for reprocessing; and
- The ban on unsorted waste has an effect roughly ten times that of the restriction.

Energy
The recycling of Glass produces no energy and removal from landfill leads to no net reduction in energy generation. The net change in energy generation, therefore, is zero.

Environmental Benefits
The environmental benefits are shown in **Table 59**.

Table 59: Net Present Value (NPV) of Environmental Benefits from Glass Waste Restrictions / Bans, £ million

	Restriction	**Unsorted Ban**
GHGs	£4	£39
Air Quality	£1	£11
Net Environmental Benefits	£5	£49

Note: +ve figures indicate a net environmental benefit

- The most significant element of the net environmental benefit from these policies is the reduction in GHG emissions;
- Air quality impacts are, relatively, more significant than for most materials, and equate to around one quarter of the total environmental benefits from reprocessing glass. As stated for textiles, the actual magnitude of these ought to reflect the reprocessing location for the material. The relatively large proportion of the benefits accounted for by air quality effects reflects, in part, the relatively low unit benefits from glass recycling; and
- The ban on unsorted waste has an effect roughly ten times that of the restriction.

Financial Savings
The financial savings are shown in **Table 60**. These suggest that:

- There are greater financial savings for the restriction when the costs are considered under the private metric. This is due to the inclusion of the landfill tax;
- For the ban on unsorted waste, a cost becomes a saving in moving from the social to the private metric, again because of the effect of landfill tax; and

- This is another material for which the net savings are significantly affected by the costs of the communications and regulation element in the case of the ban on unsorted waste.

Table 60: Net Present Value (NPV) of Financial Costs from Glass Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
Financial Saving (Social Metric)	£5	-£39
Financial Saving (Private Metric)	£17	£71
Comms / Regulation Element	-£0.47	-£70

Note: -ve figures indicate a net financial cost

Net Benefit to Society

Figures for the net benefits to society associated with the policies addressing glass are shown in **Table 61**. It can be observed that:

- Under the restriction only, where regulation costs are low, the policy is beneficial to society in all cases modelled in the Monte Carlo simulation;
- When considering the unsorted ban, in around half of the scenarios, the financial costs outweigh the monetised environmental benefits, so that there is a net cost to society from the policy;
- In either case, the policy gives very small net benefits. It is debatable whether, considered on its own, this would be considered as a sensible policy to pursue; and
- The communication and regulation costs were not included as a variable in the Monte Carlo simulations. However, it is clear that they would have a significant influence on the net benefits to society if included as a variable. This issue is explored further below.

Table 61: Net Present Value (NPV) of Net Benefit to Society from Glass Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
Net Environmental Benefits	£5	£49
Financial Saving (Social Metric)	£5	-£39
Upper (90% Interval)	£14	£29
Net Benefit to Society (median value)	**£9**	**£3**
Lower (10% Interval)	£6	-£19

Note: +ve figures indicate a net financial benefit

Key Parameters

Key parameters influencing the net social costs are identified in **Figure 9**. This shows that:

- If one ignores, for the moment, the regulation and communications costs, it is the Baseline assumptions, around the level of commercial glass recycling which occurs as a result of the landfill tax, by 2013/14, that has the most significant impact on the relative magnitude of the results. The way the model works, however, this does not affect the net social cost before the regulation and communications costs are considered – it only changes their magnitude;

- Of similar significance is the assumption around the environmental benefit associated with recycling. Changing this determines whether there is a net cost or saving to society prior to consideration of the fixed regulation and communications costs. This is explored below in a short criticality analysis; and
- The other key sensitivity is the communication / regulation cost element. This is also subjected to a criticality analysis below.

Glass Recycling Benefit Sensitivity

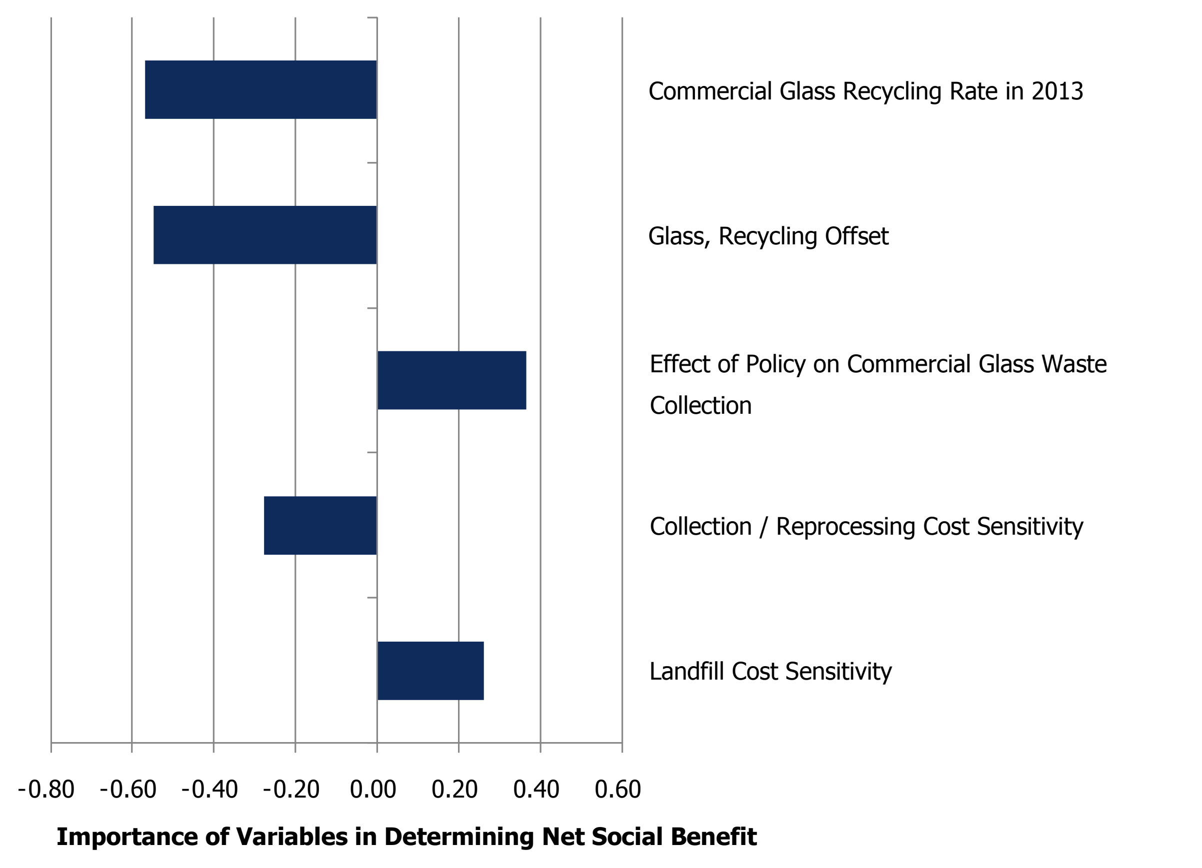
As mentioned above, the greenhouse gas benefits associated with recycling glass are a key driver of the net benefit to society. In the peer review for this report, one of the recommendations was that this recycling offset should be varied, the implication being that the central value used might be too optimistic, and hence the environmental benefits could be overstated.

The actual figure used, as the 'most likely' value in the Monte Carlo simulation, was -0.31 tonnes CO_2 eq saved per tonne of waste treated. This was the mid-range figure discussed in Appendix 9. The peer review suggested that this may be too high for glass in this study as it related specifically to a closed loop recycling process. It was felt that, at the margin, material not already collected would be of low quality and end up in open loop processes, such as for aggregate. This would seem to be more likely under the case where the restriction is applied, but as shown in **Table 61** above, the net benefit to society is always positive under all simulated scenarios (shown by both confidence limits being positive - £6 and £14 million).

Under the ban on unsorted glass waste, supported by a requirement to sort, the situation is different, as higher costs of regulation and communications come into effect. There are some circumstances when the policy results in a net cost to society. However, the requirement to sort has been included, as a complementary instrument, with one of its specific aims being to ensure capture of higher quality material (so as to maximise the likelihood of it being used in reprocessing routes that are more environmentally beneficial).

It was discussed in the stakeholder workshops, however, that there are concerns, and uncertainties, around the current, and future, levels of contamination in recyclates. To ignore this would be an oversight. Hence we fix the lower bound, for the glass recycling benefit, at -0.023 tonnes CO_2 eq saved per tonne of waste treated. This saving relates to an open loop recycling system.

Figure 9: Key Sensitivities in the Net Benefit to Society from Glass Waste Restrictions / Bans



Notes: The most sensitive input variables are at the top of the chart. Where the variable has most bearing in reducing the net benefit to society, the horizontal bar is to the left of the median (zero value). When the impact is positive, the bar is to the right.

Some studies also report greater benefits, so we choose a figure of -0.5 for an upper value. These figures set the parameters for the probability distribution chart used to describe glass recycling benefit in the Monte Carlo simulations.

As a further discreet sensitivity we performed a criticality analysis on this key variable. In essence, this means we alter the variable until the policy decision changes i.e. from a net benefit to a cost. The central assumption for the recycling benefit only has to fall by 13% before the net benefit to society switches to become a net cost. This implies that most of the additional glass collected, above the baseline, would need to be of a high enough quality to be reprocessed in a closed loop recycling system for the environmental benefits to outweigh the costs. Equally, one should not exclude the possibility that the requirement to sort could promote a shift of more of the glass which is already being collected (in the Baseline) into more environmentally beneficial uses. This could lead to an implied marginal benefit in excess of the upper end value we have chosen.

Finally, it is as well to note that there are good reasons to believe that private savings would result from the requirement to sort. This is reflected in the savings estimated under the private metric above. What this implies is that – just as with some materials today (not to mention in the 2013 Baseline) – there are recycling possibilities which are not being taken up even though it would be cheaper to recycle the material than to discard it to landfill.

Communication / Regulation Cost Sensitivity
As mentioned above it is clear that the communication and regulation costs are significant in the calculation of net benefits to society from the ban on unsorted glass waste. A set of sensitivities was run that reduced the proportion of these which were deemed to be attributable to the ban on unsorted glass, the implied assumption being that other materials could be included in the scope of such a measure (allowing costs to be shared across

materials). We assume – and believe it is sensible to assume – that the additional costs for a regulator to check whether glass was being sorted, as well as, paper / card, metals, food waste etc, would be minimal. The costs of regulation were therefore reduced to a point where they were shared evenly across 4 other materials. The results are shown in **Table 62**.

Table 62 Net Present Value (NPV) of Net Benefit to Society from Glass Waste Restrictions / Bans, Changing Costs of Communications and Regulation Attributed to Policy, £ million

	Unsorted Ban (central case)	**Unsorted Ban (25% reduction in comms / regs costs)**	**Unsorted Ban (50% reduction in comms / regs costs)**	**Unsorted Ban (80% reduction in comms / regs costs)**
Upper (90% Interval)	£29	£46	£62	£85
Net Benefit to Society (median value)	**£3**	**£20**	**£37**	**£58**
Lower (10% Interval)	-£19	-£3	£14	£36

Note: +ve figures indicate a net financial benefit

In the case where the regulation costs are reduced by 80% there is a high likelihood that the ban on unsorted glass waste will achieve net benefits for society.

If one makes the assumption that the costs of regulation and communications are shared in this way, then if one reconsiders the previous sensitivity on recycling benefits, the degree to which this parameter causes variation in the net cost to society declines hugely. Rerunning the criticality analysis under the assumption that the costs of regulation and communication are 20% of what was assumed in the original modelling shows that glass recycling would have to *emit* over 2 tonnes CO_2 eq per tonne of waste treated before the costs outweighed the benefits, strengthening the rationale for the use of the ban on glass as long as other materials are also included within scope.

Key Messages from Restriction / Unsorted Ban on Glass Waste:

- The model suggests that for glass, there would be net greenhouse gas savings of around 0.16 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 1.6 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £5 million and £49 million, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is £17 million under the landfill restriction, and £71 million under the ban on unsorted waste;
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that the benefits to society of a landfill restriction for glass are around £9 million, whilst under a ban on unsorted waste, the benefits are close to zero (£3 million). For Glass, under the restriction only, there is a net benefit to society, albeit relatively small, for all ranges in the sensitivity analysis. There is over an 80% certainty that benefits would arise, albeit that these are small. When the requirement to sort is included with a ban on unsorted wastes, the increase in communication and regulation costs outweighs the additional environmental benefit achieved. The simulation suggests a likelihood of around 40% that the policy will result in a net cost to society;
- Where the communication and regulation costs fall completely on glass (as opposed to being distributed across materials), the environmental benefit achieved from recycling needs to be maintained at a high level for the policy to continue to provide net benefits to society. This is entirely possible, especially if the requirement to sort seeks to ensure that high quality materials are captured for recycling; and
- If additional communication and regulation costs are shared across other materials, the ban on unsorted waste achieves a net benefit to society in all cases (and these are, at the median level, around six times

the level of the restriction only). In this instance, the net benefits only fall to zero if an additional 2 tonnes of CO_2 is released when an additional tonne of glass is recycled. This is an extremely unlikely scenario.

8.7 Metals Waste Restriction / Ban (Policy Scenarios 7 and 10g.)

In this policy scenario we have modelled additional Metals wastes being diverted to overseas recycling facilities. All relevant assumptions around the collection and reprocessing of this material can be found in Appendix 9. The revenues available for metal recyclates, and the ease with which they can be sorted from the residual stream, lead to relatively little material being sent to landfill in the Baseline. However, significant environmental benefits can be achieved through the recycling of certain metals, such as aluminium. Thus, despite relatively small absolute tonnage changes, significant environmental benefits can still be obtained. These are presented below.

Greenhouse Gases

The two main metal types considered in this study are 'ferrous' and 'non-ferrous'. These categories clearly do not describe a complete range of important metallic elements, for which environmental benefits could be gained through restrictions from landfill. This is recognised, but data relating to the composition of these materials and the associated GHG benefits is not sufficiently detailed. So, for simplicity, we model only the two types in this study.

The GHG benefits from the diversion of Metals waste into recycling are shown below in **Table 62**.

Table 63: Cumulative GHG Emissions (2009-2024) from Metals Waste Restrictions / Bans, million tonnes CO_2 eq

	Restriction		Unsorted Ban	
	Ferrous	Non-Ferrous	Ferrous	Non-Ferrous
Non-Traded CO_2 eq	0.00	0.00	0.05	0.03
International CO_2 eq	-0.39	-2.26	-4.24	-26
Total CO_2 eq (excluding biogenic)	-0.39	-2.25	-4.19	-26

Note: -ve figures indicate a net GHG saving

Key observations are:

- The switch of Metals waste to recycling provides a net reduction in GHG emissions. These exceed 30 million tonnes of CO_2 over the modelled period under the unsorted waste ban;
- The most significant saving is from avoided emissions resulting from the recycling of Metals. Despite the relatively low quantities of non-ferrous metals in the waste stream, the high unit benefit from recycling materials such as aluminium results in significant GHG benefits;
- For waste materials sent overseas for reprocessing there will be some emissions resulting from transportation to the dock for shipping abroad. These show in the small positive figures reported under the 'Non-Traded' sector; and
- Under the unsorted waste ban, the savings exceed those from the restriction by a factor of more than ten.

Energy

The recycling of Metals produces no energy. As the material is not biodegradable there is no reduction in the generation of energy from landfill gas, so the net change in energy generation is zero.

Environmental Benefits

The monetised environmental benefits are shown in **Table 64**. The highlights from the Table are that:

- The most significant element of the net environmental benefit from these policies relates to savings in GHG emissions;

- The air quality benefits are certainly non-trivial. They equate to around one quarter of the total environmental benefits achieved. Where metals are concerned the savings in air pollutants are derived from the offset emissions associated with the energy used in primary production of metal. As has been stated for other materials, the locus of the emissions ought to be considered as a determining factor in the value of these external benefits; and
- As for GHG savings, for the unsorted waste ban, the environmental benefits exceed those from the restriction by a factor of more than ten.

Table 64 Net Present Value (NPV) of Environmental Benefits from Metals Waste Restrictions / Bans, £ million

	Restriction		**Unsorted Ban**	
	Ferrous	Non-Ferrous	Ferrous	Non-Ferrous
GHGs	£10	£56	£100	£640
Air Quality	£5	£13	£57	£150
Net Environmental Benefits	£15	£69	£160	£790

Note: +ve figures indicate a net environmental benefit

Financial Savings
The value of metals makes them attractive targets for recycling. This is one reason why rates of recycling of metals in the Baseline are expected to be already high. The financial savings from the policies are shown in **Table 65**.

- Under the social cost metric there are net financial <u>costs</u> for both policy options, these being significantly higher for the ban on unsorted metals because of the greater quantity of material involved;
- Under the private cost metric, there are net financial savings. As for other materials, this is due to the inclusion of landfill tax under this cost metric; and
- Under the ban on unsorted waste, the communication and regulation costs are around half of the net financial costs. As mentioned previously, the contribution made to net costs could be reduced if a number of materials were being targeted at the same time.

Table 65 Net Present Value (NPV) of Financial Costs from Metals Waste Restrictions / Bans, £ million

	Restriction		**Unsorted Ban**	
	Ferrous	Non-Ferrous	Ferrous	Non-Ferrous
Financial Saving (Social Metric)	-£2	-£6	-£90	-£130
Financial Saving (Private Metric)	£7.0	-£0.5	£11	-£71
Comms / Regulation Element	-£0.47	-£0.47	-£70	-£70

Note: -ve figures indicate a net financial cost

Net Benefit to Society
The net benefit to society is displayed in **Table 66**.

