APPENDIX FOUR c

DEVELOPMENT OF A CO_2eq EMISSIONS PERFORMANCE STANDARD FOR THE MANAGEMENT OF LONDON'S MUNICIPAL WASTE

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Development of a Greenhouse Gas Emissions Performance Standard for London's Municipal Waste - Revised Report

The Greater London Authority

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Contents

1.0 Preface

The London Mayor's draft Municipal Waste Management Strategy (MWMS) was published for public consultation in October 2010. This draft included (as Appendix 4b) a first version of this Emissions Performance Standard (EPS) report undertaken by Eunomia Research & Consulting ('Eunomia'). The responses to the public consultation exercise (which ended in January 2011) resulted in both the need to reconsider some aspects of the EPS design, and to present a greater body of evidence in its support. As a result, the Greater London Authority (GLA) commissioned the following two studies:

- A peer review of the approach used to develop the EPS;[1] and
- An assessment of the costs of meeting the EPS.[2]

The first version of the report undertaken by Eunomia has been redrafted within this document to take into consideration the recommendations from the above two studies. Reference to both studies, particularly the former, is therefore made throughout. To support the peer review exercise, in addition to close liaison with, and provision of information to the review team, Eunomia participated in a workshop on the EPS, which involved a range stakeholders, including the GLA, the London Development Agency (LDA), the Department for the Environment, Food and Rural Affairs (DEFRA) and the Department of Energy and Climate Change (DECC). A list of all recommendations from this peer review, along with associated resulting actions, can be found in Appendix 8.

It should also be acknowledged that the GLA has commissioned the development of a 'Carbon Calculator' tool, to support the wider implementation of the EPS.[3]

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[1] Ove Arup & Partners (2011) Municipal Waste EPS Review: A Review of the Methodological Approach Used to Develop an Emissions Performance Standard for the Management of London's Municipal Waste, April 2011

[2] SLR Consulting (2011) Lifecycle greenhouse gas performance for municipal waste management activities: Determining the cost of meeting the EPS and Carbon Intensity Floor, May 2011

[3] This is also being undertaken by SLR Consulting on behalf of the GLA

2.0 Background and Objectives

A core objective of the MWMS is to develop a greenhouse gas (GHG) EPS for the management of London's municipal solid waste (MSW). The GHGs falling within the scope of the EPS include carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emitted during waste management activities including recycling, treatment and landfill. For simplicity, and in line global GHG accounting protocols, within this report, all non-CO_2 emissions are converted to CO_2 equivalents (CO_2e) for measurement against the EPS.[4]

The EPS concept is an increasingly popular way of regional and national authorities managing carbon emissions in the industrial, manufacturing and power generation sectors. Following an announcement by the coalition Government in May 2010, DECC is currently consulting upon the development of an EPS for all new thermal power stations, which might be achieved by either coal-fired or combined cycle gas turbine (CCGT) power stations through fitting of carbon capture and storage (CCS) infrastructure.[5] The development of an EPS for London is therefore broadly consistent with such approaches being undertaken at a national level.

Two of the key principles within the new MWMS can be summarised as:

1. Encouraging a focus on recovering materials and reprocessing routes, which deliver greater CO_2e reductions; and
2. Providing support for decentralised energy generation from waste that is no more carbon intense than the alternative form of new base-load energy generation.

To deliver upon these two principles, a 'whole waste system' or 'core' EPS has been developed, which sits alongside a carbon intensity 'floor' (CIF) for energy generation from waste. The basic methodology and rationale behind the development and setting of values for these mechanisms is described within this report, whilst a range of associated technical and environmental information is included within the related Appendices.

It is intended that both the core EPS and the CIF will function as quantitative reference points to aid London's Waste Authorities (WAs), i.e. both Boroughs and Joint Waste Disposal Authorities, determine whether they are acting in general conformity with the MWMS. This is such that WAs, in undertaking their waste management functions, can be best aligned with the wider strategic objectives of moving waste up the hierarchy and generating energy to achieve the greatest climate change mitigation benefits.

To facilitate wider understanding and practical use, the core EPS and CIF have been developed using the Environment Agency's Waste and Resources Assessment Tool

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[4] World Resources Institute & World Business Council for Sustainable Development (2007) The GHG Protocol for Project Accounting, 2007

[5] This was announced by Secretary of State for Energy, Chris Huhne, in June 2010

for the Environment (WRATE) life-cycle modelling tool, which is commercially available to all organisations. This approach is such that there are no barriers to WAs determining their own performance against the EPS, whilst also ensuring that in future, the EPS can be credibly updated to take into consideration future modifications by the Environment Agency to WRATE.

In some cases, Eunomia has identified limitations of WRATE, particularly with regard to how the tool models emissions of CO_2 and methane (CH_4) from landfill.[6] In the case of the CIF, it has also been necessary to develop a separate spreadsheet tool using data from WRATE to enable the required analysis.[7] All such issues are discussed in more detail in Appendices 4.0 and 5.0.

At the time of drafting this revised version of the report, it is understood that more detailed guidelines, along with a 'Carbon Calculator' to more easily enable determination of performance (including 'step-by-step' guide) against both the core EPS and CIF, will be published by the GLA.[8] It should be acknowledged, therefore, that in agreement with the GLA, Eunomia has deliberately not added such 'step-by-step' guidance within this report for the core EPS. As was recommended in the peer review undertaken by Ove Arup & Partners (Arup), however, Eunomia *has* added a brief 'step-by-step' guide to calculating the CIF within Appendix A.4.3 to this revised report.

The peer review undertaken by Arup also recommends that information should be provided as to *how* both the core EPS and CIF will be applied. This is an important issue, but it should be noted here that provision of such information sits outside the scope of the revised version of this report. It is understood by Eunomia, however, that such information will be provided in the final revised MWMS and also in the guidelines for the aforementioned 'Carbon Calculator'.[9]

Whilst there is significant focus within this study on GHG emissions, it is important to highlight the potential tension between the development of waste infrastructure, particularly low-carbon energy generation from waste, and the minimisation of air quality impacts. Primarily, these impacts relate to oxides of nitrogen (NOx) and particulates (PM_{10} and $PM_{2.5}$), for which in London there are currently elevated concentration levels which are estimated to exceed related targets.[10] These pollutants are of concern in London because of their potential impacts on human health. The potential air quality impacts from all new developments (not just waste-

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[6] Eunomia was recently commissioned by Defra to undertake a study into emissions of methane from landfill, such that this might inform future revisions to the WRATE model. Eunomia discussed this in detail with the Environment Agency as part of this study on behalf of the GLA

[7] It should be noted that to facilitate the inclusion of a range of technology configurations and related assumptions, Eunomia has needed to develop several 'user-defined' processes (UDPs) within WRATE. It is intended that these will be made available by the GLA to all London waste authorities

[8] This work is being undertaken by SLR Consulting on behalf of the GLA

[9] It should also be acknowledged that in developing the revised version of this report, Eunomia has not been given access to either the 'Carbon Calculator' or related guidelines

[10] GLA (2010) Clearing the Air: The Mayor's draft air quality strategy for public consultation, March 2010

related) in London are considered on a case-by-base basis through the local and strategic planning process. The development of new residual waste facilities might result in exceedances of both NOx and PM_{10} in specific locations, particularly in those areas where concentrations are already elevated. Waste treatment facilities considered in this study, however, if managed and operating as designed, located in appropriate locations and using best available abatement and mitigation technology, are unlikely to have a significant effect on meeting air quality objectives.

3.0 The 'Whole Waste System' EPS

3.1 Approach and Methodology

3.1.1 Determination of Baseline CO_2e Performance

Prior to setting an appropriate EPS level, an assessment of London's current performance with regard to CO_2e emissions from MSW management is required. Eunomia developed this baseline information by drawing upon data for 2008-9 from the Environment Agency's WasteDataFlow (WDF) tool and feeding this into WRATE. The results of this modelling exercise showed that the net emissions from waste management activities in London in 2008-9 were 150.2 kilotonnes of CO_2e per annum (ktpaCO_2e). A break-down of these emissions is set out in Table 3-1, which shows how emissions reductions provided by recycling activities offset emissions from residual treatment and landfill to give an overall *net* figure.

