Department of Energy & Climate Change

Emissions estimation for IPCC 2006 Guidelines Compliance in the UK Waste Sector

Inventory Improvement Programme 2014

January 2015

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Published by the Department of Energy and Climate Change

Emissions estimation for IPCC 2006 Guidelines Compliance in the UK Waste Sector

Final Report to the Department of Energy and Climate Change

This research was commissioned and funded by DECC. The views expressed reflect the research findings and the authors' interpretation; they do not necessarily reflect DECC policy or opinions.

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Executive Summary

Ricardo-AEA was commissioned by the Department of Energy and Climate Change (DECC) in July 2014 to undertake a review of three components of the UK's waste sector GHG inventory:

1. Biological treatment of solid waste
2. Open dumps and unmanaged landfill
3. Industrial wastewater treatment and discharge

This review was required to assess compliance with the Intergovernmental Panel on Climate Change's (IPCC) 2006 Guidelines for National Greenhouse Gas (GHG) Inventories and, where appropriate, develop estimated projections of GHG emissions to 2035. The key outcomes of the review are summarised below.

Biological treatment

Biological treatment of waste comprises anaerobic digestion, mechanical biological treatment (MBT), and centralised and home composting activities. Key Category analysis indicated that biological treatment of waste is unlikely to be a Key Category for either CH_4 or N_2O on either level or trend assessment so the continued use of IPCC 2006 default emission factors is therefore considered appropriate for the UK NIR. As such, a Tier 1 approach has been used to provide a time series of GHG emissions for biological treatment. This is based on a time series of CH_4 emissions based on default emission factors and activity data of quantities of local authority and non-local authority waste from 1990 to 2013 treated by composting, anaerobic digestion, mechanical biological treatment (MBT) and home composting. The activity data used for this part of the study originated from semi-annual surveys of UK organic waste treatment facilities published by the Wastes and Resources Action Programme (WRAP) in 2009, 2010 and 2012, and earlier surveys by The Composting Association and its successors, since 1994.

Table 1 presents a summary of the emissions time series for biological treatment. Emissions from this category have not previously been included in the annual waste sector emissions reported in the UK's previous National Inventory Report (NIR) submissions so emissions from this source will be additional to emissions reported for other sources. However, it is important to note that emissions from one tonne of biological treated waste are substantially lower than those generated by landfilling the same quantity of emissions. Therefore, diversion of organic waste from landfill will lead to an overall decrease in GHG emissions from the waste sector.

A preliminary projection of GHG emissions associated with biological treatment has also been developed for 2015-35 based on a projection of biological treatment activity data over this time period. See section 2 for further details.

Overall, it is recommended that detailed projections on GHG emissions be undertaken at the sector, rather than category level. This is because changes affecting biological treatment will also affect residual waste composition and hence emissions from solid waste disposal on land and incineration.

We would also recommend that the Key Category analysis for this source be repeated annually to ensure that a Tier 1 methodology for calculating emissions from biological treatment is appropriate for future year.

Open dumps and unmanaged landfill

This category relates to 'unmanaged' waste disposal under Part as defined in the 2006 Guidelines and focuses on emissions generated by waste disposed above ground and in holes and natural features. The UK's current approach assumes that there are no significant emissions from this source. This review assessed the validity of that assumption.

A system of managed landfill has been in place since 1945 so it is assumed that there are no unmanaged landfills in the UK due to the UK's stringent regulatory requirements for landfill operations. This review focused upon assessment of emissions from illegal dumping ('fly-tipping') of wastes. A Tier 1 methodology has been used to develop a time series of greenhouse gas (GHG) emissions associated with open dumps and unmanaged landfill[1]. This has been developed using activity data based on local authority reports of fly-tipping incidents. A summary of the time series of emissions is presented in Table 1. These estimates indicate that GHG emissions associated with open dumps and unmanaged landfill comprised approximately 0.005% of the UK's total GHG emissions in 2012. This is significantly lower that the IPCC threshold for a 'significant' source (0.05% or 500kT).

It is recommended that emissions from UK unmanaged landfill and unmanaged dumps should not be reported in the UK GHG Inventory National Inventory Report (NIR).

Industrial wastewater treatment and discharge

The UNFCCC's review of the UK's 2013 NIR highlighted a number of limitations associated with the UK's methodology for estimating GHG emissions from wastewater treatment and disposal. Namely, the use of default emission factors, broad assumptions relating to the proportion of wastewater treated or disposed of anaerobically and the potential for the double counting of emissions with those generated by domestic water treatment. Overall, it is considered that the current methodology is likely to overestimate the level of GHG emissions relating to industrial wastewater treatment and disposal. As such, this study focused upon identifying more accurate country-specific data which could be used to improve the methodology.

An extensive consultation exercise with key trade and industry bodies did not identify any suitable data for readily enhancing the current methodology. The regulatory bodies, trade associations and water industry do not currently hold, or are unable to provide, detailed data on industrial wastewater treatment.

A longer term process of engagement will be necessary to encourage the industry to provide appropriate data. We would also recommend undertaking a detailed review of the environmental permitting information held by the Environment Agency to

[1] Defined as waste dumped

identify data that can be used to improve the emission factors used by the methodology.

Table 1: Summary of GHG emission time series for biological treatment, open dumping and unmanaged landfill, and industrial wastewater treatment

Year	UK GHG inventory (kt CO_2 eq)	Biological treatment (kt CO_2 eq)	Unmanaged dump GHG inventory (kt CO_2 eq)	Industrial wastewater (kt CO_2 eq)
1990	780,680	10	81	2,720
2000	691,600	206	81	2,840
2010	601,900	1,135	30	2,525
2012	577,330	1,242	31	2,537

1) Introduction

Ricardo-AEA was commissioned in July 2014 by the United Kingdom Department of Energy and Climate Change (DECC) to undertake a review and up-date of three elements of the national GHG Inventory:

1. Biological treatment of solid waste (undertaken by Aether, under subcontract to Ricardo-AEA)
2. Open dumps and unmanaged landfill
3. Industrial wastewater treatment and discharge

The approach taken, findings and outputs of the review for each of these elements are presented in Sections 2, 3 and 4 respectively.

2) Biological treatment of solid waste

2.1) Introduction

Background

The biological treatment of solid waste is a new source category of GHGs included in the 2006 IPCC Guidelines[2]. Three key types of process fall within the source category Biological Treatment of Solid Waste, namely composting, anaerobic digestion[3] and mechanical biological treatment (MBT), which are described in Appendix.

From 2013 onwards, emissions from this category have to be reported to the United Nations Framework Convention on Climate Change (UNFCCC) according to the approach set out in the 2006 IPCC Guidelines. Activity data (i.e. the quantities of solid waste treated by each process within the source category) are to be reported for each year from the base year (1990) to the current reporting year (2013) as part of national inventory submissions. GHG emissions from each process for each reporting year are calculated from characteristic emission factors (EFs), expressed in terms of emission per unit mass of activity. Because emissions are reported two years in arrears, 2015 will be the first submission year based on the 2006 IPCC Guidelines.

The deployment of biological treatments of solid waste has increased markedly in the UK and elsewhere in Western Europe over the last two decades, driven by the need to reduce landfilling of biodegradable waste, which is a significant contributor to GHG emissions. The UK has accepted strict targets to reduce the amount of biodegradable municipal waste sent to landfill to 35% of the 1995 tonnage by 2020, under the terms of the European Union Landfill Directive[4]. As a result of the landfill tax, coupled with incentives for energy recovery from biogas, biological treatments for solid waste, along with waste minimisation, recycling and energy recovery, have grown substantially over the last two decades, as increasing amounts of

[2] Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/
[3] Anaerobic digestion is often referred to by its abbreviation "AD". We have not adopted this terminology to avoid confusion with the term "Activity Data", which is also abbreviated to AD in GHG Inventory circles.
[4] Council Directive 99/31/EC of 26th April 1999 on the landfill of waste.

biodegradable waste have been diverted from landfill[5]. This in turn has contributed to a decrease in GHG emissions from landfills[6].

Although the diversion of organic wastes such as food and green waste from landfill to biological treatments has contributed to a decrease in GHG emissions from landfill, these processes themselves emit GHGs. Under the Revised 1996 IPCC Guidelines[7] which informed inventory compilation up to 2012, no methodology was offered for emissions from biological treatment of solid waste, although Parties to the Convention could report emissions from these processes under category "6D Other". Biological treatments of solid waste are now explicitly addressed in the 2006 IPCC Guidelines under category "4B Biological treatment of waste".

Outline IPCC methodology

The basis of the IPCC methodology for calculating GHG emissions is as the product of activity data (AD) and an emission factor (EF). Emissions are then reported in yearly steps from 1990 (the base year) to the current year. For the biological treatment of waste, the activity data are the annual tonnages of material treated by each type of process under consideration (composting, anaerobic digestion and MBT). The emission factor is the quantity of GHG (CH_4, N_2O) emitted per unit mass of material treated. The basis of reporting emissions is to develop a time series of appropriate activity data and then to apply appropriate emission factors to calculate annual emissions.

There is a wide choice of potential approaches for determining emission factors. Where emissions from a sector are low in relation to overall national GHG emissions, or trend in emissions, according to a Key Category analysis, Parties may use a default emission factor produced by the IPCC. If the category is assessed to be a Key Category, then more sophisticated (and hence more costly to implement) approaches to determining more accurate emission factors are required. Please refer to the 2006 IPCC Guidelines for a detailed consideration of this topic[2].

Outputs from this study

This study reports on activity data gathered from published sources that are suitable as the starting point for reporting emissions from biological treatment of waste. It then considers the outcome of a preliminary Key Category analysis, comments on available emission factors and provides a time series of emission estimates from 1990 to 2013 in accordance with IPCC 2006 requirements. Please note that where emissions of CH_4 and/or N_2O are reported in terms of CO_2 equivalents (eq) they are based on the Global Warming Potentials over 100 years given in the IPCC Fourth Assessment Report (AR4)[8]. The study concludes with a preliminary assessment of emission projections to 2035.

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[5] AEA report to the European Commission DG Climate Action: Next phase of the European Climate Change Programme: Analysis of Member States actions to implement the Effort Sharing Decision and options for further community-wide measures. http://ec.europa.eu/clima/policies/effort/docs/esd_case_studies_waste_en.pdf. Accessed on 14th August 2014.

[6] UK Greenhouse Gas Inventory 1990 to 2012 – Annual Report for submission under the Framework Convention on Climate Change. https://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php. Accessed 14th August 2014.

[7] Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/gl/invs1.html. Accessed 14th August 2014.

[8] IPCC Fourth Assessment Report: Climate Change 2007. Working Group 1 – Physical Science Basis 2.10, Direct Global Warming Potentials. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html. Accessed 31st August 2014. The 100 year global warming potentials given in AR4 for CH_4 and N_2O are 25 and 298 respectively. The global warming potential of fossil CO_2 is defined as unity.

2.2) Scope

The purpose of this work was to develop a methodology to estimate national emissions from the biological treatment of solid waste, and to develop a time series for insertion into the UK's 2015 inventory submission, in full compliance with the requirements of the 2006 IPCC Guidelines. The methodology developed is based on a times-series of activity data of tonnages of relevant organic waste processed in UK biological treatment facilities (composting, anaerobic digestion and MBT) from 1990 to 2013, based on published survey data. Where data are lacking, appropriate inter- and extrapolations have been made. Emissions were then calculated as the product of the activity data and the default emission factors provided in the 2006 IPCC Guidelines. The approach therefore corresponds with a "Tier 1" methodology, as defined by the Guidelines. The use of a Tier 1 methodology is justified by a preliminary Key Category analysis (described below) which showed that current estimated emissions from the biological treatment of waste are unlikely to be considered Key Categories, for which a more detailed assessment would be required.

A further aim for this work was to collate information on factors that may affect future emissions from these sources and where appropriate, to project annual UK emissions from the biological treatment of waste to year 2035, taking account of methods and data used by other reporting parties.

Wastes treated by biological processes

In addition to solid wastes from household, municipal and commercial concerns, composting and anaerobic digestion are also used to treat agricultural materials such as manure and purpose-grown crops, and industrial effluents that are subsequently disposed of to receiving waters. Treatment of these materials is not considered within the source category Biological Treatment of Solid Wastes, but should be reported under the agriculture and industrial wastewater handling sectors, as appropriate (see Section 4 for further information on industrial wastewater).

Greenhouse gases of interest

The direct GHG of interest with respect to the biological treatment of solid wastes are methane (CH_4) and nitrous oxide (N_2O). CH_4 is the major component of biogas formed during anaerobic digestion. Fugitive emissions of CH_4 along with releases during the discharge of digestate and liquor from the process represent potential routes by which the gas may be released into the atmosphere. CH_4 recovery for use (or flaring of any excess) is an important means by which potential emissions of CH_4 produced in anaerobic digestion are mitigated.

Traces of CH_4 are also produced during composting from anaerobic micro-sites in the composting material, but the amounts formed are very much less than in anaerobic digestion[2]. Biofilters used to reduce the level of odour in air from composting plants are largely ineffective in reducing CH_4 concentrations[9]. In addition, traces of N_2O are also produced during composting from nitrification and denitrification processes in the decaying material. Biofilters may actually increase

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[9] National Inventory Report of the German Greenhouse Gas Emission Inventory, April 2014. http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php

emissions of this gas by converting some of the ammonia (NH_3) released during composting to N_2O[9].

Note that the carbon dioxide (CO_2) produced during decomposition is considered to be entirely of biogenic origin and so does not need to be quantified and reported.

Indirect GHGs such as non- CH_4 volatile organic compounds (NMVOCs), oxides of nitrogen (NO_x) and carbon monoxide (CO) have also been reported in emissions from the waste sector. This study provides a preliminary estimate of NMVOC emissions from composting. No information has been obtained on NMVOC emissions from anaerobic digestion or from the combustion of biogas.

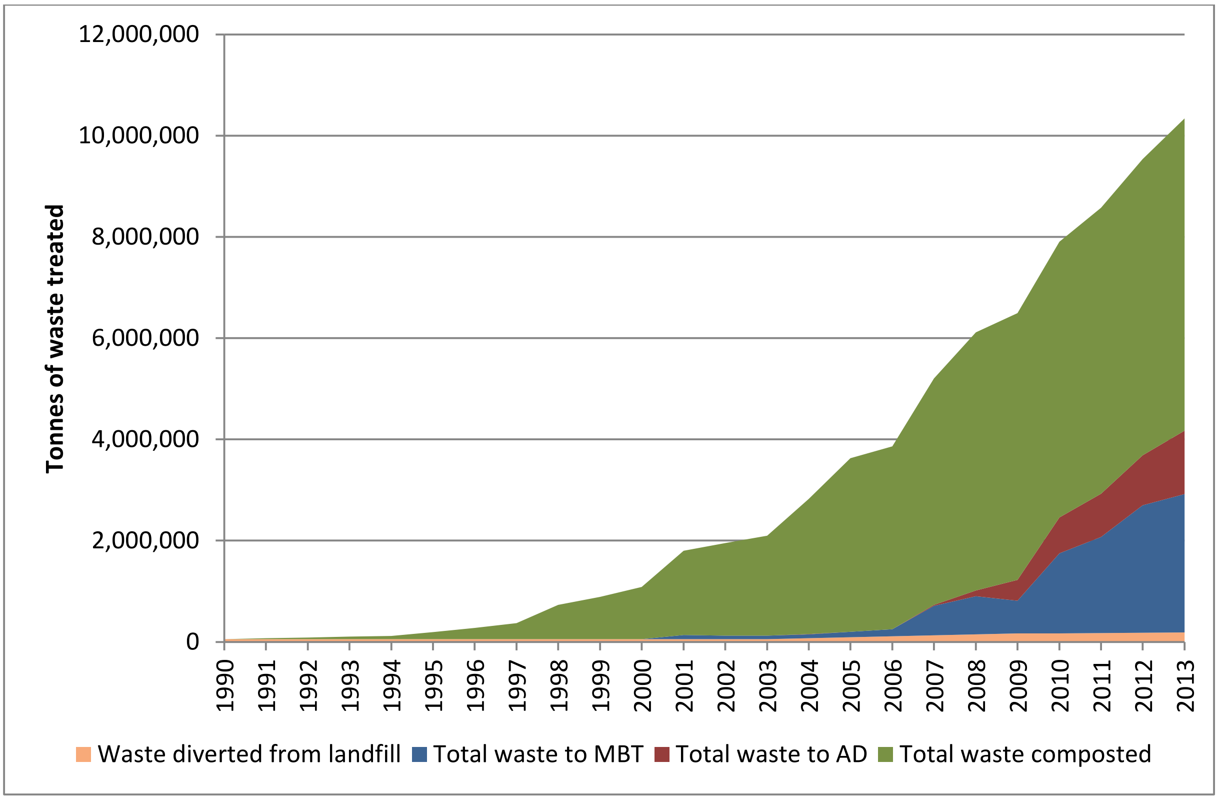
2.3) Review of activity data

Quantities of waste processed

This section summarises the activity data obtained for the biological treatment of waste (IPCC category 4B). The work focuses on reported inputs of waste to centralised commercial composting, anaerobic digestion and MBT facilities but also includes estimates of organic wastes diverted from the residual waste stream via home (i.e. “household”) composting. Details of the data obtained and methodologies employed are given in Appendix 2 and only a brief overview is given here.

The total annual tonnages of waste treated from 1990 to 2013 through the processes under consideration are shown in Figure 1. The tonnage data are derived from periodic surveys undertaken by The Composting Association and its successors (since 1994) and WRAP (2009 to 2012), as detailed in Appendix 2. Please note that these tonnages are reported on a fresh weight basis. The tonnages are broken down between local authority and non-local authority waste. Please note that figures for 2013 are estimates based on extrapolation from the average annual change that occurred over the previous five years (i.e. 2008, 2009, 2010, 2011 and 2012). Data for some other years have also been estimated, as described in Appendix 2. The data used for the graph are given in Table 8 of Appendix 2.

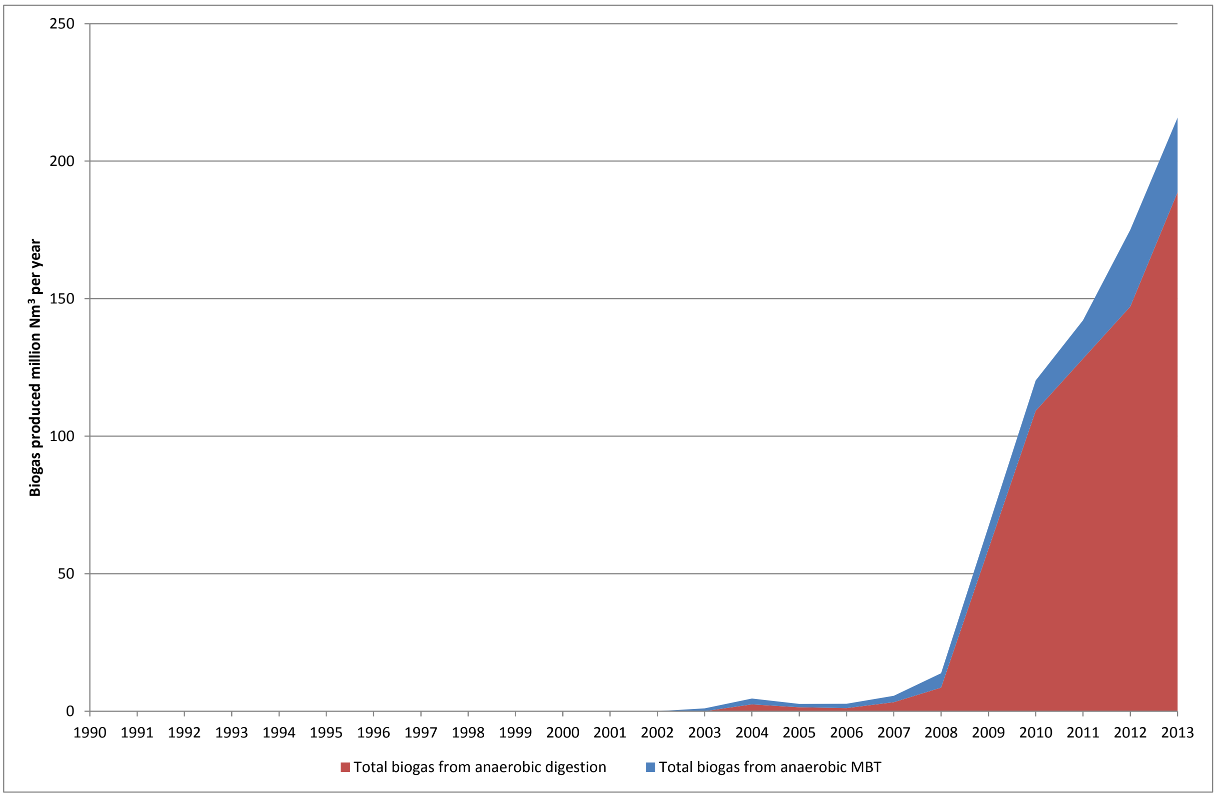
Figure 1: Time series of UK waste to biological treatments



Biogas recovery

Biogas is generated during anaerobic digestion, both at plants treating source-segregated organic waste and at those MBT facilities which have anaerobic digestion as the "biological" stage. Biogas yields per tonne of waste treated are taken from the WRAP surveys as detailed in Appendix 2. Biogas recovery is shown in Figure 2. Further details of the methodology and sources of parameter values are given in Appendix 2. Please note that all the biogas recovered is reported as used for energy recovery (nearly all in combined heat and power – CHP - applications) and no separate data are available on any that is flared. Flaring of biogas is generally only undertaken during outages of the energy recovery systems and in the experience of the consultants on modern anaerobic digestion facilities is believed to be negligible.