- The most influential factor in determining the net benefit to society, for policies directed at banning Metals waste from landfill, is the GHG saving from the recycling of the material;
- A significant benefit to society is predicted in all cases. The simulations show that, within the bounds set for the input variables, there is a greater than 80% confidence level in the benefits delivered being in

excess of £600 million in the case of the unsorted waste ban, and £55 million in the case of the restriction; and

- The vast majority of the benefit is associated with non-ferrous, as opposed to ferrous, metals (owing to the much greater environmental benefit per tonne of material).

Table 66 Net Present Value (NPV) of Net Benefit to Society from Metals Waste Restrictions / Bans, £ million

	Restriction		**Unsorted Ban**	
	Ferrous	Non-Ferrous	Ferrous	Non-Ferrous
Net Environmental Benefits	£15	£69	£160	£790
Financial Saving (Social Metric)	-£2	-£6	-£90	-£130
Upper (90% Interval)	£18	£85	£120	£770
Net Benefit to Society (median value)	**£12**	**£63**	**£69**	**£660**
Lower (10% Interval)	£8	£47	£31	£570

Note: +ve figures indicate a net financial benefit

Key Parameters

The most significant variables driving the magnitude of the net social benefit are displayed in **Figure 10** (the results are shown for ferrous metal only, for which the results are less clear-cut, but the general pattern is similar for non-ferrous metals):

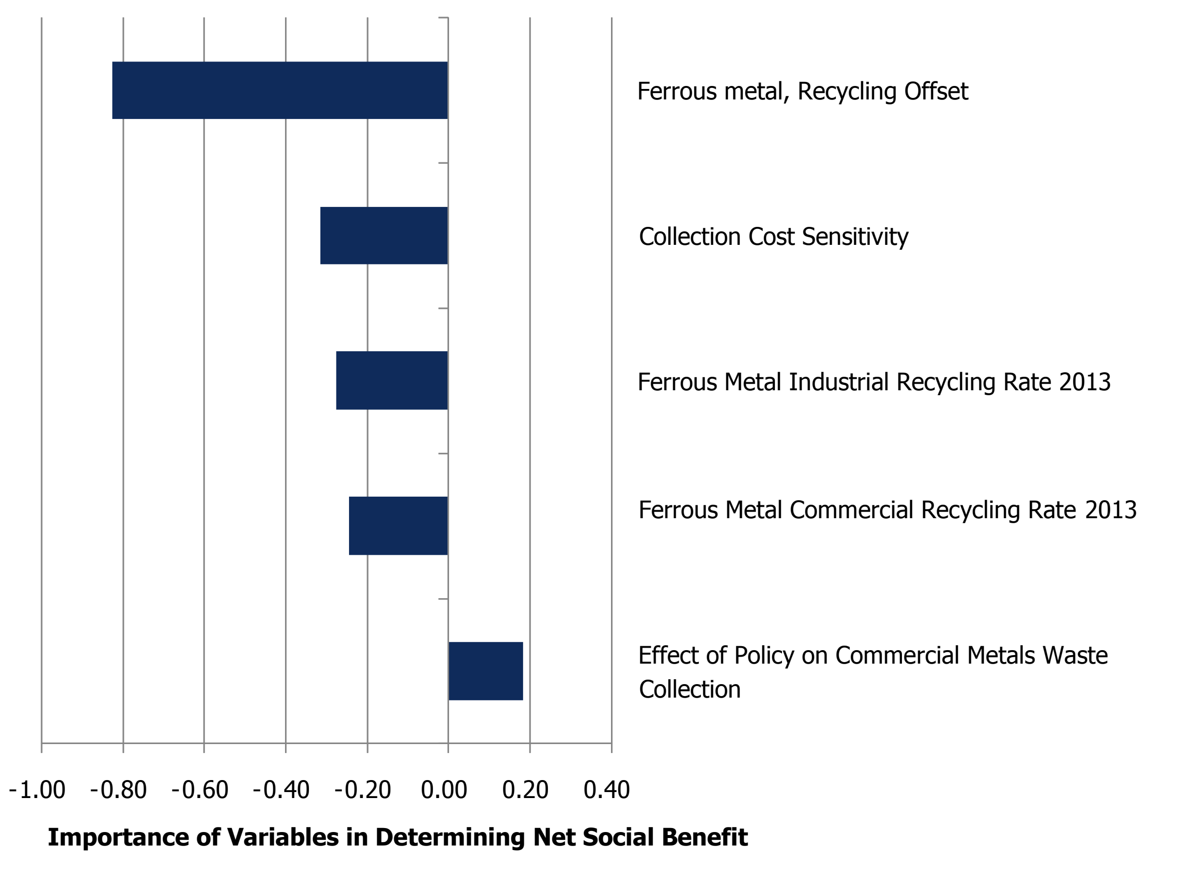
- The most significant driver of the net benefit to society is the recycling offset attributable for the material;
- For ferrous metals, the cost of collection is also an important variable; and
- The Baseline recycling rates and the assumed effects of the policy are also important variables. The fact that these are strong drivers of the net result indicates that – because these do not affect 'the sign' of the net benefit, only its magnitude – the level of certainty around the likelihood of net benefits is very high under the sensitivities we have tested.

Criticality Analysis

The recycling benefit for ferrous metal would have to fall by 75% of the median value and fall well below the minimum range we have modelled in the simulation in order for the net social benefit to fall to zero. Hence it seems unlikely that the existence of net benefits is sensitive to flexing of this variable to any value within the range reported in the literature.

Regarding collection costs, ferrous metal collection costs would have to increase by 85% for the net social benefits under the central case to be eliminated. This seems unlikely to occur.

Figure 10 Key Sensitivities in the Net Benefit to Society from Metals Waste Restrictions / Bans



Notes: The most sensitive input variables are at the top of the chart. Where the variable has most bearing in reducing the net benefit to society, the horizontal bar is to the left of the median (zero value). When the impact is positive, the bar is to the right.

Key Messages from Restriction / Unsorted Ban on Metals Waste:
Key messages regarding the policies for metals are:

- The model suggests that for metals, there would be net greenhouse gas savings of around 2.6 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 30 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £84 million and £940 million, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is £7 million under the ban on unsorted waste, and £10 million under the requirement to sort;
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for metals could result in net benefits to society of £75 million, and a ban on unsorted waste could increase these benefits to £800 million over the period examined. Under the sensitivity tests run, there is a near 100% certainty that the environmental benefits will outweigh the financial costs for these policies, especially under the requirement to sort;
- The most significant factor driving the net social benefits is the GHG benefits from recycling, though the outcomes are robust to any remotely plausible variation in this parameter; and
- The vast majority of the net social benefits relate to the non-ferrous rather than the ferrous metals.

8.8 Plastics Waste Restriction / Ban (Policy Scenarios 8 and 10h.)

In this policy scenario we have modelled additional Plastics waste being diverted to overseas recycling facilities. All of the relevant assumptions around the collection and reprocessing of this material can be found in Appendix 9. There is a high degree of uncertainty in the baseline around the composition and capture of dense plastics and plastic films in the non-municipal waste streams. Also, collection costs for some plastics are quite sensitive to a number of assumptions regarding the collection and sorting which takes place.

Greenhouse Gases

The GHG benefits from the diversion of Plastics waste into recycling are shown below in **Table 67**. The main observations are that:

- The switch of Plastics waste to recycling provides a net saving of Greenhouse gases;
- There is an increase in emissions from the non-traded sector related to increases in transport emissions;
- The benefits are split more or less equally between dense, and film plastics; and
- Total benefits are estimated to be of the order 6.8 million tonnes and 16.5 million tonnes from the restriction and the unsorted waste ban, respectively.

Table 67 Cumulative GHG Emissions (2009-2024) from Plastics Waste Restrictions / Bans, million tonnes CO_2 eq

	Restriction		**Unsorted Ban**	
	Dense Plastics	Film Plastics	Dense Plastics	Film Plastics
Non-Traded CO_2 eq	0.03	0.03	0.10	0.06
International CO_2 eq	-3.7	-3.1	-9.9	-6.8
Total CO_2 eq (excluding biogenic)	-3.6	-3.1	-9.8	-6.8

Note: -ve figures indicate a net GHG saving

Energy

The recycling of Plastics produces no energy. As the material is not biodegradable there is no reduction in the generation of energy from landfill gas, so the net change in energy generation is zero.

Environmental Benefits

The monetised environmental benefits over the modelling period are shown in **Table 68**. They highlight the following:

- Although for both film and dense plastics, the GHG benefits are the main source of total benefits, the air quality impacts are a significant part of the total environmental benefits;
- The air quality benefits are a higher proportion of the benefits for dense plastics than for films; and
- The benefits from the unsorted waste ban are around two and half times the benefit of the restriction.

Table 68 Net Present Value (NPV) of Environmental Benefits from Plastics Waste Restrictions / Bans, £ million

	Restriction		**Unsorted Ban**	
	Dense Plastics	Film Plastics	Dense Plastics	Film Plastics
GHGs	£89	£77	£240	£170
Air Quality	£42	£31	£120	£68
Net Environmental Benefits	£130	£110	£350	£230

Note: +ve figures indicate a net environmental benefit

Financial Savings
The financial savings from the policies are shown in **Table 69**. The following observations can be made:

- For all plastic types, the recycling of plastics incurs additional costs under either cost metric;
- As with other materials, the financial situation is improved under the private metric as a result of the greater avoided costs of disposal (because of the inclusion of landfill tax in the calculations); and
- The financial costs are relatively high reflecting the low bulk density of plastics, and the requirement for sorting (typically from other materials) to generate the desired revenues.

Table 69 Net Present Value (NPV) of Financial Savings from Plastics Waste Restrictions / Bans, £ million

	Restriction		Unsorted Ban	
	Dense Plastics	Film Plastics	Dense Plastics	Film Plastics
Financial Saving (Social Metric)	-£250	-£160	-£720	-£430
Financial Saving (Private Metric)	-£211	-£121	-£608	-£308
Comms / Regulation Element	-£0.47	-£0.47	-£70	-£70

Note: -ve figures indicate a net financial cost

Net Benefit to Society
Table 70 shows the net benefit to society for the policies as applied to plastics. The following observations can be made:

- As can be seen, there is a net cost to society from implementing either the restriction or the ban on unsorted plastics;
- This applies both to film and to dense plastics;
- Within the 80% confidence interval, the net benefit is never positive;
- Within the 80% confidence interval, the net benefit of the ban on unsorted plastics never reaches levels as high as -£70 million, so even if the communications and regulation cost was zero, no net benefit would be observed within this confidence interval; and
- The principle reason for this is that the costs of collecting plastics are high, and the environmental benefits are not sufficient to justify the additional costs of switching the material from landfill and into recycling.

Table 70: Net Present Value (NPV) of Net Benefit to Society from Plastics Waste Restrictions / Bans, £ million

	Restriction		Unsorted Ban	
	Dense Plastics	Film Plastics	Dense Plastics	Film Plastics
Net Environmental Benefits	£130	£110	£350	£230
Financial Saving (Social Metric)	-£250	-£160	-£720	-£430
Upper (90% Interval)	-£71	-£31	-£240	-£140
Net Benefit to Society (median value)	**-£120**	**-£54**	**-£360**	**-£190**
Lower (10% Interval)	-£160	-£85	-£480	-£260

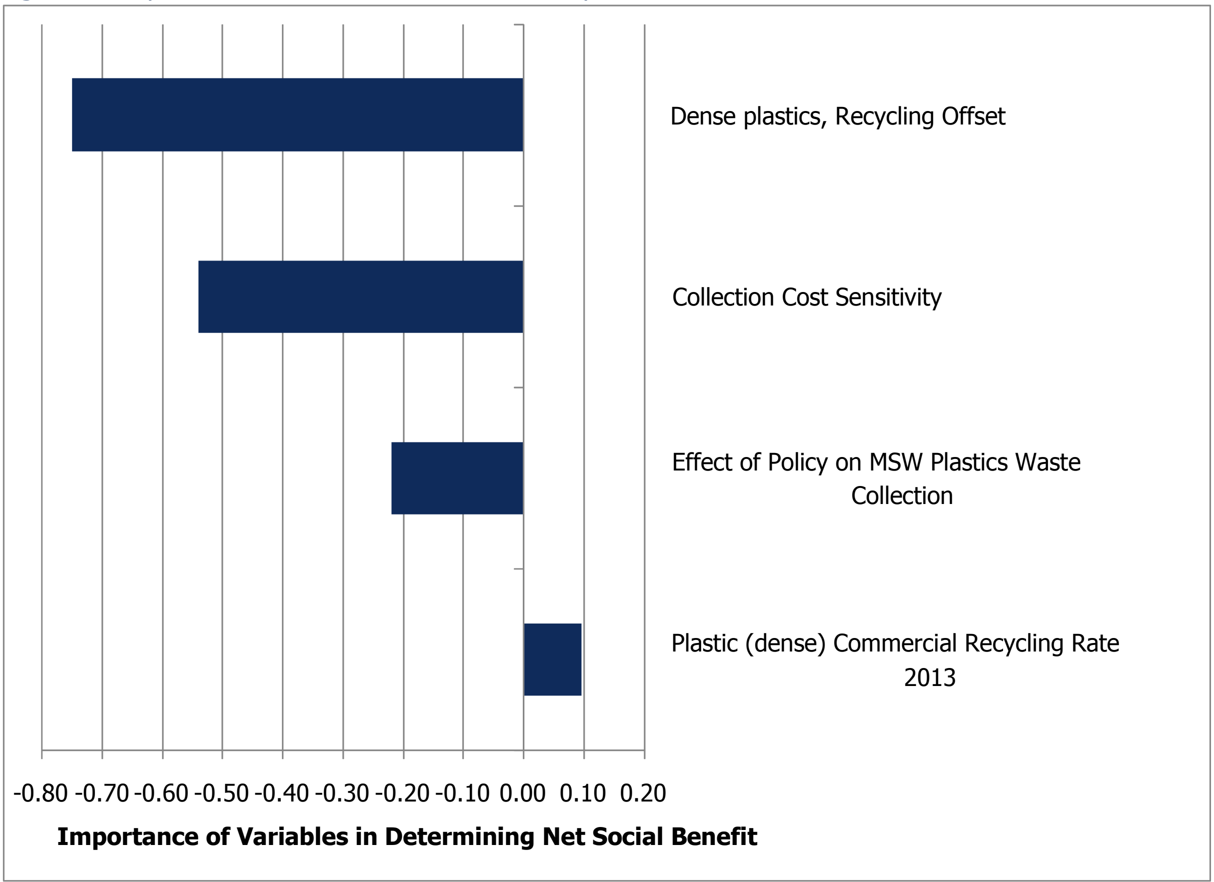
Note: +ve figures indicate a net financial benefit

Key Parameters

Key parameters driving the results are highlighted in the tornado diagram below (**Figure 11**). These are shown for dense plastics, but the pattern is similar for plastic film:

- The main influence on the results comes from the figure used for the dense plastics recycling offsets (this is the same for film);
- The second most important sensitivity check is that relating to the collection cost;
- These two figures together are the principle determinants of whether the policy implies a net cost or a net benefit to society;
- The effects of assumptions regarding the impact of the policy on MSW recycling and the assumption made concerning recycling performance in the Baseline for commercial waste are also important drivers. These, however, affect only the magnitude of the estimated cost or benefit.

Figure 11 Key Sensitivities in the Net Benefit to Society from Plastics Waste Restrictions / Bans



Notes: The most sensitive input variables are at the top of the chart. Where the variable has most bearing in reducing the net benefit to society, the horizontal bar is to the left of the median (zero value). When the impact is positive, the bar is to the right.

Criticality Tests

In line with the above analysis of the most influential parameters driving the outcomes for the policies, we have analysed how these would need to change in order for the policies to generate net benefits. We have estimated that if all other variables remain equal, then in the central scenario, for the net benefits to society to rise to zero, the recycling offset would have to double to around -2.7 tonnes CO_2 eq per tonne of waste treated. This is outside the maximum likely value we set in the Monte Carlo simulation, and we have not seen a value so high in the review we have conducted (see Appendix 9). One value approaches this, but we would suggest that the benefits are highly unlikely to be this high.

On the collection cost side, the costs would need to fall to approximately 30% in order for the policy outcome to switch from implying a cost to a zero benefit. For plastics, this is a relatively low cost given that the social cost metric implies a low cost of capital but assumes that the revenue from material sales is felt to its full extent. It should also be considered that the relevant costs are those of plastics being collected over and above that which is collected in the Baseline. In other words, the relative lower cost plastics are likely to be being collected in the Baseline.