It should be noted that total baseline emissions have changed from a figure of 130.1 ktpaCO_2e presented in the first version of this report. This change is the net result of the following three factors:

1. A change to the system boundaries of the EPS, which following the peer review, have been expanded to include emissions from reject materials, as described in more detail in Section 3.1.3;
2. A further change to the system boundaries, which have also been expanded to include emissions from transport, as described in more detail in Section 3.1.4; and
3. A reporting error within the first version of the report, such that the baseline emissions should have been marginally lower than was presented. It should be emphasised, however, that this was an issue concerned with the baseline only, and did not impact upon modelling of the core EPS from 2015 to 2031.

Table 3-1 also shows London's 2009 performance of 98.3 ktpaCO_2e. This 51.9 ktpaCO_2e reduction in emissions against the 2008 baseline shows positive progress towards meeting the EPS, as discussed in further detail in Section 3.4. This improvement is largely the result of lower tonnages being sent to landfill and incineration, along with increased levels of anaerobic digestion (AD) and glass recycling.

Table 3-1: London's 2008 Baseline and 2009 Emissions Performance

Waste Management Activity	Waste Managed (ktpa) in 2008	Associated Emissions ($ktCO_2e$) in 2008	Waste Managed (ktpa) in 2009	Associated Emissions ($ktCO_2e$) in 2009
Residual Waste				
Landfill	1,830.5	475.9	1,752.	455.5
Incineration	837.7	47.5	745.7	42.3
MBT[1]	278.4	-3.3	295.9	-3.6
Organic waste				
Anaerobic Digestion	4.4	-0.4	10.7	-0.9
In-vessel Composting	123.5	-5.8	127.8	-6.0
Open Air Windrow Composting	143.4	-6.0	133.8	-5.6
Materials Recycling / Reprocessing				
Paper / Card	385.2	-115.2	390.9	-116.9
Glass	62.2	-5.9	125.3	-11.8
Metals (ferrous)	49.5	-80.3	49.7	-80.6
Metals (non-ferrous)	12.6	-135.0	13.0	-138.9
Plastics	24.4	-28.9	28.7	-33.9
Textiles	12.0	-52.6	12.0	-52.7
Wood	33.3	0.03	50.1	0.05
Rejects	175.6[2]	8.4[3]	167.6[2]	6.9[3]
Transport	n/a	51.7	n/a	44.5
TOTAL	3,972.8[4]	150.2	3,903.3	98.3

Notes:

1. Within the information presented in WDF, it is unclear as to where the solid recovered fuel (SRF) from Mechanical-biological treatment (MBT) facilities in London is currently sent, although it is understood that some tonnage is sent to cement kilns outside London
2. The reject stream comprises materials rejected from MRFs and 'On-the-Go' recycling, incinerator bottom ash, and rejected material from MBT facilities. All material from these streams is assumed to be sent to landfill
3. To avoid double-counting, emissions from MBT rejects have been excluded as these are already included within the total emissions modelled from the MBT process itself
4. Data published by Defra (see Table 2 in http://archive.defra.gov.uk/evidence/statistics/environment/wastats/download/mwb200910.xls) suggests that this figure should be 3,975 ktpa. Within the scope of this study it has not been possible to verify why Eunomia's analysis of WDF resulted in a figure 2.2 ktpa lower than that reported by Defra. It is not considered, however, that this has a significant impact on the results of this study

Table 3-1 shows that materials recycling, and to a lesser degree, organic (food and green) waste treatment and mechanical-biological treatment (MBT) of residual waste play a significant role in lowering the overall emissions baseline. In Table 3-2, therefore, we have provided a summary of the emissions factors used within WRATE to model the benefits of recycling, composting, and AD of specific materials. WRATE also includes a range of emissions factors should any of these individual materials be sent for energy generation, which we have included within Appendix 7.0.

Table 3-2: Emissions Reduction Factors for Materials Recycling (WRATE)

Material	Impact of Activity (tCO_2/tonne of waste managed)		
	Recycling ('closed loop')	Anaerobic digestion (electricity only)	Composting
Paper	-0.299	n/a	n/a
Food waste	n/a	-0.0829	-0.471[1]
Garden waste	n/a	n/a	-0.042[2]
Wood	0.0009	n/a	n/a
Textiles	-4.372	n/a	n/a
Plastic (dense)	-1.182	n/a	n/a
Metals (ferrous)	-1.623	n/a	n/a
Metals (non-ferrous)	-10.721	n/a	n/a
Glass (closed-loop)[3]	-0.169	n/a	n/a
Glass (open-loop)[4]	0.025	n/a	n/a
Aggregate materials (exc. glass)	-0.013	n/a	n/a

Notes:

1. In-vessel composting (IVC)
2. Open-windrow composting (OWC)
3. Glass is assumed to be reprocessed back into glass
4. Glass is assumed to be crushed for use in aggregate applications

3.1.2 Basis for Development and System Boundaries of the EPS

On behalf of the GLA, in 2009-10, Eunomia undertook a study to assess the costs of different waste management approaches to meeting the proposed recycling or composting targets set out in the Mayor's MWMS.[11] This study was also published as

[11] Eunomia (2010) Economic Modelling for the Mayor's Municipal Waste Management Strategy, on behalf of The Greater London Authority, August 2010

an Annex to the Mayor's draft MWMS in October 2010. The study focused on modelling 11 'whole waste system' scenarios, six of which meet the Mayor's proposed recycling and composting targets in 2015, 2020 and 2031. In agreement with a Project Steering Group, which helped inform the development of the study, these six scenarios have been used as the core basis for modelling and setting the EPS.[12]

The six scenarios vary according to whether there is an initial 'focus' on the collection of dry recyclables or upon food waste collection in order to meet the proposed recycling and composting targets, with a further variant being a sole 'focus' on doorstep recycling collection services. Details of the waste flows for these six scenarios can be found in Appendix 6.0, along with information relating to the order in which new collection services are introduced from 2008 to 2015, which is the key differentiating factor between the 'focus on dry' and 'focus on food' scenarios.

All six scenarios include every element of the waste management system for which waste authorities are responsible, including:

- Materials and bulky waste reuse;
- Household and small business recycling and composting collection services, on-the-go recycling, 'bring' sites and Household Waste Recycling Centres (HWRCS) for subsequent materials reprocessing (including the intermediate use of MRFs);
- Treatment of source separated organic (food and green) wastes by composting and AD; and
- Treatment of residual waste, including materials recovery, energy generation and any reject streams sent to landfill;[13] and
- Direct landfill of wastes.

Although included within the aforementioned 'economics' study undertaken by Eunomia, it should be noted that the EPS does not include any CO_2e savings which might be achieved from reusing waste. This is because there is currently significant uncertainty over appropriate emissions factors to ascribe to different reuse routes and thus such factors are not included within WRATE. The problems associated with the inclusion of reuse activities are readily acknowledged in the peer review undertaken by Arup, although the review does still recommend that reuse should be incorporated within the EPS. Eunomia maintains, in agreement with the GLA, that reuse should be excluded for the present time, due to ongoing uncertainties associated with the related data. It should be acknowledged, however, that the EPS

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[12] This Steering Group included participants from North London Waste Authority, West London Waste Authority, Tower Hamlets Borough Council, Croydon Borough Council, London Borough of Barking and Dagenham, London Waste and Recycling Board, London Councils and the Environment Agency

[13] It should be noted that to facilitate the inclusion of a range of technology configurations and related assumptions, Eunomia has needed to develop a range of 'user-defined' processes (UDPs) within WRATE. These will be made available by the GLA to all London waste authorities

has been developed to be flexible over time to accommodate reuse activities, particularly should future versions of WRATE include related relevant emissions factors.

It should be noted that the six scenarios upon which the EPS is based (see Section 3.2 for the specific methodology), include an annual one per cent waste reduction ‘factor’, in line with achieving the Mayor’s waste reduction target set out in his MWMS. This is equal to an assumed zero per cent growth in waste produced per household between 2008 and 2031 when the number of households in London is expected to grow by approximately 20 per cent.

Albeit, therefore, with the exclusion reuse impacts, and taking into consideration that WAs manage varying tonnages of waste, the most appropriate metric for setting the EPS is according to ‘tonnes of CO_2e emitted per tonne of waste managed’ (tCO_2e/t waste managed).