Figure 2: Time series of UK biogas recovery from biological waste treatment



2.4) Emission factors

Key Category analysis

A preliminary Key Category analysis using the IPCC Approach 1 methodology has been undertaken using 2012 inventory data, substituting emissions of CH_4 and N_2O (in terms of Gg CO_2 eq) in category "6D Other". This encompasses processes that will report to category "4B Biological Treatment of Solid Waste" in the 2006 IPCC Guidelines and had been annotated as "Not Applicable" in the UK's inventory submissions up to 2014. A similar analysis has been undertaken for 2018, using forward projections based on linear extrapolation of inventory submissions over the previous five years. Details of the methodology and outcome are given in Appendix 2.

The results of the Approach 1 Key Category analysis show that biological treatment of waste would not be a Key Category for either level or trend, using the 2012 inventory data, for either CH_4 or N_2O emissions. However, the outcome is much closer for the emissions extrapolated to 2018, where emissions of both gases are much closer to meeting the key category criterion, especially for trend. The results are shown in Figure 7 to Figure 10 in Appendix 3). It is concluded therefore that for the 2015 submission at least, a Tier 1 methodology based on default emission factors will be sufficient to comply with the 2006 IPCC Guidelines. However, please note that this analysis, along with an Approach 2 methodology (accounting for uncertainty), will need to be repeated annually to ensure that this conclusion holds good in future years as the outcome will inform the Tier level of emission calculation methodology to be employed, in particular, whether or not the use of default emission factors can continue to be justified. Please see Appendix 3 for further details.

Default emission factors

The 2006 IPCC Guidelines[2] cites default emission factors for composting and anaerobic digestion. The relevant table from the 2006 IPCC Guidelines is reproduced as Table 2 below.

Table 2: Default emission factors from 2006 IPCC Guidelines.

TABLE 4.1
DEFAULT EMISSION FACTORS FOR CH_4 AND N_2O EMISSIONS FROM BIOLOGICAL TREATMENT OF WASTE

Type of biological treatment	CH_4 Emission Factors (g CH_4/kg waste treated)		N_2O Emission Factors (g N_2O/kg waste treated)		Remarks
	on a dry weight basis	on a wet weight basis	on a dry weight basis	on a wet weight basis	
Composting	10 (0.08 - 20)	4 (0.03 - 8)	0.6 (0.2 - 1.6)	0.3 (0.06 - 0.6)	Assumptions on the waste treated: 25-50% DOC in dry matter, 2% N in dry matter, moisture content 60%. The emission factors for dry waste are estimated from those for wet waste assuming a moisture content of 60% in wet waste.
Anaerobic digestion at biogas facilities	2 (0 - 20)	1 (0 - 8)	Assumed negligible	Assumed negligible	

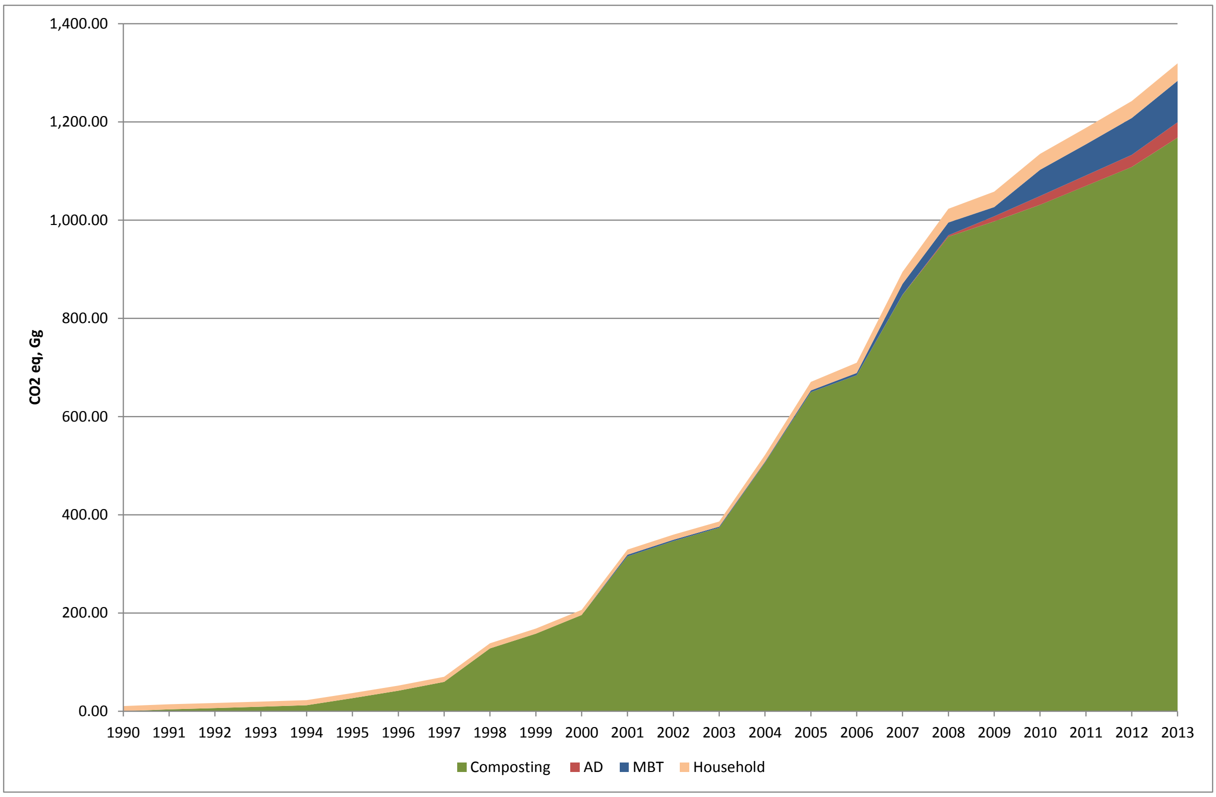
Sources: Arnold, M.(2005) Personal communication; Beck-Friis (2002); Detzel *et al.* (2003); Petersen *et al.* 1998; Hellebrand 1998; Hogg, D. (2002); Vesterinen (1996).

Further emission factors are available in the scientific literature and in the national inventory submissions of other countries. The IPCC has established an on-line database of emission factors, including those relevant to the biological treatment of wastes. Further details are provided in Appendix 4.

Estimated GHG emissions using Tier 1 methodology

Emissions were calculated from the IPCC default emission factors ("wet weight" basis – i.e. on a fresh weight basis) shown in Table 2 and the activity data (fresh weight basis) in Table 8 (Appendix 3). Details of emission by process, gas and source of waste are given in Table 10 in Appendix 5, along with overall emissions in terms of CO_2 eq (Table 11). Overall emissions with the contribution from each process are illustrated in Figure 3 below. Emissions are dominated by CH_4 from centralised composting.

Figure 3: Overall GHG emissions from Biological Treatment of Waste



In 2012, the estimated emissions from the biological treatment of waste were about 1,240 Gg CO_2 eq. This represents 5.7% of the emissions reported for the Waste sector (21,700 Gg CO_2 eq) and 0.22% of net UK emissions (577,300 Gg CO_2 eq)[6]. The corresponding emissions estimated for 2013, based on extrapolated activity data for 2007 to 2012, are 1,319 Gg CO_2 eq. This estimate should be updated for the 2015 submission when new activity data for 2013 are made available from WRAP[10]. Emissions in 1990 were estimated to be about 10 Gg CO_2 eq.

It will be appreciated that GHG emissions from biological treatment of waste have not been included in annual Waste sector emissions reported in previous NIR submissions. Therefore emissions from this source reported in future years will be entirely additional to emissions from all other sources, and not simply a re-allocation of emissions already reported elsewhere. It should also be noted that total emissions per tonne of organic waste processed through biological treatments are considerably less than had the same quantity of waste been landfilled[11]. Diversion of organic wastes from landfill to biological treatments will therefore lead to an overall decrease in emissions from solid waste management.

During the course of this work, we became aware of three apparent inconsistencies in the 2006 IPCC Guidelines relating to biological treatment of waste. These are described in Appendix 6, along with the approach we have adopted in applying the default emission factors in this study.

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[10] We understand that this will be available in October 2014.
[11] But note that emission from biological treatment all take place in the year the waste is processed, whilst emissions from landfilled waste is spread out over a number of years because the decay process is much slower.

Precursor and indirect emissions

The Common Reporting Format tables provided for completion as a major output from this study include Table 5.B.1 for reporting emissions of NO_x, CO and NMVOC from composting. We note that the 2006 IPCC Guidelines (Volume 1, Table 7.1) reports emissions of NO_x and CO as "Not Occurring". For NMVOC, we have identified two emission factors. The first, of 1.56 kg/tonnes is sourced from EMEP-EEA Guidebook[12] and appears to refer to emissions from landfills. The second, 1.7 kg/tonnes, was obtained from the Swiss NIR[13]. Emissions have therefore been based on this latter emission factor and have been calculated from the tonnes of organic waste composted in both centralised and home composting, using the activity data given Table 8 in Appendix 2. The results are given in CRF-5.B.1, as detailed in Appendix 7. Emissions of NMVOC increased from zero in 1990 to an estimated 10.8 Gg in 2013, in step with the activity data.

Projections to 2035

Biological treatment of solid waste is one of a number of options for treating and disposing of waste. Where the compost or digestate produced by these processes meet the requirements for no-longer being treated as waste, the processes are classed as recycling, rather than recovery or disposal operations. Currently only compost or digestate produced from separately-collected green or food waste can meet the end of waste criteria. Recent work[14] suggests that European Union policy is moving towards the achievement of a "circular" economy and a programme of zero waste across all EU Member States, including a target for recycling municipal wastes of 70% recycling rate by 2030. It appears extremely unlikely that such a target could be achieved without targeting organic wastes.

At the same time that such measures would affect the availability of feedstock for biological treatment facilities, it is obvious that they would also have a consequential effect on categories in the waste sector dealing with residual waste, especially solid waste disposal on land and, to some extent, incineration (note that emissions from incineration with energy recovery, which is now universal for incinerators for municipal and similar wastes in the UK, are reported in the Energy sector of the inventory). Changes in residual waste composition as a result of increased source segregation of organic wastes would impact on emissions from these other sectors.

The most effective way of projecting emissions would therefore be on a solid waste-sector wide basis, rather than by individual categories, such as biological treatment, to ensure consistency of approach across the categories. To do a detailed assessment on this basis would be a demanding task well beyond the remit of the present project. However, it is possible to make a fairly crude top-down assessment based on currently available data and assumptions on future developments. Details of this analysis are given in Appendix 8.

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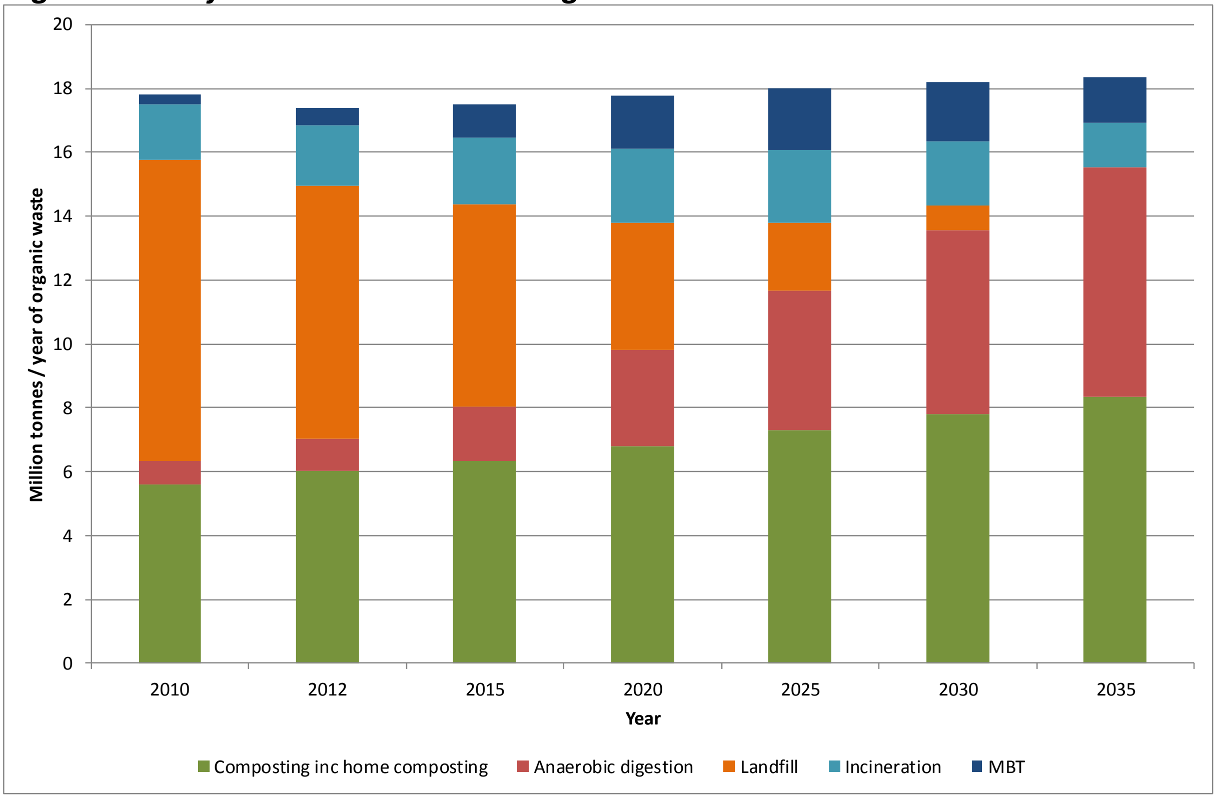
[12] EMEP/EEA air pollutant emission inventory guidebook 2013. Technical guidance to prepare national emission inventories. EEA Technical report No 12/2013. ISSN 1725-2237.
[13] Switzerland's Greenhouse Gas Inventory 1990–2011: National Inventory Report 2013, including reporting elements under the Kyoto Protocol. https://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/7383.php. Accessed 30th August 2014
[14] Eunomia Research & Consulting. Anaerobic Digestion Market Update – Addressing the Feedstock Famine. June 2014. http://www.eunomia.co.uk/reports-tools/anaerobic-digestion-market-update/

The projected activity data for the biological treatment of solid waste are shown in Figure 4.

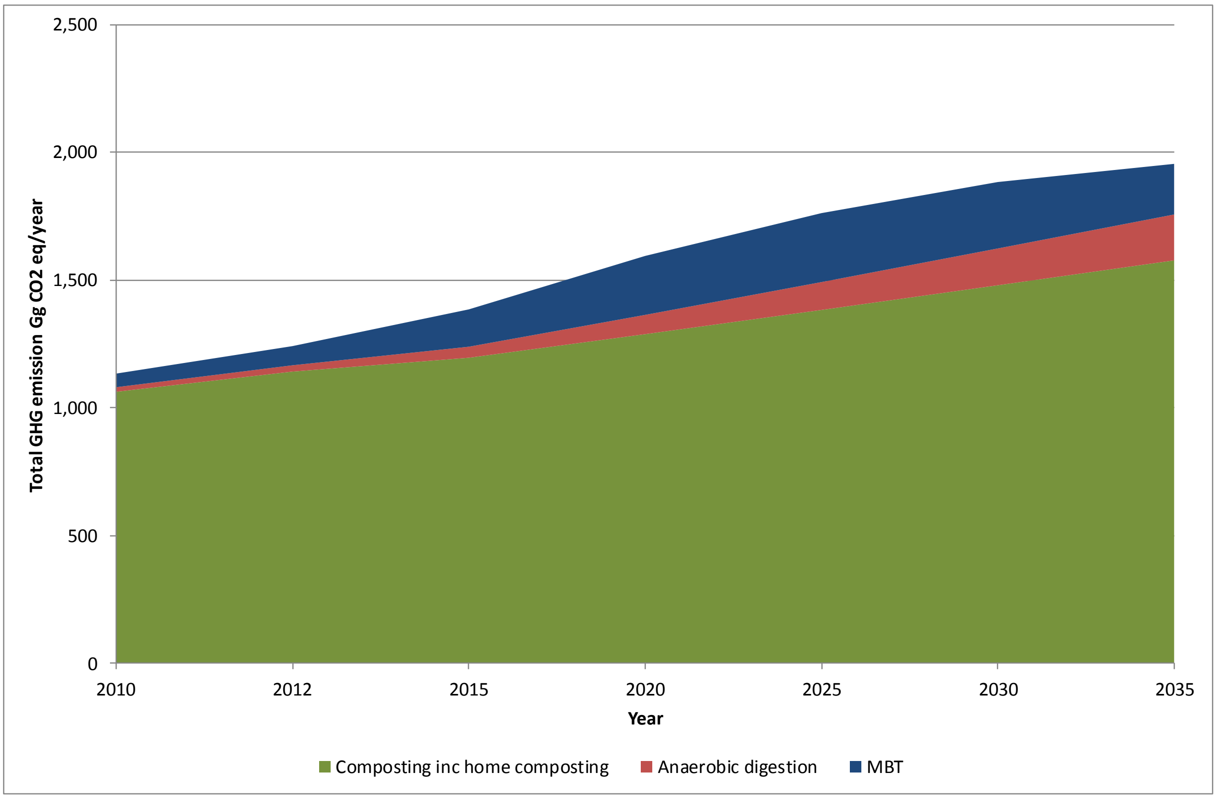
Figure 4: Projected destination of organic wastes[15].



Total GHG emissions from composting (including home composting), anaerobic digestion and MBT are illustrated in Figure 5.

[15] Note the intervals on the horizontal axis are not scaled evenly.

Figure 5: Projected GHG emissions from biological treatment of solid waste[16].



Emissions are dominated by CH_4 from composting. Emissions of total GHGs from biological treatment of waste are projected to increase from approximately 1,242 Gg CO_2 eq in 2012 to about 1,956 Gg CO_2 eq in 2035. Further details are provided in Appendix 8. Please note that the projections shown above depend entirely on how well-founded the underlying assumptions are. Further work is needed to ensure that these are firmly grounded and this highly preliminary review should not be regarded as the last word on this topic.

2.5) Conclusions & Recommendations

1. The study has developed a time series of activity data of quantities of local authority and non-local authority waste from 1990 to 2013 treated by composting, anaerobic digestion, MBT and home composting, based on surveys by WRAP, The Composting Association and its successors.

2. The activity data has been used with IPCC default emission factors to produce a time series of of CH_4 and N_2O emissions, based on IPCC Tier 1 methodology. A time series of CH_4 from anaerobic digestion used for energy recovery is also provided for reporting under the Energy sector. The data are provided in CRF format.

3. In 2012, the estimated UK GHG emissions from the biological treatment of waste was about 1,240 Gg CO_2 eq. This represents 5.7% of the emissions reported for the Waste sector (21,700 Gg CO_2 eq) and 0.22% of net UK emissions (577,300 Gg CO_2 eq). Emissions in 1990 were estimated to be about 10 Gg CO_2 eq.

[16] Note the intervals on the horizontal axis are not scaled evenly.

4. The corresponding emissions estimated for 2013, based on extrapolated activity data for 2007 to 2012, are 1,319 Gg CO_2 eq. This estimate should be updated for the 2015 submission when new activity data for 2013 are made available from WRAP.
5. Because emissions from the biological treatment of waste have not been reported prior to 2013, emissions from this category will be additional to GHG emissions reported in all other sectors, and not simply a re-allocation of emissions already reported in other categories. Diversion of organic waste from landfill to biological treatments will, however, result in a net decrease in GHG emissions.
6. Emissions of NMVOC from composting are estimated to have increased from zero in 1990 to about 10.8 Gg in 2013, in step with the activity data.
7. A preliminary Key Category analysis using the 2006 IPCC Approach 1 methodology has been undertaken for CH_4 and N_2O emissions from biological treatment of waste for 2012 and for 2018 using linear extrapolation of the 2007 to 2012 data. It is concluded that, on the basis of the 2012 data, biological treatment is unlikely to be a Key Category for either gas for level or trend.
8. The use of IPCC 2006 default emission factors is therefore considered appropriate, at least for the inventory submission of 2015. However, it is recommended that, in line with IPCC good practice, the Key Category analysis is repeated annually using both an Approach 1 and Approach 2 methodology, when the underlying data become available from WRAP. In particular, the Key Category analysis of emissions extrapolated to 2018 shows that biological treatment is much closer to falling within the definition of Key Category, especially for trend, for both gases. Early consideration should therefore be given to the resources and approaches needed to move to a higher tier methodology in the event of biological treatment becoming a key category in the future.
9. Data on country-specific emission factors from national inventory submissions and the scientific literature are available on-line at the IPCC Emission Factors Data Base (EFDB). Such information may help to inform the choice of methodology in the future, should biological treatment become a Key Category.
10. Only a preliminary top-down projection of GHG emissions has been undertaken for this study. A key assumption is that a 70% recycling rate of municipal waste is achieved by 2030. Emissions of total GHGs from biological treatment of waste is projected to increase from approximately 1,242 Gg CO_2 eq in 2012 to about 1,956 Gg CO_2 eq in 2035.
11. It is recommended that detailed projections on GHG emissions be undertaken at the solid waste sector level, rather than at category level. This is because changes affecting biological treatment will also affect residual waste composition and hence emissions from solid waste disposal on land and incineration. This would be a significant piece of work beyond the resources of the present study.

3) Open dumps and unmanaged landfill

3.1) Introduction

The UK's GHG inventory includes an assessment of CH_4 emissions from open dumps and unmanaged landfill. At present, it is assumed by the UK that there are no significant emissions from this source.