Key Messages from Restriction / Unsorted Ban on Plastics Waste:

- The model suggests that for dense plastics, there would be net greenhouse gas savings of around 6.8 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 17 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £240 million and £590 million, respectively, under the two policies;
- Under the private cost metric, the costs of the landfill restriction appear to be around £330 million, the figure rising to £850 million under the ban on unsorted waste;
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for plastics could result in net costs to society of £170 million, and a ban on unsorted waste could increase these costs to £480 million over the period examined. For plastics, therefore, although the environmental benefits are significant, they do not appear to be justified by the additional costs. It should be considered that this observation applies to additional plastics recycling over and above levels already assumed to occur in the baseline, and does not necessarily imply that existing levels of recycling are not justified. For Plastics, under all the sensitivity tests run, there is a near 100% certainty that the environmental benefits are lower than the financial costs, under the social metric, of these policies. Fundamentally, this relates to the relatively high costs of collecting plastics, particularly those that would need to be collected over and above the ones being collected in the Baseline; and
- Only if the GHG benefits from recycling plastics were in excess of the upper range from the literature review, or if costs were 30% lower than we have modelled in the central scenario, would the outcome be such as to generate a zero benefit to society (as opposed to a net cost).

8.9 WEEE Waste Restriction / Ban (Policy Scenarios 9 and 10i.)

In this policy scenario we have modelled additional WEEE waste being diverted to overseas recycling facilities (all relevant assumptions around the collection and reprocessing of this material can be found in Appendix 9).

Greenhouse Gases

WEEE is generally composed of non biodegradable materials. Hence the GHG savings generally arise only from the benefits of recycling the component materials. The GHG benefits from the diversion of WEEE waste into recycling under the policies being modelled are shown below in **Table 71**. The benefits are particularly difficult to estimate for 'WEEE' since this is a heterogeneous category of materials.

The Table shows that:

- The switch of WEEE waste to recycling provides a net GHG saving associated with the avoided emissions from recovering secondary materials;
- There is a small increase in emissions from the non-traded sector related to transport; and
- The benefits are small, though they are five times higher for the unsorted waste ban than for the restriction.

Table 71 Cumulative GHG Emissions (2009-2024) from WEEE Waste Restrictions / Bans, million tonnes CO_2 eq

	Restriction	Unsorted Ban
Traded CO_2 eq	0.00	0.00
Non-Traded CO_2 eq	0.00	0.03
International CO_2 eq	-0.04	-0.24
Total CO_2 eq (excluding biogenic)	-0.04	-0.21

Note: -ve figures indicate a net GHG saving

Energy
The recycling of WEEE produces no energy. As the material is not biodegradable there is no change in the energy generated from landfill gas, so the net change in energy generation is zero.

Environmental Benefits
Reflecting the GHG outcomes highlighted in **Table 71**, the environmental benefits are shown in **Table 72**:

- The benefits are relatively small (achieving a level of £73 million over the modelled period);
- The benefits are dominated by those associated with GHG reductions; and
- The effects of the ban on unsorted waste are more than five and a half times the effects of a restriction only.

Table 72 Net Present Value (NPV) of Environmental Benefits from WEEE Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
GHGs	£13	£77
Air Quality	-£1	-£3
Net Environmental Benefits	£13	£73

Note: +ve figures indicate a net environmental benefit

Financial Savings
The financial savings are shown in **Table 73**. The following observations can be made:

- The recycling of WEEE incurs additional costs under either cost metric;
- As with other materials, the financial situation is improved under the private metric as a result of the greater avoided costs of disposal (because of the inclusion of landfill tax in the calculations); and
- The financial costs are far higher under the unsorted waste ban than under the restriction only.

Table 73 Net Present Value (NPV) of Financial Costs from WEEE Waste Restrictions / Bans, £ million

	Restriction	Unsorted Ban
Financial Saving (Social Metric)	-£33	-£270
Financial Saving (Private Metric)	-£16	-£176
Comms / Regulation Element	-£0.47	-£70

Note: -ve figures indicate a net financial cost

Net Benefit to Society
The net benefits to society are shown in **Table 74**.

Table 74 Net Present Value (NPV) of Net Benefit to Society from WEEE Waste Restrictions / Bans, £ million

	Restriction	**Unsorted Ban**
Net Environmental Benefits	£13	£73
Financial Saving (Social Metric)	-£33	-£270
Upper (90% Interval)	-£14	-£170
Net Benefit to Society (median value)	**-£20**	**-£200**
Lower (10% Interval)	-£29	-£230

Note: +ve figures indicate a net financial benefit

The following observations can be made:

- As can be seen, there is a net cost to society from implementing either the restriction or the ban on unsorted WEEE;
- Within the 80% confidence interval, the net benefit is never positive;
- Within the 80% confidence interval, the net benefit of the ban on unsorted WEEE never reaches levels as high as -£70 million, so even if the communications and regulation cost was zero, no net benefit would be observed within this confidence interval; and
- The principle reason for this is that the costs of collecting WEEE have been estimated as being high, and the environmental benefits are not sufficient to justify the additional costs of switching the material from landfill and into recycling. It needs to be appreciated that, as with plastics, the relevant recycling cost is not the cost that prevails, on average today. It is the cost of recycling the WEEE that remains unrecycled under the Baseline (which includes the effects of landfill tax).

Key Parameters

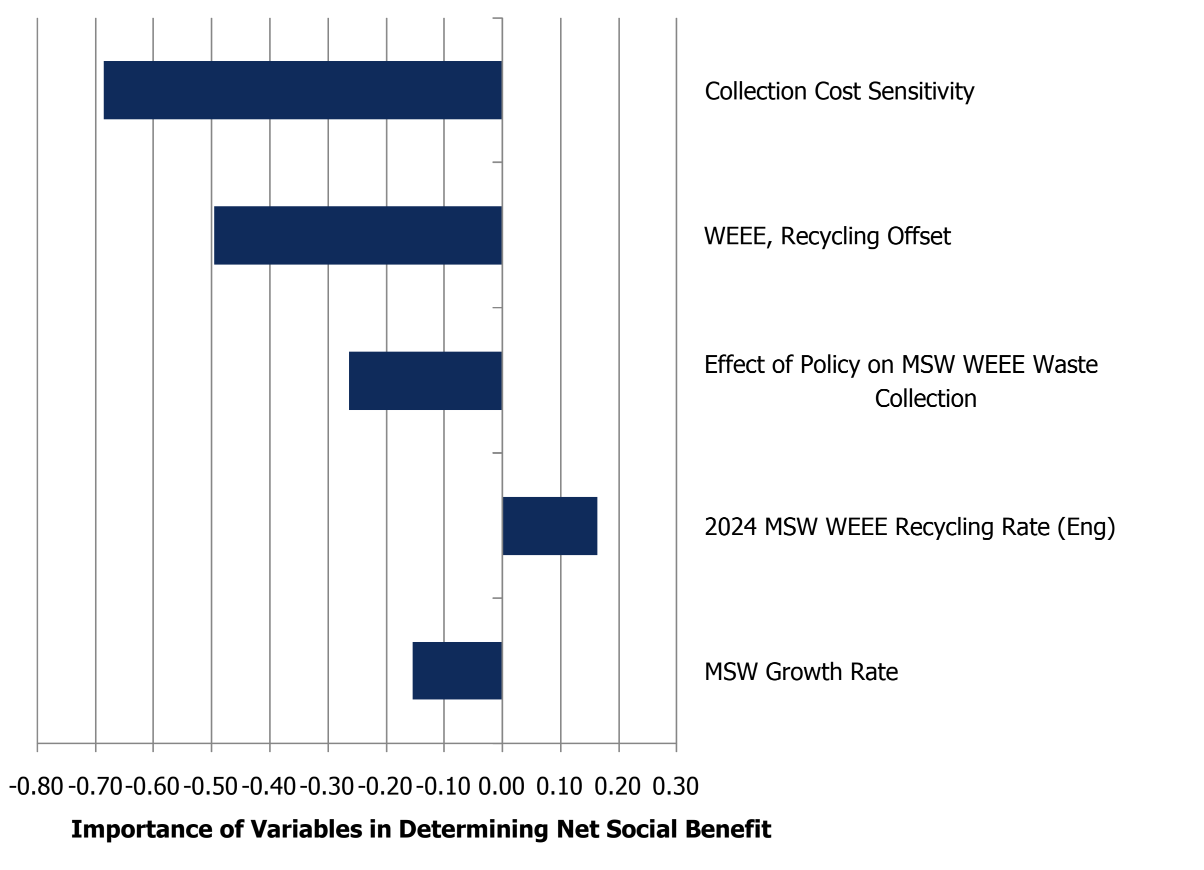
Key parameters influencing the net social benefits of the WEEE policies are shown in **Figure 15**. The figures suggest:

- For WEEE, the collection cost is the most important driver of the outcomes. The is the only material for which this is the case;
- The assumed recycling offsets are the second most influential driver of the outcomes;
- Also important are the factors affecting the quantity of material assumed to be recycled under the policy.

Criticality Analysis
For WEEE the collection / treatment cost has to fall to nearly one quarter of the central value for the policy to become a benefit. WEEE would have to be collected and treated at around £50 per tonne for the net social benefits to achieve a zero value. Whilst this is not impossible, this probably reflects the costs for those items already being collected, and likely to be collected even more effectively once landfill tax rises to £72 per tonne. Costs could change, of course, if technology changes or if producers make particular efforts to redesign products for ease of disassembly.

The environmental benefits of WEEE recycling are also not well characterised on the average. The recycling benefit for WEEE would have to reach -4.45 tonnes CO_2 equ per tonne of WEEE for the environmental benefits to match the financial costs. The central figure is -1.12 tonnes CO_2 eq per tonne of WEEE. Given that an increasing proportion of what needs to be collected would be small WEEE items, we believe that this figure is unlikely to be reflected in reality.

Figure 12 Key Sensitivities in the Net Benefit to Society from WEEE Waste Restrictions / Bans



Notes: The most sensitive input variables are at the top of the chart. Where the variable has most bearing in reducing the net benefit to society, the horizontal bar is to the left of the median (zero value). When the impact is positive, the bar is to the right.

Key Messages from Restriction / Unsorted Ban on WEEE Waste:

- The model suggests that for WEEE, there would be net greenhouse gas savings of around 0.04 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 0.21 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £13 million and £73 million, respectively, under the two policies;
- Under the private cost metric, the costs of the landfill restriction appear to be around £16 million, with the figure rising to £176 million under the ban on unsorted waste;
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for WEEE could result in net costs to society of £20 million, and a ban on unsorted waste could increase these costs to £200 million over the period examined. For WEEE, therefore, although there are environmental benefits, they do not appear to be justified by the additional costs. It should be considered, also, that this observation applies to additional WEEE recycling over and above levels already assumed to occur in the baseline, and does not necessarily imply that existing levels of recycling are not justified. In addition, the costs for collecting additional WEEE are highly uncertain, and heavily dependent upon the pre-existing infrastructure and how easy this is to adapt to collection of, for example, small WEEE items;
- For WEEE, under all the sensitivity tests run, there is a near 100% certainty that the environmental benefits are insufficient to justify the financial costs, as measured using the social metric, of these

policies. Fundamentally, this relates to the relatively high costs of collecting WEEE, particularly those that would need to be collected over and above the ones being collected in the Baseline; and

- Only if the GHG benefits from recycling plastics were 400% of the central value used here, or if the costs under the social metric were only a quarter of what we have used as a central value, would the benefits and the costs, as measured under the social metric, become equal.

8.10 Biodegradable Waste Ban (Policy Scenario 11)

This policy aims to limit biodegradability of waste entering the landfill. The effect is modelled as a switch away from landfill and into alternative means of dealing with residual waste. The resultant treatment is not specified in this report, and hence a range of potential outputs are given. These outputs are not additive. They make an extreme assumption that all targeted wastes are switched into one of the treatments under examination.

Greenhouse Gases

One of the key objectives of this policy is to reduce the problems associated with landfilling biodegradable waste. The generation of methane in the landfill is the main issue. The GHG benefits from the diversion of residual waste into the different treatments are shown below in **Table 75**.

Table 75 Cumulative GHG Emissions (2009-2024) from Biodegradable Waste Ban, million tonnes CO_2 eq

	Incineration (elec)	Incineration (CHP)	MBT: Output to landfill	MBT: SRF to Dedicated	MHT: Output to gasification
Traded CO_2 eq	-35	-7	7	-16	-7
Non-Traded CO_2 eq	7	-30	-59	5	-21
International CO_2 eq	-11	-11	-28	-25	-16
Total CO_2 eq (excluding biogenic)	-39	-49	-80	-37	-44

Note: -ve figures indicate a net GHG saving

The key observations are as follows:

- The switch of residual waste to other treatment options provides a net saving of Greenhouse gases in all cases;
- There are reductions in emissions in the traded sector for processes which are generating energy, and offsetting power generation from the electricity sector;
- For processes which have a thermal element, the direct process emissions (from combusting fossil based carbon) contribute to emissions in the non-traded sector. In less efficient conversion processes, these can outweigh the savings from avoiding emissions of methane;
- The net position depends on the assumed capture rate for landfill gas, and the fossil carbon content of residual waste;
- Different options are credited with different benefits for recycling of materials sorted at the facilities; and
- There is relatively little to choose between options, but all generate benefits in terms of GHG emissions reduction in our analysis. The savings range from 39 to 80 million tonnes CO_2 equivalent over the period 2009 to 2024. Note, however, that the model assumes a fixed residual waste composition, and this type of analysis will be sensitive to the composition of residual waste (which would be affected by other policies, such as the material based approaches discussed above).

Energy

The different treatment options vary significantly in the energy they generate. The outputs are shown in **Table 76**. These show that the incinerator in 'electricity only' mode generates most electricity, whilst in CHP mode, it generates the most heat. There is a net use of energy by the MBT facility where the output is sent to landfill, and so, a net reduction in energy generated. Other options give varying contributions of energy. The Table does not account for the energy embodied in materials which are sorted, and may subsequently be recycled.

Table 76 Net Change in Energy Generation from Biodegradable Waste Ban (2009 to 2024), GWh

	Incineration (elec)	Incineration (CHP)	MBT: Output to landfill	MBT: SRF to Dedicated	MHT: Output to gasification
Electricity (Total)	110,000	33,000	-10,000	56,000	37,000
Heat (Total)		140,000			63,000

Note: -ve figures indicate a net reduction in energy generated

Environmental Benefits

The monetised environmental benefits are shown in **Table 77**. Key observations are:

- The benefits related to the GHG emissions cannot be derived simply from multiplying the net GHG benefits by a constant figure since the GHG benefits are valued differently depending upon whether they relate to emissions from inside or outside the traded sectors. Hence, the benefits of GHG reductions from electricity generation are attributed lower value than savings from the non-traded sector. This means that processes which generate more of the savings in GHG emissions in the non-traded sector fare better than those (for example, those generating electricity) for which the majority of benefits are derived within the traded sector. This also implies that the facilities generating most energy (in whatever form) do not necessarily deliver the greatest benefit;
- The air quality effects make significant contributions to the environmental impacts in the case of incineration options, with slightly lower impacts from the MBT to SRF and MHT to gasification options; and
- The total environmental benefits are positive for all switches with the exception of the case where incineration is used to generate electricity only, and for the MBT option where SRF is sent to a dedicated waste facility. In these cases, the greenhouse gas benefits from electricity generation are valued in line with savings from the traded sector (see **Table 75** for the breakdown of the GHG savings) and are assigned much lower value than other options. Of the variants examined, the greatest environmental benefits occur when waste is treated at an MBT plant and the stabilised waste is sent to landfill. Here, air quality impacts are relatively low and significant GHG savings occur in the traded sector because there are no emissions from the combustion of fossil materials.

Table 77 Net Present Value (NPV) of Environmental Benefits from Biodegradable Waste Ban, £ million

	Incineration (elec)	Incineration (CHP)	MBT: Output to landfill	MBT: SRF to Dedicated	MHT: Output to gasification
GHGs	-£100	£870	£2,200	-£30	£620
Air Quality	-£310	-£290	-£4	-£100	£65
Net Environmental Benefits	-£410	£580	£2,200	-£130	£680

Note: +ve figures indicate a net environmental benefit

Financial Savings

The financial savings are shown in **Table 78**. These are all negative irrespective of the cost metric used. The changes between the social and private metric are more complicated to explain than in the case of dry recyclables. The effect of landfill tax is different across the various facilities, with some landfilling larger quantities of residue than others. In addition, the various incentives for energy recovery also play a role. It should be noted that an attempt was made to estimate the extent to which the effects of the ETS are internalised in the market price of energy, and this was stripped out of the estimation of costs under the social cost metric. It should also be noted that all facilities are 'fully costed' so that wherever MBT outputs are sent to a landfill, they are charged the full cost of landfilling (including tax under the private metric), and where SRF is sent to a dedicated facility, the treatment facility is also fully costed. It is recognised that markets may deliver lower costs than these under specific conditions, so that private cost reductions relative to landfill could, in practice, be realised. Against the social metric, however, this is highly unlikely because of the low cost of landfilling under this metric.

Table 78 Net Present Value (NPV) of Financial Costs from Biodegradable Waste Ban, £ million

	Incineration (elec)	Incineration (CHP)	MBT: Output to landfill	MBT: SRF to Dedicated	MHT: Output to gasification
Financial Saving (Social Metric)	-£3,500	-£5,500	-£3,700	-£4,600	-£5,900
Financial Saving (Private Metric)	-£360	-£4,000	-£3,100	-£2,900	-£2,500
Comms / Regulation Element	-£0.47	-£0.47	-£0.47	-£0.47	-£0.47

Note: -ve figures indicate a net financial cost

Net Benefit to Society

Table 79 shows the net benefit to society from the biodegradable waste ban and how it varies across the choice of treatments:

- For all treatments, median benefits are negative and significantly so, ranging from -£1.5 billion to -£5.2 billion;
- The median benefits vary significantly, but the key point relates to the extent to which the net social benefits are negative; and
- The results are robust to changes in the value of some of the key variables, as demonstrated by the fact that even at the upper end of the range of benefits in the 80% confidence interval, the benefits remain negative.