3.1.3 Inclusion of Emissions from Rejects

It is important to highlight that the baseline data presented for 2008-9 in Table 3-1 includes 176 ktpa of ‘reject’ material for which there is no easily identifiable composition. As such, impacts associated with the treatment of this material were excluded from the previous version of the report. As recommended in the peer review undertaken by Arup, however, we have now modelled these impacts as best we are able, within this new version of the report. This ‘reject’ waste stream comprises materials rejected from both MRFs and ‘On-the-Go’ recycling, incinerator bottom ash, and rejected material from MBT facilities, all of which are assumed to be sent to landfill.

Emissions from rejects from MRFs and ‘On-the-Go’ recycling have been modelled using data from published by WRAP.[14] To avoid double-counting, although the tonnages of MBT rejects are included in the totals in Table 3-1, the related emissions have been excluded as these are already included within the total emissions modelled from the MBT process itself (within line 5 of the Table).

3.1.4 Inclusion of Emissions from Transport

During the development of the first version of this report (published in October 2010), it was agreed with Project Steering Group that emissions from transport, including those both from kerbside collection and onward movement of waste, would be excluded from the scope of the EPS on the basis that:

- They are currently extremely challenging to model with any degree of accuracy;[15] and

[14] Enviros (2009) MRF Quality Assessment Study, Final Report for WRAP, November 2009

[15] This is because accurate information on transport movements is not reported by waste authorities into the Environment Agency’s WasteDataFlow tool. Furthermore, waste authorities are often not fully aware of the final destination of materials collected for recycling and reprocessing

- They usually contribute a relatively small proportion of total emissions from waste management activities.

It was therefore agreed by Eunomia with the Project Steering Group that National Indicator (NI) 185 provided sufficient incentive for waste authorities to reduce emissions from their transport operations. Furthermore, TFL has developed a Freight Operation Recognition Scheme (FORS) to help Boroughs reduce emissions from their vehicle fleets. As pointed out in the peer review undertaken by Arup, however, since the publication of the first version of this study, NI185 has been abolished, whilst FORS is a voluntary scheme only, and therefore should transport be excluded from the EPS, there would be little real incentive for WAs to reduce associated emissions. In agreement with the GLA, therefore, Eunomia has now included emissions from transport of waste within this revised EPS. The method of inclusion is detailed in Appendix 1.0.

3.2 Setting the Level of the EPS

Based on the scenario modelling described above, the EPS has been set at the level of the *poorest* performing of the six key scenarios within the aforementioned Waste Economics Study undertaken by Eunomia on behalf of the GLA (Scenario 1 – 'Low Biomass – New Tech').[16] Again, it should be noted that all of the six scenarios meet the recycling and composting targets set within the MWMS.

Scenario 1 results in an EPS of -0.24 tCO_2e/t waste managed in 2031. It is acknowledged that this represents a change of 0.18 tCO_2e/t waste managed when compared with the level of -0.42 tCO_2e/t, which was proposed in the first version of this report. It should be emphasised, however, that this apparent significant shift 'upwards' in the EPS does not represent any real change in the challenge it presents to Boroughs and WAs. To give further context, the reduction in the level of the EPS, between this version and the first version of the report, is the *net* result of a number of key amendments to the model following the peer review undertaken by Arup. In several cases, these amendments have resulted in a change to the system boundaries of the EPS, such that the scope of what is being measured is slightly broader to that which was being measured within the first version of the report.

The key amendments made to the model following the peer review can be summarised as follows:

- Emissions associated with sending reject streams to landfill have now been included within the system boundaries of the EPS. This has had an 'upward shifting' influence on the level of the EPS;
- Emissions associated with the transport of waste have now been included within the system boundaries of the EPS. Again, this has had an 'upward shifting' influence on the level of the EPS;

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[16] Relative to other five scenarios, Scenario 1 includes greater amounts of lower performing residual treatment technologies

- The carbon intensity of the electricity assumed to be displaced by waste facilities generating electricity themselves has been increased from 387 gCO_2/kWh to 400 gCO_2/kWh (see Section 4.1 for related discussion with regard to the CIF). Again, this has had an 'upward shifting' influence on the level of the EPS;
- The assumed electrical efficiencies associated with waste incineration in 2015 have been reduced to be more closely aligned with efficiencies achieved by London's incinerators today, thus raising their carbon intensity.[17] This has had an 'upward shifting' influence on the level of the EPS;
- It has now been assumed that 50% of glass recycling is 'open-loop', i.e. this glass is sent into aggregate production, rather than 100% being sent for reprocessing back into glass (closed-loop) as within the first version of this report. This has again had an 'upward shifting' influence on the level of the EPS;
- A technical problem associated with exporting 'user defined processes' (UDPs) out of WRATE has been identified by Eunomia.[18] This has now been corrected, but once more, has had an 'upward shifting' influence on the level of the EPS; and
- An amendment to the mass flows for non-ferrous metals, following further interrogation of WasteDataFlow, which has again had an 'upward shifting' influence on the level of the EPS.

Figure 3-1 summarises the revised results of the modelling for all target years, which are broken down according to emissions from recycling, treatment of source-separated organics (food and green wastes) and residual wastes. Again, it should be noted that the emissions performance of each waste activity is expressed in tonnes of CO_2e per tonne of waste treated (t CO_2e /tonne). In line with the increasing levels of recycling and composting performance required within the Mayor's MWMS, Figure 3-1 shows that the EPS becomes stricter over time from 2015 to 2031.

All assumptions relating to capture rates of materials from different recycling activities and the modelled roll out (and performance) of different waste treatment technologies have been developed using information published by WRAP.[19] The peer review undertaken by Arup highlights that these capture rates, although being the most current at the time at which Eunomia developed the EPS, have now been updated by WRAP to include information from Wales and Scotland. Arup does not recommend, however, that the EPS is immediately updated to take these into consideration, although does suggest that the related, aforementioned related study

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[17] Please see discussion on Page 13 for the modelled profile of efficiencies between 2015 and 2031

[18] This problem has since been confirmed in an official communication to all WRATE users from the Environment Agency

[19] WRAP (2009) *Analysis of kerbside dry recycling performance in England 2007/08,* available at: http://www.wrap.org.uk/local_authorities/research_guidance/collections_recycling/benchmarking.html

on waste economics (undertaken by Eunomia on behalf of the GLA) might be updated in this respect in the future.

Figure 3-1: Setting the EPS for London (2008-2031)