The aim of this component of the project was to review the UK's current assumption on emissions from open dumps and unmanaged landfill. This task was carried out in accordance with the 2006 Guidelines[17]

This task consisted of the following elements.

1. Review of the definition of "open dumps and unmanaged landfill" in the 2006 guidelines. Based on this review, assessment of what constitutes open dumps and unmanaged landfill in the UK.
2. Collation of data on open dumps and unmanaged landfill, including illegal dumping.
3. Evaluation of CH_4 emissions from open dumps and unmanaged landfill sites in the UK in accordance with the methods laid out in the 2006 guidelines.
4. Assessment of the significance of the calculated CH_4 emissions in the context of significance criteria in the 2006 Guidelines and waste sector emissions in the UK GHG Inventory.

3.2) Scope

Managed and unmanaged landfill

The 1929 Dawes Report highlighted the existence of unmanaged dumps in London and the south-east[18]. During the 1930s, the worst existing tips were closed, and a system of managed landfill was introduced. As a result of these controls, a managed system of landfill has been in operation throughout the UK since 1945.

Consequently, the UK GHG Inventory has been developed on the basis that all waste deposited to land in the UK takes place via the managed landfill system. Waste disposed of via the managed landfill system has been accounted for in statistical data gathered by the regulatory authorities. These waste quantities have in turn been represented in the UK GHG Inventory by data on annual quantities of waste disposed of to landfill for every year going back to 1945.

Effectively, this approach assumes that emissions from open dumps and unmanaged landfill make no significant contribution to the GHG Inventory compared with the managed landfill CH_4 inventory. This reflects the situation in the UK, whereby uncontrolled disposal of waste to land (or "fly-tipping") is illegal, contravening the Clean Neighbourhoods and Environment Act 2005 and the Environmental Protection Act 1990, ss.33, 34 and 59 (and similar provisions in Devolved Administrations). Additionally, transportation of waste for uncontrolled disposal would also contravene waste carrier registration requirements.

Responsibilities

The National fly-tipping protocol sets out the roles and responsibilities of local authorities, the Environment Agency and landowners in dealing with fly-tipping[19,20].

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[17] IPCC 2006 Guidelines available here: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
[18] Herbert L, "*Centenary history of waste and waste managers in London and south-east England*," 2007
[19] Local Government Association and the Environment Agency, "*National fly tipping protocol,*" January 2005
[20] House of Commons, "*Fly tipping—the illegal dumping of waste*," August 2010

Local authorities deal with smaller scale fly-tips on public land. This involves taking appropriate enforcement action, and removing waste illegally dumped on public land, illegally dumped hazardous waste, and illegally dumped waste which is posing an amenity hazard or flood risk.

The **Environment Agency** deals with large-scale (more than one lorry load or about 20 m^3) illegal dumping, tips involving hazardous waste or criminal activity. The Agency will normally arrange for the removal of waste which poses a pollution risk, or a significant flood risk in a main river.

Private landowners are responsible for the removal of waste on their land. If the fly-tipper is caught and prosecuted, it may be possible to reclaim the costs involved. Local authorities may assist landowners in fulfilling this responsibility, although it is not their responsibility to do so.

Landfill methane GHG Inventory

The UK National Inventory Report for 2012 (issued in 2014) estimates of emissions of GHGs to the atmosphere from landfill sites are shown in Table 3:

Table 3: UK landfill GHG inventory

Year	UK GHG inventory ($Gg\ CO_2$ eq)	UK landfill GHG inventory ($Gg\ CO_2$ eq)	Landfill as % of total
1990	780,680	42,817	5.5%
1995	728,250	43,886	6.0%
2000	691,600	35,073	5.1%
2005	672,570	26,284	3.9%
2008	639,880	24,545	3.8%
2009	586,440	23,066	3.9%
2010	601,900	20,008	3.3%
2011	558,780	19,490	3.5%
2012	577,330	18,483	3.2%

This indicates that landfill CH_4 emissions make an appreciable contribution to the UK GHG Inventory, although this contribution has been declining since the mid-1990s with the introduction of landfill gas collection and combustion systems.

Methods

Emissions of CH_4 from uncontrolled waste dumping were evaluated using the following methodology:

1. Statistics on the numbers of fly-tipping incidents in England and Wales were taken from official publications[21,22]. These statistical compilations provided data on the quantities and types of materials tipped.
2. The coverage of these statistics was checked with government officials responsible for collating these statistics.
3. Comparable statistics are not available for Scotland and Northern Ireland. The numbers of fly-tipping incidents in Scotland and Northern Ireland were estimated from the figures for England and Wales, by scaling in proportion to the quantity of residual waste sent to landfill in these Devolved Administrations. This approach was discussed and agreed with officials from the Scottish Environmental Protection Agency (SEPA) and Department of the Environment Northern Ireland (DOENI).
4. A first-order model was used to estimate CH_4 emissions during the period between waste being illegally dumped and it being identified and removed for appropriate disposal. At this point, any CH_4 emissions would be accounted for in the main GHG Inventory. The first-order model was constructed and operated in accordance with guidance in the 2006 Guidelines. A sensitivity analysis was carried out to identify the key factors which could affect these forecasts.
5. The calculated quantities of CH_4 were evaluated against the significance criteria in the 2006 Guidelines. The UNFCCC reporting guidelines state that:

   "*An emission should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions, and does not exceed 500 kt CO_2 eq. The total national aggregate of estimated emissions for all gases and categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions.*"

3.3) Review of activity data

Defra publishes "Fly-tipping statistics for England" annually with data on incident numbers and approximate waste quantities[23]. This report is based on data compiled by local authorities. The annual report makes a number of comments on this activity data:

- Incidents handled by the Environment Agency or cleared by private landowners are not included in the dataset. Data on incidents handled by the Environment Agency is produced in a separate report[24].
- The Environment Agency has worked with authorities to improve reporting quality and has produced guidance to reduce the possibility of double counting in authority returns. This can occur for example when an incident is recorded at the point a local authority is notified and also by a waste management contractor who clears up the fly-tip.

These records were discussed with the Defra fly-tipping officer in order to establish their relevance to this project. The Defra officer's view was that the activities covered by these statistical records correspond to the definition of open dumps and

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[21] National Statistics, "Fly-tipping incidents and actions (national level data) 2007/08 to 2012/13", October 2013, available from https://www.gov.uk/government/publications/fly-tipping-in-england
[22] StatsWales, "*Envi0003: Recorded fly-tipping incidents in Wales*," November 2013, available from https://statswales.wales.gov.uk/Catalogue/Environment-and-Countryside/Fly-tipping
[23] Defra, "Fly tipping statistics for England," October 2013
[24] National Statistics, "Environment Agency action on illegally deposited waste 2011/12 to 2012/13," available from https://www.gov.uk/government/statistical-data-sets/env24-fly-tipping-incidents-and-actions-taken-in-england

unmanaged landfill in the 2006 guidelines: "*waste dumped above ground and in holes and natural features.*"

Table 16 in Appendix 9 sets out the number of incidents reported by local authorities in England and Wales, by size of incident. Table 16 also sets out the estimated average weight of waste in each incident size category. This was estimated by the project team, and revised in discussion with an officer from Defra's fly-tipping team.

Comparable data on the numbers of incidents were not available for Scotland or Northern Ireland, and so the quantities of material illegally dumped in these administrations were estimated by considering the quantities of residual waste sent to landfill relative to the quantities landfilled in England and Wales. Table 17 in Appendix 9 also shows the calculated breakdown in fly-tipping between the DAs. This is equivalent to the breakdown between residual waste landfilled for Scotland and Northern Ireland, whereas the breakdown between England and Wales is based on the reported incidence for local authorities in these administrations.

Multiplying the assumed weight of material by the numbers of incidents gives the estimated total material quantities fly-tipped (see Table 18). Table 19 in Appendix 9 also sets out the reported numbers of fly-tipping incidents in England and Wales the estimated numbers of incidents in Scotland and Northern Ireland.

The robustness of this data was checked in a number of ways:

- Some local authorities in Northern Ireland report fly-tipping incidents to the WasteDataFlow database. Discussions with regulatory officers in DOE Northern Ireland and the Northern Ireland Environment Agency (NIEA) indicate that this dataset is likely to under-estimate the actual number of incidents because of incomplete reporting. DOE NI provided data derived from WasteDataFlow, but advised that: "*This data is not fit for use because it has not been subject to the same Quality Control and Quality Assurance procedures as the published DOE/NIEA waste statistics outputs. Analytical Services Branch are aware of at least two data quality problems: firstly not all councils fill in this question; and secondly, those that do fill in this question do not do so in a consistent manner. The data will be an undercount of the actual number of fly-tipping incidents and subsequent quantity of waste arising, but by how much we cannot tell.*" The incomplete data indicated 4,552 incidents in 2009/10, with clearance of 7,387 Tonnes of material. Separate evaluation of the WasteDataFlow database indicated that 4,781 incidents were reported in 2012.

  The regulatory officers advised that this dataset was not sufficiently robust to use as the basis for estimates of unmanaged dumping in Northern Ireland, but could potentially be used as a sense check on the estimates obtained from the data for England and Wales. The numbers of reported incidents are substantially below the estimated 48,000 (2009) and 44,000 (2012) incidents shown in Table 19. This is consistent with the view of the regulatory officers that the WasteDataFlow records under-report fly-tipping in Northern Ireland, and gives confidence that the numbers of incidents in Northern Ireland have not been under-estimated.

- Most (28 out of 32) Scottish local authorities report fly-tipping incidents to the WasteDataFlow database. A number of notes in this database indicate that the WasteDataFlow data are incomplete, and this dataset was therefore considered unreliable for the evaluation of fly-tipping in Scotland. As a cross-check, the numbers of reported fly-tipping incidents in 2012 were extracted from the database. It was found that 41,045 incidents were reported in 2012. This is substantially below the estimated number of 110,000 incidents shown in Table 19, and gives confidence that the numbers of incidents in Scotland have not been under-estimated.

Zero Waste Scotland (ZWS) carried out a study to quantify the scale and cost of litter and fly-tipping[25]. This study found that: "*At least 26,000t of waste is illegally fly-tipped each year and dealt with by local authorities, with an estimated 61,000 incidents occurring per year. This estimate excludes the vast majority of cases occurring on private land.*" These estimates are for 2011. The ZWS report does not make an estimate of the contribution to fly-tipping on private land. These estimates are significantly lower than the values in Table 19, of 107,000 incidents in Scotland giving rise to 38,000 tonnes of fly-tipped waste. This gives further confidence that the estimates in Table 19 are likely if anything to be an overestimate of the quantity of waste fly-tipped in Scotland. Furthermore, the ZWS study indicated an average quantity of waste per incident of approximately 0.43 tonnes. This is comparable to the values derived in this study, which vary from 0.57 tonnes per incident in 2007 to 0.36 tonnes per incident in 2011.

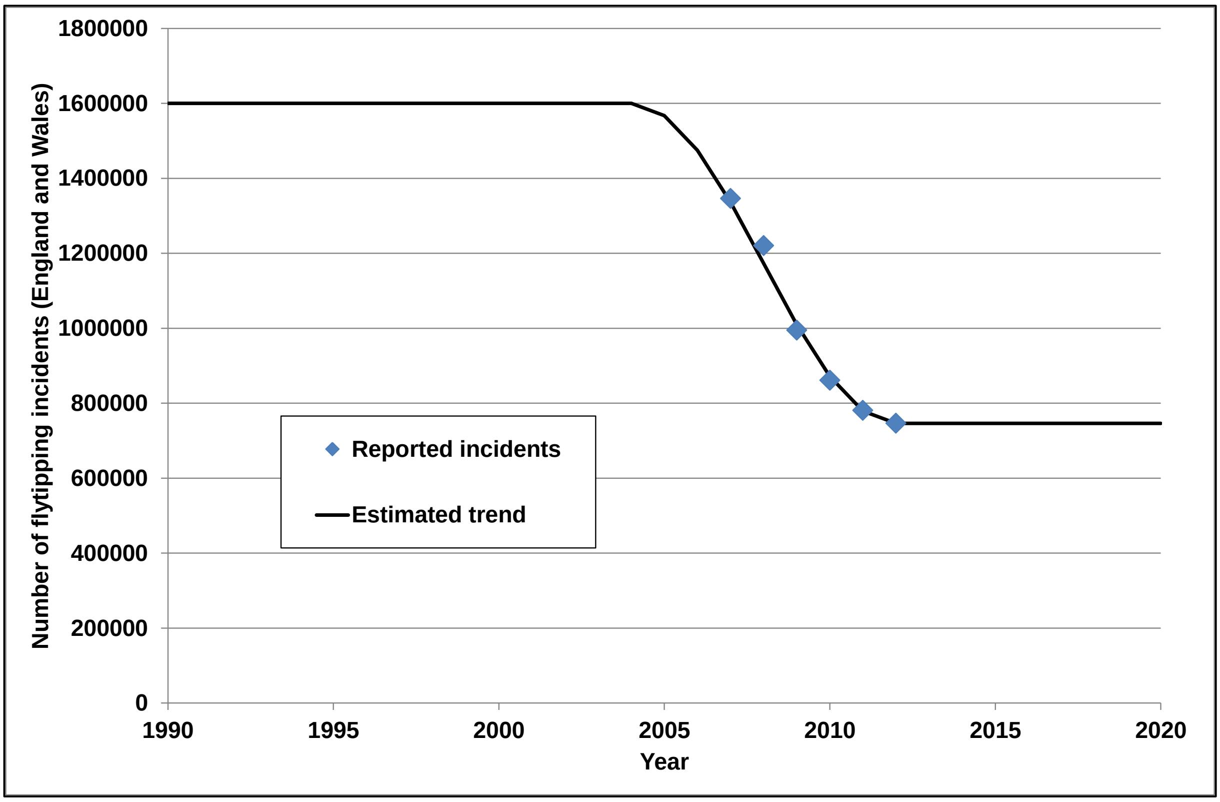
- The numbers of incidents reported in England and Wales does not include incidents dealt with by the Environment Agency. Information from the Environment Agency[24] indicates that the Agency investigated 107 large-scale incidents in 2012/13. Including these incidents in the assessment described above would result in a 1% increase in the estimated total quantity of material illegally dumped. This is not considered to be significant.
- The greatest contribution to the estimated quantities of fly-tipped materials is the "Significant/Multi-loads" category. This category accounted for 64% of the total estimated weight of material illegally dumped in 2012. As this category of materials is open-ended in terms of the weight of material, one of the key uncertainties in this assessment is the estimated average quantity of waste associated with "Significant/Multi-load" incidents. In discussion with an officer in Defra's fly-tipping team, the average quantity of waste in these category incidents was assumed to be 40 tonnes. If a much higher value of 100 tonnes is assumed for this category, the total estimate of fly-tipped waste would be increased by a factor of approximately 2. This was taken into account by means of a sensitivity test.

Trends in the incidence of fly-tipping were estimated from consideration of the local authority reports for England and Wales (see Table 17 and Figure 6). The data show a declining trend over the period 2007 to 2012, but this trend appears to be levelling off from 2012 onwards. This trend was confirmed by an officer from Defra's fly-tipping team. Prior to 2007, there are likely to have been progressive reductions in the incidence of fly-tipping in response to Government initiatives running from the early 2000s. The significant changes in waste collection arrangements in the UK over the period from 2007 to 2012, and increased cost of disposal of waste to landfill resulting from the landfill tax, do not appear to have had a significant influence on the incidence of fly-tipping.

The observed trend was replicated by identifying a sine curve as providing the best fit to the reported data, with a constant value from 2004 and earlier years, and a constant value from 2012 onwards, as shown in Figure 6. In the absence of other data, this constant value was assumed to apply for the entire period up to 2035.

[25] Scotland's Litter Problem, "*Quantifying the scale and cost of litter and flytipping*," July 2013

Figure 6: Reported and estimated incidence of fly-tipping in England and Wales



3.4) Emission factors

Emissions of CH_4 from open dumps and unmanaged landfill were estimated using a First Order Decay model, in accordance with the approach set out in the 2006 Guidelines. The approach to implementing the First Order Decay model was as follows:

Waste composition: The biodegradable components of fly-tipped waste are as follows:

- Householder waste (black bags)
- Green waste
- Commercial waste (black bags)
- Animal Carcasses

The estimated quantities of these materials in fly-tipped waste were estimated on the basis of the breakdown of reported numbers of incidents involving each material type between 2007 and 2012 inclusive.

Table 4: Breakdown of quantity of fly-tipped waste by material type

Year	Estimated quantity of material fly-tipped (Tonnes)			
	Household Waste (Black Bags)	Commercial Waste (Black Bags)	Green Waste	Animal Carcasses
2007	259,400	32,100	33,900	5,500
2008	202,200	33,300	23,500	4,000
2009	154,700	16,600	17,000	3,100
2010	129,200	15,600	13,600	2,900
2011	115,100	9,300	12,200	2,600
2012	143,300	9,200	13,700	3,200

For 2007 to 2012 inclusive, the composition of black bag waste was taken to be as implemented in the UK MELMod system for this period. Waste composition prior to 2007 was taken to be the same as in 2007. Waste composition after 2012 was taken to be the same as in 2012. The materials used for waste definitions in MELMod were allocated to appropriate source categories in the IPCC First Order Decay Waste Model are presented in Appendix 10.

Degradable organic fraction: This was specified to give the same model inputs as the UK MELMod system, when multiplied by a DOCf value (fraction of DOC dissimilated) of 0.5. The values assigned are presented in Appendix 11.

As a sensitivity test, the effect on modelled emissions of using the IPCC default values was also investigated.

Methane generation rates: The IPCC default values are all higher than the values used in the UK MELMod system. The MELMod values do not map directly to the IPCC values, and furthermore there is no guarantee that the values used for UK managed landfills are appropriate for open dumps and unmanaged landfills. Consequently, the IPCC default values for CH_4 generation rates for each waste type were used in this assessment.

Timescale: In order to adopt a conservative approach to the study, it was assumed that wastes could be present for up to 1 year before being identified. It was then assumed that wastes could be present for up to a further year before being removed and properly disposed. This gave a total time period of 2 years for generation of CH_4 to take place. This approach was discussed with officer from Defra's fly-tipping team, who advised that while there is considerable variability in the length of time that wastes could be in place, in many instances waste is identified within a few days of being dumped, and/or removed within a few days of being identified. On average this approach would represent a conservative assumption to the modelling of CH_4 production. It was assumed that wastes would start generating CH_4 immediately.

This was represented in the model by setting a 6 month delay period, which resulted in the model forecasting no CH_4 generation in the first year after tipping (it was not possible to set this figure to zero because of an error in the IPCC spreadsheet). The calculated CH_4 generation for Year 2 and Year 3 were added to give the CH_4 emitted from open dumps and unmanaged landfills.

Methane correction factor: The 2006 guidelines state that "*wastes in shallow open dumps generally decompose aerobically and produce little CH_4, and the emissions decline in shorter time than the anaerobic conditions.*" Consequently, a Methane Correction Factor of 0.4 was used in accordance with the 2006 guidelines.

Partitioning between CH_4 and CO_2: The fraction of carbon decomposing to CH_4 was assumed to be 0.5 in accordance with the IPCC spreadsheet.

Interpretation

The IPCC model was used to estimate the quantity of CH_4 produced from open dumps and unmanaged landfill for the period 2007 to 2012. These estimates were then backcast to 1990 and projected forward to 2009 by scaling from the 2007 and 2012 results following the trend shown in Figure 6. Separate estimates were provided for each Devolved Administration.

Sensitivity tests were carried out to assess the potential significance of the following key study inputs:

- Changing the estimated quantity of material in the "Significant/Multi-loads" category from 20 tonnes to 100 tonnes
- Using the IPCC default values for Degradable Organic Carbon (DOC) content of waste fractions

The forecast levels of CH_4 were assessed against the significance criteria in the 2006 Guidelines. The UNFCCC reporting guidelines indicate that a source can be considered insignificant if it accounts for less than 0.05% of the national total of GHG emissions, and less than 500 Gg CO_2 eq.

Based on this assessment, recommendations were made for the inclusion or otherwise of this source in the UK GHG Inventory, together with text for use in the NIR.

3.5) Conclusions and Recommendations

Study results

The calculated quantity of CH_4 produced from open dumps and unmanaged landfill in the UK is summarised in Table 5. A full schedule of CH_4 emission calculations from this source is provided in Appendix 12.

Table 5: UK landfill and unmanaged dump GHG Inventory

Year	UK GHG inventory ($Gg\ CO_2$ eq)	UK landfill GHG inventory ($Gg\ CO_2$ eq)	Landfill as % of total	UK unmanaged dump GHG inventory ($Gg\ CO_2$ eq)	UK Unmanaged dump as % of total	UK Unmanaged dump as % of landfill
1990	780,680	42,817	5.5%	81.4	0.0104%	0.190%
1995	728,250	43,886	6.0%	81.4	0.0112%	0.185%
2000	691,600	35,073	5.1%	81.4	0.0118%	0.232%
2005	672,570	26,284	3.9%	79.7	0.0119%	0.303%
2008	639,880	24,545	3.8%	50.7	0.0079%	0.206%
2009	586,440	23,066	3.9%	39.6	0.0067%	0.171%
2010	601,900	20,008	3.3%	29.8	0.0050%	0.149%
2011	558,780	19,490	3.5%	26.6	0.0048%	0.136%
2012	577,330	18,483	3.2%	31.1	0.0054%	0.168%
2013	n/a	n/a	n/a	31.1	n/a	n/a

Sensitivity tests

Sensitivity Test 1: The greatest uncertainty with the potential to influence the estimated CH_4 emissions set out in Section 3.5 is the assumed quantity of materials in the category “Significant/Multi-loads.” As discussed in Section 0, this category accounted for 47% of the total estimated weight of material illegally dumped in 2012. In discussion with an officer from Defra’s fly-tipping team, the average quantity of waste in these category incidents was assumed to be 20 tonnes. If a much higher value of 100 tonnes is assumed for this category, the total estimate of fly-tipped waste would be increased by a factor of approximately 2. This would give the following results for 2012:

- UK unmanaged dump GHG inventory 62 kt CO_2 eq
- UK Unmanaged dump as % of total: 0.011%
- UK Unmanaged dump as % of landfill: 0.34%

Sensitivity test 2: The effect of using IPCC default values for DOC content of waste was investigated. This was found to result in a 1.3% increase in UK unmanaged dump GHG emissions for 2012. This was considered to constitute an insignificant uncertainty.