Table 79 Net Present Value (NPV) of Net Benefit to Society from Biodegradable Waste Ban, £ million

	Incineration (elec)	Incineration (CHP)	MBT: Output to landfill	MBT: SRF to Dedicated	MHT: Output to gasification
Net Environmental Benefits	-£410	£580	£2,200	-£130	£680
Financial Saving (Social Metric)	-£3,500	-£5,500	-£3,700	-£4,600	-£5,900
Upper (90% Interval)	-£2,900	-£3,800	-£500	-£3,700	-£4,100
Net Benefit to Society (median value)	**-£3,900**	**-£4,900**	**-£1,500**	**-£4,700**	**-£5,200**
Lower (10% Interval)	-£1,400	-£1,500	-£1,500	-£900	-£500

Note: +ve figures indicate a net financial benefit

Key Parameters

The key parameters driving the results are:

- The landfill gas capture rate is the most significant driver of the results; and
- The net cost to society is also sensitive to the variation in costs of the treatment process being examined, as well as the cost of landfill.

This is as expected. Effectively, the issue is whether the costs of the switch are justified by the benefits: the major driver of cost is the cost of the treatment itself, and the major driver of benefits are the GHG emissions reductions in the non-traded sector, these being, principally, the avoided emissions from landfilling.

Key Messages from the Biodegradable Waste Ban

- Depending on the landfill assumptions, the policy will deliver large GHG savings;
- The most significant factors affecting the net benefit to society are the landfill gas capture rate and the cost of the treatment processes themselves;
- Under all cases there appear to be social costs – sometimes significant ones - stemming from the ban on biodegradable wastes. This is expected to be sensitive to factors such as composition of residual waste, which was not explored in this analysis; and
- There are also private costs associated with the change. The model reflects fully costed treatment options, all of which depend on dedicated waste facilities. It is recognised that the market place can deliver gate fees lower than landfilling for some processes, but the focus has been on costs, not gate fees, and the Steering Group requested analysis of options which are dedicated to the treatment of waste.

8.11 Private Cost Analysis of Greenhouse Gas Savings

Cost benefit analysis is used to help make policy decisions around whether to implement a new policy, or not. Conventionally, and in this study, the key results are presented using the social cost metric, in which taxes and subsidies are stripped away, and the discount rate used is lower than might be applied in the private sector. These costs are less familiar to operators in the market place.

Table 80 below shows the financial costs of the policy options under both the social cost metric and a 'private cost' metric, which incorporates the effects of taxes and support mechanisms. These figures are for the financial costs only (i.e. there is no consideration of environmental benefits). For the individual materials, as well as for material groupings, we also show the CO_2 savings, and derive, for each of the cost metrics, the net financial costs per tonne of CO_2 equivalent saved. In the calculation of financial costs a regulation and communications element was added to each policy. However, if multiple material based policies were implemented, then the regulation and communications cost could be spread across them. Thus we have reduced the overall costs by (x – 1) * £70 million [where x = the number of material based policies included in the calculation] to ensure that the regulation and communications costs are not double-counted.

Under the social costs metric, the cost of GHG abatement for all materials is £37 per tonne CO_2 eq. This falls to only £8.00 per tonne CO_2 eq. if one includes in the analysis only those materials which generate net social benefits in our analysis (see above). When the private metric is used as the basis for an assessment of costs, if one considers only the materials which generate net social benefits, the costs of abatement are, in fact, negative. There is a financial saving of £8.72 per tonne CO_2 eq. avoided. For the whole group of materials, using the private metric, there are small financial savings of the order £0.54 for each tonne CO_2 eq. avoided.

For the materials which do not generate net social benefits, when considered as a separate group, the material based measures could generate savings of 47 million tonnes CO_2 eq. at a cost of around £12 per tonne CO_2 eq.

A variety of conclusions can be drawn from this. However, an important one is that, to the extent that Government has no strong desire to amend the main policies affecting the cost of landfill bans (notably, the landfill tax), then it might be more preferable to consider hybrid cost metrics to understand the implied cost of different policies. Equally, such analyses could imply that there might be more efficient, or cost-effective, policies available than those currently in place.

Table 80 Costs and Levels of GHG Abatement

	Cost (social metric)	Cost (private metric)	CO_2 saving from requirement to sort	Cost per tonne CO_2 saved (social metric)	Cost per tonne CO_2 saved (private metric)
Food (AD: Elec)	£2,100	-£340	26	£80	-£13
Green – OAW	£330	-£110	4.3	£76	-£25
Paper / Card	£20	-£560	26	£0.94	-£22
Textiles	£180	£100	10	£17	£10
Wood	£120	-£100	5.5	£22	-£18
Glass	£40	-£71	1.6	£25	-£44
Metals	£220	-£10	30	£7.33	-£0.32
Plastics	£1,150	£846	167	£69	£51
WEEE	£270	£176	0.21	£1,286	£839
All Materials	£4,430	-£65	120	£37	-£0.54
All Materials With Net Social Benefit	£580	-£637	73	£8.00	-£8.72
Note: all figures are 2009 to 2024 inclusive, and costs are NPV figures in 2009 real terms. Costs are shown as positive figures in this Table, with savings shown as negative figures.					

8.12 Further General Sensitivities

Some additional sensitivities were raised in the context of the peer review process. These are described in what follows.

8.12.1 Global Warming Potential

In calculating emissions for the purpose of UK carbon budgets, the global warming potential (GWP) of methane relative to CO_2 has been set at 21. This is the figure which has been used in all the modelling undertaken thus far.

However, there is some discussion as to what this value ought to be. Recent reports from the Intergovernmental Panel on Climate Change propose a value of 25. Some other sources suggest higher values still, and the GWP used increases the shorter one's time horizon becomes. The figures 21 and 25 both arise from consideration of effects over a 100 year time horizon.

Table 81 below shows the median values for the central case under the biodegradable waste ban, along with a variation where the GWP of methane is increased from 21 to 25. As expected, given the sensitivity of the analysis to landfill gas captures described above, a higher weighting for the fugitive emissions of methane increases the benefits from the ban, and increases the likelihood that society will generate net benefits from the ban irrespective of the choice of treatment for residual waste.

8.12.2 Sensitivity Results

For all of the treatments, the median values show an increase in environmental benefit compared with the central case, but not enough to change the net social benefits from negative to positive.

Table 81 Net Present Value (NPV) of Net Benefit to Society Environmental Modelling Sensitivities, £ million

	Incineration (elec)	Incineration (CHP)	MBT: Output to landfill	MBT: SRF to Dedicated	MHT: Output to gasification
Net Benefit to Society (central case)	-£3,900	-£4,900	-£1,500	-£4,700	-£5,200
Net Benefit to Society (GWP to 25)	-£3,500	-£4,500	-£1,100	-£4,300	-£4,800

Note: +ve figures indicate a net financial benefit

8.13 Summary of Results

The key results from the modelling are summarised in **Figure 13** and **Figure 14**. The first shows the median net benefits for the material-based restrictions and unsorted waste bans, and the 80% confidence intervals. The second does the same for the biodegradable waste ban. Key materials for consideration for inclusion within the scope of the material based policies are:

- Paper and card;
- Food
- Green waste
- Non-ferrous metals
- Textiles
- Wood;
- Glass (particularly having explored sensitivities); and
- Ferrous metal.

Median values of the net social benefits suggest that a total benefit with a Net Present Value of £910 million could be derived by society over the period 2009-24 from a mechanism requiring that these materials be sorted for recycling and kept out of residual waste treatment. The GHG savings would amount to 120 million tonnes over the same period.

Figure 13 Net Benefit to Society from Material-based Restrictions and Unsorted Waste Bans, £ million NPV, 2009-2024

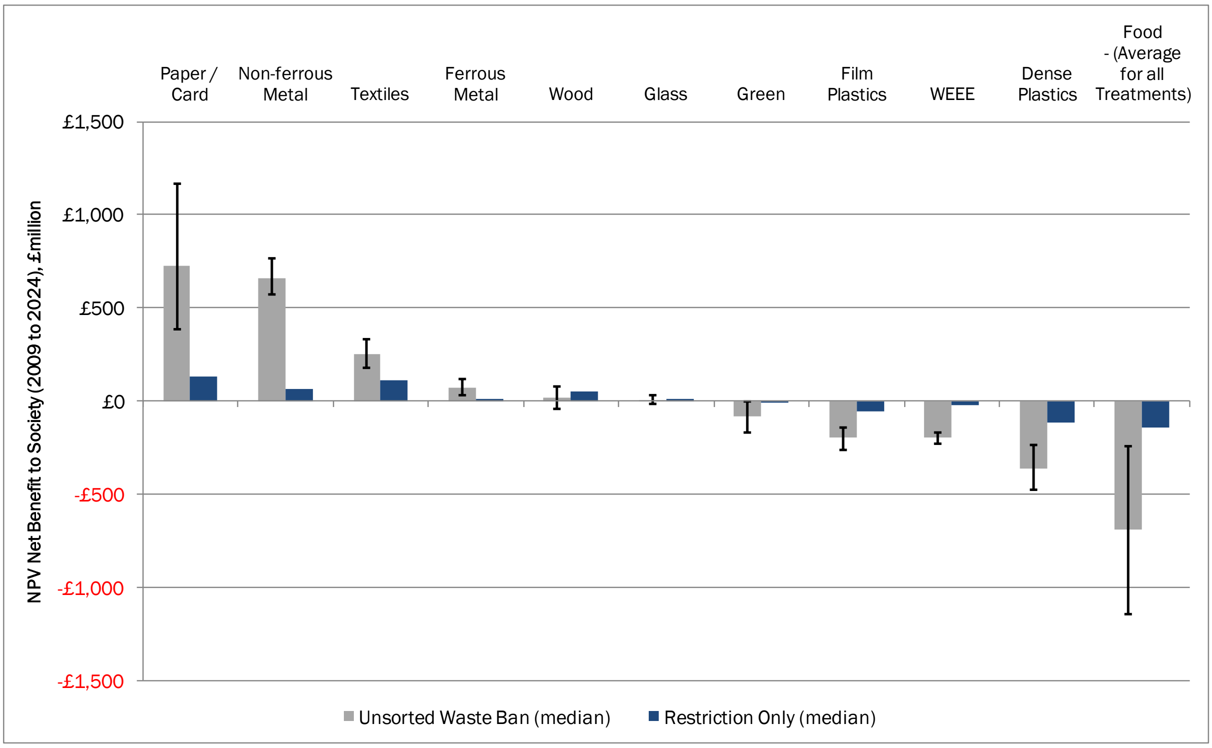
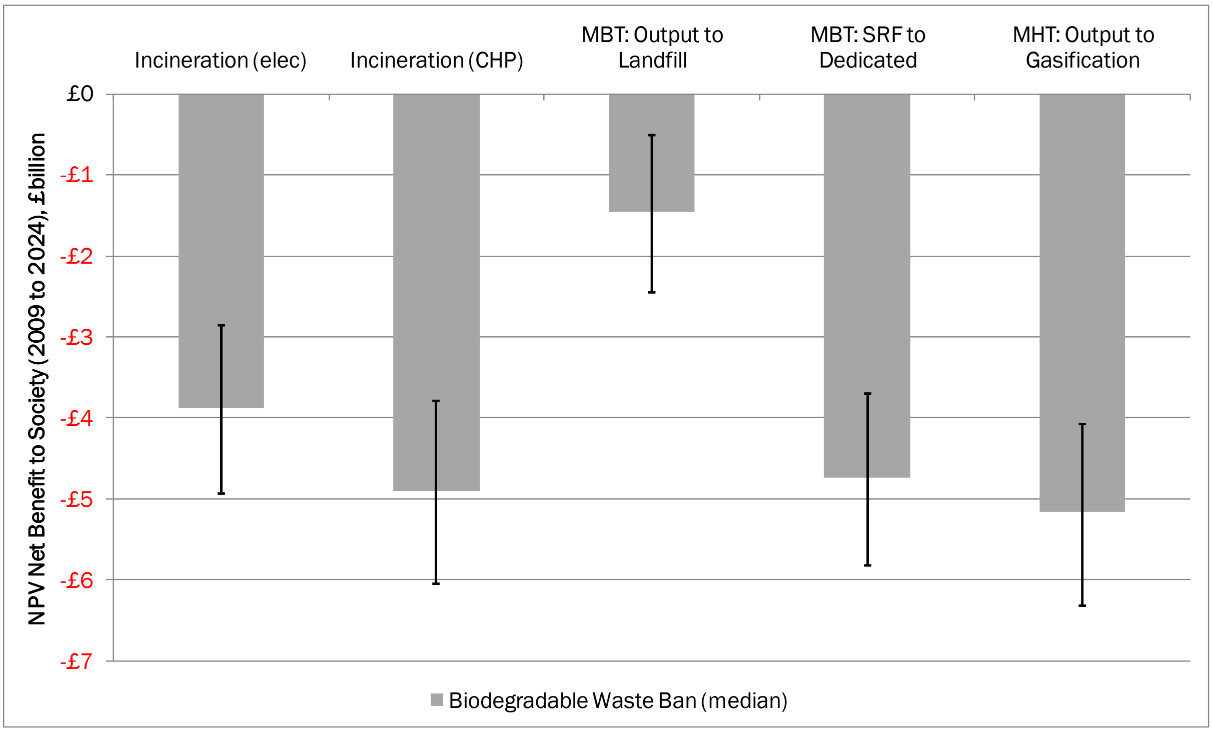


Figure 14 Net Benefit to Society from Material-based Restrictions and Unsorted Waste Bans, £ billion NPV, 2009-2024



From the perspective of net social costs, Food, Green waste, WEEE and plastics are less promising candidates for material based restrictions or a ban on unsorted wastes. If these materials were excluded the benefits would increase to £2.1 billion over the period 2009-24, but greenhouse gas savings would fall to around 73 million tonnes.

Where the biodegradable waste ban is concerned, the results are less equivocal from an economic perspective. There is no denying the potentially large GHG benefits to be derived from this ban (median savings range from 42 to 82 million tonnes CO_2 equivalent). However, the question is whether the benefits can be justified by the additional costs. None of the treatment routes appears to pass this 'test' at the 80% confidence level under the sensitivity testing we have run.

8.13.1 Costs of Implementing the Restrictions / Bans

The following sections outline our estimates of the cost of implementing the restrictions.

Material Restriction

For the material restriction only, we have assumed that this will be done through visual inspection at the landfill and through existing paperwork requirements. The visual inspection will occur as it does at present and will not represent an additional regulatory cost.

Unsorted Waste Ban plus Sorting Requirement

In this case, we have assumed that there is a requirement for enforcement / inspections upstream. We have assumed that the waste producer will be inspected. Local authorities, and therefore householders, are not expected to require additional regulation. Therefore we have estimated the cost of regulating commercial and industrial producers of waste.

Based on the assumptions in Appendix 14 it was determined that the yearly cost of enforcing this restriction (plus requirement to sort) will be in the order of £9.53 million in 2009/10 terms. In addition to this cost there will be an initial communication cost. Communication costs are detailed in the Section below. It should be noted that this cost is heavily dependent on the number of premises that are investigated, and this will be determined relative to the resource available. We have allocated a cost to each regulator based on a breakdown of C&I VAT registered businesses in each of the devolved nations, shown in **Table 82**.

Table 82 Regulation Costs per Nation

	England	Wales	Scotland	Northern Ireland	Total
C&I premises Inspected	307,018	16,020	27,112	11,849	**361,999**
Estimated Cost	£7,055,207	£789,497	£977,705	£702,727	**£9,525,137**

Biodegradable Ban

Much of the regulation of a ban on biodegradable waste would be likely to occur through permitting. Permits would be granted to treatment facilities, and regulating against the threshold would form part of the regulation of the permit. The cost of obtaining a permit is intended to cover the cost of processing a permit, for the relevant agency. To model the cost of regulating a biodegradable ban it was agreed that the cost would relate to the number of new facilities and the cost of acquiring a permit. As a result we have not included the cost of regulating a biodegradable ban; as the regulator is not expected to incur an additional cost.

An initial implementation cost is expected, as current landfill permits may need to be re-evaluated. Landfills will have obtained permits under gas capture and leachate management models that will need to be readjusted if biodegradable waste were to be eliminated from landfill. This initial cost could be in the region of £150,000, assuming that every permit is re-evaluated and the process takes three days, at a Grade 4 pay grade (£37,000 pa). It is unclear whether all permits would need to be re-evaluated. Due to the difficulty in accurately estimating these costs they have not been included in the modelling, but may result in an additional initial cost.

More important, where the biodegradable ban is concerned, is the likely cost to the operator of the treatment facility, and the operator of the landfill, of testing which would need to be carried out to verify that the waste being accepted fell below the biodegradability threshold. In principle, it would be possible to use one of a number of tests, including the BM100 test and measurements for the Dynamic Respiration Index (DRI). Our preference is for a measurement of the DRI, this being relatively cheap and giving results relatively swiftly (which is not true of the BM100 test). We have estimated that conservatively, for an effective testing regime, the cost of the test might add £2 per tonne at facilities seeking to demonstrate that they achieve these standards. In addition, we have added an additional £1 per tonne for material received at the landfill for periodic testing of the material. At the landfill, however, the principle means of enforcement would be expected to be:

1 Visual inspection; and
2 Through paperwork (Duty of Care).

The former would be expected to be relied upon where carriers claimed that material was almost wholly absent of any biodegradable material. The latter would be expected to be used to check that material arriving at the landfill was either a) of a source which was likely to be more or less devoid of biodegradable content, or b) coming from a facility which had been accredited for its ability to treat waste down to the DRI threshold level.