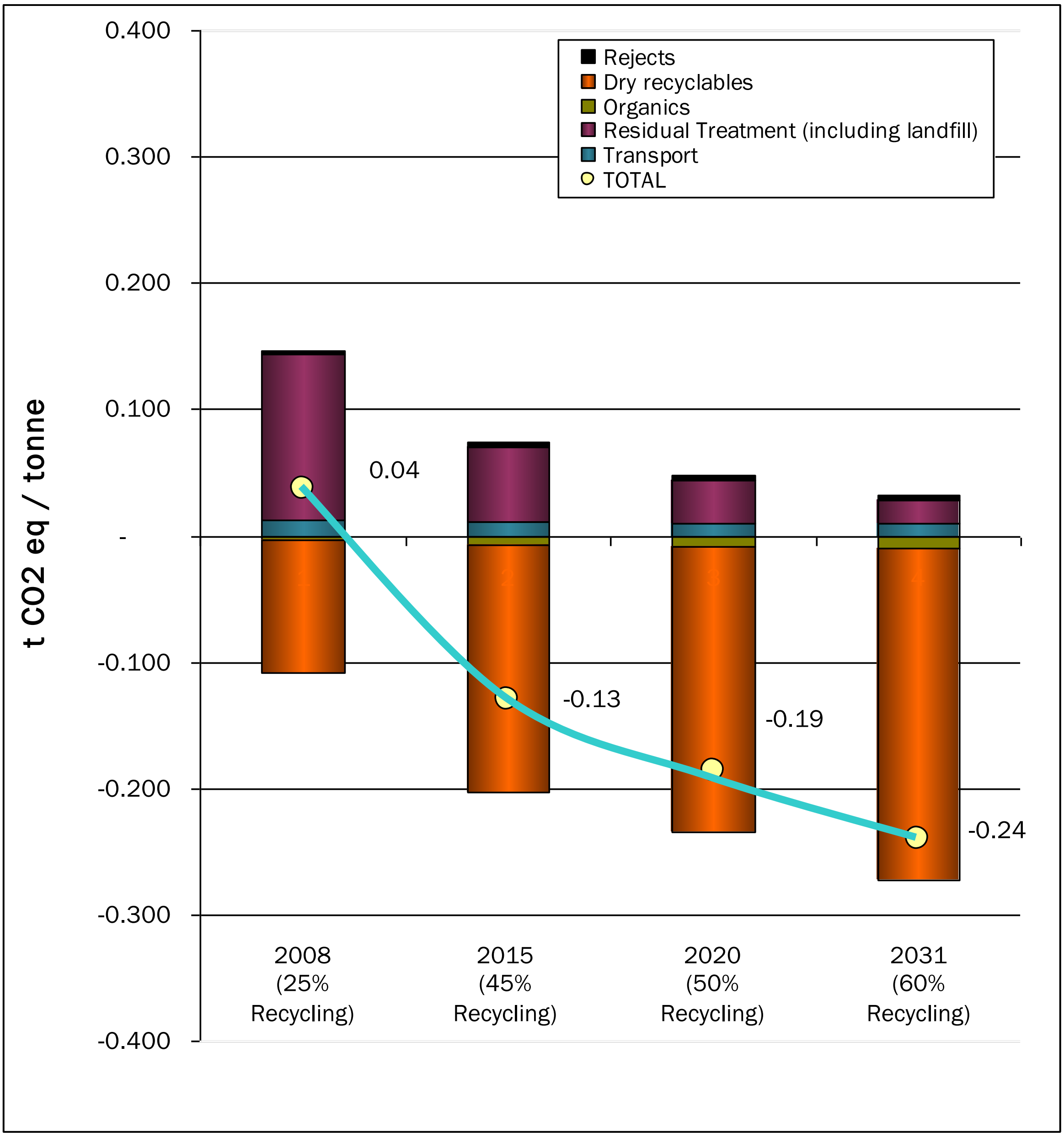

Table 3-3 presents the total emissions associated with meeting the EPS in each target year, alongside related tonnages of waste managed by each different activity. As mentioned above, it should be noted that the EPS is set at the level of the *poorest* performing of the six key scenarios (Scenario 1 – 'Low Biomass – New Tech'), and therefore not all residual technologies employed in the wider modelling are included. Notably, autoclaving is absent from Table 3-3, but is included within the other scenarios used as a basis for deriving the EPS, as set out within the aforementioned Economics report undertaken by Eunomia on behalf of the GLA. Should such technologies be employed by Boroughs and WAs, these would have a greater chance of meeting the EPS.

With regard to the modelling of residual waste treatment, the following should be acknowledged:

- There is a reduction in incineration capacity over the period 2015 to 2020 due to the assumed closure of the Edmonton plant;
- For all residual technologies, the CO_2 impact of each tonne of waste treated changes over time. This is because, due to year-on-year increases in the level of recycling vary across different materials, it is assumed that the residual waste composition becomes more 'carbon intense' in each target year. In the case of incineration, for example, this results in a situation whereby in 2031, whilst less waste is being treated than in 2020, there are higher total CO_2 emissions;[20]
- Between 2015 and 2020, there is assumed to be a fall in the total level of residual treatment as, due to the increasing tonnage of materials recycled to meet the 2020 target, some of the residual capacity developed before 2015 will no longer be required for processing of MSW;
- Incineration plant in 2008 and 2015 are assumed to generate electricity only, with efficiencies based on current performance in London, i.e. 21-23%. It is assumed there will be increased market development of heat networks over time. As a result, in 2020 it is assumed that 50% of waste incineration will take place in CHP plant with the remainder continuing to be treated at facilities generating electricity only. In 2031, it is assumed that 100% of incineration is undertaken at CHP plant;[21]
- The MBT technology modelled for this study is 'bio-drying', which produces a relatively low-biomass (or 'carbon intense') fuel compared to alternative forms of pre-treatment. Other technologies, such as autoclaving, are often designed to produce a high-biomass fuel; and
- The WRATE model cannot currently take into consideration the impact of 'biostabilising' reject streams from MBT 'bio-drying' facilities prior to landfill. CO_2e emissions from these streams are modelled by WRATE as if they are untreated waste, which results in significantly higher emissions than would be the case in reality.[22]

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[20] Targeting high-embodied carbon materials, such as plastics, for recycling will reduce the carbon intensity of residual waste

[21] It is assumed that all such CHP plant operate at 19% electrical efficiency with an additional 30% of energy converted into heat, which is used to displace alternative heat supply at all times of operation. See Appendix 4.2 for further discussion of this calculation, which is provided with regard to the CIF

[22] See Appendix 5.0 for further discussion of this issue

Table 3-3: Total Emissions associated with meeting the EPS for London

Waste Management Activity	Waste Managed (ktpa)			Associated Emissions (ktCO2e)		
	2015	2020	2031	2015	2020	2031
Residual Waste[1]						
Landfill	300	150	0	76.8	36.9	0.0
Incineration[2]	1,318	1,318	778	139.7	76.7	17.1
MBT Incineration[3]	445	360	385	22.3	18.5	36.9
MBT Gasification (ST)[3]	111	82	107	10.6	8.7	16.6
MBT Gasification (GE)	0	41	321	0.0	-1.1	4.7
Organic waste						
AD	126	157	205	-10.8	-13.4	-17.5
IVC	247	278	329	-11.6	-13.1	-15.4
OAW	199	213	277	-8.3	-8.9	-11.6
Materials Recycling / Reprocessing						
Paper / Card	713	780	905	-213.1	-233.1	-270.6
Glass[4]	208	210	249	-19.6	-19.8	-23.6
Metals (ferrous)	73	83	99	-118.0	-134.1	-161.2
Metals (non-ferrous)	31	35	43	-334.1	-379.5	-456.4
Plastics	65	76	97	-76.8	-89.7	-115.1
Textiles	15	18	22	-64.6	-79.6	-98.3
Wood	42	44	58	0.0	0.0	0.1
Rejects	322	307	411	15.7[5]	17.2[5]	20.1[5]
Transport				47.2	44.2	43.9
TOTAL	**4,214**	**4,151**	**4,286**	**-546..2**	**-771.1**	**-1,029.8**
EPS (tCO2/t)				**-0.13**	**-0.19**	**-0.24**

Notes:

1. The EPS is set at the level of the *poorest* performing of the six key scenarios ('Low Biomass – New Tech'), and therefore not all residual technologies, for example, autoclaving, which are employed in the wider modelling are included here. Should such technologies be employed by Boroughs and WAs, these might have a greater chance of meeting the EPS
2. It is assumed that Edmonton closes between 2020 and 2031
3. The fall in tonnage sent to MBT facilities for subsequent incineration or gasification (with a steam turbine) is to the result both of increasing tonnage of materials recycled to meet the 2020 recycling and composting targets and the introduction of new gasification facilities which use gas engines
4. It is assumed that 50% of the glass is recycled using a closed loop recycling process, and the remainder recycled using an open loop process
5. To avoid double-counting, emissions from MBT rejects have been excluded as these are already included within the total emissions modelled from the MBT process itself

3.3 Key Approaches to Meeting the EPS

3.3.1 A Focus on Materials Recycling

Figure 3-1 above demonstrates that the bulk of emissions reductions required to meet the EPS will be delivered by materials recycling and reprocessing, whilst Figure 3-2 below provides a further breakdown of the *relative* contribution each material type makes towards meeting the EPS in each year. To give further context, an additional bar has been included in Figure 3-2 to show the emissions reductions which might be delivered by maximum (100%) recovery of each different material. As mentioned above, all assumptions relating to capture rates of materials for recycling or composting have been developed using information published by WRAP, albeit this revision of the report does not include new data from WRAP which includes information from Scotland and Wales.[23]

The key principle of the 'whole system' EPS is that, as much as possible, it is flexible and 'output' based. The approach allows, for example, the potential for WAs which may find it difficult to collect high volumes of recyclables (due to significant amounts of high density housing) to focus attention on the recovery of materials which deliver greater CO_2 benefits. This is demonstrated in Figure 3-3 by the modelling of the EPS for 2015 (of -0.130 tCO_2e/t waste managed) alongside three further scenarios whereby:

1. The EPS is met (with performance of -0.402 tCO_2e/t waste managed) by focusing on collection of 'higher impact' materials such as plastics and metals, but the tonnage recycling targets are not met;

2. There is a focus on 'lower impact' materials such as glass and paper, and whilst the tonnage targets are met, the EPS is not (performance is -0.123 tCO_2e/t waste managed); and

3. 100% of all materials are collected to demonstrate the maximum potential CO_2 performance of -0.598 tCO_2e/t waste managed.