Significance

The calculated quantity of emissions from open dumps and unmanaged landfills amounts to substantially less than 500 Gg per year, even when adopting the worst case approaches set out in the sensitivity test.

The calculated quantity of emissions from open dumps and unmanaged landfills amounts to less than 0.05% of UK GHG emissions throughout the period from 1990 to 2012.

Recommendations

In view of estimated emissions amounting to substantially less than 0.05% of total UK GHG emissions and substantially less than 500 Gg per year, and in view of the potential influence of key uncertainties as described in Section 3.5, it is recommended that emissions from UK landfill and unmanaged dumps should not be reported in the UK GHG Inventory, and do not need to be discussed in the NIR.

4) Industrial wastewater treatment and discharge

4.1) Introduction

The third part of this study considers the UK's methodology for estimating GHG emissions from industrial wastewater treatment and discharge (IPCC Category 6B2). As the UNFCCC noted in its review of the UK's 2013 submission[26], the UK has recently sought to improve its data in this category by developing a time series of CH_4 emission estimates for industrial wastewater, using a combination of default emission factors from the IPCC 2006 Guidelines[27] and country-specific data. However, it is recognised that the methodology is largely reliant upon default factors and could potentially be improved. As such, the aim of this task was to:

1) Review and, if possible, improve the methodology used for estimating GHG emissions for this category.
2) Seek data relating to future trends from industrial wastewater and, if appropriate, produce projections to 2035.

In reviewing the methodology and seeking additional data sources relating to industrial wastewater treatment, the project team conducted a desk-based data review and consultation exercise to identify data which would allow the methodology and the emissions time series to be improved. Data sources reviewed and organisation consulted are summarised in Appendix 13.

[26] http://unfccc.int/national_reports/annex_i_ghg_inventories/inventory_review_reports/items/6947.php
[27] http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

4.2) Scope

Industrial wastewater management and GHG emissions

Industrial wastewater in the UK is either treated on site before discharge to watercourses or to sewer, or sent direct to sewer for treatment by water companies with domestic wastewater. Only uncontaminated water is discharged untreated into the environment.

Industrial wastewater can be treated or disposed of aerobically (e.g. through use of aeration, shallow lagoons or reed beds) or anaerobically (via anaerobic digestion or in deep lagoons). Anaerobic degradation of organic matter in wastewater produces CH_4.

IPCC Category 4D2 is concerned with potential CH_4 emissions from on-site industrial wastewater treatment (i.e. from wastewater which is treated via anaerobic digestion or which is allowed to degrade anaerobically in deep lagoons).

GHGs emitted by industrial wastewater disposed to sewer and treated together with domestic wastewater are reported under Category 4D1 (domestic wastewater). It is also important to note that emissions from the landfilling, incineration or land spreading of sludge generated by industrial wastewater treatment processes, and emissions resulting from energy recovery from the treatment of industrial wastewater, are reported separately under the relevant energy, agriculture of waste disposal IPCC categories.

Industrial Wastewater GHG Inventory

Table 6 shows the trends in reported estimates of GHG emissions from the treatment of industrial wastewater, as included in the UK National Inventory Report for 2012 (issued in 2014).

Table 6: The trend in national and industrial waste water GHG emissions according to the current UK GHG Inventory[28]

Year	UK GHG inventory ($Gg\ CO_2$ eq)	UK industrial wastewater GHG inventory ($Gg\ CO_2$ eq)	Industrial wastewater as % of total
1990	789,116	2,720	0.34%
1995	736,242	2,720	0.37%
2000	694,542	2,840	0.41%
2005	674,333	2,736	0.41%
2008	642,321	2,785	0.43%

[28] This is according to the values calculated after the 2006 IPCC guidelines update, which resulted in some changes to industrial waste water estimates

Year	UK GHG inventory ($Gg\ CO_2$ eq)	UK industrial wastewater GHG inventory ($Gg\ CO_2$ eq)	Industrial wastewater as % of total
2009	588,617	2,479	0.42%
2010	603,500	2,525	0.42%
2011	560,607	2,725	0.49%
2012	579,088	2,537	0.44%

Current Methodology for Estimating Wastewater GHG Emissions

The methodology applied by the UK to estimate GHG emissions from industrial wastewater management follows the approach set out by the 2006 Guidelines[29]. These recommend that reporting parties focus on those industrial sectors that generate wastewater with large quantities of organic carbon, by evaluating total industrial product, degradable organics in the wastewater and wastewater produced. The guidelines then suggest that reporting parties focus on 3-4 key industries that treat their waste anaerobically.

The UK uses its two largest industrial sectors in terms of gross value added[30] for its data: food and drink processing (15%) and organic chemicals (13%). The other potential sector for consideration mentioned by the IPCC is pulp and paper manufacture, but this currently only represents about 3% of UK gross value added and is contracting, while the others are expanding. In 2012 the Environment Agency regulated 80 paper and textiles sites via its permitting regime, as opposed to 528 chemicals sites and 350 food and drink sites[31]. By way of comparison, the table at Appendix 14 shows the industrial sectors for similar countries to the UK for which emissions have been calculated using a similar method.

A different approach has been applied for the food & drink and organic chemicals sectors due to the different availability of data on COD and wastewater loading.

Chemicals Sector

On the basis that there is no country-specific COD and wastewater outflow data available for the organic chemicals sector, an approach based on IPPC default values has been applied. In summary, this is as follows:

1. Use annual UK production figures (Mg) for organic chemicals from ONS Index of Production[32] data (see Appendix 15).
2. Apply IPCC 2006 default assumption for wastewater produced (67m^3 per Mg production).

[29] IPCC 2006 Guidelines available here: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html
[30] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/31785/10-1333-manufacturing-in-the-UK-an-economic-analysis-of-the-sector.pdf
[31] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297237/LIT_8546_b08a53.pdf

[32] http://www.ons.gov.uk/ons/rel/iop/index-of-production/index.html

3. Use IPCC 2006 default assumption for degradable organic component of wastewater (3kg COD per m3 wastewater) to arrive at a figure for kg COD p.a.
4. Apply IPCC default for Bo maximum CH_4 producing capacity (0.25 kg CH_4/kg per kg COD).
5. Assume a CH_4 conversion factor of 70% (i.e. 70% of waste is assumed to be treated or disposed of anaerobically).
6. Calculate total annual emissions for each sector in Gg CH_4.

Food and Drink Sector

For the food and drink sector, a paper published by Defra[33], detailing data on discharges for ten food and drink sub-sectors, has been used. This has allowed a more refined approach to be applied for estimating emissions:

1. Use total organic load figures (expressed in population equivalents) for industrial discharges not going to sewer for ten sub-sectors obtained from 2002 Defra paper[34] scaled using ONS Index of Production[35] data (Appendix 15).
2. Convert organic load figures to kg BOD p.a. using IPCC default conversion rate of 0.054 kg BOD x PE x 365.
3. Convert kg BOD p.a. to kg COD pa by multiplying by 2.4 as per IPCC 2006 guideline
4. Apply IPCC default for Bo maximum CH_4 producing capacity (0.25 kg CH_4/kg per kg COD).
5. Assume a CH_4 conversion factor of 70% (i.e. 70% of waste treated anaerobically).
6. Calculate total annual emissions for each sector in Gg CH_4.

Although these approaches are in line with IPCC guidelines, in its review of the UK's 2013 submission the UNFCCC raised some concerns about the reliance on IPCC default methodology and some of the assumptions made.

For example, the UNFCCC queried the assumption of a 30:70% split between aerobic and anaerobic treatment and suggested the need for further research on the representative shares. The UK's GHG Inventory 1990-2012[36] highlights the absence of data underpinning this split.

The review also expressed two other concerns. Firstly, the potential for double counting due to the assumption that all industrial wastewater is treated on site and none is disposed to municipal sewers. It is understood that some industrial wastewater is disposed to sewer so a proportion of the emissions from industrial wastewater will also be counted in the domestic wastewater emissions inventory. Secondly, the current methodology assumes that, of industrial wastewater which is either treated or disposed of anaerobically, no CH_4 recovery is undertaken to generate energy.

Overall, the current approach applies conservative assumptions and, through double-counting, is likely to overestimate emissions associated with industrial wastewater treatment and disposal.

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[33] https://www.gov.uk/government/publications/sewage-treatment-in-the-uk-2002
[34] https://www.gov.uk/government/publications/sewage-treatment-in-the-uk-2002
[35] http://www.ons.gov.uk/ons/rel/iop/index-of-production/index.html
[36] http://uk-air.defra.gov.uk/assets/documents/reports/cat07/1404251327_1404251304_ukghgi-90-12_Issue1.pdf

4.3) Review of activity data

Organic chemicals

The UK currently uses IPCC default estimates for wastewater generated and associated COD for organic chemicals, adjusted for annual production.

Clearly it would be preferable to use country-specific data. However, the industry (Chemical Industries Association) does not hold information on wastewater treatment or discharges. Neither does the Environment Agency publish aggregated information on wastewater treatment for the chemical sites it regulates via permits. In its 2012 Sustainable Business report[37], the Environment Agency only aggregated information relating to the release of particular substances in wastewater discharges that make a significant contribution to failure to reach Water Framework Directive objectives. For example, it noted that 1% of copper and 1% of zinc discharged to water comes from the chemicals sector but it does not refer to organic loading from the chemicals sector.

The application of the IPCC default estimates to the activity data means that no account has been taken of the application of waste minimisation techniques in the sector. These are however difficult to quantify.

The industry does not have any figures to challenge the assumed aerobic/anaerobic split, but the assumption seems very conservative by international standards. Certainly there is much less evidence of anaerobic treatment for chemicals than for food and drink processing (see below), although we understand that there is increasing interest in AD solutions for complex effluents such as chemicals.

Food and drink processing

There is also very limited accessible and up-to date information relating to wastewater treatment in the food and drink processing industry. There is however a country-specific element in the information currently provided, as this is derived from estimates for organic load in wastewater not discharged to sewer for 10 sub-sectors of the industry. These estimates (see Appendix 16) were made in Defra's 2002 report on implementation of the Urban Waste Water Treatment Directive[38], on the basis of information from 99 regulated sites (as noted above, the Environment Agency currently regulates 350 some food and drink processing sites). The information for half of the subsectors covered is derived from 3 sites or less, which may skew the data. Furthermore, some key sub-sectors (e.g. soft drinks manufacturing) are excluded altogether.

Defra published a subsequent progress report on implementation of the UWWTD in 2012[39]. This did not however contain any information about industrial wastewater treatment or discharges. Neither does the Environment Agency aggregate this information for the food and drink sector.

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[37] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/31785/10-1333-manufacturing-in-the-UK-an-economic-analysis-of-the-sector.pdf
[38] http://ec.europa.eu/environment/water/water-urbanwaste/index_en.html
[39] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69592/pb13811-waste-water-2012.pdf

Industry associations do not hold information on wastewater treatment. However, the Food and Drink Federation felt that the adoption of waste minimisation techniques such as reverse osmosis and membrane separation and reduced water use would mean that simply adjusting the 2002 figures for annual production would result in over-estimates of organic load. Reduced water use by the UK food and drink industry is exemplified by progress with the Federation House Commitment[40], under which the food industry is looking to achieve a water reduction target of 20% (excluding that in product) by 2020 against a 2007 baseline. By 2014 signatories had already achieved a 15.6% reduction.

This impression is borne out by the results of the second stage of the Courtauld Commitment[41], under which the grocery supply chain reduced its waste by 7.4% over the period 2009 to 2012. This included a reduction of 6.8% in wastewater going to sewer.

Industry associations also consider that more anaerobic treatment with CH_4 recovery for energy generation is taking place, reducing waste and recovering CH_4 for CHP (encouraged by feed-in-tariffs). This is borne out by figures from WRAP[42] showing that by the end of 2013 there were 25 AD plants in the food and drink processing industry, covering in particular brewing, distilling and fruit and vegetable processing. This figure was up from 9 in 2009.

Double counting issues

There is clearly double counting of discharges to sewer of untreated or partially treated water from the chemicals and food and drink sectors in the figures for domestic and commercial wastewater.

Formerly water companies reported data on the BOD from trade waste (to sewer or tankered) and the total BOD treated in their returns to regulators. These showed that the total BOD from trade waste in 2008 (i.e. before the economic down-turn), and therefore reported under Category 4B2, was 13.2%, but from 2009-12 the figure was in the range of 10.8-11.7%. Water companies are no longer required to report this information in their new risk and compliance statements, however, and some prefer to treat it as a commercially confidential factor in setting their fees.

There is currently no separate data for industrial wastewater in the Carbon Accounting Workbook (the tool developed by UK WIR for the water industry to fulfil its reporting obligations to Defra). The industry is however looking at the potential for including this information. Anglian Water have however estimated that of the 925 million litres of water they treat every day over 63 million (7%) is trade effluent[43].

Figures from the Northern Ireland Environment Agency suggest that the majority of wastewater from regulated chemicals and food and drink sites there goes to sewer, rather than being treated on-site before discharge into the environment, although much of the wastewater going to sewer is partially treated.

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[40] http://www.wrap.org.uk/node/15646/download/854386e92206e2f2863001c579b09c37
[41] http://www.wrap.org.uk/sites/files/wrap/Courtauld%20Commitment%202%20Final%20Results.pdf
[42] http://www.wrap.org.uk/content/operational-ad-sites
[43] http://www.anglianwater.co.uk/_assets/media/LED225_Trade_Effluent_Explained_Jjun2014.pdf

As mentioned above, discussions with stakeholders and data from WRAP suggest that CH_4 recovery and sludge recycling following wastewater treatment are increasingly evident, particularly in the food and drink and chemicals industries. As noted above, the current assumption is that neither takes place. Whilst this is a conservative assumption it is important to note that CH_4 recovery and sludge recycling are likely to continue to increase.

The National Inventory Reports show significant variations in estimates of sludge recycling following industrial wastewater treatment by countries similar to the UK, with many containing information that is not used for Common Reporting Framework purposes.

4.4) Emissions factors

Methane correction factor

Once the yearly organic load in COD is established for relevant industrial sectors, the IPCC guidelines state it is good practice to use the default factor to determine the maximum CH_4 producing activity if there are no country specific data. This value (0.25kg CH_4 per kg COD) is used by the UK and by some comparable countries.

A CH_4 correction factor (MCF) is then applied, representing an expert judgment on the fraction of wastewater treated anaerobically. The 2006 guidelines recommend that surveys should be conducted frequently enough to account for major trends in industry practice. But the guidelines also provide some default MCFs, ranging from 0 for well–managed aerobic treatment (i.e. no emissions) through 0.2 (i.e. 20%) for shallow lagoons to 0.8 (i.e. 80%) for anaerobic digestion for sludge or energy and deep lagoons. The UK applies an MCF of 0.7 (i.e. 70%) across the board. As mentioned above, this seems very conservative for chemicals, where there is little evidence of use of anaerobic digestion. Whilst anaerobic digestion is increasingly used in the food and drink industry, the data from WRAP suggests the CH_4 produced is generally recovered.

Australia and the US use different MCFs for different industries. Australia applies an MCF of 0.4 for wastewater from meat and poultry processing, whilst the US applies the IPCC default MCF of 0.8. For fruit and vegetable processing Australia applies an MCF of 1 (although where sludge is produced, it applies an MCF of 0.2), whilst the US again applies the default MCF of 0.8. For organic chemicals, Australia uses an MCF of 0.1, considerably lower than that used by the UK.

4.5) Conclusions and recommendations

Conclusions

The methodology used for estimating emissions from industrial wastewater treatment and disposal applies a relatively conservative approach which is based on default emissions factors (with the exception of some country-specific data for COD loads in the food and drink sector). For example, the use of an MCF of 0.7, which implies that the majority of industrial wastewater is either treated or disposed of anaerobically with no CH_4 recovery, is likely to be producing substantial overestimates for the levels of CH_4 generated by this sector. There is also considered to be double counting of emissions due to the inclusion of some industrial wastewater in the estimates derived for domestic wastewater treatment. Overall, it is considered that the inventory for this sector currently overestimate emissions. Table 7 below provides a more detailed summary of activity and emission factor data for this sector.

Table 7: Status of Industrial Wastewater GHG Emissions Estimation Methodology

Sector	Status of activity data	Status of emissions factors
Organic chemicals	Poor and conservative • uses IPCC default values based on international averages • no account taken of adoption of waste minimisation techniques • no allowance made for waste water sent to sewer for treatment by water companies	Poor and conservative • assumption of low level of aerobic treatment at variance with assumptions in similar countries
Food and drink manufacturing	Poor and probably conservative • uses selective information based on regulated industry in 2002 • no account taken of adoption of waste minimisation techniques • no allowance made for waste water sent to sewer for treatment by water companies.	Poor and conservative • anaerobic digestion increasingly used, but with CH_4 recovery and sludge recycling

We have approached the relevant industry associations and environmental regulators across the UK to see what information might be available to inform better activity data and emission factors. Despite extensive discussions with key consultees, very little robust information has been identified. However, discussions suggest that the activity data and emission factors do not accurately represent the current methods of industrial wastewater management in the UK.

Given the very limited level of information in this area we have not produced forward looking forecasts for emissions from treatment of industrial wastewater. However in general terms we can expect to see some growth in the food and drink sector given UK and global population growth projections. The resulting competition for food resources, exacerbated by the expected impacts of climate change on global food production, is expected to fuel increases in production of both domestic agricultural produce and manufactured foodstuffs. Whilst changes in dietary habits may impact on particular products, overall production can therefore be expected to rise. The chemicals sector in the UK is more vulnerable to the impacts of global restructuring by the larger companies, who can supply global markets from anywhere in the world. But currently there is no reason to expect much change in production in the short to medium term.

The extent to which GHG emissions arising from growth in the food industry will be counterbalanced by further increases in both water efficiency and the use of anaerobic digestion with methane recovery depends on a number of factors. These include government policies and incentives, energy and water costs and availability and water company charges for treating industrial effluent. On balance, we can expect anaerobic digestion, with attendant CH_4 recovery and sludge recycling, to increase faster than production, at least in the short to medium. So overall emissions from the treatment of industrial wastewater can be expected to decline. We can also expect gradual increases in the use of anaerobic digestion in the chemicals industry, again with emissions recovery, albeit from a lower base.

Recommendations

Continued efforts need to be made to substantially improve the quality of the data used for estimating GHG emissions for the treatment of industrial wastewater in the UK. Given that suitable data is not available via current sources (e.g. the water industry, regulators and trade associations), we believe a process of longer term engagement with the industry is required to develop an appropriate approach to developing and maintaining this data. In particular better data is needed on three key issues:

1. The quantity of wastewater or COD load produced per unit of production for key industrial sectors.
2. The wastewater treatment and disposal routes used by each key industrial sector. This data needs to include information on the proportion of waste-water disposed of via aerobic versus anaerobic methods and the level of CH_4 recovery used for the latter.
3. The quantity of wastewater disposed to sewer and therefore included in the estimates based on water company information regarding treatment of domestic wastewater).

Based on the discussions held with consultees during this study, we recommend that a multi-faceted approach is used to address these information needs:

- Using the Environment Agency's pollution inventory data sets and the knowledge of their sector co-ordinators to identify a small number of representative sites (e.g. 4-5) in each key sector. Arrangements can then be made to view the permits, permit applications and other relevant documentation held in hard copy at the appropriate local Environment Agency offices. This information will be variable in quality and usefulness, depending for example on the regime in place when the permit was issued (i.e. IPC, IPPC or IED – see below). In some instances it could include COD per tonne of production. Information on industrial wastewater management practices could also be extrapolated from those findings, particularly where, for example, associated anaerobic digestion plants are themselves subject to regulation. Overall, we believe that, given the existing lack of information, there is value in dedicating resources to interrogating this source.
- Detailed analysis of the information provided on current and potential wastewater treatment in in the EU reference documents on Best Available Techniques (BRefs)

produced for the purposes of implementing the Industrial Emissions (formerly Integrated Pollution Prevention and Control) Directive. These have been produced for the food, drink and milk industries (2006[44]), and the organic chemicals sector (2003[45] - currently being revised[46]) and use information specifically derived from sites in the EU. They are thus likely to be more applicable to industry in the UK than the IPCC default assumptions.

- Continuing to work with the water industry to identify the scope for including separate data on industrial wastewater emissions in its carbon accounting workbook, so that account can be taken of industrial wastewater going to sewer or tankered for treatment by water companies.
- This exercise could be streamlined by restricting the data on food and drink processing to those sub-sectors accountable for the majority of the sites and organic load quoted in the 2002 Defra paper, namely meat processing, fruit and vegetable processing, including potato processing; dairy; alcohol and alcoholic drink production, including brewing. We would also recommend that soft drink production be added to the methodology as it is a growing sector that generates significant amounts of wastewater with high organic content.