8.13.2 Costs of Communicating the Restrictions / Bans

We have assumed that, for each policy scenario, essentially all householders and commercial & industrial (C&I) premises will have to be communicated with, as it is likely each restriction will affect these groups. For C&I we have assumed that the information will be disseminated mainly through dedicated seminars and the development of press releases. These costs provide an estimate to the regulator of communicating a ban to the target group. The costs may vary depending on the nature of the restriction and the target group.

The cost of a generic communications campaign is comprised mainly of the following elements[60]:

- External advertising costs (media costs);
- Operational costs (marketing collateral);
- Printed literature;
- Website development;
- Seminars; and
- PR Costs.

[60] *WRAP (2007) Behavioural Change Local Fund: Indicative Cost Guide, available at:* *http://www.wrap.org.uk/downloads/IndicativeCostGuideV7final1.3322a518.2672.pdf*

It is assumed that the development of guidance will be incurred as part of the regulatory costs discussed above.

The costs reported by WRAP reflect the cost of communicating a change in collection system to the householder and other users of the service. For a ban on material to landfill we have assumed that communication costs will focus on the cost of informing industry and householders.

Waste producers include industry and householders. In terms of communicating a ban to householders there will be an overlap between regulator and local authority spending. We have assumed that some of the potential communication costs to householders will be undertaken by the regulator, prior to LA funded communications.

Table 83 summarises the costs associated with the elements of a communication campaign. These costs are based on estimates for England and have been approximated for each of the devolved nations by relative population figures. Marketing collateral refers to the design of the communication campaign and associate press package. The cost of communicating a restriction will vary depending on the structure of the restriction, and on the relevant stakeholders. It is difficult to pinpoint a cost of a communication campaign; the cost will vary as the specification of the client varies.

The cost below does not include the cost of delivery of leaflets to C&I premises. It is assumed that householders will be covered by local authority budgets or as an add-on to current communications costs. The additional cost of delivery to C&I premises would be in the order of £780,000 thus producing a total communication cost of £1.65 million. Depending on the lead time of a ban additional advertising might be required. Marketing collateral and website design represent a one-off cost. However, during the lead time of a restriction, each additional round of advertising would incur additional seminar and PR costs. Two further rounds of advertising in the lead up to a ban would result in an additional £1.1 million.

A further additional cost would be the use of television advertising, which is not currently accounted for. We expect that the cost detailed in **Table 83** is the lower bound and that the communication cost could increase depending on lead time and the advertising methods chosen.

Table 83 Communication Cost of Material Ban to Landfill

Nation / **Cost**	**England**	**Wales**	**Scotland**	**Northern Ireland**	**Total**
Marketing Collateral					
Sub-Total	£175,000	£10,181	£17,583	£6,038	**£208,802**
PR Element (press release, newsletters, media communications)					
Sub-Total	£375,000	£21,817	£37,678	£12,938	**£447,433**
Website (design, viral marketing)					
Sub-Total	£125,000	£7,272	£12,559	£4,313	**£149,144**
Other					
Seminar (With C&I)	£45,000	£6,000	£12,000	£3,000	**£66,000**
Total	**£420,000**	**£27,817**	**£49,678**	**£15,938**	**£871,379**

9.0 Other Key Issues for Consideration

This Section highlights other issues which need to be considered in the design and implementation of a restriction on landfilling. The Section is unchanged since the original version.

9.1 Announcement and Lead-times

There are various issues which would need to be considered if a landfill restriction or ban was to be introduced. In summary, these relate to:

1. The timing and nature of the announcement;
2. The time at which the legislation is drafted; and
3. The time at which the announcement takes effect.

The timing of any announcement ought to be such that it gives adequate time for the different actors being affected to ensure they are complying with the restriction or ban, however that may be phrased. As importantly, the announcement should not state anything which is not known with certainty. Any matter of design which is inadvertently mentioned prior to the matter being pinned down risk setting hares running, and can lead to expectation in the market which might be impossible, ultimately to fulfil. The key is to:

1. Give the market a signal as regards what will happen; and
2. Make sure that no incorrect signals are given to the market (which might lead investors down what turn out to be blind alleys).

Ideally, in respect of 2 above, announcements are made only once the statutory instrument is in place (so that the announcement can be an informed one). In practice, this may not be possible, and there may be a desire to develop an instrument quickly, in which case the detailed instrument may be worked up post-announcement. It would be desirable in such situations for full details to be developed as quickly as possible post-announcement.

The lead time for the restriction has to consider what is expected to happen. In the case of material based restrictions, where actors are expected to have in place collection systems of the required standard, in principle, the period could be relatively short, and the longest lead times might relate to local authorities. For those materials where kerbside collections are unlikely to be the major sources of material, therefore, the lead-times could be quite short.

Wood reprocessors comment that they have surplus capacity (not merely associated with the current downturn in construction). At the same time, whilst there are plans for a range of biomass power plants to receive wood, it is far from clear that the wood that is currently not segregated would be of a sufficient quality to be combusted in facilities which were not compliant with the Waste Incineration Directive (WID), though some biomass plants clearly will be. Our assumption has been that the additional quantities sorted from the waste stream as a result of the restrictions are likely to be, to a large extent, suitable only for combustion at facilities which are WID compliant (especially the quantities over and above what is expected to occur in the Baseline). Hence, one would like to be confident that such capacity exists locally (unless one is happy to see such material exported for recovery).

For the biodegradable waste ban, the emphasis is upon the development of infrastructure for residual waste treatment. Given the pace at which this currently happens, it would be difficult to imagine the requisite infrastructure being in place much before the end of the next decade. The planning (and permitting) system is likely to be struggling to deliver the facilities which are already 'in the baseline', let alone the additional capacity that would be required to ensure the restriction is fully implemented.

At one level, this is not so worrying. It would be a mistake, in our view, to push the biodegradable waste restriction forward without first seeking to ensure that the options for recycling and waste prevention had been more or less exhausted to the extent that they were deemed socially beneficial. The reason for this is that the biodegradable waste restriction focuses upon delivering residual waste treatment capacity instead of landfill, and whilst, at the margin, this could have an effect on recycling, the principle effect would be to give a spur to non-landfill residual waste treatments. If this was pushed through too early, then tensions between residual waste treatment supply, and the desire for higher recycling rates would most likely be exacerbated, potentially leading to excess capacity for residual waste or a cap being placed upon recycling (since prices for residual waste treatment would be expected to fall in the event of over-supply). The example of Denmark is perhaps worthy of closer examination in this regard.

Although one of the interesting features of a ban is that it might be possible to substitute for a longer lead-in time through allowing for exemptions, in practice, in the restrictions we are considering, this is likely to be of greatest relevance for the biodegradable waste ban. On reflection, therefore, precisely for reasons just highlighted (the desirability of *not* introducing such a ban too quickly), we would tend to the view that the exemptions based approach would risk jeopardising what appear to be potentially greater benefits from recycling options and waste prevention. This is not to say that the biodegradable waste ban could not be announced at an early stage. It is merely to highlight the fact that in the UK, where Defra and the different DAs are still evolving their strategies and improving performance in respect of recycling and waste prevention, it would not be appropriate to force the pace of development of fixed throughput investments in residual waste treatment. This might 'ossify' future development, as appears to have been the case in Denmark following the development of incineration capacity in past decades.

9.2 Constraints Around Existing Planning System

The planning system was highlighted in all of the workshops as a key factor in constraining the effects of the bans / restrictions. The constraints will be different for the different bans / restrictions.

- Biodegradable Ban – this will cause the greatest strain on the planning system as large scale residual infrastructure will need to be built;
- The material based restrictions will not cause as much need for infrastructure, other than waste transfer stations etc, except for the bans on food and green waste where composting infrastructure will be required.

The key point is that waste infrastructure is likely to become smaller scale and more widespread. It will have to be an accepted fact that if one is moving away from large scale disposal at far off landfills, treatment infrastructure will be more visible and subjected to more scrutiny in the planning process. If this scrutiny is too tight it will hold up the development of much of the infrastructure that would need to be in place for the bans to be effective.

9.3 Effect of Bans on Market Certainty for Collection and Reprocessing

A landfill ban which was designed to force the rate of recycling should, as long as it is regulated and enforced, give greater certainty to those seeking to develop collection and reprocessing infrastructure. Whilst it is, in principle, a valid approach to seek to shift behaviours through communications and through softer cajoling, the downside of this approach is that it lacks the certainty which financial backers require to support new investments in collection and reprocessing, understood here to include treatment of biowaste.

The current situation with regard to food waste provides telling evidence of this – there are large numbers of would be investors who are willing and keen to invest in anaerobic digestion. The fact remains, however, that certainty of supply of feedstock remains a major issue for project developers outside the municipal waste contracting area. Whilst there are examples of some developers aligning themselves with collection companies, more generally, this matter seems unlikely to be overcome on a widespread basis until the policy framework drives the segregation of food waste, both at the household level and at the commercial level. Requiring the sorting of food waste, or the provision of quality services to collect it, therefore becomes important in delivering this certainty. A properly enforced approach of this nature should give greater confidence to developers and their financial backers that there is a viable market prospect. This is likely to be especially relevant for biowaste from households and commerce, where the requirement for source separation as well as appropriate treatment can constitute something of a chicken and egg situation.[61]

A very important aspect of the additional certainty for collectors is that this not only makes the offering of a service for the materials specified a requirement, but to the extent that users would have to avail themselves of the service, the costs of the collection service itself might show a tendency to decline relative to the situation where take-up of the service is uncertain. The requirement for additional marketing spend per additional

[61] *For this reason, there is still a general shortage of capacity for treatment of biowaste containing food waste. Such material moves strangely large distances at present (given its low value and its bulk), but this reflects an absence of strong drivers on the supply side.*

customer ought to decline, and the costs of collection themselves may also fall because the economies of density on the round would improve. The effect would only become negative, at the margin, where the additional pick-ups were generating very little material. In these cases, however, it seems reasonable to suggest that costs would be unlikely to escalate to levels experienced in the household sector. These economies of density are far less likely to be realised where the enforcement is weak or uncertain, so that in these cases, it would seem more likely that the costs of any 'required' services would be higher than might otherwise be the case.

9.4 Effect of Bans on Market Certainty for Residual Waste Treatment

For bans, such as the biodegradable waste ban, that effectively outlaw the landfilling of untreated residual waste, again, the issue of certainty becomes important. It needs to be borne in mind that the ban would be implemented against the backdrop of a baseline in which the landfill tax has risen to £72 per tonne in nominal terms, or around £65 per tonne in real (2009) terms.[62] Given median landfill gate fees of £20.50 per tonne in early 2009,[63] the real price (in 2009 terms) of landfilling is expected to be of the order £85 per tonne in 2013.

At this stage, the costs of alternative residual waste treatments will be looking increasingly competitive with landfill, depending upon:

- What they are;
- How they are procured; and
- Their scale.

Although gate fees for incineration and other residual waste treatments already are higher than this in some municipal waste tendering processes, we suspect this partly reflects the nature of the contracts and the risk transfer which is being sought, as well as, more recently, the tightening terms of credit in the financial markets. The last of these factors will also affect companies seeking to construct merchant facilities unless they are able to fund the investments through corporate financing or other routes, but the absence of the same contract requirements might lead to lower gate fees in the merchant market because of the less stringent demands in terms of risk transfer (related to PPP-style projects in the municipal sector).

Figure 15 shows how the gap between landfill and the costs of incineration and other residual waste treatments is likely to close as the landfill tax increases to £72 per tonne. As can be seen, the differential is likely to be quite small, and in some cases, may be negative.

This has important implications for the likelihood of further increases in recycling being achieved once the landfill tax has reached £72 per tonne. Unless regulatory matters dictate otherwise, efforts made in respect of recycling and waste prevention are likely to be affected principally by the avoided cost of the collection and treatment of residual waste. If the costs of landfill increase further, either as a result of further increases in tax, or (implicitly) through the implementation of a landfill ban, then because alternative treatments are likely to be 'more or less' competitive on price, then as long as alternative treatments are delivered and capacity is available, there would be expected to limited additional stimulus to recycling over and above attempts to intensify existing efforts.

This is an important point for the modelling. It does rest on the important caveat that the alternative treatments are developed, and that capacity is available. If they are not, or if they prove, in the course of time, to be more expensive, then further stimulus to recycling and waste prevention would be expected to follow.

What will be of significance, therefore, is whether a given 'ban' makes it more or less likely that the targeted materials or wastes will really be *'banned'*. In the case where the ban is strong (as in the case of the 'biodegradable waste' ban), then the expectation would be that treatment facilities would be developed, and that the principle effect would be a switch from landfill to other residual waste treatments. Where the ban is of a softer nature – reflecting what the carriers are required to declare, and the way the ban will be enforced – then we would expect some changes in respect of the approach to collection and sorting, with existing approaches intensified, and some additional systems being developed. Effectively, a tightly enforced ban on a material being landfilled amounts, as described in earlier Sections of this report, to a ban on mixed wastes which contain these materials.

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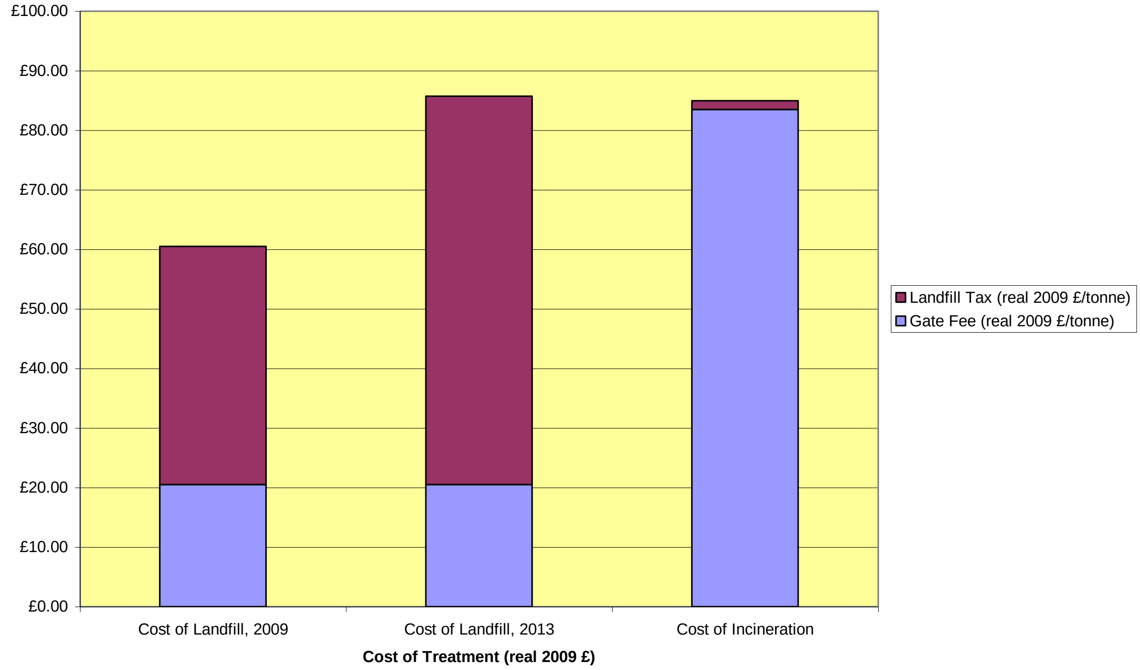
[62] *Calculated assuming inflation of 2.5% annually.*

[63] *WRAP (2009) WRAP Gate Fees Report 2009: Comparing the Costs of Alternative Waste Treatment Options, results from a survey of gate fees carried out by Eunomia, http://www.wrap.org.uk/downloads/W504GateFeesWEB.8e41c64a.7613.pdf*

Figure 15 Relative Costs of Landfill (2009 and 2013) and Incineration



Significantly, therefore, for those materials for which alternative residual waste treatments are available, the more 'absolute' is the declaration, the more likely it becomes that the ban will lead not to more recycling, but to alternative treatment of residual waste. The extent to which recycling will be further incentivised will be related to the cost differential between landfill, inclusive of tax, and the alternative residual treatment. As suggested above, this is unlikely to be very high for most of the materials we are addressing since they are all amenable to incineration, and the cost differential between landfill and incineration may be relatively low. As a result, we would expect the incentive for additional recycling to be correspondingly small under, for example, the biodegradable waste ban.

9.5 Quality of Materials

An interesting feature of the workshops with reprocessors of dry recyclables was that those present conveyed a very strong message that increases in recycling resulting from a landfill restriction or ban would be unwelcome unless outstanding issues regarding the quality of materials collected were addressed. If they are not addressed, then depending upon the details of implementation and enforcement, the effect might be to exacerbate some of the problems which already exist in respect of exports of questionable legality.

There are reasons to believe that a well-specified 'requirement to sort', where it is carefully considered so that it maintains a focus on quality, might actually improve the situation in respect of the quality of materials being collected. This could actually have a positive impact in reducing the problems which persist, even in the light of increases efforts to address them, in respect of illegal exports of some materials.