This approach supports the principle of delivering 'real' environmental benefits, rather than seeking to deliver upon 'weight-based' targets, which offer negligible gain, for example, collecting glass which subsequently crushed for use in aggregate markets. Associated materials capture rates modelled for both the 'higher' and 'lower' impact approaches are provided in Appendix 2.0.

Discussion of how the core EPS interacts with the CIF is provided in Section 5.0.

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[23] WRAP (2009) *Analysis of kerbside dry recycling performance in England 2007/08,* available at: http://www.wrap.org.uk/local_authorities/research_guidance/collections_recycling/benchmarking.html

Figure 3-2: Materials assumed to be recovered for Recycling and Reprocessing

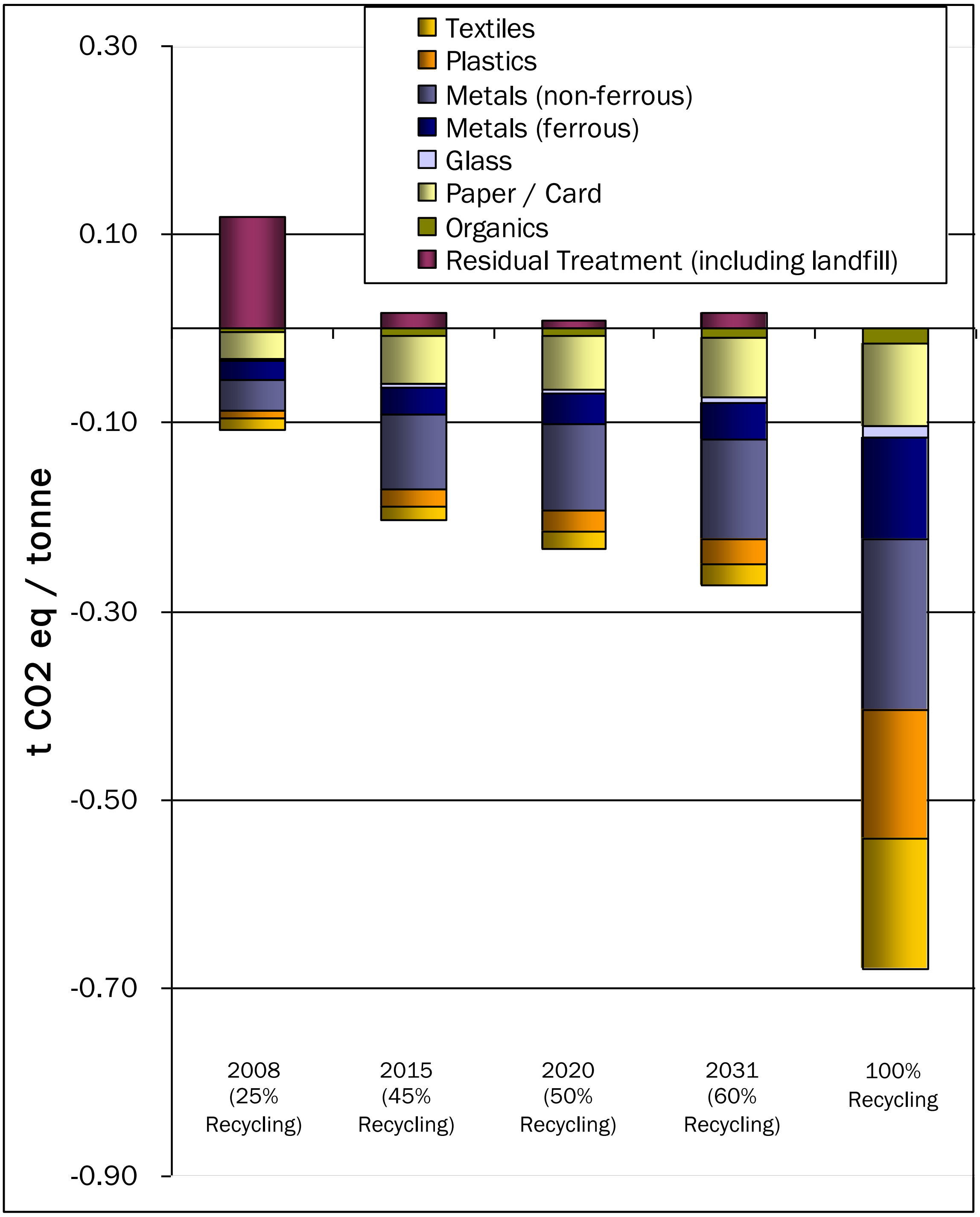
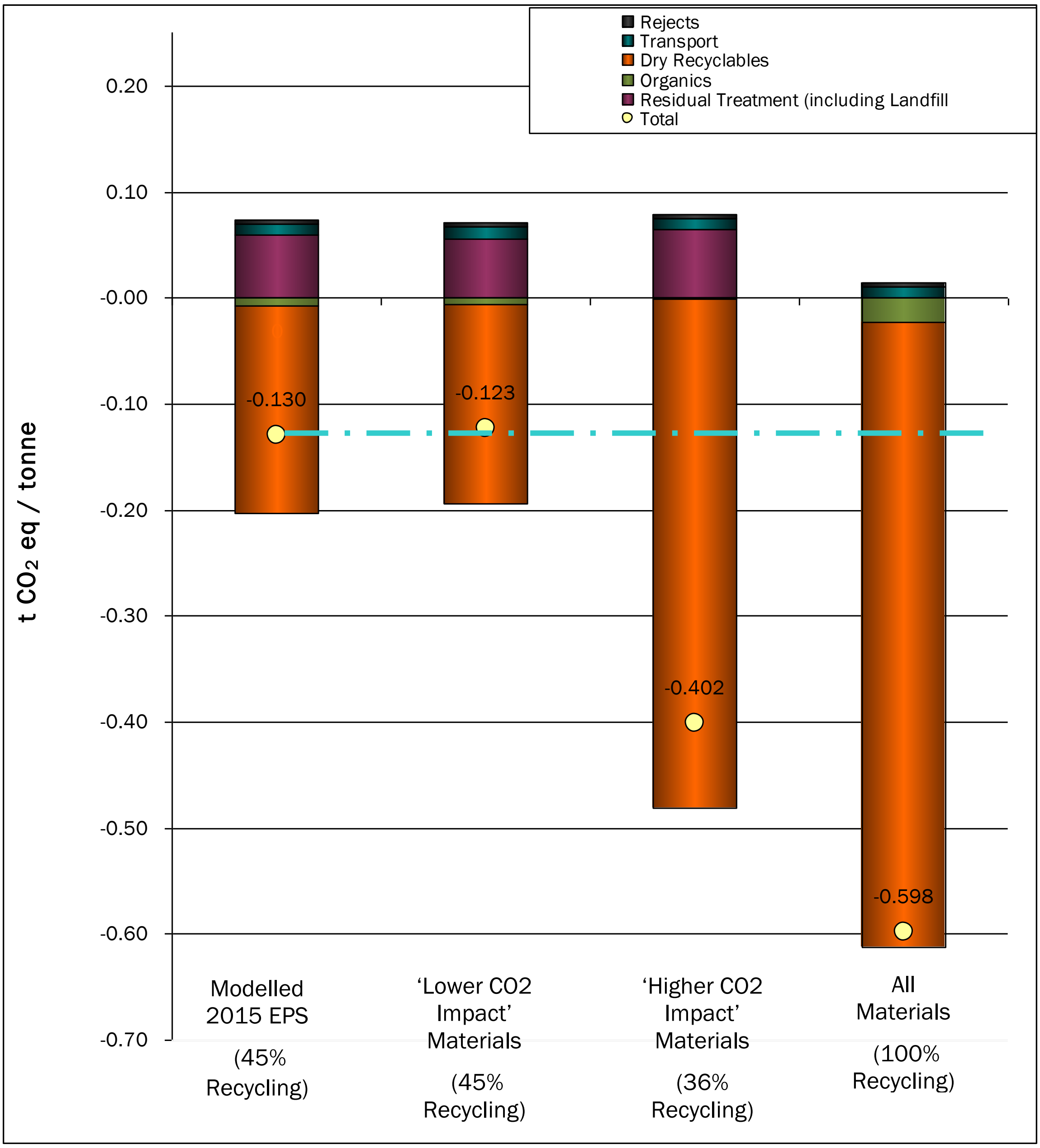