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[44] http://eippcb.jrc.ec.europa.eu/reference/BREF/fdm_bref_0806.pdf
[45] http://eippcb.jrc.ec.europa.eu/reference/BREF/lvo_bref_0203.pdf
[46] http://eippcb.jrc.ec.europa.eu/reference/BREF/LVOC042014.pdf

Appendices

Appendix 1: Summary description of biological treatments

Composting

Composting is the breakdown of organic matter by microorganisms using molecular oxygen in the air as the oxidising agent. During composting, complex organic molecules such as polysaccharides, proteins and, to some extent, lignin are oxidised to CO_2, water and a solid residue resistant to further rapid decomposition known as compost. To ensure optimal composting rates, the decaying waste needs to be kept well-aerated and moist. The decomposition processes are highly exothermic and in commercial scale composting plants the decaying waste typically reaches 50-70° C, which is needed to ensure rapid completion of the process.

Commercial composting facilities are designed to achieve these requirements of aeration, moisture and warmth but use a number of alternative techniques to deliver them. The most widely used approach is windrow composting. Here the organic waste is set out in heaped rows (windrows) which are then turned regularly and sprayed with water to prevent drying out. The turning is usually accomplished by specialised vehicles that pick up the composting material from one windrow, mixes and sprays it with water, before depositing it in a new windrow parallel with the line of the first. An alternative to windrow composting is the use of aerated static piles. In this case, aeration is achieved by blowing air into the base of the piles, rather than by turning. The third major type of commercial composting operation is based on in-vessel composting (IVC). Here, as the name implies, the waste is contained within a vessel and air injected and drainage water removed. There are numerous variations on these basic themes.

Composting is usually applied to "green waste", such as waste from parks and gardens. Food waste (from households, retailers and food manufacturers) is also sometimes composted, either alone or with green waste, and usually treated via IVC. Commercial scale composting processes are usually complete with about 5-15 weeks, although occasionally this may extend to 20 weeks, depending on conditions[47].

Provided the input wastes have been separately collected from residual waste streams and the output meets quality criteria, the output compost may be used in agriculture or horticulture and is no longer considered to be a waste. Its use is therefore not controlled by the waste management permitting regime.

In addition to composting at centralised facilities, home composting has been practiced by generations of gardeners over the centuries and is still recognised as having a role to play in diverting household waste from landfill. It is noted, however, that the 2006 Guidelines are ambiguous about whether household composting should be included within activity data, merely stating that it should be confirmed whether or not home composting is included within the activity data.

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[47] A survey of the UK organics recycling industry in 2012 – A report on the structure of the UK organics treatment/recycling sector and the markets for its outputs. WRAP. http://www.wrap.org.uk/content/annual-survey-organics-recycling-industry-2012-rak005-002. Accessed 30th August 2014.

Anaerobic digestion

In contrast to composting, anaerobic digestion takes place in the absence of molecular oxygen in the air – i.e. under "anaerobic" conditions. Anaerobic digestion therefore has to take place inside sealed vessels. The process has been widely used for over a century to treat organic liquid effluents for sewage treatment and more recently for processing organic rich liquors before discharging the treated effluent. It is increasingly being used to treat other organic wastes, typically food wastes from households and commercial and industrial sources, which are less fibrous than green waste.

During anaerobic digestion, initial decomposition of complex organic molecules converts the substrates into smaller molecules such as fatty acids. These are then converted to a biogas and water. The biogas typically contains about 60% by volume of CH_4, the balance mostly made up of CO_2[48]. The solid residue ("digestate") may be used as a form of compost (often after a further period of aerobic composting), provided it meets the quality criteria to achieve end of waste status.

There are numerous configurations and designs of anaerobic digestion processes. They include high- and low- solids systems, single or multistage digestion and operation at mesophilic (30-50°C) or thermophilic (>50°C) conditions. Further details of the configuration of anaerobic digestion facilities are given by WRAP[47].

The biogas is typically burnt on-site in engines and used to generate electricity which is usually exported to the power grid. Heat recovered from the engines is used to warm the digesters. Because anaerobic digestion does not oxidise all the degradable organic carbon to CO_2, less heat is produced than during composting a similar quantity of organic matter, and the heat recovered from the gas engines is necessary to ensure that the digesters reach the right temperature to operate effectively. Biogas is sometimes used as a direct fuel, such as for vehicles, or after up-grading, for injection into the natural gas distribution grid. However, at the present time the predominant use is for CHP generation as outlined above. This is because of the commercial incentives for developers that have been made available by the government since 1990 to stimulate biogas use as a renewable source of electricity.

Mechanical biological treatment

Unlike composting and anaerobic digestion as outlined above, MBT typically takes as its input material the residual wastes collected by local authorities after recyclable materials (such as glass, plastic, paper, cardboard, metals, green and food waste) have been segregated by the waste producer for separate collection. The residual waste is usually processed mechanically by shredding followed by sorting according to size, density, optical and electromagnetic properties into a number of outputs, depending on the configuration of the facility. Light material such as paper and card and plastics report may be discharged as a refuse-derived fuel (RDF). This may account for 40-50% by mass of the input. Heavy items such

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[48] The CH_4 content of biogas varies with the type of waste digested. For household waste, the concentration is typically 50-60% vol, agricultural waste is usually higher, at 60-75% vol and agri-food industry waste is around 68%. http://www.biogas-renewable-energy.info/biogas_composition.html. Accessed 1st September 2014.

as stones and glass are discharged to landfill (typically about 20-35% of the input). An organic-rich fraction, comprising food residues and fine material, proceeds to the biological part of the process. About 2-3% of the output consists of metals that are recovered for recycling.

The biological process may either be based on composting or anaerobic digestion. The aim of this stage of the process is to reduce the quantity and degradability of the resulting “compost” or “digestate” for when it is either used or disposed of to landfill. There are many configurations of MBT, using either anaerobic or aerobic treatment. In some facilities the mechanical treatment comes before the biological step; in others the composting stages occurs first.

A key driver for the recent increase in interest in MBT has been a shortage of residual waste treatment capacity, in the form of energy from waste plants, in the UK. Much of the recovered combustible material from MBT facilities, as RDF, is exported to energy from waste plants on the continent, which, provided the facilities achieve a given level of energy efficiency, the process is classed as “recovery” rather than “disposal”. Note that raw residual waste, as opposed to RDF, cannot be exported for either recovery or disposal purposes.

Because the input to MBT processes is not source-segregated organic matter but mixed residual waste, the outputs do not meet current end of waste criteria and so can only be used under the terms of a waste management permit. In fact, the output from the biological stage should not be referred to as digestate or compost, but is defined as “compost-like output”, or CLO. Typical uses for such material are for landfill final cover and other site-restoration uses as allowed under the terms of a waste management permit.

Appendix 2: UK biological treatment activity data

Treatment of organic wastes in centralised facilities

Activity data for centralised composting

The most recent survey[47] of the UK's organic processing industry reported was undertaken by the Waste & Resources Action Programme (WRAP) in 2013 and reports on the status of the industry in 2012. The survey builds on previous studies for 2010[49] and 2009[50] by WRAP and on approximately annual surveys undertaken since the mid-1990s, originally by The Composting Association and more recently by WRAP with support of the Association for Organics Recycling (AfOR), the Renewable Energy Association (REA), the Organics Recycling Group (ORG) and the Environmental Services Association (ESA). These studies are available on the WRAP and ORG websites[51]. The WRAP reports for 2010 and 2012 are based on a survey of facilities' returns to the appropriate regulatory body and follow-up interviews. A grossing-up methodology was employed to scale up the findings from the responding sites to national data for the UK's four constituent nations[52]. Details of the methodology and findings are given in the survey reports and so only a summary of key findings needs repetition here.

The first three rows of Table 8 show the estimated tonnages of organic waste processed by composting since 1990. In 2012, the total had increased to 5.85 million tonnes of which 88% was local authority waste and the remaining 12% being non-local authority waste from retail, hospitality, food processors and manufactures and other commercial concerns. Some 63% of input waste to composting facilities was green/garden waste, 26% was a mixture of food and garden waste, with the remainder (11%) coming from food and other wastes. About 78% of separated green and garden wastes were treated through open-air windrow composting plants, whilst IVC (or IVC with another process, such as anaerobic digestion) accounted for most of the separated food waste and mixed green and food waste.

There were 323 active composting sites in the UK in 2012, an increase of 11% since the previous WRAP survey in 2010. The vast majority of these sites were in England (84%), followed by Scotland (9%), Wales (5%) and Northern Ireland (2%).

The earliest survey (undertaken by The Composting Association) was for year 1994, which showed a total UK input to composting plants of 64 kt. By 1996 this had increased to 220 kt. These earliest surveys did not report separately on local authority and non-local authority waste composted. For the purposes of the activity data shown the table in Annex 1, the split between these waste sources is derived from the 1997 survey which does report separately on these waste sources. We have been unable to locate reliable tonnage data for the base year (1990) to 1993,

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[49] A survey of the UK organics recycling industry in 2010. A report on the structure of the UK organics processing/recycling sector and the markets for its outputs. WRAP. http://www.organics-recycling.org.uk/page.php?article=2439&name=WRAP+-+A+survey+of+the+UK+organics+recycling+industry+in+2010. Accessed 30th August 2014.

[50] A study of the UK organics recycling industry in 2009. A report on the structure of the UK organics processing/recycling sector and the markets for its outputs. WRAP. http://www.organics-recycling.org.uk/dmdocuments/2009_Organics_Report_Final.pdf. Accessed 30th August 2014.

[51] http://www.organics-recycling.org.uk/category.php?category=972&page=0&name=Publications. Accessed 30th August 2014.

[52] The WRAP report for 2010 and 2012 reports provides some data on tonnages of waste treated at so-called "exempt" sites. These are believed to be largely small field scale compost heaps, often as manure heaps. These sites were granted exemptions when the new Waste Management Permitting Regime came in in 2008 and farm advisers are believed to have encouraged land owners to register such sites for exemption. Many of the larger formerly exempt sites are now included in the permitting regime. WRAP is no longer collecting data on the exempt sites and they have been excluded from the current work on the grounds of lack of data and the belief that most such sites are in fact manure heaps.

therefore the activity data for these years are based on linear extrapolation between 1990 (assumed to be zero) and 1994. No survey was reported for 2011: the data shown in the table in Appendix 1 are the average of 2010 and 2012 tonnages. Data for 2013 are not yet available, although WRAP expects that this will be available in Autumn this year. In the meantime, the data shown for 2013 are based on a linear extrapolation over the previous five years.

It should be noted that the quality of the data is believed to be highest for the last year reported by WRAP (2012) and lower for the earlier years. Note that the methodology evolved since the early 1990s and therefore the data for intervening years may not necessarily be completely comparable. Note also that the reporting basis changed from the early surveys (up to 2008/09) from a financial year to a calendar year basis from 2009 onwards. We have not converted this earlier data to calendar year. We can have reasonable confidence that the level of composting in 1990 (assumed to be zero) is likely to have been only a tiny proportion of the 2012 estimate. In the absence of other information, the data reported here are believed to be robust and appropriately conservative.

Activity data for anaerobic digestion

Tonnages of waste treated by anaerobic digestion in the UK are shown for 1990 to 2013 in Table 8. WRAP reported that some 392 kt of separated food solids, 5.2 kt of mixed food and green waste and 35 kt of "other" waste were processed via anaerobic digestion, a total throughput of 432 kt. Note that this tonnage refers only to waste that falls within the Waste category of the 2006 Guidelines: purpose – grown crops (200 kt) and manures (158 kt), which report to the Agriculture sector, and liquid wastes where the effluent is discharged to sewer (3,645 kt) and which reports to the industrial wastewater handling sector, have been excluded from this analysis. Note that most on-farm anaerobic digestion plants that treat manure and/or purpose grown crops also co-process other wastes that do fall within the Waste category.

WRAP reported that in 2012 about 30% of anaerobic digestion feedstock waste was sourced from local authority collections, the remainder from supermarkets and other retailers, hospitality companies, food manufacturers and processors and other commercial concerns. There were 76 operational anaerobic digestion facilities in the UK in 2012 (excluding those for industrial wastewater handling with discharge to sewer), of which the majority (62) were located in England, with 8 in Scotland, 4 in Wales and 2 in Northern Ireland. There has been a huge increase in the tonnage of waste going to anaerobic digestion since 2003, the increase being particularly marked for non-local authority waste.

WRAP also reported on the biogas yield and use from anaerobic digestion. An average biogas yield of 173 Nm^3/tonne was reported in 2012. This figure was used to calculate biogas recovery for years where actual recovery was not reported by WRAP or in other industry surveys mentioned earlier surveys, namely 2003-2008. The results are shown in Table 9. By 2012, almost 200 million normal cubic metres of biogas is estimated to have been recovered from UK anaerobic digestion facilities (excluding biogas from purpose-grown crops, manure and industrial wastewater handling facilities).

For 2012, WRAP reported that 92% of anaerobic digestion facilities used the biogas in on-site CHP engines. Some 4% supplied the gas to an external heat user and 3% exported to the gas grid. Many anaerobic digestion facilities have flares for treating any excess biogas that cannot be used by an energy recovery system, for example, during CHP system maintenance. We have no data on the extent of flaring of biogas but believe this to be negligible, given the commercial value to the operators of the energy that can be recovered by utilising the biogas. We note that flaring of biogas is not required to be reported under the Tier 1 methodology, according to the 2006 IPCC Guidelines[2], and has therefore not been estimated in this study.

The 2006 IPCC Guidelines also comments on the issue of fugitive emissions (i.e. unintentional leaks and releases during system disturbances) from anaerobic digestion of waste, noting that this "will generally be between 0 and 10%of the amount of CH_4
generated. In the absence of further information, use 5 % as a default value for the CH_4 emissions. Where technical standards for biogas plants ensure that unintentional CH_4 emissions are flared, CH_4 emissions are likely to be close to zero". In our experience, all anaerobic digestion facilities in the UK are of a modern design and will use air from within anaerobic digestion buildings and digestate processing facilities to feed flares and engines which will effectively destroy virtually all CH_4 released as fugitive emissions. This assumption is implicit in the values of the default emission factors for CH_4 from anaerobic digestion reported in the 2006 IPCC GPG, and shown in Table 2 of this report.

Activity data for mechanical biological treatment.

The total tonnage of waste processed by MBT in the UK in 2012 was 2.52 million tonnes, at a total of 30 active sites, of which 24 were in England, 5 were in Scotland and one was in Northern Ireland. There were none in Wales. About 70% (or 1.74 million tonnes) of the waste treated via MBT was processed in facilities with an aerobic biological stage based predominantly on bio-drying or IVC. The remaining 0.747 million tonnes was processed at sites with an anaerobic biological stage. Several sites have been omitted from the WRAP survey because they perform the function of an MBT plant but do not produce an organic output, for instance, those operating solely as a pre-treatment for landfilling or only produce RDF for energy recovery. Virtually the entire input for UK MBT plants comes from local authority waste, accounting for 98% of input waste in 2012. Note that prior to 2012, nearly all MBT facilities operated with an aerobic biological treatment stage.

As explained in Appendix 1 not all the incoming waste is necessarily treated through the biological stage of an MBT process and in many systems only a readily degradable material is processed through an aerobic or anaerobic stage. The proportion of material so treated will vary with the design of the facility and the local waste composition. According to the WRAP survey in 2010, 21.3% of incoming residual waste to MBT facilities was accounted for as the organic fraction that is processed through a biological treatment stage. In the absence of site specific data, this factor has been applied across all years when MBT plants were operating. It is important to include this factor to avoid over-estimating emissions from the composting and/or anaerobic treatment as emission factors apply only to the waste actually treated, not to the entire throughput of materials, much of which will be mechanically processed into RDF, recycling and residual material to landfill.

The time series of waste treated via MBT in the UK is shown in Table 8, divided between local authority and non-local authority waste and between facilities with aerobic or anaerobic biological treatments. The estimated biogas output of MBT sites with an anaerobic biological treatment stage is shown in Table 9. Biogas production was estimated using the same approach described for anaerobic digestion, above, assuming that only 21.3% of the incoming residual waste is processed via a biological process. All the biogas is believed to be used for on-site CHP engines, with a negligible proportion being flared during breakdowns or maintenance. It can be seen from Table 9 and Figure 2 (in Section 2.3.2) that MBT facilities contribute much less to the recovered biogas than anaerobic digestion facilities operating on source segregated input waste.

Activity data for home composting

Accurate and complete activity data on home composting is in particularly short supply since no direct measurements have been made. A study undertaken for 2009 suggested that there were about 0.98 million home composters in England in 2001 and that this had increased to 2.96 million in 2009[53]. Between 2006 and 2009, WRAP ran a scheme to promote home composting and to provide composting bins to households; many local authorities also provided bins and promoted home composting, with the objective of reducing the amount of biodegradable waste going to landfill and therefore reducing the risk of incurring financial penalties under the former Landfill Allowance Trading Scheme (LATS)[54], which was subsequently abolished in 2010. For the purposes of the time series and in the absence of better information, we have assumed that the number of home composters remained at the 2001 level in England back to 1990, since home composting was not officially encouraged prior to 2001. It has assumed that the number increased linearly from 2006 up to the 2009 level. These estimates have been scaled up to the UK on the basis of relative population size[55]. This indicates that there would have been some 3.53 million composting households in the UK in 2009.

It is uncertain how many home composters are currently active. Previous work[56] suggested that households that had recently taken up home composting tend to fall away at a rate of about 3% per annum, so no doubt a proportion of those taking up home composting will have fallen away since the end of the WRAP promotion in 2009. On the other hand, it does not appear reasonable to assume that there has been no overall growth in home composting since the end of the WRAP promotion in 2009, and that levels have since plateaued or even decreased. We have assumed for the purposes of generating a time series that the UK home composting

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[53] Resource Futures 2009. Analysis of Future Potential for Home Composting Participation in England. Prepared for Straight plc. November 2009. http://www.straight.co.uk/assets/pdf/news/news_rf1142.pdf. Accessed 13th August 2014.
[54] Beginners' guide to the Landfill Allowance Trading Scheme (LATS) Defra. http://archive.defra.gov.uk/environment/waste/documents/lats-beginners-guide.pdf. Accessed 15th August 2014.
[55] The mid 2013 population of the UK and England were 64.106 and 53.866 million respectively. Office of National Statistics Subnational Population Projections, 2012-based projections, http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-335242 , accessed 6/8/2014
[56] Tucker, P and Speirs, D. Understanding Home Composting Behaviour – A technical monograph. 2001. University of Paisley. http://www.uws.ac.uk/schools/school-of-science/ibehr/cer/environmental-initiatives-research-group/household-waste-project/understanding-home-composting-behaviour/. Accessed 13th August 2014.

population did continue to increase after 2009 but at a slower rate than previously, reaching a nominal 4 million households in the UK in 2012.

Parfitt[57] has developed a regression model to predict levels of food and garden waste diverted from the waste management system (i.e. from household collections of residual waste, food, garden waste, and from household waste recycling site facilities for residual and garden waste). Parfitt's best estimate was that households that compost at home divert an average of 150 kg food and garden waste/household/year. Of this material, about 47 kg/hh/year is diverted from the residual waste stream by composting households and a further ~100kg/hh/year is diverted from segregated garden and food waste streams. For the purposes of reporting GHG emissions, waste diverted from garden/food waste collections or from green waste at HWRCs to home composting can be considered to have a neutral impact, assuming that emissions from home composting and centralised facilities have similar emission factors. Applying the 47 kg/hh/year diversion from residual waste to the 2.96 million composting households in the UK in 2009 suggests that some 166 kt of garden and food waste was diverted from the residual waste stream into home composting. The corresponding figure for diversion from the residual waste stream in 2012 is 182 kt.

Activity data on home composting diversion of waste from the residual waste stream is shown in Table 8. The relatively small contribution of home composting to total biological waste treatment compared with centralised facilities is illustrated in Figure 1.

Consistency of the activity data times series

Please note that a complete activity data time series is not available, either because of the absence of data or because of variations in the survey methodologies invalidate some inter-year comparisons. In addition to the data gaps mentioned above, in some cases it has been necessary to interpolate where data for particular years are questionable and appear to underestimate tonnages. Particular examples include data on anaerobic digestion in 2009, and for MBT in 2002 and for 2008 to 2010. Similar issue affect estimates of biogas recovered for these years. In order to preserve a conservative approach to inventory reporting, the questionable data have been replaced by a linear interpolation between the years before and after the anomalous years.

[57] Parfitt, J. 2009. Home composting diversion – District level analysis. Final report to WRAP, September 2009.. http://www.wrap.org.uk/sites/files/wrap/Home%20Composting%20Diversion%20District%20Level%20Analysis.pdf. Accessed 13th August 2014.