It should be recognised that the requirement to sort would affect not just the additional material being collected, but also, that which is being collected already. Such a positive impact might be less likely to arise in the case of, for example, WEEE, where the key issues might be less related to the quality of exported material, and more to the incorrect declaration of its ultimate fate.

9.6 Side-Effects of Bans

Implementing a ban might be expected to have various consequences which should be anticipated and preferably addressed.

9.6.1 Operational Effects on Landfill Operators and Implications for Gate Fees

If a landfill ban is introduced which has a significant effect on the quantity of material sent to landfill, and if the proportion which is biodegradable is significantly affected, then the way in which the landfill functions effectively changes. There will be operational issues to be considered related to the pace of settlement, the rate of gas generation and the generation of leachate.

In the case of the biodegradable waste ban, then where the specification of the ban allows for landfilling of waste which has been treated to a pre-set level of stability, it would be expected that the material received at the landfill would have a low tendency to generate gas. This would have implications for the design and operation of new cells / landfills.

The lower gas generation would also be expected to affect the economics of landfill operation. Operators seek to generate funds to support aftercare costs through revenue from gate fees, these being set, effectively, net of revenue from generation of electricity (or sales of biomethane). If these revenues (from energy sales) decline, then in principle, the gate fee may need to rise to compensate for the expected reduction in revenue.

At the same time, a competing effect may come from operators seeking to fill their sites, at least those who are coming towards the end of their operational life. Hence, once such a ban is announced, it is quite possible that there may be a reduction in prices at some facilities. This was very much the experience of Germany in the wake of the announcement of a landfill restriction not so dissimilar to the one proposed here for biodegradable waste. Having said this, the scope for drops in price at German landfills might have been greater than it may be in future in the UK. To the extent that landfill tax makes other treatments and management routes more competitive relative to landfill, the scope for landfill gate fees to incorporate excess rents in future might be reduced. In Germany, no such landfill tax was in place at the time the restriction was implemented.

In the case of very rapid declines in landfill tonnages – which we suspect to be somewhat unlikely since the development of alternative infrastructure would need to be correspondingly rapid – then some sites might struggle to fill up. This could have some important effects on the potential to support aftercare activities in the case of some operators.

9.6.2 Illegal / Evasive Activities

Fly-tipping is a persistent problem in the UK. It is therefore of concern that incidences of fly-tipping might increase following the implementation of bans on certain waste streams being landfilled. This might be most likely under the biodegradable waste ban, or where 'mixed' loads had sufficiently high proportions of one material that it became obvious that the load had clearly not been subjected to adequate sorting.

Fly-tipping of tyres in particular has been prevalent in the UK for several years. Following the landfill ban in 2006, however, the frequency of illegal dumping of tyres remained largely invariant, as per Environment Agency data and the Flycapture database.[64]

Findings relating to the impact of the 2004 ban on co-disposal of hazardous waste were conflicting regarding fly-tip occurrences. CIWM found no evidence to suggest that fly-tipping of hazardous waste had increased subsequent to the ban, whereas the ESA did find examples of illegal activities.[65] A further concern was that significant quantities of hazardous waste were unaccounted for following the implementation of the legislation.[66] CIWM concluded that waste was being illegally disposed of in non-hazardous landfills, citing the following in support of this view:

- A lack of evidence to suggest that fly-tip occurrences increased after the ban; and
- Pre-treatment facilities had not received the anticipated increase in business following the ban, as proportional to the quantities of hazardous waste believed to exist.

The latter point is relevant because of the pre-treatment requirements contained in the Directive. The observation suggests that hazardous waste is not receiving the requisite pre-treatment before being sent to non-hazardous waste landfill sites.

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[64] *Defra (2007)* Waste Strategy for England 2007 Annex C12: Tyres*, Available:* *http://www.defra.gov.uk/Environment/waste/strategy/strategy07/documents/waste07-annex-c12.pdf*

[65] *House of Commons (2005)* Waste policy and the Landfill Directive: Fourth Report of Session 2004-2005*, March 2005, Available:* *http://www.publications.parliament.uk/pa/cm200405/cmselect/cmenvfru/102/102.pdf*

[66] *House of Commons (2005)* Waste policy and the Landfill Directive: Fourth Report of Session 2004-2005*, March 2005, Available:* *http://www.publications.parliament.uk/pa/cm200405/cmselect/cmenvfru/102/102.pdf*

A counter-argument was that this observed trend was merely a testament to the effectiveness of the policy, which succeeded in incentivising more innovative approaches to waste minimisation and source separation of waste on site, thereby minimising the amount of waste classified as 'hazardous'.[67] However, independent research contradicted these assertions. A detailed analysis of the fate of hazardous waste found that measures such as waste minimisation or storage of waste could not account for the apparent shortfall which occurred in the wake of the ban on co-disposal. Many believe that it is more likely that the waste is being illegally disposed of in non-hazardous landfill (to the tune of around 694,000 tonnes per annum in 2004).[68] This was attributed to two main factors:

- Ignorance of the new requirements amongst producers; and
- Mis-description of hazardous wastes as non-hazardous.

The latter cause is likely to have been incentivised by the substantial cost implications resulting from the differential between disposal in hazardous and non-hazardous landfill.

The mis-description explanation is especially important in the context of some of the approaches which have been suggested in the context of this work in respect of material based restrictions and bans. Although landfill operators are required, as part of their Duty of Care, to visually inspect loads, and to ensure paperwork is in order, in practice, once waste arrives at the landfill site, the opportunities for thorough checks are often limited. This may be, for example, because of the nature of containment of the waste, or because some 'restricted' or 'banned' materials are present in small quantities, or because they are effectively hidden. It is partly for these reasons that we expect limited effects from material based restrictions, and more significant effects only where there is a requirement to sort, and measures to enforce the requirements of the ban.

Other legislation relating to landfill – such as the landfill tax – is also cited as a driver behind waste-related crimes. Imposing additional landfill bans could serve to exaggerate these sorts of practices, unless tighter enforcement and monitoring comes into effect. In Scotland, there is no empirical evidence to suggest the landfill tax has resulted in an increase in fly-tipping.[69] On the contrary, England is said to have seen an increase in illegal dumping. Depositing construction and demolition waste in environmentally vulnerable locations is widespread, on the order of hundreds or even thousands of lorry loads.[70] Landowners in receipt of the waste are commonly either unaware or misled regarding these practises. This does not mean that they escape prosecution, however, as ignorance is not acceptable as evidence of innocence in European Law.

9.6.3 Other Consequences

Preceding the ban on co-disposal of hazardous waste in 2004, arisings of hazardous waste were declining year-on-year. However, just prior to its implementation in July, arisings significantly increased. This reverse in trend has been attributed to the urgency felt by operators to dispose of as much waste as possible before the ban applied, in order to fill spare hazardous waste landfill capacity; coincident increases in deliveries to landfill sites were observed (especially of contaminated soil).[71]

Whilst, across the UK, the annual capacity for hazardous waste has been deemed sufficient to cope with demand, the spatial distribution between nations is not consistent with arisings of hazardous waste within nations.[72] This

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[67] *House of Commons (2005)* Waste policy and the Landfill Directive: Fourth Report of Session 2004-2005*, March 2005, Available:* http://www.publications.parliament.uk/pa/cm200405/cmselect/cmenvfru/102/102.pdf

[68] *House of Commons (2005)* Waste policy and the Landfill Directive: Fourth Report of Session 2004-2005*, March 2005, Available:* http://www.publications.parliament.uk/pa/cm200405/cmselect/cmenvfru/102/102.pdf

[69] *Environ (2001)* Review of the Environmental Effects of the Landfill Tax in Scotland*, Environment Group Research Programme Research Findings No. 10, Available:* http://www.scotland.gov.uk/Publications/2007/08/landfill/landfill

[70] *Sutton, M. (2008)* A Criminal Waste: The Organised Crime Involvement in the UK Muckaway and Disposal Process*, June 2008, Available:* http://www.fig.net/pub/fig2008/papers/ts08g/ts08g_01_sutton_3045.pdf

[71] *Defra (2007)* Waste Strategy for England 2007 Annex C9: Hazardous Waste*, Available:* http://www.defra.gov.uk/environment/waste/strategy/strategy07/documents/waste07-annex-c9.pdf

[72] *Defra (2007)* Waste Strategy for England 2007 Annex C9: Hazardous Waste*, Available:* http://www.defra.gov.uk/environment/waste/strategy/strategy07/documents/waste07-annex-c9.pdf

has resulted in cross-boundary movements of hazardous waste, being transported longer distances than before. Cited impacts include noise pollution, increased traffic, general nuisance and possible risks to health for those in close proximity to hazardous waste sites.[73]

Gypsum, a mineral commonly used in construction as plasterboard, is not classified as a hazardous waste.[74] However, if the sulphate content of a product exceeds 10%, then it is banned from being disposed of in non-hazardous landfills. This is the case with plasterboard. As a consequence, common practise amongst waste producers and waste transfer stations is to dilute plasterboard waste with other waste, such that the 10% threshold is not surpassed and the waste is accepted in non-hazardous landfill.[75] Partly in response to this, the 10% limit has effectively been removed (in other words, an outright ban is intended to apply).

9.6.4 Cross Border Waste Movements

It was mentioned above that increases in landfill tax, and the effect of a ban, might lead to additional exports of waste from the UK, possibly of questionable legality. It is possible that, without measures to ensure the quality of the materials collected, and without tight enforcement of the trans frontier shipment regulations, the materials being collected for recycling will ultimately be exported illegally to foreign markets as a means to circumvent any additional costs implied by a ban.

Where the biodegradable waste ban is concerned, the policy could lead to increased pressure to export residual waste to recovery facilities, although this is only possible with the consent of the receiving state. This already happens from the UK, with, for example, some solid recovered fuels exported for recovery. The change in definition of incineration from 'disposal' to 'recovery', subject to energy efficiency standards being met, under the revised Waste Framework Directive effectively makes it possible for residual waste to be shipped to other EU countries where the destination is a recovery installation, subject to agreement from the receiving country. Although it is not known exactly how much surplus capacity exists at incinerators overseas, it is clear that such over-capacity exists, and it is worthy of note that this is to be found mainly in countries with landfill bans already implemented.

9.6.5 Intra-UK Differences

In principle, since this work is for Defra and the devolved administrations, each country could choose to implement a ban differently. To the extent that the bans chosen were different, it seems reasonable to ask whether, and under what conditions, this might cause problems.

In principle, where the material based restrictions and the ban on unsorted wastes are concerned, in neither case is it the intention to enforce this through heavy-handed supervision at the landfill. In principle, therefore, under neither type of restriction would it be the case that mixed loads of waste would be banned from landfill. This being the case, it seems unlikely that any haulier in a country where the restriction, or a ban on unsorted waste, was in place, would feel that the incentive to cross the border to dispose of waste was especially strong unless:

1. The load being carried was obviously of a nature that could not be landfilled (i.e., it would be clear from visual inspection). Such materials would be expected – implicitly – to be relatively homogeneous, and might therefore be expected to be unlikely candidates for landfilling anyway, especially as landfill tax rises (some exceptions could relate to, for example, (contaminated) plastic films); or
2. The load was one to which no attempt to sort had been applied. This might be more likely in the case of the restrictions as opposed to the bans on unsorted wastes. In this case, the extent of regulation would be weaker, and the possibility would remain that collectors who had no desire to offer recycling services simply sought to landfill out of country since they did not wish to mis-describe their waste and risk being found guilty of an offence.

Probably far more problematic would be the case where, for example, a ban on biodegradable waste was implemented in one country but not another. In this scenario, one country would be seeking to ensure that no waste with more than a low level of biodegradability was sent, without prior treatment, to landfill. In this

[73] *House of Commons (2005)* Waste policy and the Landfill Directive: Fourth Report of Session 2004-2005*, March 2005, Available:* http://www.publications.parliament.uk/pa/cm200405/cmselect/cmenvfru/102/102.pdf

[74] *Environment Agency Landfill Regulatory Guidance Note 11*

[75] *Market Transformation Programme (2006)* BNPB3: Plasterboard – legislation and policy drivers*, WRAP (2006)* Review of Plasterboard Material Flows and Barriers to Greater Use of Recycled Plasterboard

situation, there might be an incentive to take material across the border to landfill it direct if no (cheaper) alternative was locally available. This, therefore, might create a problem if the measure was applied unilaterally.

Northern Ireland constitutes a somewhat special case in that it is the only UK country which shares a border with a non-UK country, i.e. the Republic of Ireland. Here, it is worth considering the situation in the Republic. In the near future, it is expected that the Minister will announce a revised landfill levy, in which it is expected that the tax on landfill will be significantly increased, with a tax also applying to incineration. In July, the EPA in the Republic published pre-treatment Guidelines setting out Ireland's approach (somewhat belatedly) to meeting the requirements of Article 6 of the Landfill Directive. This includes a requirement that, come 2016, no waste would be allowed to be landfilled unless it had been pre-treated to meet a defined stability standard. This is effectively akin to the biodegradable waste ban which has been discussed in this report. In principle, if Northern Ireland saw merit in such a restriction, it may make sense to develop a joint approach with the Republic (where the details of implementation appear to be still in development).

9.6.6 Cross-material Effects

It is generally appreciated – at least where municipal waste is concerned – that broadening the scope of materials covered by a kerbside collection service can increase the capture of those materials which were already being targeted. The publicly available evidence to support a similar effect in the commercial and industrial waste sector is not so widely available or discussed. Even so, in the commercial waste sector, there are likely to be some cross-material effects. For example, a ban on unsorted metals might, in the commercial sector, be expected to lead naturally to the adoption of a service covering plastic bottles also.

More generally, one might speculate as to the effects of including a broader array of materials under a requirement to sort rather than a small number of selected materials. There may be positive behavioural influences working across the material divide, as well as, possibly, more beneficial logistics for collectors which arise from broadening the scope of a ban. As discussed Section 8.0, for some of the individual materials, the sharing of the costs of communication and regulation would improve the apparent performance of the ban considerably. This is most notably the case for glass.

9.6.7 Prevention Effects

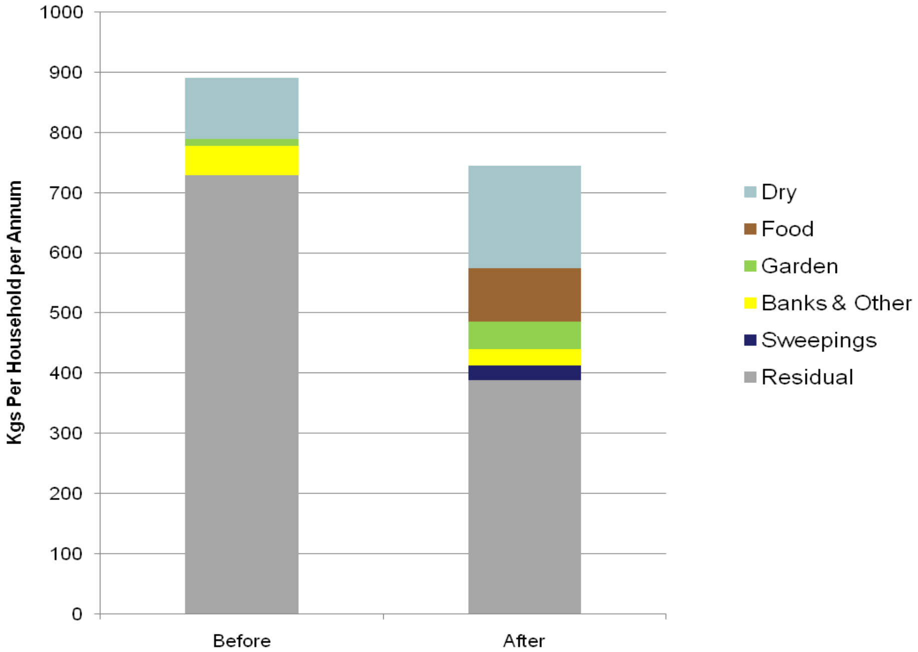
Where food waste is concerned, there is some emerging evidence regarding the effects of targeted collections on the quantity of waste generated in the first place. In other words, it is possible that there may be a link between food waste recycling, and the generation of food waste. Plausible speculation suggests that individuals may become more sensitised to the amount of food they waste once they are asked to sort it for recycling.

In the case shown in Figure 16 below, the system switch involves introducing a food waste collection system alongside a reduction in collection frequency for refuse from fortnightly to weekly. As well as the system giving rise to a significant uplift in dry recycling, an important subsidiary benefit, the introduction of food waste collections and the drop in refuse frequency gives rise to a significant reduction in waste generation (almost 20%). In this system, on the basis of 'before and after' composition analysis, the scheme estimated a reduction in food waste generation of 25%.

These effects – the link between the collection system and the generation of waste – are still relatively poorly understood, but it seems far from fanciful to imagine that as households are asked to sort kitchen waste from their refuse, they would become more aware of exactly the form of wastage which has been exposed by WRAP in various studies.[76] Other evidence comes from survey work. Efforts to recycle appear to be linked to reduced quantities of food waste generation, suggesting that these may be linked behaviours (see Figure 17).