Figure 3-3: Performance of Differing Approaches to Materials Collection



3.3.2 Selection of Low-carbon Residual Treatment Technologies

As highlighted above, the EPS is set at the level of the poorest performing of the six key scenarios ('Low Biomass – New Tech') modelled within the Waste Economics study undertaken by Eunomia on behalf of the GLA.[24] As a result, not all residual

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[24] Eunomia (2010) Economic Modelling for the Mayor's Municipal Waste Management Strategy, on behalf of The Greater London Authority, August 2010

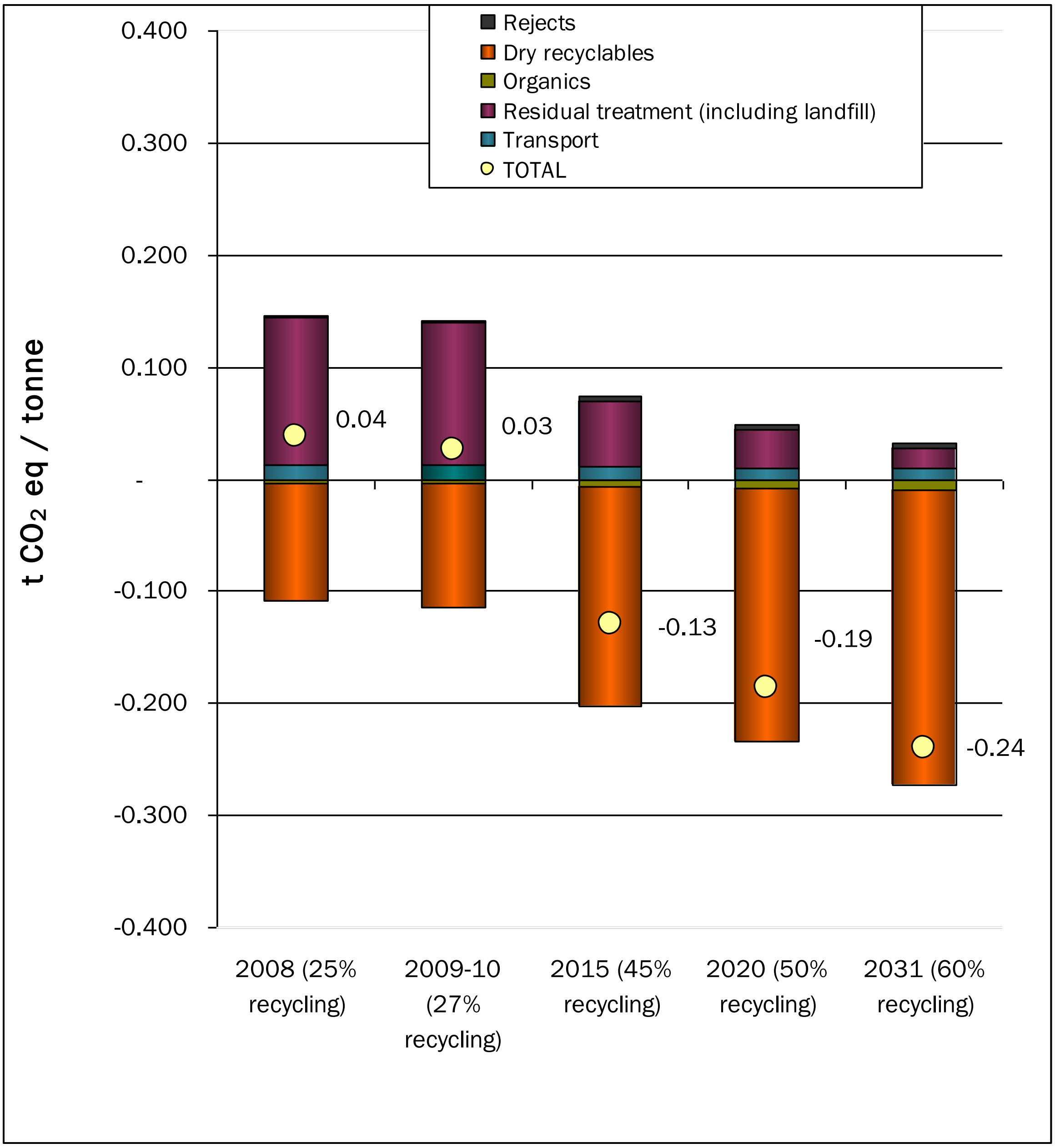
treatment technologies, for example, autoclaving or alternative forms of MBT (aside from bio-drying), were used to set the level of the EPS for 2015, 2020 and 2031. It should emphasised, therefore that should such lower carbon pre-treatment technologies be employed, these would provide Boroughs and WAs with a greater chance of meeting the EPS.

3.4 Performance against the Whole System EPS in 2009-10

Since the development of the first version of this report, 2009-10 data has become available from WasteDataFlow. This has allowed assessment of London's overall progress towards the EPS, as shown in Figure 3-4, which demonstrates limited progress has been made towards the 2015 EPS target. The reduction of 0.01 tCO_2e/t from 0.04 tCO_2/t in 2008-9 to a 2009-10 performance of 0.03 tCO_2e/t should be considered relatively modest, particularly in the context of London needing to meet the EPS target of -0.13 tCO_2e/t by 2015. This modest improvement is likely to be due to London's (weight-based) recycling and composting performance increasing from 25% in 2008-9 to 27% in 2009-10 resulting in slightly lower amounts of residual waste going to landfill or incineration. It should be noted, however, that there are a further five years of potential improvement before 2015. Should the annual rate of performance improvement be increased, therefore, for example, to 0.04 tCO_2e/t for each of the next five years (year-on-year), a level of -0.17 tCO_2e/t would be reached, which would meet the 2015 EPS.

.As discussed above, the EPS has been designed to be flexible, and therefore WAs and Boroughs might use a range of techniques to meet it. For example, a focus on materials recovery and reprocessing of materials which deliver greater CO_2 benefits (as discussed in Section 3.3.1), coupled with a low-carbon approach to residual waste treatment presents the greatest opportunity to meeting the EPS.

Figure 3-4: Performance against the Whole System EPS in 2009-10



4.0 Carbon Intensity 'Floor' for Energy Generation from Waste

4.1 Approach and Methodology

4.1.1 Setting the Level of the CIF

Energy generation forms an element of the 'whole waste system' EPS. In line with the Mayor's principle within the MWMS of providing support for low carbon, decentralised energy, an additional, distinct 'floor' level of performance is required.

Setting a CIF aligns the Mayor's waste management policy goals with those in his Climate Change Mitigation and Energy Strategy (CCMES) for delivering low carbon energy in London.[25] In aligning the MWMS and the CCMES, the Mayor proposes that all London's MSW used for energy generation *should have a carbon intensity less than, or equal to, the source of energy generation it displaces* (otherwise known as the 'marginal source' of generation), regardless of the location of the facility.

In the first version of this study, based on Defra guidance, and in line with the approach taken in the 2007 National Waste Strategy for England, Eunomia modelled the 'marginal' source of electricity generation (i.e. that which is considered to be displaced by generation of electricity from waste) to be combined cycle gas turbine (CCGT) plant.[26] Within this Defra Guidance, such facilities were assumed to generate electricity at a carbon intensity of 387 g CO_2 per kilowatt hour (gCO_2/kWh).[27] In the first version of this study, therefore it was proposed that facilities generating energy from London's MSW should perform at a carbon intensity equal to or below this level.