Table 8: Summary activity data for biological treatments

	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Composting																														
	Local Authority waste	0	11,225	22,451	33,676	44,902	98,222	154,349	221,000	512,000	619,000	775,000	1,331,000	1,428,000	1,525,000	2,241,000	2,907,000	2,965,000	3,937,000	4,342,000	4,198,918	4,790,801	4,970,760	5,150,720	5,419,710	5,663,903	5,908,096	6,152,289	6,396,483	6,640,676
	Non-Local Authority waste	0	8,057	10,743	14,324	19,098	41,778	65,651	94,000	163,000	214,000	259,000	333,000	400,000	447,000	431,000	522,000	646,000	538,000	759,000	1,066,793	653,291	676,414	699,537	746,815	750,999	755,182	759,366	763,549	767,733
	Total waste composted	0	19,283	33,194	48,000	64,000	140,000	220,000	315,000	675,000	833,000	1,034,000	1,664,000	1,828,000	1,972,000	2,672,000	3,429,000	3,611,000	4,475,000	5,101,000	5,265,711	5,444,092	5,647,175	5,850,257	6,166,525	6,414,902	6,663,278	6,911,655	7,160,032	7,408,409
AD																														
	Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,810	1,686	1,686	9,554	63,504	245,032	426,561	361,314	296,068	484,425	556,069	627,713	699,356	771,000	842,644
	Non-Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,190	1,314	1,314	7,446	49,496	168,626	287,756	489,290	690,825	767,781	906,506	1,045,232	1,183,958	1,322,684	1,461,410
	Total waste to AD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,000	3,000	3,000	17,000	113,000	413,658	714,316	850,605	986,893	1,252,206	1,462,575	1,672,945	1,883,315	2,093,684	2,304,054
MBT																														
Aerobic treatment of organic fraction																														
	Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	84,852	68,699	52,545	36,582	83,653	62,000	459,647	570,499	403,580	884,621	1,311,244	1,737,867	1,804,014	2,063,854	2,323,693	2,583,532	2,843,372	3,103,211
	Non-Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	0	0	1,072	747	1,707	48,640	83,031	58,770	34,431	397,439	208,940	20,441	183,899	198,201	212,502	226,804	241,106	255,408
Anaerobic digestion of organic fraction															53,618	37,329	85,360	110,640	542,678	629,269	438,011	1,282,060	1,520,184	1,758,308	1,987,913	2,262,054	2,536,195	2,810,337	3,084,478	3,358,619
	Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	0	0	17,515	36,582	20,913	15,500	34,597	119,444	204,292	289,139	373,987	747,973	736,441	862,594	988,747	1,114,900	1,241,053	1,367,206
	Non-Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	0	0	357	747	427	12,160	6,250	5,787	5,324	4,862	4,399	8,798	6,715	6,946	7,178	7,410	7,642	7,874
	Total waste to MBT	0	0	0	0	0	0	0	0	0	0	0	84,852	68,699	71,490	74,657	106,700	138,300	583,525	754,500	647,627	1,576,061	1,898,570	2,515,079	2,731,068	3,131,594	3,532,120	3,932,647	4,333,173	4,733,699
Home composting																														
	Waste diverted from landfill	54,816	54,816	54,816	54,816	54,816	54,816	54,816	54,816	54,816	54,816	54,816	54,816	54,816	54,816	73,275	91,733	110,191	128,650	147,108	165,567	171,175	176,783	182,392	188,000	208661.3631	219042.5683	229423.7734	239804.9785	250186.1836
Total waste treated																														
	Local Authority waste	0	11,225	22,451	33,676	44,902	98,222	154,349	221,000	512,000	619,000	775,000	1,415,852	1,496,699	1,595,060	2,316,974	3,013,252	3,044,186	4,440,798	5,095,447	5,051,822	6,391,122	7,017,306	7,932,628	8,444,590	9,146,419	9,848,249	10,550,078	11,251,907	11,953,737
	Non-Local Authority waste	0	8,057	10,743	14,324	19,098	41,778	65,651	94,000	163,000	214,000	259,000	333,000	400,000	448,430	434,683	525,448	708,114	634,727	873,053	1,275,174	1,343,347	1,379,043	1,419,601	1,705,209	1,862,652	2,020,095	2,177,538	2,334,982	2,492,425
	Total centrally treated waste	0	19,283	33,194	48,000	64,000	140,000	220,000	315,000	675,000	833,000	1,034,000	1,748,852	1,896,699	2,043,490	2,751,657	3,538,700	3,752,300	5,075,525	5,968,500	6,326,996	7,734,469	8,396,349	9,352,229	10,149,799	11,009,071	11,868,344	12,727,616	13,586,889	14,446,162
	Grand total, including waste diverted via home composting	**54,816**	**74,099**	**88,010**	**102,816**	**118,816**	**194,816**	**274,816**	**369,816**	**729,816**	**887,816**	**1,088,816**	**1,803,668**	**1,951,515**	**2,098,306**	**2,824,932**	**3,630,433**	**3,862,491**	**5,204,175**	**6,115,609**	**6,492,563**	**7,905,644**	**8,573,132**	**9,534,621**	**10,337,799**	**11,217,733**	**12,087,386**	**12,957,040**	**13,826,694**	**14,696,348**

Key:

COLOUR CODING	Assumptions / assumed values
Input data	Conversion factors & constants
Calculation /linked cells	*Checks*
Data sourced from another spreadsheet	General notes
Extrapolated / interpolated figure	Warnings or things to check

Notes: The units are in tonnes fresh weight per year. Tonnages reported for MBT include recyclable and materials sent to landfill as well as the organic material processed via the biological stage of the process.

Table 9: Estimated biogas recovered for utilisation for anaerobic digestion facilities.

	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
AD																														
	Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2.1	1.2	0.9	2.0	0.0	0.0	0.0	13.8	27.6	24	29	34	39	44	48
	Non-Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.4	0.2	0.2	1.3	8.6	58.9	109.2	114.4	119.5	165	192	219	247	274	301
	Total biogas from anaerobic digestion	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2.5**	**1.4**	**1.1**	**3.3**	**8.6**	**58.9**	**109**	**128**	**147**	**189**	**221**	**253**	**285**	**318**	**350**
MBT																														
Anaerobic digestion of organic fraction																														
	Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	0	0	1.0	2.1	1.2	0.9	2.0	5	8	11	13.8	27.6	26.9	31.4	35.9	40.4	45.0	49.5
	Non-Local Authority waste	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	0.7	0.4	0.3	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.1
	Total biogas from anaerobic MBT	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**2**	**1**	**2**	**2**	**5**	**8**	**11**	**14**	**28**	**27**	**32**	**36**	**41**	**45**	**50**

Notes: The units are million normal cubic metres (M Nm^3) and exclude the contribution from farm waste, wastewater treatment and non-waste inputs such as purpose-grown crops.

Appendix 3: Key category analysis for biological treatment

The decision as to which tier of methodology to employ in calculating GHG fluxes is informed by the Key Category analysis. The 2006 IPCC Guidelines[2] (volume 1) identifies two approaches for key category analysis. Both approaches identify key categories in terms of their contribution to the absolute level of national emissions and removals and to the trend of emissions and removals. In Approach 1, key categories are identified using a pre-determined cumulative emission threshold. Key categories are those that, when summed together in decreasing order of magnitude add-up to 95% of the total level or trend in emissions or removals since the base year (1990). Under Approach 2, categories are sorted as to their contribution to uncertainty. Approach 2 requires knowledge of category and parameter uncertainty. In the absence of this uncertainty information, we have undertaken a preliminary Approach 1 key category analysis.

The key category analysis has been performed using inventory submission data for 2012 from the UK's 2014 CRF Tables[6] submitted to the UNFCCC for level and trend. The analysis is based on the sectors and categories specified by the Revised 1996 Guidelines for National GHG Inventories[7], which defined reporting requirements for submissions made up to and including 2014. It is recognised that the sector and categories have changed in the current guidance in the 2006 IPCC Guidelines which apply for submissions from 2015 onwards. However, for the purposes of this preliminary key category analysis it is considered unnecessary to restructure the sectors and categories for alignment with the 2006 IPCC Guidelines. The analysis has been undertaken using the global warming potentials given in AR4[58], which have been adopted for use in reporting according to the 2006 IPCC Guidelines[2].

The Key Category analysis has been undertaken using UK's 2012 inventory data, substituting emissions of CH_4 and N_2O (in terms of Gg CO_2 eq) in category "6. Waste D. Other". This encompasses processes that will report to category "4B Biological Treatment of Solid Waste" in the 2006 IPCC Guidelines and has been annotated as "Not Applicable" in the UK's inventory submissions up to 2014. Detailed results of all the Key Category analyses described below are given in Appendix 3.

The results of the Approach 1 Key Category analysis show that biological treatment of waste would not be a Key Category for either level or trend, using the 2012 inventory data, for either CH_4 or N_2O emissions (See Figure 7 and Figure 8 for the results of the 2012 level and trend Key Category analyses).

The analysis has been repeated for emissions projected to 2018 to obtain an indication of the likelihood of biological treatments of waste becoming a Key Category within the next five years. This required an estimate of emissions and removals for all sources and sinks in 2018, including biological treatment. The emission projections were based on linear extrapolation for each source and sink,

[58] IPCC Fourth Assessment Report: Climate Change 2007. Working Group 1 – Physical Science Basis 2.10, Direct Global Warming Potentials. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html. Accessed 31st August 2014. The 100 year global warming potentials given in AR4 for CH_4 and N_2O are 25 and 298 respectively. The global warming potential of fossil CO_2 is defined as unity.

following the same trend as for the previous five years (i.e. from 2008 to 2012, inclusive). In a few instances where sources had been declining, the extrapolation method led to the projected emissions becoming negative in 2018, clearly a physical impossibility. To remove this artefact, negative forecast emissions in 2018 were re-set to zero if the emission in 2012 was positive.

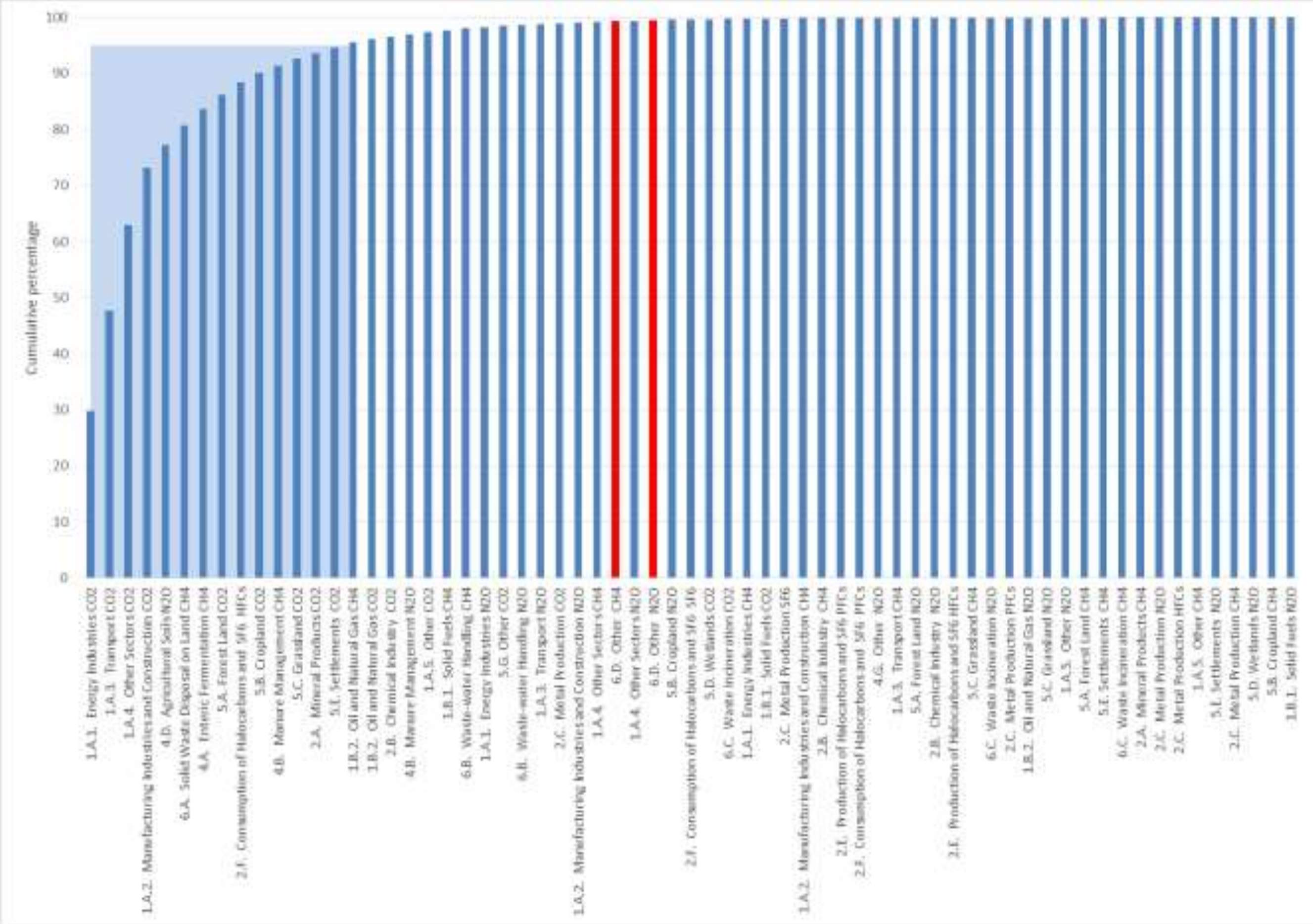
The results of the level and trend analysis for 2018 also showed that biological treatment was not a key category for either level or trend for CH_4 or N_2O (Figure 9 and Figure 10). For both 2012 and 2018, the results showed that the category was closer to falling within the Key Category criteria for trend rather than level, and in 2018 the trend analysis shows biological treatment to be only just outside the limit for being a key category. This is predominantly because the estimated absolute trend (regardless whether the category trend is increasing or decreasing, or is a sink or source[2]) for the new category Biological Treatment of Solid Waste (shown as ‘6D Other’ in Figures 7-10) diverges significantly from the total UK inventory trend.

As a result of the Key Category analysis, we conclude that the use of a Tier 1 methodology, based on 2006 IPCC Guidelines Default emission factors for CH_4 and N_2O is likely to be justified for the 2015 inventory submission and perhaps for later years also, although this assumption will need to be tested by repetition of the Key Category analysis each year.

For future years when source and parameter uncertainty data are available, the Approach 1 Key Category analysis should be supplemented with an Approach 2 analysis. The 2006 IPCC Guidelines note that it is *good practice* to report the results of the Approach 2 analysis in addition to the results of the Approach 1. Results of both Approach 1 and 2 should then be used when setting priorities for inventory compilation.

It may be anticipated on the basis of the above preliminary assessment that biological treatment may become a key category some years hence and that a higher tier of reporting methodology will then be required.

Figure 7: Key Category analysis for level, 2012[59]



[59] The Key Category analysis shows the cumulative percentage contribution of each category and gas to total reported emissions in CO_2 eq (for "level" KCA) or to absolute change in emissions relative to overall absolute change in emissions from 1990 to the current year under consideration (for the "trend" KCA). Categories are ranked in decreasing order of cumulative contribution. Key Categories are defined as those falling within the top 95% of overall level or trend. The shaded blue box shows the categories gases that are Key. Contributions from "6. Other" (which corresponds with biological treatment) emissions of CH_4 and N_2O are shown in red. The analysis is based on the categories identified in the 1996 Revised IPCC Guidelines and uses the global warming potentials given in AR4.

Figure 8: Key Category analysis for trend, 2012[59]

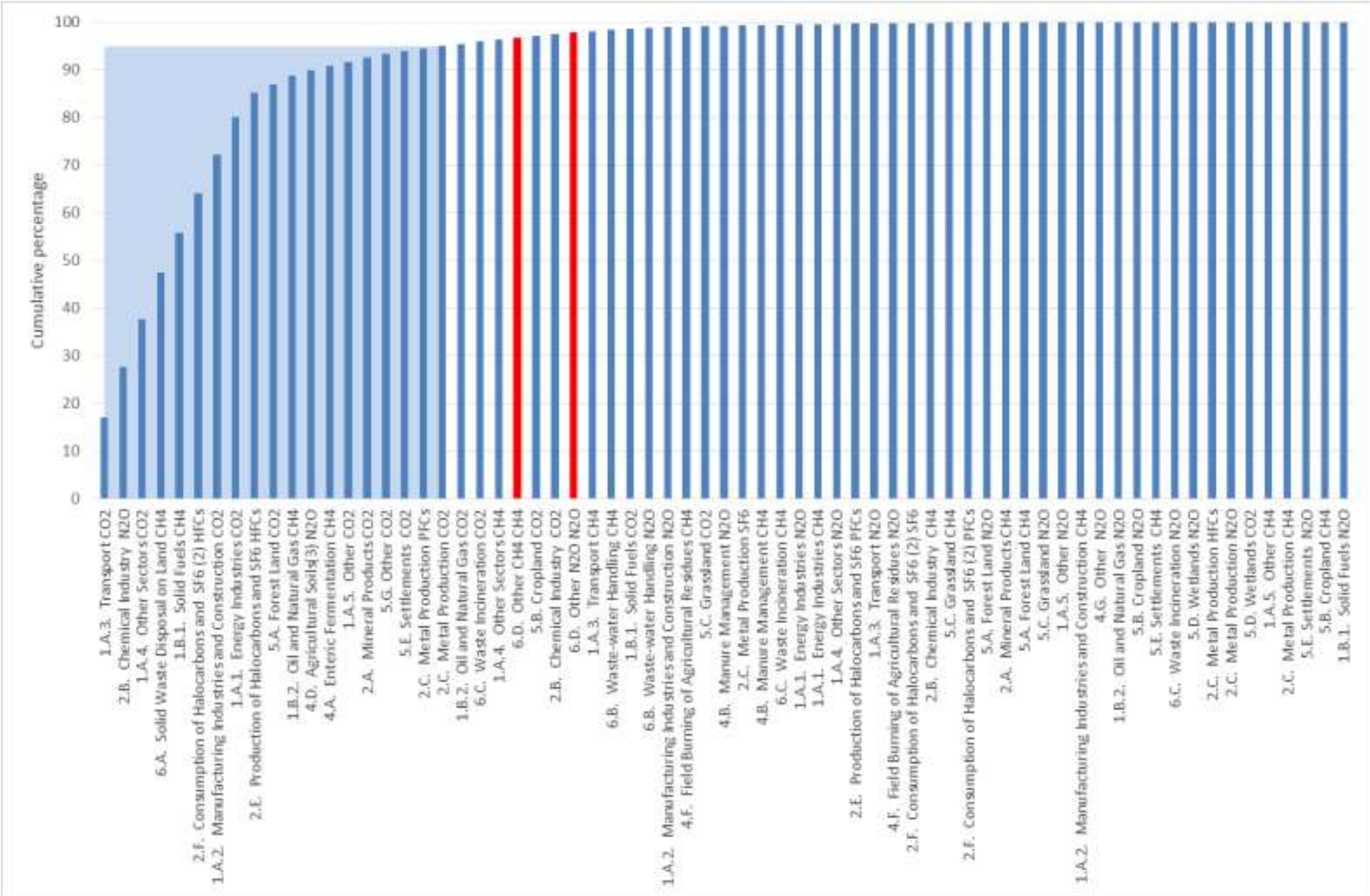


Figure 9: Key Category analysis for level, 2018[59]