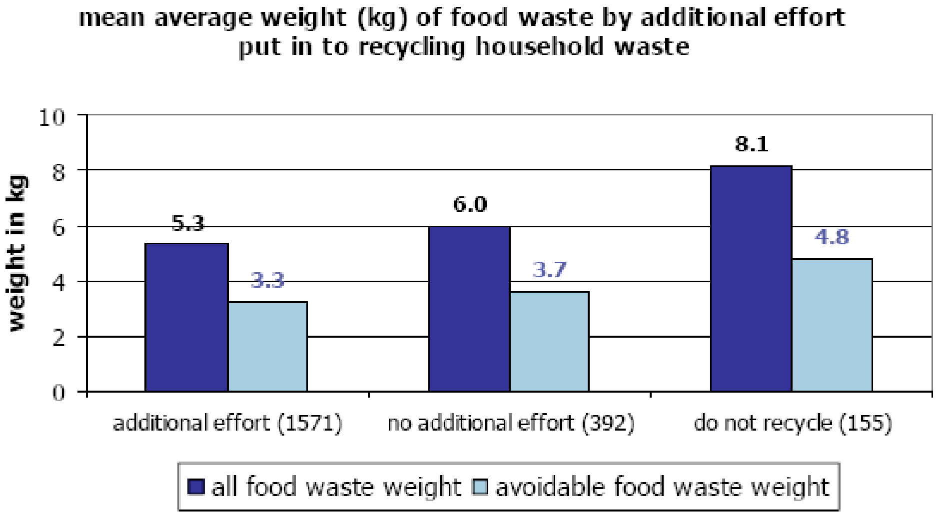
[76] *See, for example, Exodus Market Research (2008) The Food We Waste, Report for WRAP, April 2008*

Figure 16: Effects of Introducing Weekly Food Waste Collections and Fortnightly Refuse Collection in Somerset, UK



Source: May Gurney

Figure 17: Links between Food Waste generation and Efforts Made to Recycle in the UK



Source: Exodus Market Research (2008) The Food We Waste, Report for WRAP, April 2008

There is also some anecdotal evidence of effects in the commercial waste sector. Describing the effects on one business in Bexley of taking up a food waste collection service, the BREW Centre for Local Authorities made the following comment:[77]

The Council was able to offer a service for all their main waste streams and once they became aware of the waste they produced they were able to rationalise orders and make decisions on the packaging their stock came in. It is a typical case of how the final disposal method of waste influences how you order your supplies. Although this is not the average savings for all SMEs, this example clearly shows how this scheme helps the businesses to reduce their waste management costs and has positive environmental impacts by promoting waste minimisation.

[77] *BREW Centre for Local Authorities (2008) Trade Waste Recycling Collection Service – London Borough of Bexley, January 2008.*

It remains to be seen whether more widespread uptake of food waste collections might generate similar behavioural changes in respect of waste prevention. These could be extremely beneficial, and highly significant, if further research was to warrant its inclusion as part and parcel of the environmental effect of a ban on unsorted food waste. WRAP estimates that for every tonne of food waste prevented, the CO_2 savings are of the order 4.2 tonnes CO_2 eq. per tonne of food.[78]

9.6.8 Transition Costs

In implementing either material based restrictions or bans on unsorted waste, or the ban on biodegradable waste, there may be costs associated with the transition, but also, some potential savings. We consider those in what follows.

The Monitoring of Biodegradable Waste Landfilled for the LASs

If a ban on biodegradable waste was introduced, and if this was implemented as suggested (through a threshold level of biodegradability, this being set at a level equivalent to low gas generation potential), then it would make sense to propose this standard as being the standard which determines when waste is no longer considered biodegradable for the purposes of the Landfill Directive. If, as a result, no waste could be landfilled where it failed to meet this threshold, then clearly, the implication would be that the LASs would become redundant once the ban took full effect.

It would be interesting to speculate as to how much, on average, local authorities across the UK spend on monitoring their balance of landfill allowances, their strategic position relative to the allowance market, their strategy for dealing with landfill allowances, and related matters. In addition, the regulators in all four countries are also charged with monitoring performance under the LASs on (at least) a quarterly basis. This resource would effectively no longer be utilised in this way once a ban on biodegradable waste was in place.

Existing Residual Waste Treatment Facilities

Under the material-based policies, especially where the unsorted waste ban is chosen, and in the case of the ban on biodegradable waste, there might be some impact upon existing residual waste treatment facilities, and (given that most of these have been built under, or with support from, municipal contracts) upon existing municipal waste contracts.

In the case of the material-based bans, if requirements to sort materials such as food waste and glass are implemented, then where this is supported also by similar restrictions applied to all residual waste treatments, the effect of the restriction may be such that the quantity of residual waste falls significantly. This may reduce the quantity of residual waste which the waste disposal authority (WDA) is responsible for to a quantity below the minimum tonnage which the WDA has committed to pay for the contractor to manage. This effectively implies that until alternative uses for the capacity freed up can be found, the cost implications for local authorities would be higher than the modelling suggests (because the authority is not making savings, at the margin, from avoided disposal) unless contracts were renegotiated in anticipation of this outcome.

Many authorities are already in this situation. There would appear to be merit in assisting WDAs in renegotiating existing contracts, or to assist them in identifying residual waste to cover such shortfalls, where this situation seems likely to arise. In some cases, particularly where contracts were negotiated with unitary payments for residual waste treatment which are below the costs of landfill in 2013, then some mutually beneficial renegotiation of the contract may be possible. The contractor would then be treating more (commercial and industrial) waste through spot market transactions, and the parties sharing risk and reward on the revenue from sales of this capacity.

In the case of the biodegradable waste ban, where MBT facilities are already operational, and where they send waste to landfill, the question would arise as to whether the waste being sent to landfill met the stability requirement implied by the threshold. The LASs do not require any specific level of stability to be achieved by facilities. In the wake of the new threshold being established, some facilities which were found to be sending materials to landfill which had not been pre-treated to the required standard would have to consider some alterations to their process. Other things being equal, this might – owing to a possible need to lengthen retention

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[78] *See WRAP (2009) Household Food and Drink Waste in the UK, Final Report, http://www.wrap.org.uk/downloads/Household_food_and_drink_waste_in_the_UK_-_report.78c4ee17.8048.pdf. If food waste arisings genuinely fell by 25% when intensive food waste collections were introduced, the net saving per household would be of the order 0.2 tonnes CO_2 per household served.*

times within the facility – lead to a reduction in the throughput which the facility could handle. This would effectively increase unit costs for the treatment of the waste concerned.

Other transition costs may arise in specific situations. On balance, this type of transition might lead to some savings (e.g. on LAS monitoring) as well as some costs. The distribution of these is likely to be uneven, and to the extent that these might apply more in the case of the biodegradable waste ban than in other cases, the argument made in Section 9.1 for a longer lead time for this ban may help to reduce transition costs by giving more time for adjustment.

10.0 Conclusions and Recommendations

10.1 Key Conclusions

- Climate change benefits and resource efficiency gains are likely to be greatest where landfill bans are coupled with a requirement to sort materials (defined here as a 'ban on unsorted waste');
- If all materials considered in this report are within the scope of a ban on unsorted waste, the median value of the net benefit to society is estimated at £910 million (NPV over 2009 – 2024) and the median value of GHG savings achieved over the same period is estimated at 120 million tonnes of CO_2 eq;
- If one considers only those materials for which there are net social benefits (i.e. where the environmental benefits exceed the costs as assessed using the social metric), the median value of GHG savings achieved over the period 2009 to 2024 is estimated at around 73 million tonnes CO_2 eq, and the median value of the net benefit to society from a ban on unsorted waste covering these materials from landfill is estimated at £2.1 billion (NPV over 2009 – 2024). This indicates that banning/restricting some materials to landfill (i.e. those materials for which there is a net social benefit) has a high net cost to society;
- On a material by material basis, we have summarised the position in the following figure. The key observations related to this figure for the bans on unsorted waste are as follows:

	Increase in Private Costs	**Reduction in Private Costs**	
Net Benefit to Society	Textiles	Metals Paper/card	Wood Glass
Net Cost to Society	WEEE Plastics	Food Green	

- For some materials the analysis shows clear benefits to society from introducing landfill bans. These are metals, paper / card, textiles, wood and glass. For food waste, the outcome in terms of the costs to society varies depending on the technology chosen, though an average of the technologies indicates a net cost to society would be the likely outcome;
- For all of these materials, except textiles, there are savings to business under the private cost metric. The analysis for food is, as with the analysis of benefits to society, sensitive to the choice of treatment (especially use of biogas). The more commonly deployed options generate financial savings under the private cost metric;
- For textiles, the analysis based on social costs suggests that the additional private costs which result are likely to be justified by the environmental benefits which result from increasing the recycling of textiles;
- For WEEE and plastics, there are environmental benefits associated with recycling, and not landfilling, the material, but the additional costs of collection (and sorting) - which are subject to some uncertainty – do not appear to be justified by the size of the benefits. Indeed, these materials give rise to net costs to society as well as increases in financial costs when assessed using the private cost metric;
- If one considers the analysis using the private cost metric (as opposed to the social cost metric), then for the whole range of materials considered, for each tonne CO_2 eq which is avoided, there is a saving of £0.54. If one considers only those materials which generate net social benefits, there is a saving of £8.72 for each tonne of CO_2 eq using the private cost metric;

- Additional GHG benefits can be secured through a ban on biodegradable waste being sent to landfill, though the magnitude of these depends upon the residual waste treatment utilised;
- However, in all cases, the biodegradable waste ban leads to net costs to society. This is due to the increased costs of residual waste treatment options (such as incineration, or mechanical biological treatment) which would be used more widely under such a ban and the fact that the environmental benefits of switching away from landfill are lower than the additional costs of using these treatments; and
- Costs, for the biodegradable waste ban, increase under the private metric also, irrespective of technology.

10.2 Effects of Landfill Bans

The key results concern the private costs of the policy variants, and the net benefit to society – the sum of the environmental and the financial benefits. These results are sensitive to a number of variables and the Main Report highlights the use of techniques to model, simultaneously, the effects of varying some of our central assumptions. This has allowed us to derive 'most likely' (or median) values for the net social benefit as well as an 80% confidence interval (representing the range of values within which one can be 80% certain that the true value will fall).

10.2.1 Material-based Policies

All results are for the period 2009-2024.

Food

- The model suggests that for food, there would be net greenhouse gas savings of around 6.2 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 27 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £300 million and £1.3 billion, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is sensitive to the way the biogas is used. Under the landfill restriction, this might result in savings of £92 million or costs of up to £290 million, depending on whether the gas was used for electricity generation, or cleaned for injection into the grid. Under the ban on unsorted waste, the equivalent range is from potential savings of £340 million to a cost of £1.3 billion. It should be noted that the market appears to be responding in a rational manner as the lower cost options are the most common ones;
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a food waste to landfill restriction could results in net costs to society of £230 million or net benefits of £2 million, depending on the technology used. Under the ban on unsorted waste, the range increases from a net cost of £57 million to a net cost of £1.1 billion; and
- This is a case where it appears that the market is already tipping in favour of a growing uptake of food waste collections. The private costs, therefore, appear to be moving in favour of separate collection, though the cost benefit analysis indicates that costs might exceed benefits where food waste is concerned. Some additional work undertaken in respect of household food waste indicates the potential savings to be derived from food waste collections under the private cost metric, these being significant in some cases where the introduction of food waste collections can be used to improve the efficiency of the existing collection operations.

Metals

- The model suggests that for metals, there would be net greenhouse gas savings of around 2.6 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 30 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £84 million and £940 million, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is £7 million under the ban on unsorted waste, and £10 million under the requirement to sort; and
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for metals could result in net benefits to society of £75 million, and a ban on unsorted waste could increase these benefits to £800 million over the period examined.

Paper and Card

- The model suggests that for paper and card, there would be net greenhouse gas savings of around 3.9 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 26 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £110 million and £750 million, respectively, under the two policies;

- The level of financial savings available, as assessed under the private cost metric, is £110 million under the landfill restriction, and £560 million under the ban on unsorted waste; and
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for paper and card could result in net benefits to society of £130 million, and a ban on unsorted waste could increase these benefits to £720 million over the period examined.

Textiles

- The model suggests that for textiles, there would be net greenhouse gas savings of around 3.4 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 10 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £140 million and £430 million, respectively, under the two policies;
- Under the private cost metric, the costs of the landfill restriction appear to be around £13 million, the figure rising to £100 million under the ban on unsorted waste; and
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for textiles could result in net benefits to society of £110 million, and a ban on unsorted waste could increase these benefits to £250 million over the period examined. For textiles, therefore, although modelling suggests there would be additional private costs associated with introducing restrictions or bans (in terms of collection and management), the analysis of benefits from the societal perspective suggests that the environmental benefit justifies the additional costs.

Plastics

- The model suggests that for dense plastics, there would be net greenhouse gas savings of around 6.8 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 17 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £240 million and £590 million, respectively, under the two policies;
- Under the private cost metric, the costs of the landfill restriction appear to be around £330 million, the figure rising to £850 million under the ban on unsorted waste; and
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for plastics could result in net costs to society of £170 million, and a ban on unsorted waste could increase these costs to £480 million over the period examined. For plastics, therefore, although the environmental benefits are significant, they do not appear to be justified by the additional costs. It should be considered that this observation applies to additional plastics recycling over and above levels already assumed to occur in the baseline, and does not necessarily imply that existing levels of recycling are not justified.

Wood [79]

- The model suggests that for wood, there would be net greenhouse gas savings of around 3.7 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 5.5 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £82 million and £130 million, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is £110 million under the landfill restriction, and £96 million under the ban on unsorted waste. Note that there is a drop in savings under the requirement to sort as it assumed that more of the wood is of lower grade, and costs more to manage through recycling / recovery systems; and
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for wood could result in net benefits to society of £48 million, with the equivalent figure under a ban on unsorted waste being £21 million over the period examined.

Green waste

- The model suggests that for green waste, there would be net greenhouse gas savings of around 0.71 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 4.3

[79] Results of the Cost Benefit Analysis for Wood Waste have already been updated and provided in 'Landfill Bans Feasibility Research: Wood Update,' August 2012, published to coincide with Defra's Call for Evidence on Banning Landfill of Wood Waste. http://www.wrap.org.uk/content/wood-waste-update-0

million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £40 million and £240 million, respectively, under the two policies;

- The level of financial savings available, as assessed under the private cost metric, is £37 million under the landfill restriction, and £110 million under the ban on unsorted waste; and
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that the benefits to society of a landfill restriction for garden waste are close to zero, whilst there may be net costs to society of £84 million under a ban on unsorted waste. Existing market drivers are already strongly influencing the sorting of garden waste, even though the cost benefit analysis might suggest this is not justified. This highlights the fact that excluding the major driver of behaviour regarding garden waste management – the landfill tax – from the financial analysis can lead to conclusions that appear counterintuitive in the current market context.

Glass

- The model suggests that for glass, there would be net greenhouse gas savings of around 0.16 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 1.6 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £5 million and £49 million, respectively, under the two policies;
- The level of financial savings available, as assessed under the private cost metric, is £17 million under the landfill restriction, and £71 million under the ban on unsorted waste; and
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that the benefits to society of a landfill restriction for glass are around £9 million, whilst under a ban on unsorted waste, the benefits are close to zero (around £3 million). Once again, this highlights the fact that existing market drivers are already strongly influencing the sorting of materials, in this case, glass, even though the cost benefit analysis might suggest this is not strongly justified.

WEEE

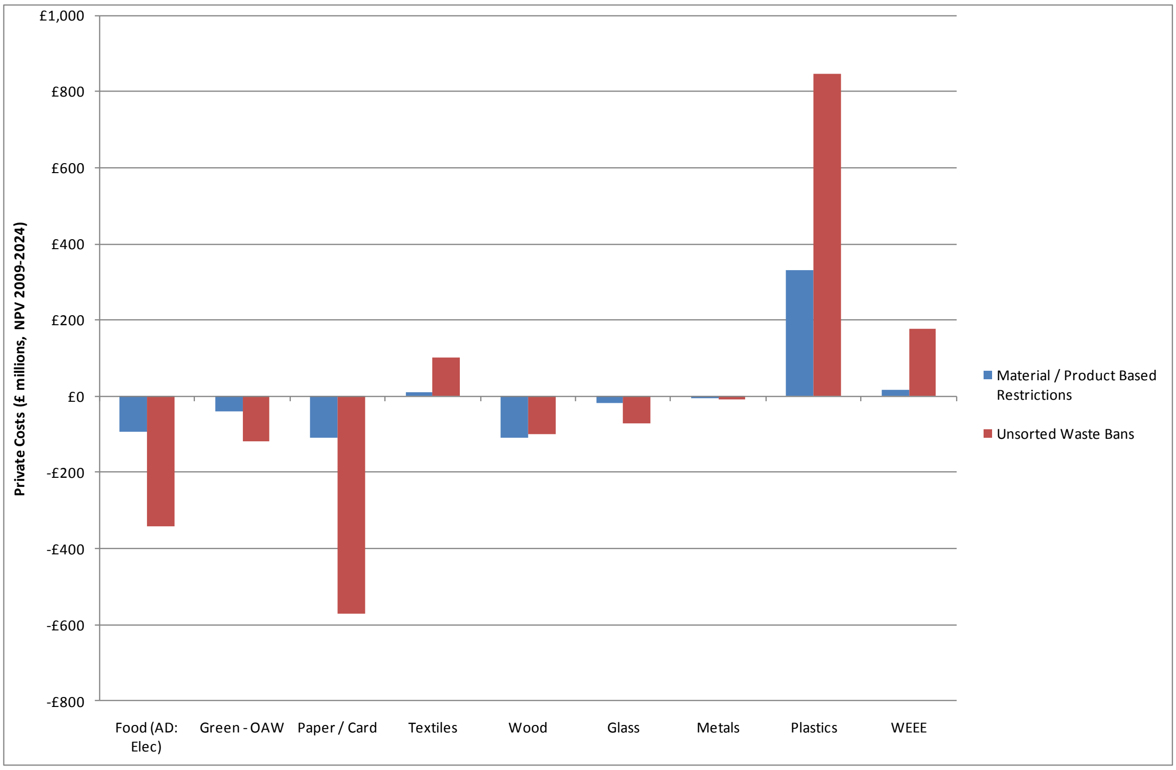
- The model suggests that for WEEE, there would be net greenhouse gas savings of around 0.04 million tonnes of CO_2 eq over this period from the introduction of restrictions on landfilling, and 0.21 million tonnes under a ban on unsorted waste. The Net Present Value of the quantified environmental benefits would be £13 million and £73 million, respectively, under the two policies;
- Under the private cost metric, the costs of the landfill restriction appear to be around £16 million, with the figure rising to £176 million under the ban on unsorted waste; and
- Taking environmental benefits and costs using the social cost metric together, the modelled cost benefit analysis suggests that a landfill restriction for WEEE could result in net costs to society of £20 million, and a ban on unsorted waste could increase these costs to £200 million over the period examined. For WEEE, therefore, although there are environmental benefits, they do not appear to be justified by the additional costs. It should be considered that this observation applies to additional WEEE recycling over and above levels already assumed to occur in the baseline, and does not necessarily imply that existing levels of recycling are not justified. In addition, the costs for collecting additional WEEE are highly uncertain, and heavily dependent upon the pre-existing infrastructure and how easy this is to adapt to collection of, for example, small WEEE items.