The peer review undertaken by Arup goes into significant detail on the rationale for the use of CCGT as the marginal source of generation, or indeed whether the marginal source (as opposed to the carbon intensity of average grid mix) should be used in this context. Ultimately, however, the review states that it considers that the 'appropriate' approach was undertaken by Eunomia.

The peer review also highlights a slightly higher carbon intensity for CCGT plant of 393 gCO_2/kWh, which was taken from an updated version of the aforementioned Defra Guidance, the responsibility for which has now been assumed by DECC.[28] The review suggests that the CIF should be raised to 'at least' this level. The GLA has considered

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[25] Mayor of London (2010) Delivering London's energy future: The Mayor's draft Climate Change Mitigation and Energy Strategy for consultation with the London Assembly and functional bodies, February 2010

[26] Defra (2006) Greenhouse Gas Policy Evaluation and Appraisal in Government Departments, April 2006

[27] Performance against the CIF must therefore be expressed in terms of g CO_2/kWh (of electricity generated

[28] DECC (2010) Valuation of Energy Use and Greenhouse Gas Emissions for Appraisal and Evaluation, June 2010

this recommendation, alongside evidence within the study on the financial and technical implications of meeting both the core EPS and CIF (undertaken by SLR Consulting), and has decided to set the revised CIF at a level of 400 gCO_2/kWh.

It should be highlighted that it is intended that this level will remain static going into the future unless further evidence for change emerges. It is also understood that the GLA will review the CIF at least every three years to ensure the level set aligns with Defra guidance on emissions performance of energy generation in the UK, as recommended in the ARUP peer review.

4.1.2 System Boundaries of the CIF

Towards alignment with the Mayor's wider approach in the CCMES to appraising all types of energy generation plant in London, i.e. not solely those generating energy from waste, performance against the CIF needs to focus on modelling of emissions from the thermal facility alone, such that the scope of the 'life-cycle' boundaries:

- Exclude any CO_2 benefits of materials capture and subsequent reprocessing;
- Exclude the emissions from any reject streams sent to landfill;
- Exclude the parasitic load of fuel preparation facilities, but includes the 'parasitic load' of facilities generating energy;
- Exclude direct emissions (including N_2O) from fuel preparation facilities; and
- Include the benefits of heat production and subsequent use when operating in CHP mode.

It should be noted that WRATE has been designed as a life-cycle assessment tool, and as a result, has not been developed to express the CO_2e performance of energy generation from waste in g CO_2/kWh, as is required for the CIF. Eunomia therefore developed a separate tool (in Excel) using data from WRATE to enable modelling of performance of different residual treatment technologies against the CIF.[29] The methodology for developing this tool is summarised in Appendix 4.0. Again, it is anticipated that more detailed guidelines, alongside an associated 'Carbon Calculator' tool (compatible with WRATE) to enable greater ease of measurement of performance for WAs, will be published at a subsequent time.[30]

4.2 Options for Meeting the Carbon Intensity 'Floor'

4.2.1 Required Biomass Content of Feedstocks for Energy Generation

The ability of a particular WA to meet the CIF depends upon three key variables:

[29] Furthermore, as mentioned above, it should be noted that to facilitate the inclusion of a range of technology configurations and related assumptions, Eunomia has needed to develop a range of 'user-defined processes' (UDPs) within WRATE. These were made available to both Arup and SLR Consulting, and it is intended that they will be made available by the GLA to all WAs on request

[30] As mentioned above, this is being developed by SLR Consulting on behalf of the GLA

- The core generation technology employed, i.e. combustion or gasification, and also for the latter, whether a steam turbine or gas engine is used;
- The amount of biomass in the feedstock supplied to the facility and, to a lesser extent, whether this has been pre-treated (or not); and
- The amount of CO_2 displaced by the generation of energy from waste. Whilst electricity generation might be the most common route in this context, there are other options which might be preferable from a CO_2 reduction perspective. For example, production of a liquid biofuel for use in transport applications, or production of gaseous fuels (such as syngas and biogas), which might be sufficiently processed for injection into the natural gas grid.[31]

Ultimately, pre-treatment technologies such as MBT or autoclaving might be configured to produce SRF which contains sufficient levels of levels of biomass to meet the CIF. It should be noted, however, that all MBT (bio-drying) facilities operating in the UK are currently configured to produce high calorific value fuels (with significant levels of plastic) for the cement industry. Furthermore, whilst autoclave suppliers claim their processes can produce very high biomass fuels, it has not yet been possible to gain sufficient market data to verify this.

Table 4-1 provides indicative requirements, in terms of biomass content, for meeting the CIF under a range of different generation technology scenarios, for both treated and untreated wastes. In Table 4-2 a range of further scenarios are detailed to demonstrate how varying levels of generation efficiency and biomass content will impact upon the ability to meet the CIF value.

It should be emphasised that these are scenarios only, and do not purport to represent either the full technical potential of any particular technology or the mix of facilities currently operating in London. It is intended, however, that both Table 4-1 and Table 4-2 will function as reference points for WAs when considering options to generate energy from MSW. The efficiency of incineration plant currently operating in London (Edmonton and SELCHP) is understood to be around 21%, and therefore the information presented in Table 4-1 suggests that such plant would require untreated waste input with approximately 78% biomass content to meet the CIF value.

The peer review undertaken by Arup suggests the need to consider the performance of facilities against the 'R1' formula contained within the revised EU Waste Framework Directive (WFD). The revised WFD makes a distinction between thermal facilities that are primarily considered to be waste disposal facilities, and those which are considered to be 'recovery' operations.[32] This distinction is made on the basis of the efficiency with which energy is generated at the facility. The R1 formula is used to define the threshold at which the thermal plant is designated as a 'recovery' facility.

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[31] As discussed in Section 4.2.3, WRATE does not currently allow for developing UDPs for modelling of such alternatives. It is understood by Eunomia, however, that SLR Consulting will be including this capability within the aforementioned 'Carbon Calculator', although Eunomia has not been given access to this tool at the time of writing

[32] Directive 2008/98/EC on Waste

The formula calculates the electrical and heat generation efficiency of the thermal plant and expresses it as a factor, by calculating the total energy produced by the plant as a proportion of the energy of the fuel consumed at the facility (including the plant's parasitic load).[33]

Alongside highlighting the types of facilities that will meet the CIF, Table 4-2 identifies those which meet the R1 requirements. It is important to note that the focus of the R1 formula is generation efficiency, whilst that of the CIF is greenhouse gas emissions. Although generation efficiency will have a bearing on the CIF it is nonetheless possible for a facility to meet the R1 threshold and *not* meet the Energy CIF, depending on the nature and composition of the residual waste being thermally treated at the plant. Meeting R1 requirements should therefore be considered as a lower 'hurdle' than meeting the CIF. This is shown in the examples contained within Table 4-2.

Table 4-1: Indicative Requirements for achieving the Carbon Intensity 'Floor'

Technology	Mode of operation	Electricity generation efficiency[1]	Net heat delivered to user[2]	CV from Biomass (%)[3]	
				Untreated waste	SRF
Incineration[4]	Electricity only	28%	n/a	69%	66%
	Electricity only	17%	n/a	82%	80%
	CHP	19%	30%	57%	54%
Gasification (steam turbine)	Electricity only	20%	n/a	78%	75%
	CHP	17%	27%	62%	59%
Gasification (gas engine)	Electricity only	27%	n/a	68%	66%
	CHP	27%	24%	48%	45%

Notes:

1. The data presented is in the form of 'net' efficiencies, i.e. taking into consideration both parasitic load and all other energy 'losses' from input of fuel to the plant to output of useful energy. It should also be noted that the efficiencies presented are scenarios only, and do not purport to represent either the mix of facilities currently operating in London or the full technical potential of any particular technology
2. Please see Appendix 4.2 for details of the methodology by which heat generation and use is included in the calculation of the CIF
3. Values for SRF are calculated in WRATE on a dry matter basis, whereas those for untreated wastes are calculated on a fresh matter basis (i.e., including the impact of the moisture content)
4. It should be noted that there are significant differences in the scale and related efficiency of incineration plant, with smaller facilities of 50-60ktpa dwarfed by larger plant of 800-900ktpa. This is reflected in the potential differences in the efficiencies presented

[33] The output of the R1 formula is not the same as electrical generation efficiency which is typically expressed as a percentage.