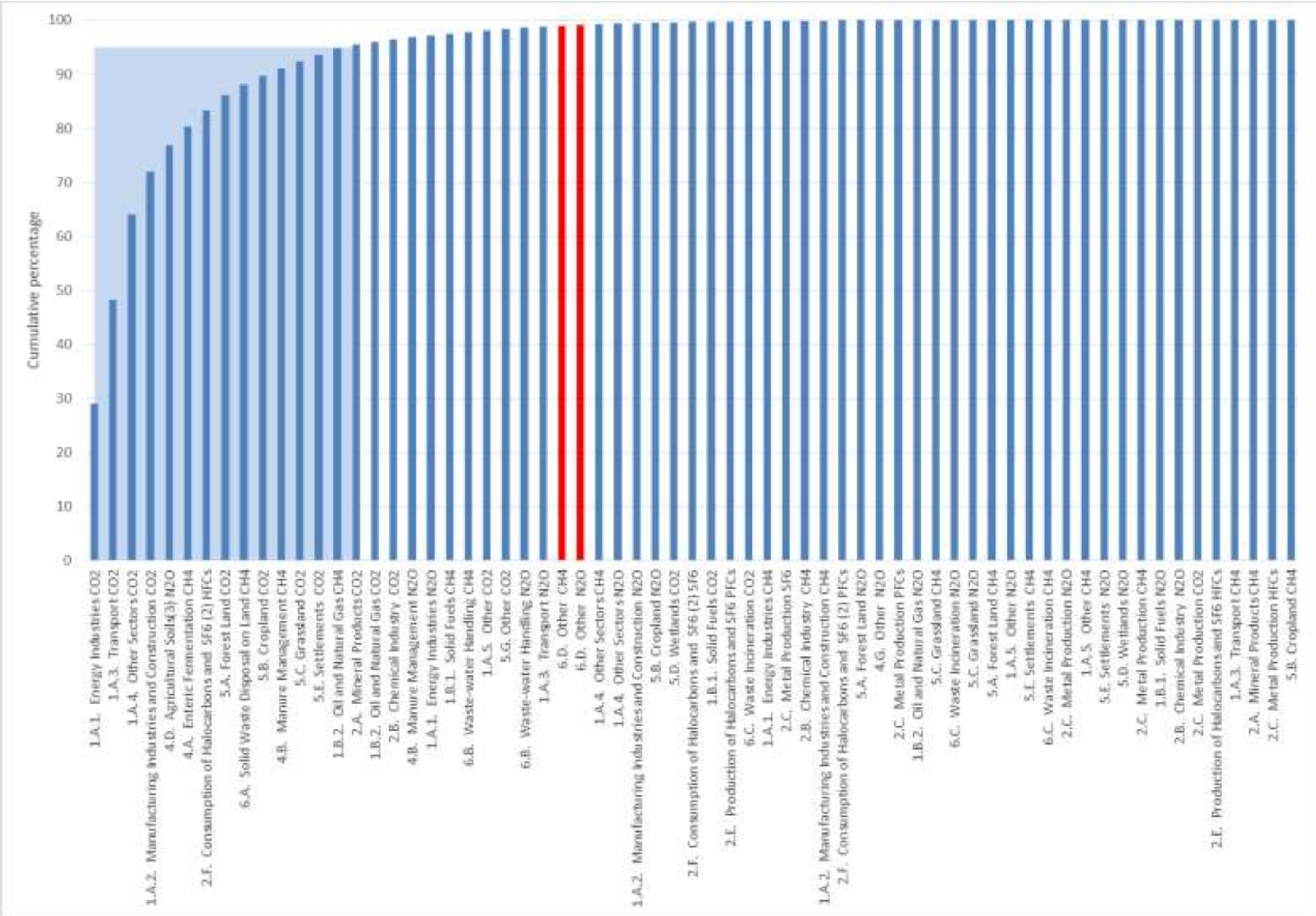
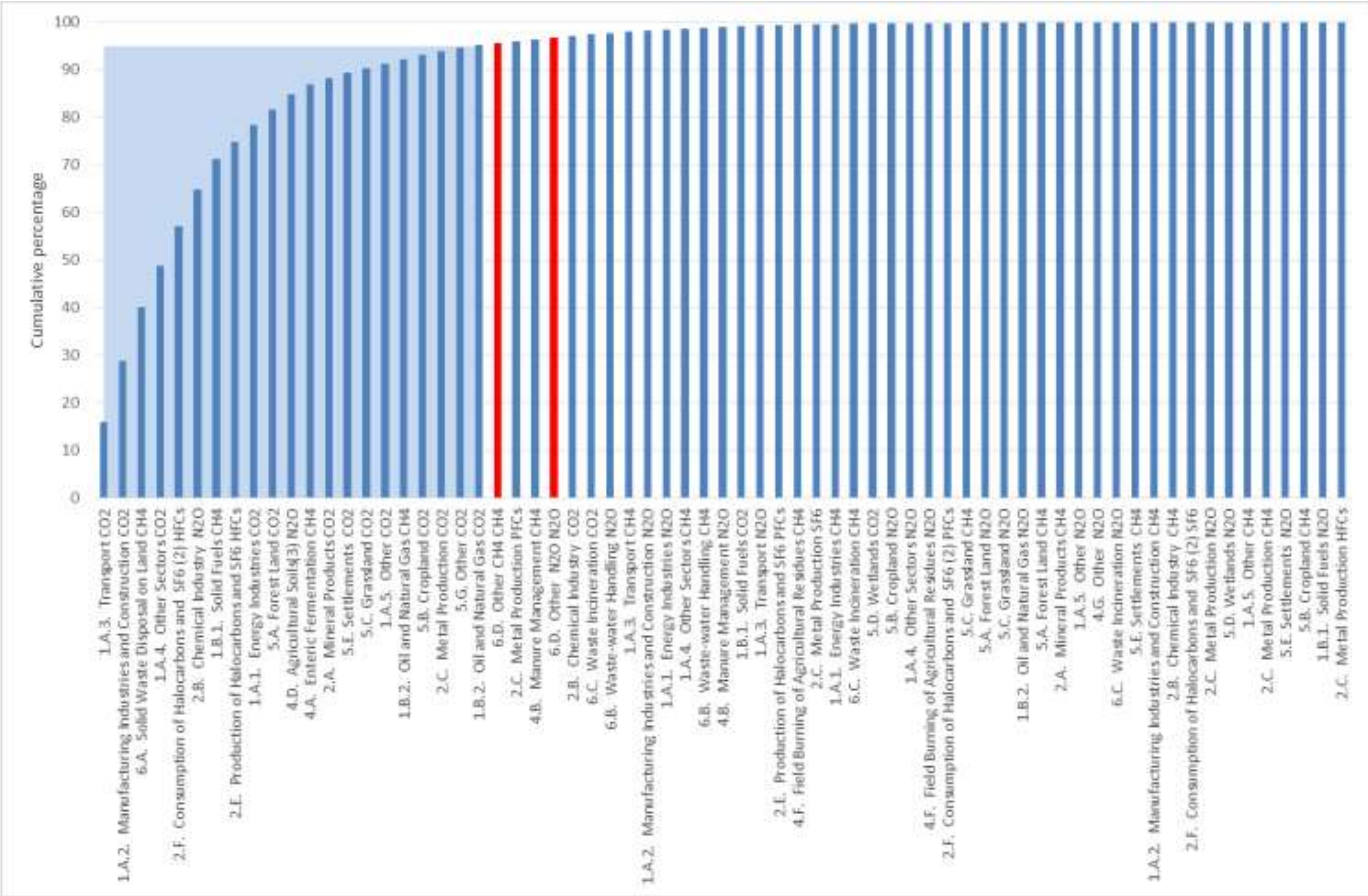


Figure 10: Key Category analysis for trend, 2018[59]



Appendix 4: Other emission factors for biological treatment of waste

Emission factors used by other European countries

Information on the approaches used for reporting emissions from biological treatment of waste by other countries can be obtained from the relevant latest (2014 submission) national inventory reports. Emissions from the biological treatment of solid waste are, however, reported under numerous sub-categories within the "6 Waste, 6D Other" category. Of the 16 sub-categories listed in the UNFCCC Locator database, some appear to be duplicates (for example, there are five sub-categories termed "composting", plus a further four categories with the term "composting" in their title). Some of these sub-categories contain no emission data and so cannot be searched.

The sub-category "Compost production" yields the greatest number of countries reporting emissions. According to the latest (2014) edition of UNFCCC Locator, the following countries reported emissions of CH_4 for 2012: Austria, Belgium, Bulgaria, Denmark, Finland, Iceland, Italy, Latvia, Luxembourg, and the Netherlands. All of these countries also reported N_2O emissions, with the exception of Belgium and Italy. Austria, Denmark and Italy used a country-specific methodology.

Other countries using country-specific methodologies are:

- Liechtenstein reported emissions of CH_4 and N_2O under the heading "Open air composting".

- Switzerland reported CH_4 and N_2O emissions reported under "Fermentation".

- Germany reported CH_4 and N_2O emissions reported under "Mechanical Biological Waste treatment".

Some other countries have also reported emissions for 2012 based on IPCC methodologies:

- France reported CH_4 and N_2O emissions by means of a tier 1 methodology under "6.D.1 Compost production (CH_4, N_2O), and CH_4 only under "6.D.2 Biogas production (CH_4)".

- Spain reported CH_4 and N_2O emission under "Anaerobic digestion at biogas facilities" using tier 2 methodologies.

- Estonia reported CH_4 and N_2O emissions under "Biological Treatment", based on tier 1 methodologies.

- In addition, Greece, Slovakia and Switzerland reported emissions of CH_4 and N_2O under the heading "Composting". Greece and Slovakia are reported to use the default and tier 1 methodology respectively, whilst the methodology type has not been specified for Switzerland.

Further information on emission factors and methodologies used to estimate emissions of GHGs from biological waste treatments are available from the scientific literature and abstracts are also available from the Emission Factors Database (EFDB), maintained by the National GHG Implementation Programme of the IPCC (http://www.ipcc-nggip.iges.or.jp/EFDB/main.php). The EFDB currently contains 18 emission factors relevant to this category. New data are added annually from the scientific literature and other sources, following assessment for their relevance and suitability by the editorial board members.

Appendix 5: Tier 1 emission data for biological Treatment of Solid Waste

Table 10: Sub-category emissions in Gg per gas

	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Composting																									
5.B.1.a	Local Authority waste																								
CH4	LA-CH4	0.000	0.045	0.090	0.135	0.180	0.393	0.617	0.884	2.048	2.476	3.100	5.324	5.712	6.100	8.964	11.628	11.860	15.748	17.368	16.796	19.163	19.883	20.603	21.679
N2O	Non-LA-N2O	0.000	0.003	0.007	0.010	0.013	0.029	0.046	0.066	0.154	0.186	0.233	0.399	0.428	0.458	0.672	0.872	0.890	1.181	1.303	1.260	1.437	1.491	1.545	1.626
5.B.1.b	Non-Local Authority waste																								
CH4	LA-CH4	0.000	0.032	0.043	0.057	0.076	0.167	0.263	0.376	0.652	0.856	1.036	1.332	1.600	1.788	1.724	2.088	2.584	2.152	3.036	4.267	2.613	2.706	2.798	2.987
N2O	Non-LA-N2O	0.000	0.002	0.003	0.004	0.006	0.013	0.020	0.028	0.049	0.064	0.078	0.100	0.120	0.134	0.129	0.157	0.194	0.161	0.228	0.320	0.196	0.203	0.210	0.224
AD																									
5.B.2.a	Local Authority waste																								
CH4	LA-CH4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.002	0.002	0.010	0.064	0.245	0.427	0.361	0.296	0.484
N2O	Non-LA-N2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5.B.2.b	Non-Local Authority waste																								
CH4	LA-CH4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.001	0.001	0.007	0.049	0.169	0.288	0.489	0.691	0.768
N2O	Non-LA-N2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
MBT																									
Aerobic treatment of organic fraction																									
5.B.3.a	Local Authority waste																								
CH4	LA-CH4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.072	0.059	0.045	0.031	0.071	0.053	0.392	0.487	0.344	0.755	1.118	1.482	1.539
N2O	Non-LA-N2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.004	0.003	0.002	0.005	0.004	0.029	0.036	0.026	0.057	0.084	0.111	0.115
5.B.3.b	Non-Local Authority waste																								
CH4	LA-CH4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.041	0.071	0.050	0.029	0.339	0.178	0.017	0.157
N2O	Non-LA-N2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.005	0.004	0.002	0.025	0.013	0.001	0.012
Anaerobic digestion of organic fraction																									
5.B.4.a	Local Authority waste																								
CH4	LA-CH4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.008	0.004	0.003	0.007	0.025	0.044	0.062	0.080	0.160	0.157
N2O	Non-LA-N2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
5.B.4.b	Non-Local Authority waste																								
CH4	LA-CH4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.001	0.001	0.001	0.001	0.001	0.002	0.001
N2O	Non-LA-N2O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Home composting																									
5.B.5.a	Household food and green waste																								
CH4	Household-CH4	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.293	0.367	0.441	0.515	0.588	0.662	0.685	0.707	0.730	0.752
N2O	Household-N2O	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.022	0.028	0.033	0.039	0.044	0.050	0.051	0.053	0.055	0.056

Table 11: Overall GHG emissions in Gg CO_2 eq

Gas	Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
CH4 Gg	Composting	0.000	0.077	0.133	0.192	0.256	0.560	0.880	1.260	2.700	3.332	4.136	6.656	7.312	7.888	10.688	13.716	14.444	17.900	20.404	21.063	21.776	22.589	23.401	24.666
	AD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.003	0.003	0.017	0.113	0.414	0.714	0.851	0.987	1.252
	MBT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.072	0.059	0.050	0.040	0.077	0.100	0.472	0.563	0.418	1.156	1.377	1.661	1.854
	Household	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.219	0.293	0.367	0.441	0.515	0.588	0.662	0.685	0.707	0.730	0.752
N2O Gg	Composting	0.000	0.006	0.010	0.014	0.019	0.042	0.066	0.095	0.203	0.250	0.310	0.499	0.548	0.592	0.802	1.029	1.083	1.343	1.530	1.580	1.633	1.694	1.755	1.850
	AD	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	MBT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.004	0.003	0.002	0.005	0.007	0.035	0.040	0.028	0.082	0.097	0.112	0.127
	Household	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.022	0.028	0.033	0.039	0.044	0.050	0.051	0.053	0.055	0.056
Total CO2 eq	Composting	0.00	3.65	6.29	9.09	12.12	26.52	41.67	59.66	127.85	157.77	195.84	315.16	346.22	373.50	506.08	649.45	683.92	847.57	966.13	997.33	1,031.11	1,069.57	1,108.04	1,167.94
	AD	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.08	0.08	0.43	2.83	10.34	17.86	21.27	24.67	31.31
	MBT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.43	2.77	2.26	1.71	3.56	4.62	22.14	26.08	18.81	53.35	63.42	75.05	84.25
	Household	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38	10.38	13.88	17.37	20.87	24.37	27.86	31.36	32.42	33.48	34.54	35.61
	Total	**10**	**14**	**17**	**19**	**23**	**37**	**52**	**70**	**138**	**168**	**206**	**329**	**359**	**386**	**522**	**670**	**709**	**894**	**1,023**	**1,058**	**1,135**	**1,188**	**1,242**	**1,319**

Note: Overall emission in CO_2 eq have been calculated from CH_4 and N_2O emissions using the 100-year GWPs of 25 and 298 respectively, as given in AR4 **Error! Bookmark not defined.**.

Appendix 6: Apparent inconsistencies in the 2006 IPCC Guidelines chapter on biological treatment of waste

During the course of this work, we have noticed three apparent internal inconsistencies in the 2006 IPCC Guidelines.

The first concerns the emission factors and moisture content data (Table 1 in Section 2.3.2). If the activity data are converted from a wet (i.e. fresh) to a dry weight basis according to the assumed moisture content (60%), then emissions of CH_4 from anaerobic digestion and N_2O from composting are 25% *less* than the emissions calculated using activity data on a wet weight basis and the corresponding wet basis emission factors. For example, CH_4 emissions from 100 kg of wet waste treated through anaerobic digestion would indicate an emission of 100 g, but if the calculation is repeated having converted the 100 kg to 40 kg of dry matter and applying the "dry" basis emission factor we get an emission of only 80g CH_4. Note that in the case of CH_4 emissions from composting, the wet- and dry-matter based calculations yields the same emission. For the purposes of this study, and in the interest of providing a conservative[60] result, we have based emission estimates on fresh weight activity data and the IPCC "wet" basis emission factor. We are currently awaiting a response from IPCC on this matter.

The second concerns the CH_4 recovery and whether or not this is included within the default emission factors given in the Guidelines. Section 4.1.1 states:

The CH_4 and N_2O emissions of biological treatment can be estimated using the default method given in Equations 4.1 and 4.2 shown below:

EQUATION 4.1
CH_4 EMISSIONS FROM BIOLOGICAL TREATMENT

$$CH_4\ Emissions = \sum_i (M_i \bullet EF_i) \bullet 10^{-3} - R$$

Where:

CH_4 Emissions = total CH_4 emissions in inventory year, Gg CH_4

M_i = mass of organic waste treated by biological treatment type *i*, Gg

EF = emission factor for treatment *i*, g CH_4/kg waste treated

i = composting or anaerobic digestion

R = total amount of CH_4 recovered in inventory year, Gg CH_4

It is apparent from the above extract that the emission factors (EFi) for CH_4 *exclude* CH_4 recovered. Given that CH_4 is a trace product from (aerobic) composting but typically makes up about 60% by volume of biogas produced by anaerobic digestion, it is immediately apparent the emission factor for anaerobic digestion in

[60] "Conservative" in the sense that emissions will be over- rather than under-estimated.

Table 1 are *exclusive* of CH_4 recovered, and already represent a net emission. On this basis therefore it would be incorrect to subtract the recovery factor R from the product of activity data and emission factor as shown above.

We have since received the following clarification of this matter from IPCC National GHG Inventory Programme (NGGIP): "The equation 4.1 should be without recovery term as the emission factor given assumes that in anaerobic treatment CH_4 is always recovered"[61]*. Further, NGGIP intend to "initiate a formal process of corrigendum following the IPCC Error Protocol to address the issue". This response confirms our understanding that the emission factor excludes recovered CH_4.*

The third apparent inconsistency relates to whether or not fugitive emissions of CH_4 from anaerobic digestion facilities have been included within the default 2006 IPCC emission factors. The Guidelines state that unintentional leakages of CH_4 "will generally be between 0 and 10 %" of CH_4 generated, and in the absence of further information to use 5% as "a default value for the CH_4 emissions". The Guidelines goes on to state that where "technical standards for biogas plants ensure that unintentional CH_4 emissions are flared, CH_4 emissions are likely to be close to zero". It is apparent that the default emission factor given in Table 4.1 of the Guidelines (1 g CH_4/kg wet waste) is too low to include a 5 percent leakage rate, and therefore the default emission factor must therefore apply to plants of a high technical standard. This is in accordance with Aether and Ricardo-AEA's experience from working with anaerobic digestion plant operators, where a 5% leakage rate would be far too high for modern, well-maintained and operated plants which represent the current UK stock, for which a leakage rate of zero would be appropriate. We have therefore not included any additional emission for leakage and have simply applied the IPCC 2006 default emission factor.

As of 17th October 2014, the authors are still awaiting a response from the NGGIP in relation to first and third points noted above.

[61] Email from Baasansuren Jamsranjav (IGES) to Richard Claxton (Aether) dated 15th August 2014 at 12.01.

Appendix 7: Copies of CRF tables for biological treatment of solid waste

The worksheet labels correspond with the following processes and wastes:

Label	Process and waste treated
CRF 5.B.1	Precursor & indirect GHG emissions from composting
CRF 4.B.1.a	Composting of local authority waste
CRF 4.B.1.b	Composting of Non-local authority waste
CRF 4.B.2.a	Anaerobic digestion of local authority waste
CRF 4.B.2.b	Anaerobic digestion of Non-local authority waste
CRF 4.B.3.a	MBT with aerobic stage - local authority waste
CRF 4.B.3.b	MBT with aerobic stage - Non-local authority waste
CRF 4.B.4.a	MBT with anaerobic stage - local authority waste
CRF 4.B.4.b	MBT with anaerobic stage - Non-local authority waste
CRF 4.B.5.a	Home composting of household food and green waste

Note that the CRF tables 4. B specify that the annual amount of waste treated be reported on a dry matter basis. All the information so far obtained in this study has been provided on a fresh (or "wet") weight basis. To convert from fresh weight to dry matter basis, we have applied a moisture content of 60%, which is consistent with the value stated in the 2006 IPCC Guidelines.

CRF_5.B.1

United Kingdom of Great Britain a	**GBR_2014_1_Inventory**			**Thu Jun 19 12:27:05 CEST 2014**																					
[5. Waste][5.B Biological Treatment of Solid Waste][5.B.1 Composting]																									
[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual waste amount treated	kt dm																								
Method																									
CH4																									
N2O																									
Emission factor information																									
CH4																									
N2O																									
Emissions																									
CH4																									
Emissions	kt																								
Amount of CH4 flared	kt																								
N2O	kt																								
NOx	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
CO	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
NMVOC	kt	0.09	0.13	0.15	0.17	0.20	0.33	0.47	0.63	1.24	1.51	1.85	2.92	3.20	3.45	4.67	5.99	6.33	7.83	8.92	9.23	9.55	9.90	10.26	10.80
Implied emission factor																									
CH4	g/kg																								
N2O	g/kg																								
Documentation box																									

Notes: NMVOC emissions from centralised composting and home composting based on emission factor of 1.7 kg/Mg (Switzerland's Greenhouse Gas Inventory 1990–2011: National Inventory Report 2013, including reporting elements under the Kyoto Protocol. https://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/7383.php. Accessed 30th August 2014)

CRF_4.B.1.a

United Kingdom of Great Britain a GBR_2014_1_Inventory Thu Jun 19 12:27:07 CEST 2014

[4. Waste][4.B Biological Treatment of Solid Waste][4.B.1 Composting][4.B.1.a Local authority waste]

[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual waste amount treated	kt dm	0.00	4.49	8.98	13.47	17.96	39.29	61.74	88.40	204.80	247.60	310.00	532.40	571.20	610.00	896.40	1162.80	1186.00	1574.80	1736.80	1679.57	1916.32	1988.30	2060.29	2167.88
Method																									
CH4		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
N2O		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
Emission factor information																									
CH4		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
N2O		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Emissions																									
CH4																									
Emissions	kt	0.00	0.04	0.09	0.13	0.18	0.39	0.62	0.88	2.05	2.48	3.10	5.32	5.71	6.10	8.96	11.63	11.86	15.75	17.37	16.80	19.16	19.88	20.60	21.68
Amount of CH4 flared	kt	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N2O	kt	0.00	0.00	0.01	0.01	0.01	0.03	0.05	0.07	0.15	0.19	0.23	0.40	0.43	0.46	0.67	0.87	0.89	1.18	1.30	1.26	1.44	1.49	1.55	1.63
Implied emission factor																									
CH4	g/kg																								
N2O	g/kg																								

Notes:

Actity data were converted from fresh weight data using an assumed moisture content of 60%, as stated in Table 4.1 of Volume 5 Chapter 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories.

CRF_4.B.1.b

United Kingdom of Great Britain a GBR_2014_1_Inventory Thu Jun 19 12:27:07 CEST 2014

[4. Waste][4.B Biological Treatment of Solid Waste][4.B.1 Composting][4.B.1.b Non-local authority waste]

[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual waste amount treated	kt dm	0.00	3.22	4.30	5.73	7.64	16.71	26.26	37.60	65.20	85.60	103.60	133.20	160.00	178.80	172.40	208.80	258.40	215.20	303.60	426.72	261.32	270.57	279.81	298.73
Method																									
CH4		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
N2O		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
Emission factor information																									
CH4		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
N2O		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Emissions																									
CH4																									
Emissions	kt	0.00	0.03	0.04	0.06	0.08	0.17	0.26	0.38	0.65	0.86	1.04	1.33	1.60	1.79	1.72	2.09	2.58	2.15	3.04	4.27	2.61	2.71	2.80	2.99
Amount of CH4 flared	kt	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N2O	kt	0.00	0.00	0.00	0.00	0.01	0.01	0.02	0.03	0.05	0.06	0.08	0.10	0.12	0.13	0.13	0.16	0.19	0.16	0.23	0.32	0.20	0.20	0.21	0.22
Implied emission factor																									
CH4	g/kg																								
N2O	g/kg																								

Notes:

Actity data were converted from fresh weight data using an assumed moisture content of 60%, as stated in Table 4.1 of Volume 5 Chapter 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories.