It should be noted that the above analysis assumes that all the wastes are diverted from landfill, and that the conclusions in respect of the requirement to sort are likely to change if the model is adapted so that the nature of the residual waste treatment used to deal with unsorted waste reflects the expected mix of treatments which may be in place in future. Additional analysis is planned to update results to reflect the expected mix of residual waste treatments used to manage unsorted materials in future.

It is as well to note that the cost of regulating the requirement to sort is likely to be relatively constant irrespective of the range of materials covered. If a number of material-based restrictions are implemented then the costs of communications and enforcement would be spread across the chosen materials, effectively strengthening the case for including in any new policy measure those materials for which the net benefit to society is marginal when modelled in isolation (as is the case of glass and wood, and for some technologies, food – see above).

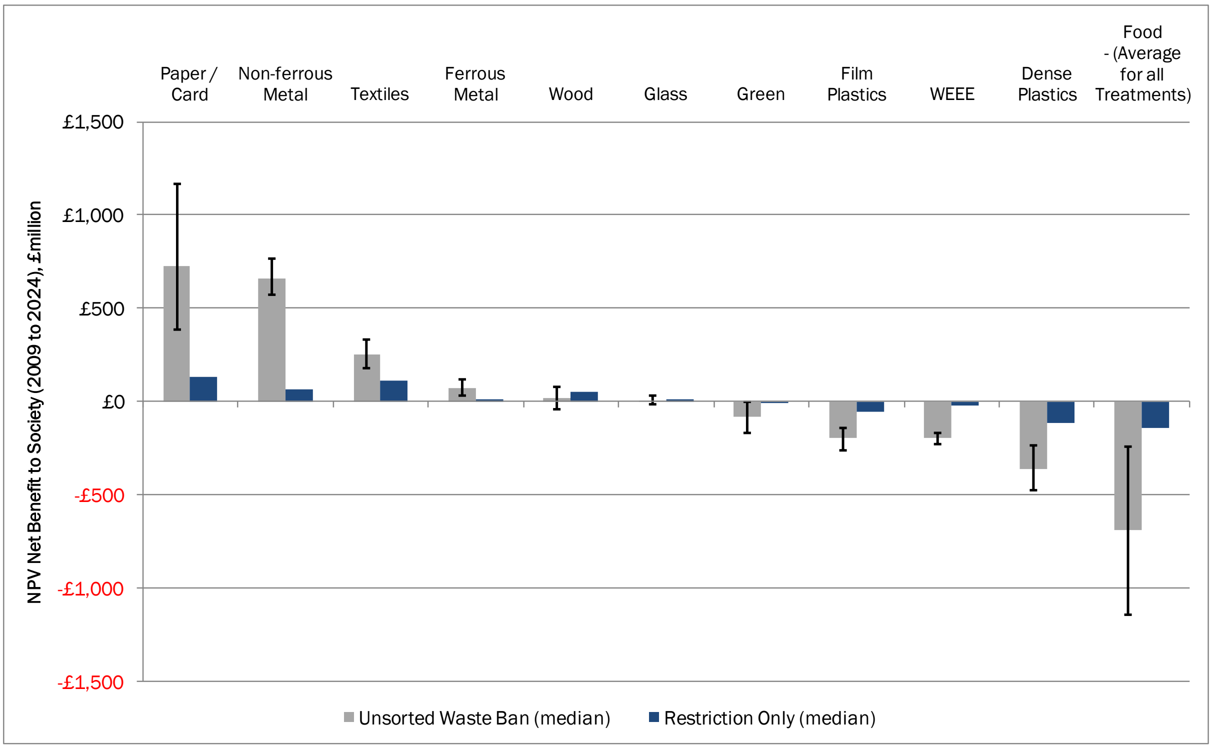
The private cost implications of the policies for the specific materials are shown in **Figure 18.** The key results for the net benefit to society for each material are displayed in **Figure 19**

Figure 18 Private Costs to Society from Material-based Restrictions and Unsorted Waste Bans, £ million NPV, 2009-2024



Note: The private costs for food waste reflect the situation where the material is treated in AD plants where the biogas is used to generate electricity using CHP engines.

Figure 19 Net Benefit to Society from Material-based Restrictions and Unsorted Waste Bans, £ million NPV, 2009-2024

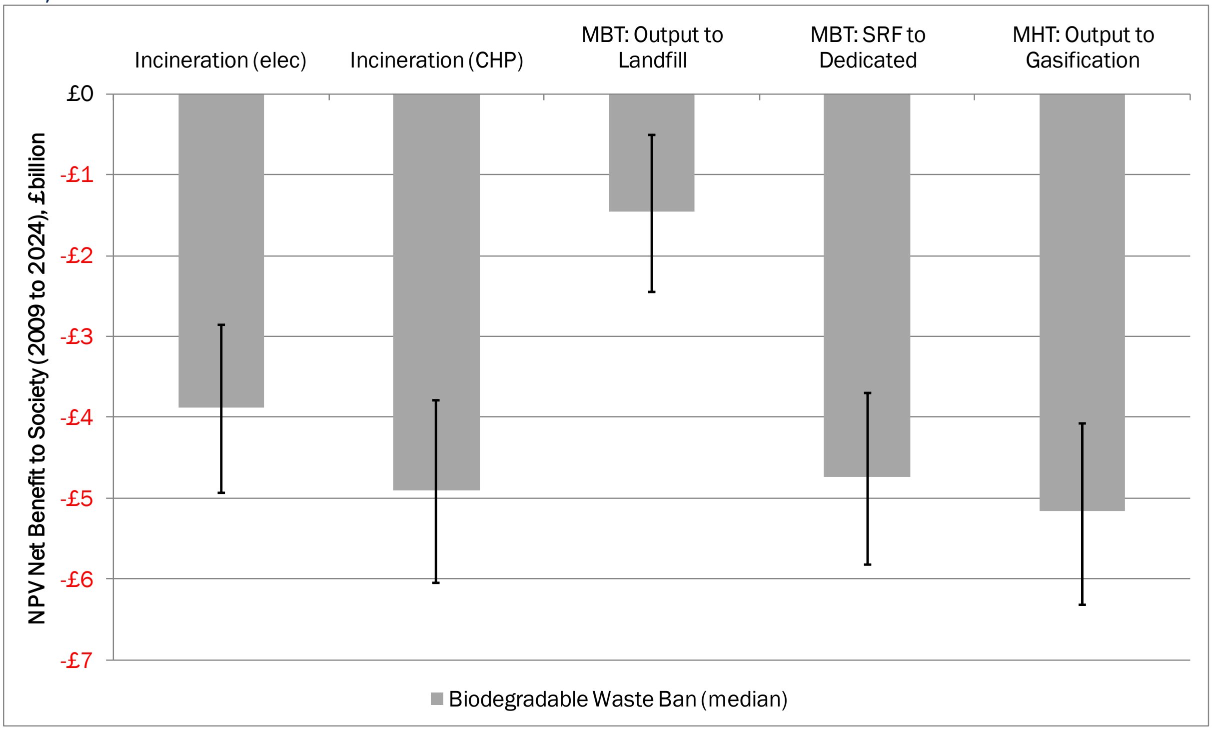


Note – vertical lines represent the upper and lower values bounding the 80% confidence interval

10.2.2 Biodegradable Waste Ban

The biodegradable waste ban was considered separately. The modelling assumed that none of the material based measures were implemented. Hence, the main effect is to shift the majority of waste from landfill into other residual waste management options, of which the Steering Group agreed a small number to be modelled. The net benefit to society is shown in **Figure 20** for the different treatment destinations (note that negative figures indicate a net social cost).

Figure 20 Net Benefit to Society from Biodegradable Waste Ban under Different Treatment Options, £ billion NPV, 2009-2024



Note – vertical lines represent the upper and lower values bounding the 80% confidence interval

- As **Figure 20** shows, the median net benefit to society is negative in all cases. This means that there are social costs in all cases, and these costs are most pronounced for treatments which include thermal processes (such as incineration and gasification);
- This reflects the balance of two key factors: the avoided impact associated with not landfilling the waste, and the costs of the switch;
- The option with MBT[80] including stabilisation of waste and output to landfill, performs the most favourably, from society's perspective, in this modelling when compared with the four thermal treatments for the following reasons:
  - The GHG benefits are marginally higher than any of the thermal treatments;
  - More GHG emissions are saved under the 'non-traded' sector by the stabilisation option. These emission savings are credited with a higher value under the UK's carbon reporting system than those from within the traded sectors;
  - Air quality damage costs are higher than the gasification option, but significantly lower than any process which involves the direct combustion of waste; and
  - The financial costs are comparable to incineration with electricity generation only, but much lower than for any of the other options.
- When viewed from the perspective of private costs, the analysis does not change fundamentally. There are still net financial costs, although these are lowest (and relatively small) where the switch is into incineration. It should be noted that the analysis effectively assumes a closed market for residual waste treatment, and

[80] *Mechanical Biological Treatment*

that no allowance has been made for recent developments in respect of, for example, the export market for RDF;

- Sensitivity tests suggest that:
    - If higher values for the global warming potential (GWP) of methane are used, environmental benefits increase but not enough to change the net social benefits from negative to positive for the relevant policies. For example, the Main Report explores, for the biodegradable waste ban, the implications of changing the GWP from 21 (the value preferred by Defra) to 25 (the figure now proposed by the Intergovernmental Panel on Climate Change).
- A ban on biodegradable waste would be expected to improve investor confidence in the provision of alternatives to landfill, and this effect might be expected to be stronger in the case of the commercial and industrial waste sector, where security of supply of waste into treatment facilities remains a major barrier to securing financial support. The issue of security of supply might not, however, be completely resolved by such a ban as long as covenants provided by commercial waste producers remain weak from the perspective of investors.

10.3 Practical Considerations

- As regards lead-in times, it would seem that few of the material based measures could be implemented in such a way that their enforcement was intended to be meaningful in a period of any less than five to seven years. This is likely to be true especially for those wastes, for example, Food, Wood and Garden waste, where reliance upon treatment infrastructure might be expected to be significant (for some other materials, the main change required is in respect of collection, with materials being reprocessed either domestically or overseas);
- For the ban on biodegradable waste, a longer lead-in period of the order 7-10 years seems likely to be warranted partly because of the pressure that would be faced by the planning system as currently configured, and also because the measure would affect a greater quantity of wastes than any of the other measures (in fact, more than ten times as much). Timescales at the lower end of this period might be achievable in the DAs, where the measure affects a much smaller absolute quantity of waste;
- Before a ban on biodegradable waste was implemented it would seem to be important to make sure that the levels of recycling have attained something close to what is deemed desirable from the point of view of society. If this was not the case, then the (generally greater) gains, in terms of climate change and resource efficiency, which flow from recycling and composting / digestion might not be realised to their fullest extent. It is worth noting that many countries with bans / restrictions in place have sought to ensure that instruments designed to encourage recycling and composting / digestion are in place *prior to*, or shortly after, a ban has been announced;
- The quality of the additional materials / products being collected from the waste stream for treatment and reprocessing would need to be considered. A 'requirement to sort' – as the key complementary measure for the ban on unsorted wastes - should seek to strike a balance between ensuring quality of materials on the one hand, whilst not being too prescriptive, in terms of collection system, on the other. This should be possible through specifying the requirement to sort in terms of 'customer experience' rather than designating specific collection / sorting systems. Where 'system specification' is *necessary* to safeguard quality, such specification should be considered as a means to reduce the likelihood quantity of lower quality recyclates;
- In the case where a requirement to sort is used, it would seem sensible to extend the 'ban on unsorted waste' to all residual waste treatments so that the requirement to sort is not 'sidestepped' where material is being sent to alternative residual waste management method; and
- Restrictions or bans may also (especially as landfill tax rises) see increased incidences of fly-tipping and illegal exports. This is likely to place additional requirements on regulators as they seek to grapple with an already challenging set of circumstances. For this reason, additional resources may be necessary to minimise

unintended consequences of restrictions / bans. Equally, if a requirement to sort is specified so that materials collected for recycling are of high quality, this might actually alleviate some existing problems.

10.4 Robustness of the Analysis

The approach to modelling, described in the Main Report, has sought to take into account the sensitivity of results to variation in key parameters. The modelling incorporates some variation in values around central estimates and uses random variation in these to generate the 80% confidence intervals. Appendix 13 also highlights the assumptions that have been made and their influence on the final results.

All of the results are somewhat sensitive to:

- The assumptions made around the costs of collecting and treating waste; and
- The modelling of the environmental costs and their quantification.

It is extremely difficult to model the costs of all possible collection configurations for a given material across a given waste stream. We have sought to model what we believe will be costs likely to be incurred in collecting materials over and above what is collected in the Baseline situation. These figures might, therefore, be 'above average' for some materials since the materials which are less costly to collect are assumed to be already captured in the Baseline (a good example for this would be for WEEE, where the costs of recycling the different end-of-life products are almost as varied as the products themselves).

The financial cost of treatment facilities (under the social metric) would be expected to vary with scale. Again, the modelling includes some variation in these treatment costs.

Environmental performance also varies within facility types, and modelled performance is dependent upon assumptions used, as well as the damage costs used to estimate environmental costs. The modelling has also explored variation in the key drivers of these (for example, landfill gas capture rates) and so has sought to take this into consideration. In short, the modelling has tried to capture the main sensitivities to variation in parameters deemed likely to affect the analysis.

Evidently, the case for bans is greater in cases where:

- Collection systems are well designed and optimised for cost (so the costs of switching from landfill are kept at lower levels);
- Treatment costs are kept at low levels;
- Environmental performance of collection and treatment is as good as can be expected; and
- The assumptions made regarding landfill imply higher impacts of landfilling.

In each of these cases, the level of net social benefit clearly increases (either because the *financial* cost of the switch from landfill would be lower, or because the *environmental* benefit from the switch would be higher). In addition, the change implied by moving from the baseline to a given 'policy-on' scenario affects the absolute magnitude of the changes being considered.

As noted above, the costs used to model the net social benefits of the bans are not the costs which would be incurred by actors in the market place today because the effects of taxes and price support mechanisms (for example, associated with renewable energy generation) were excluded from the analysis. For food waste, some additional analysis was undertaken to understand the costs and benefits of switching from one system to another. The key results from that analysis suggest that in all cases modelled in which the starting point was a system with weekly refuse collection and no food waste collection, the switch to a system with weekly food waste collection and fortnightly refuse collection would save money once the effects of landfill tax and renewable energy support were included, as they are for actors operating in the marketplace. The costs are higher where the starting point is a system with refuse already collected on a fortnightly basis. In these cases, the balance of costs and benefits is finely balanced, but if the food waste collection exerts even a relatively minor effect in terms of waste prevention (as some anecdotal reports suggest it might), then the benefits outweigh the additional costs.

This highlights two points regarding the modelling conducted here:
- The fact that the costs exclude some key drivers which influence behaviour in the market for waste collection and management (and this is especially true regarding the biodegradable waste ban); and
- The fact that our macro-level model cannot fully account for the system level effects of changes in collection systems (so that the cost estimates might be regarded as rather simplistic).

The first of these points would mean that responding to drivers from the market might still generate outcomes which are seen not to be the best outcomes for society. This indicates a market failure given existing drivers, insofar as we can know what the best outcome for society might be. It should be considered that not all external costs and benefits are captured in our analysis. There might also be costs incurred for example, through a need for more work by UK businesses to sort their waste than have been expected to meet the new requirements, or benefits through more growth in domestic recycling and reprocessing businesses than anticipated.

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