Table 4-2: Further Example Scenarios modelled against the Carbon Intensity 'Floor'

Technology	Feedstock	Mode of operation	Electricity generation efficiency[1]	Net heat delivered to user[2]	CV from Biomass (%)[3]	Meets R1 efficiency threshold?[4]	Meets CIF?
Incineration	SRF	Elec only	29%	n/a	66%	yes	yes
		Elec only	25%	n/a	66%	no	no
		Elec only	28%	n/a	66%	yes	no
		Elec only	28%	n/a	69%	yes	yes
	Untreated wastes	CHP	20%	26%	60%	yes	yes
		CHP	18%	33%	53%	yes	no
		CHP	18%	16%	69%	no	yes
Gasification Steam turbine	SRF	Elec only	18%	n/a	76%	no	yes
		Elec only	20%	n/a	70%	no	no
		CHP	18%	23%	64%	yes	yes
		CHP	16%	30%	58%	yes	no
Gasification Gas engine	SRF	Elec only	26%	n/a	65%	yes	yes
		Elec only	31%	n/a	53%	yes	No

Notes:

1. The data presented is in the form of 'net' efficiencies, i.e. taking into consideration both parasitic load and all other energy 'losses' from input of fuel to the plant to output of useful energy. It should also be noted that the efficiencies presented are scenarios only, and do not purport to represent either the mix of facilities currently operating in London or the full technical potential of any particular technology
2. Please see Appendix 4.2 for details of the methodology by which heat generation and use is included within the CIF
3. Values for SRF are calculated in WRATE on a dry matter basis, whereas those for untreated wastes are calculated on a fresh matter basis (i.e., including the impact of the moisture content)
4. Measured against the threshold for newer facilities (i.e. those permitted after 1 January 2009)

4.2.2 Inclusion of AD within Calculation of the CIF

The analysis in the first version of this report presented a case for excluding AD of source separated organic (i.e. food or green wastes) from functioning as part of performance against the CIF. The report noted, however, that any such firm recommendation should be subject to further analysis of the costs of meeting the CIF. This further analysis has now been undertaken on behalf of the GLA by SLR Consulting, and presents some evidence in favour of integrating the performance of AD into the CIF, whilst the peer review undertaken by Arup also recommends this inclusion.[34] Eunomia has therefore now included the CO_2 benefits AD offers within the scope of the revised CIF.

As AD does not generate any energy from fossil fuels (i.e. plastics), if operated in isolation, such facilities will themselves always meet the CIF of 400 gCO_2e/kWh. This is demonstrated by modelling of AD of 100% food wastes using the default AD model within WRATE, which results in a carbon intensity of 0.3 gCO_2e/kWh; therefore some way below the proposed CIF. As a result, if such an AD facility was included within the CIF calculation on a 'tonne per tonne' basis, it would improve the overall performance of the WA concerned. For example, if a WA sends both 100ktpa of residual waste to a gasification facility with a carbon intensity of 415 gCO_2e/kWh, and 20ktpa of food waste to an AD facility with a carbon intensity of 0.3 gCO_2e/kWh, the overall performance of that WA against the CIF will be 346 gCO_2e/kWh.[35]

4.2.3 Performance of Liquid Biofuel based Management Routes

It should be noted that WRATE does not currently include the capability to develop UDPs to model the carbon intensity of producing liquid or gaseous transportation biofuels from waste.[36] Furthermore, as such fuels displace fossil fuel transportation rather than electricity, any calculation of performance against the CIF would also require a detailed conversion metric. As a result, it was agreed with the Project Steering Group for the first version of this study that, as a 'proxy' for a direct calculation, WAs following this approach should be considered as meeting the EPS if there is a minimum of 50% biomass in the SRF sent for processing.

The peer review undertaken by Arup suggested that greater evidence be provided for this minimum level. Whilst it is not possible to do this quantitatively within the scope of this revised report, we believe it is sufficient to state that the 50% biomass requirement was considered a 'safe' level. This is because all such biofuels are used in very efficient combustion engines to directly displace very carbon intense fossil fuels such as petrol and diesel.

4.2.4 Performance of Cement Kiln based Management Routes

It is acknowledged that some waste authorities in London currently, or plan to, produce a solid recovered fuel (SRF) from pre-treatment processes which is sent for use as a fuel in cement kilns. Cement kilns focus on the generation of heat for the cement production process, and do not produce any electricity. As for biofuels, therefore, performance cannot be easily modelled against the CIF. Similarly, processing of SRF will usually displace coal, a far more carbon intense fuel than gas (if the SRF was to be used to generate electricity at CCGT plant). Again, therefore, it

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[34] SLR Consulting (2011) Lifecycle greenhouse gas performance for municipal waste management activities: Determining the cost of meeting the EPS and Carbon Intensity Floor, May 2011

[35] (100*415)+(20*0.3) / 120 = 345.9

[36] It is understood by Eunomia, however, that SLR Consulting will now be including this capability within the aforementioned 'Carbon Calculator', although Eunomia has not been given access to this tool at the time of writing

was agreed with the Project Steering Group that it will be assumed, as for biofuels, that a 'safe' level as a proxy for a direct calculation against the EPS, was to require a minimum of 50% biomass in the SRF sent for processing.[37]

[37] It is again understood by Eunomia that SLR Consulting will now be including the capability to model sending SRF to cement kilns against the CIF within the aforementioned 'Carbon Calculator'

5.0 Interaction between the Core EPS and CIF

The peer review undertaken by Arup states that it would be of benefit to show how the core EPS and CIF are designed to be 'met together'. This is a reasonable suggestion, which Eunomia acknowledges was not fully addressed in the first version of this report.

It is first important to acknowledge that the core EPS has been developed to deliver upon the Mayor's goal for the management of *all* London's municipal waste to achieve a year-on-year reduction in CO_2e emissions.[38] At the same time, the CIF has been developed to ensure that any facility generating energy from London's municipal waste will not generate energy which is more carbon intense than that which it 'displaces'.

The core EPS is measurement of *net* CO_2 emissions across all waste management activities. As a result, it is flexible such that high performance in one area, for example recycling and composting, can potential offset lower performance in another, for example, residual treatment. The CIF is an absolute measurement of CO_2 emissions performance of one (or more) residual waste treatment facilities generating energy at any given point in time.

A concern raised has been that the CIF could provide an incentive for WAs to landfill waste rather than direct it towards residual waste treatment facilities generating energy. With the two measures operating simultaneously, however, this cannot be the case, as if any significant amounts of waste are sent to landfill, the WA doing so would not meet the core EPS.

The responses to the Mayor's consultation on the draft MWMS indicate that a larger number of WAs are concerned that whilst the performance of their collection and recycling activities might mean they meet the EPS, at the same time their method of residual waste management might not meet the CIF. Whilst it is acknowledged that in some cases this is a possibility, the following points of guidance for Boroughs and WAs, towards meeting both measures, should be noted:

1. The 'Carbon Calculator' to be published by the GLA, has been developed to enable ease of planning how any changes to service delivery would impact upon meeting both measures;[39]
2. Meeting both the core EPS and the CIF will require a balance between choosing the right materials to collect and recycle, whilst leaving sufficient biomass in the residual waste stream. A focus on collecting and reprocessing of 'high embodied' carbon materials, such as plastics, textiles and metals will aid performance (as demonstrated in Figure 3-2 in Section 3.3.1) against both measures;

[38] See Policy 2, Page 10 of the Mayor's draft MWMS (October 2010)

[39] It should be acknowledged, however, that at the time of writing, Eunomia has not been given access to this tool being developed by SLR Consulting

3. WAs should plan to use ‘best of breed’ technologies for residual waste management and to model the performance of these (alongside as accurate as possible forecast biomass content) against the CIF, prior to procuring any new related contract;
4. Collection of food waste for AD can be used to offset the performance of residual facilities against the CIF (see example set out in Section 4.2.2);
5. The modelling in the aforementioned Economics study, undertaken by Eunomia on behalf of the GLA, demonstrates that, largely due to the Landfill Tax Escalator, meeting the EPS can be achieved at similar or less cost than a range of ‘do nothing’ (or ‘business as usual’) scenarios.

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