CRF_4.B.2.a

United Kingdom of Great Britain ai GBR_2014_1_Inventory Thu Jun 19 12:27:07 CEST 2014

[4. Waste][4.B Biological Treatment of Solid Waste][4.B.2 Anaerobic digestion at biogas facilities][4.B.2.a Local authority waste]

[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Annual waste amount treated	kt dm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.12	0.67	0.67	3.82	25.40	98.01	170.62	144.53	118.43
Method																								
CH4		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
N2O		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
Emission factor information																								
CH4		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
N2O		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Emissions																								
CH4																								
Emissions	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.06	0.25	0.43	0.36	0.30
Amount of CH4 flared	kt	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N2O	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Implied emission factor																								
CH4	g/kg																							
N2O	g/kg																							

Notes:
Actity data were converted from fresh weight data using an assumed moisture content of 60%, as stated in Table 4.1 of Volume 5 Chapter 4 of the
2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories.

CRF_4.B.2.b

United Kingdom of Great Britain ai GBR_2014_1_Inventory Thu Jun 19 12:27:07 CEST 2014

[4. Waste][4.B Biological Treatment of Solid Waste][4.B.2 Anaerobic digestion at biogas facilities][4.B.2.b Non-local authority waste]

[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual waste amount treated	kt dm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88	0.53	0.53	2.98	19.80	67.45	115.10	195.72	276.33	307.11
Method																									
CH4		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
N2O		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
Emission factor information																									
CH4		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
N2O		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Emissions																									
CH4																									
Emissions	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05	0.17	0.29	0.49	0.69	0.77
Amount of CH4 flared	kt	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N2O	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Implied emission factor																									
CH4	g/kg																								
N2O	g/kg																								

Notes:
Actity data were converted from fresh weight data using an assumed moisture content of 60%, as stated in Table 4.1 of Volume 5 Chapter 4 of the
2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories.

CRF_4.B.3.a

United Kingdom of Great Britain a GBR_2014_1_Inventory Thu Jun 19 12:27:07 CEST 2014

[4. Waste][4.B Biological Treatment of Solid Waste][4.B.3 Treatment at MBT facilities with aerobic processing][4.B.3.a Local authority waste organic fraction]

[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual waste amount treated	kt dm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.24	5.86	4.48	3.12	7.14	5.29	39.21	48.66	34.43	75.46	111.85	148.24	153.88
Method																									
CH4		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
N2O		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
Emission factor information																									
CH4		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
N2O		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Emissions																									
CH4																									
Emissions	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.06	0.04	0.03	0.07	0.05	0.39	0.49	0.34	0.75	1.12	1.48	1.54
Amount of CH4 flared	kt	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N2O	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.03	0.04	0.03	0.06	0.08	0.11	0.12
Implied emission factor																									
CH4	g/kg																								
N2O	g/kg																								

Notes:
Actity data were converted from fresh weight data using an assumed moisture content of 60%, as stated in Table 4.1 of Volume 5 Chapter 4 of the
2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories.

CRF_4.B.3.b

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[4. Waste][4.B Biological Treatment of Solid Waste][4.B.3 Treatment at MBT facilities with aerobic processing][4.B.3.b Non-local authority waste organic fraction]

[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual waste amount treated	kt dm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.06	0.15	4.15	7.08	5.01	2.94	33.90	17.82	1.74	15.69
Method																									
CH4		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
N2O		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
Emission factor information																									
CH4		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
N2O		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Emissions																									
CH4																									
Emissions	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.07	0.05	0.03	0.34	0.18	0.02	0.16
Amount of CH4 flared	kt	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N2O	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.01	0.00	0.01
Implied emission factor																									
CH4	g/kg																								
N2O	g/kg																								

Notes:
Actity data were converted from fresh weight data using an assumed moisture content of 60%, as stated in Table 4.1 of Volume 5 Chapter 4 of the
2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories.

CRF_4.B.4.a

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[4. Waste][4.B Biological Treatment of Solid Waste][4.B.4 Treatment at MBT facilities with anaerobic processing][4.B.4.a Local authority waste organic fraction]

[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual waste amount treated	kt dm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.49	3.12	1.78	1.32	2.95	10.19	17.43	24.66	31.90	63.80	62.82
Method																									
CH4		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
N2O		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
Emission factor information																									
CH4		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
N2O		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Emissions																									
CH4																									
Emissions	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.03	0.04	0.06	0.08	0.16	0.16
Amount of CH4 flared	kt	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N2O	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Implied emission factor																									
CH4	g/kg																								
N2O	g/kg																								

Notes:
Actity data were converted from fresh weight data using an assumed moisture content of 60%, as stated in Table 4.1 of Volume 5 Chapter 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories.

CRF_4.B.4.b

United Kingdom of Great Britain a GBR_2014_1_Inventory Thu Jun 19 12:27:07 CEST 2014

[4. Waste][4.B Biological Treatment of Solid Waste][4.B.4 Treatment at MBT facilities with anaerobic processing][4.B.4.b Non-local authority waste organic fraction]

[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual waste amount treated	kt dm	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.06	0.04	1.04	0.53	0.49	0.45	0.41	0.38	0.75	0.57
Method																									
CH4		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
N2O		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
Emission factor information																									
CH4		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
N2O		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Emissions																									
CH4																									
Emissions	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Amount of CH4 flared	kt	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N2O	kt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Implied emission factor																									
CH4	g/kg																								
N2O	g/kg																								

Notes:
Actity data were converted from fresh weight data using an assumed moisture content of 60%, as stated in Table 4.1 of Volume 5 Chapter 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories.

CRF_4.B.5.a

United Kingdom of Great Britain a	**GBR_2014_1_Inventory**	**Thu Jun 19 12:27:07 CEST 2014**																							
[4. Waste][4.B Biological Treatment of Solid Waste][4.B.5 Home composting][4.B.5.a Household food and greenwaste]																									
[5. Waste][5.B Biological Treatme	Unit	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Annual waste amount treated	kt dm	21.93	21.93	21.93	21.93	21.93	21.93	21.93	21.93	21.93	21.93	21.93	21.93	21.93	21.93	29.31	36.69	44.08	51.46	58.84	66.23	68.47	70.71	72.96	75.20
Method																									
CH4		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
N2O		T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1	T1
Emission factor information																									
CH4		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
N2O		D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D	D
Emissions																									
CH4																									
Emissions	kt	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.29	0.37	0.44	0.51	0.59	0.66	0.68	0.71	0.73	0.75
Amount of CH4 flared	kt	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
N2O	kt	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.05	0.06
Implied emission factor																									
CH4	g/kg																								
N2O	g/kg																								

Notes:
Actity data were converted from fresh weight data using an assumed moisture content of 60%, as stated in Table 4.1 of Volume 5 Chapter 4 of the 2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories.

Appendix 8: GHG emissions projections for biological Treatment of Solid Waste

The projection is based on the following assumptions:

- The source of organic waste to composting (including home composting) and anaerobic digestion facilities in the future will come from material that would otherwise report to the residual waste stream and that the development of additional treatment capacity is based on the assumption of increased availability of source-segregated feedstock.
- The starting point for estimating residual waste tonnages of organic waste (for the purposes of this exercise are defined as food and garden waste) are the tonnages of these wastes destined for landfill in 2012, according to the UK's landfill CH_4 emissions model, MELMod, for local authority and non-local authority waste.
- In addition to the residual waste stream for landfill, we have included estimates of garden and food waste sent to incineration. The tonnage of local authority waste incinerated in 2010 (3.98 Mt) was taken from a Defra report on incineration[62]. The tonnage of non-local authority waste was estimated at 3.32 Mt, assuming a total UK incineration capacity of 8.30 Mt and similar utilisation rate as for local authority waste).
- In addition, a further 2.515 Mt of residual waste was processed in 2012 through MBTs, as given in Table 8.
- The composition of waste sent to incineration and MBT was assumed to be the same as waste sent to landfill, the composition of which was taken from MELMod. The tonnages of garden and food waste were calculated on this basis.
- The underlying trend in garden waste from 2012 to 2035 is assumed to be zero change. There seems to be no reason to suspect either a significant increase or decrease in the production of this waste stream.
- On the other hand, food waste is directly proportional to the population. Estimates of food waste to 2035 were therefore based on a scaling up of the quantity in 2010 according to World Bank projection of the UK population to 2035.
- Recalling the likely ambitions of the European Union for a "circular economy" and "zero waste" aspirations and possible 70% recycling target by 2030, we have assumed that by 2035, an additional 75% of garden and food waste that would otherwise have reported to the residual waste stream will be source segregated for composting and anaerobic digestion. This figure is linearly interpolated from zero additional source segregation in 2012.
- We have assumed that all the green waste and about 17% of the food waste (based on estimates reported by WRAP[47]) will report to composting facilities[63]. The remaining 83% of the food waste will go to anaerobic digestion facilities.
- Of the remaining organic material that remains in the residual waste, we assume that by 2035 none goes to landfill and the rest is split evenly between incineration and MBT. The trends are linearly interpolated from the 2012 values of landfill (79.3%), incineration (18.8%) and the remaining 1.9% to MBT.
- We assume that the current split between MBTs with an aerobic or anaerobic biological stage remains the same as in 2012.
- The approach adopted for this assessment takes a top-down approach based on the assumption given above. It does not include any consideration of potential policy measures such as bans on the landfilling of organic materials[64], which would also

[62] Defra February 2013. Incineration of Municipal Solid Waste.
[63] Note that virtually all the food waste that goes to centralised composting facilities will be processed at In-Vessel composters.
[64] Landfill bans appear to have been ruled out by Defra, according to a press report in May 2014. http://www.mrw.co.uk/news/defra-rules-out-organic-landfill-ban/8662658.article. Accessed 13th October 2014.

affect the outcome and trend in the estimated projections. Nor does it include consideration of any distinct policy initiatives that may be implemented in the Devolved Administrations. Such issues should form part of a detailed waste sector-wide projection study.

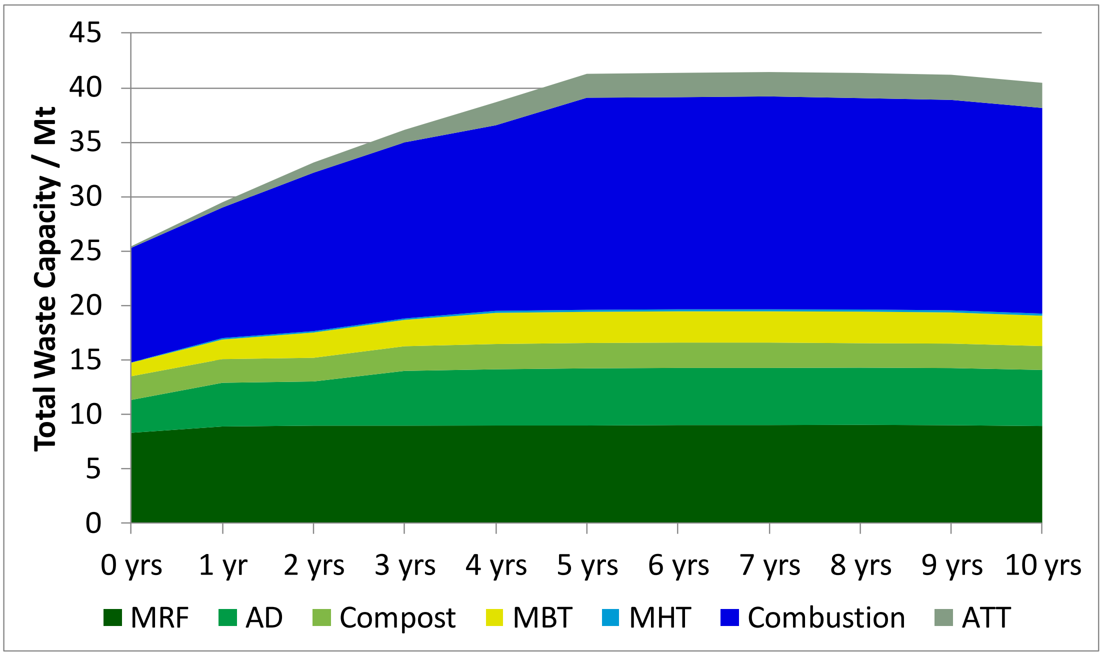
- In order to provide a ‘sense check’ of the projected trend used for estimating future GHG emissions from biological treatment, we have also compared the projection with the estimates of future waste treatment capacity predicted by Ricardo-AEA’s proprietary ‘FALCON’ database.

  The FALCON database estimates future treatment capacity based on an informed assessment of planned treatment plant projects, taking into account such factors as the likelihood of individual projects successfully progressing through planning, financing, development and commissioning to operation. As such, the projections contained in the FALCON database are based on assumptions regarding the success rate of individual projects at each stage of their development (i.e. it is assumed that only a small proportion of projects ‘on the drawing board’ will successfully become operational). Note that the FALCON database only projects for the next ten years (so, to 2024), because it only includes facilities that have been publically announced and assumes that, if a plant is going to be built, it will be completed within a period of ten years.

  The FALCON database suggests that biological treatment capacity (excluding windrow composting) might be expected to increase by 61% between 2014 and 2020 (see Figure below). Whilst the inclusion of composting capacity might be expected to increase the trend, it is considered likely that the majority of new treatment capacity will relate to anaerobic digestion and MBT technologies. The growth of 61% predicted by the FALCON database, this compares favourably to the projection used above, which represents an increase of 54% for the same period.

  Clearly, both of these projection are dependent on a number of assumptions so need to be treated with caution. However, the relatively similar rates of increase provide some additional confidence in the projections used for estimating GHG emissions from biological treatment. As highlighted above, we would recommend revisiting the projections on a sector-wide basis given the interactions between different forms of waste treatment and disposal.

Figure 11: Summary of Waste Treatment Capacity from FALCON Database



The results of the projection of emissions are summarised in the following tables.

Table 12: Projected activity data for organic waste.

Year	2010	2012	2015	2020	2025	2030	2035
Composting inc home composting	5.615	6.033	6.319	6.806	7.306	7.817	8.331
Anaerobic digestion	0.714	0.987	1.728	3.016	4.365	5.764	7.185
Landfill	9.430	7.934	6.312	3.969	2.107	0.769	0.000
Incineration	1.728	1.882	2.115	2.323	2.287	1.989	1.416
MBT	0.336	0.536	1.044	1.649	1.929	1.859	1.416
Totals	**17.824**	**17.372**	**17.518**	**17.763**	**17.994**	**18.197**	**18.348**

Table 13: Projected CH_4 emissions from biological treatment.

Gg CH_4/year

Year	**2010**	**2012**	**2015**	**2020**	**2025**	**2030**	**2035**
Composting inc home composting	22.461	24.131	25.275	27.225	29.226	31.266	33.325
Anaerobic digestion	0.714	0.987	1.728	3.016	4.365	5.764	7.185
Landfill							
Incineration							
MBT	1.1563	1.6612	3.2350	5.1086	5.9753	5.7567	4.3860
Totals	**24.332**	**26.779**	**30.238**	**35.350**	**39.566**	**42.787**	**44.896**

Table 14: Projected N_2O emissions from biological treatment.

Gg N_2O/year

Year	2010	2012	2015	2020	2025	2030	2035
Composting inc home composting	1.685	1.810	1.896	2.042	2.192	2.345	2.499
Anaerobic digestion	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Landfill							
Incineration							
MBT	0.0820	0.1125	0.2191	0.3459	0.4046	0.3898	0.2970
Totals	**1.767**	**1.922**	**2.115**	**2.388**	**2.597**	**2.735**	**2.796**

Table 15: Projected total GHG emissions from biological treatment.

Gg CO_2 eq/year

Year	2010	2012	2015	2020	2025	2030	2035
Composting inc home composting	1,064	1,143	1,197	1,289	1,384	1,480	1,578
Anaerobic digestion	18	25	43	75	109	144	180
Landfill							
Incineration							
MBT	53	75	146	231	270	260	198
Totals	1,135	1,242	1,386	1,595	1,763	1,885	1,956

Appendix 9: Estimation of fly-tipping

Table 16: Fly-tipping incidents recorded in England and Wales

Year	Single Black Bag	Single Item	Car Boot or Less	Small Van Load	Transit Van Load	Tipper Lorry Load	Significant / Multi Loads
2007/08	155,995	277,348	372,669	339,565	154,700	23,402	13,642
2008/09	159,673	212,330	358,669	319,292	126,831	20,554	9,785
2009/10	92,362	198,060	289,851	286,841	98,435	16,986	7,007
2010/11	76,342	165,694	252,097	264,391	85,659	16,763	4,906
2011/12	71,787	144,142	231,246	248,299	83,123	12,282	4,048
2012/13	75,297	128,317	216,660	234,781	81,294	12,293	5,165
Assumed weight (kg)	10	100	40	100	500	2,500	40,000

Table 17: Breakdown of residual waste landfilled and fly-tipping incidents by DA

Year	Residual waste landfilled % of total				Fly-tipping % of total			
	England	Scotland	Wales	NI	England	Scotland	Wales	NI
2007	78.4%*	11.8%*	5.7%*	4.1%*	80.6%	11.8%	3.5%	4.1%
2008	78.4%*	11.8%*	5.7%*	4.1%*	79.9%	11.8%	4.2%	4.1%
2009	78.4%	11.8%	5.7%	4.1%	79.5%	11.8%	4.6%	4.1%
2010	80.2%	9.8%	5.7%	4.3%	81.9%	9.8%	4.1%	4.3%
2011	78.8%	11.3%	5.5%	4.3%	79.4%	11.3%	4.9%	4.3%
2012	76.8%	12.1%	6.2%	4.8%	79.0%	12.1%	4.0%	4.8%

* Assumed to be the same as 2009

Table 18: Breakdown of residual waste fly-tipped (quantity), by DA

Year	Estimated quantity of material fly tipped (tonnes)			
	England	Scotland	Wales	NI
2007	732,000	107,000	28,000	37,000
2008	550,000	81,000	25,000	28,000
2009	412,000	61,000	21,000	21,000
2010	321,000	38,000	14,000	17,000
2011	267,000	38,000	16,000	14,000
2012	309,000	47,000	15,000	19,000

Table 19: Breakdown of waste fly-tipped (number of incidents), by DA

Year	Reported or Estimated number of incidents			
	England (Reported)	Scotland (Estimated)	Wales (Reported)	NI (Estimated)
2007	1,272,349	188,000	64,972	65,000
2008	1,152,422	170,000	54,712	58,000
2009	941,423	139,000	48,119	48,000
2010	823,979	98,000	41,873	43,000
2011	759,348	107,000	35,579	40,000
2012	719,871	110,000	33,936	44,000

Appendix 10: MELMod source category allocation for fly-tipped waste

Householder black bag waste

- Food: MELMod food waste
- Garden: MELMod garden + soil and other organic
- Paper MELMod Paper + Card
- Wood MELMod wood + combustibles + non-inert fines
- Textile MELMod textiles + 50% of furniture + 50% of mattresses
- Nappies MELMod nappies
- Plastics, other inert MELMod inert + 50% of furniture + 50% of mattresses

Commercial black bag waste

- Food: MELMod food & abattoir, food effluent, sewage sludge
- Garden: MELMod garden
- Paper MELMod Paper and card
- Wood MELMod wood + combustibles
- Textile MELMod textiles + 50% of furniture
- Nappies MELMod sanitary
- Plastics, other inert MELMod Other inert + 50% of furniture

Green waste was modelled as “Garden” waste, and animal carcasses were modelled using the same parameters as food waste.

Appendix 11: Degradable organic fraction values for fly-tipped waste

- Food waste 0.190
- Garden 0.174
- Paper 0.322
- Wood and straw 0.251
- Textiles 0.133
- Disposable nappies 0.086
- Sewage sludge 0.023

Appendix 12 – Estimated GHG emissions from open dumps and unmanaged landfill

Table 20: Calculated CH_4 emissions from open dumps and unmanaged landfill

Year	kT CH_4	kT CO_2 eq	kT CO_2 eq	kT CO_2 eq	kT CO_2 eq	kT CO_2 eq
	UK	UK	England	Scotland	Wales	NI
1990	3.87	81.4	66.0	9.6	2.5	3.3
1991	3.87	81.4	66.0	9.6	2.5	3.3
1992	3.87	81.4	66.0	9.6	2.5	3.3
1993	3.87	81.4	66.0	9.6	2.5	3.3
1994	3.87	81.4	66.0	9.6	2.5	3.3
1995	3.87	81.4	66.0	9.6	2.5	3.3
1996	3.87	81.4	66.0	9.6	2.5	3.3
1997	3.87	81.4	66.0	9.6	2.5	3.3
1998	3.87	81.4	66.0	9.6	2.5	3.3
1999	3.87	81.4	66.0	9.6	2.5	3.3
2000	3.87	81.4	66.0	9.6	2.5	3.3
2001	3.87	81.4	66.0	9.6	2.5	3.3
2002	3.87	81.4	66.0	9.6	2.5	3.3
2003	3.87	81.4	66.0	9.6	2.5	3.3
2004	3.87	81.4	66.0	9.6	2.5	3.3
2005	3.80	79.7	64.6	9.4	2.4	3.2
2006	3.57	75.0	60.8	8.9	2.3	3.0
2007	3.26	68.5	55.5	8.1	2.1	2.8
2008	2.41	50.7	40.8	6.0	1.9	2.1
2009	1.88	39.6	31.6	4.7	1.6	1.6
2010	1.42	29.8	24.6	2.9	1.1	1.3
2011	1.27	26.6	21.2	3.0	1.3	1.1
2012	1.48	31.1	24.7	3.8	1.2	1.5
2013	1.48	31.1	24.7	3.8	1.2	1.5
2014	1.48	31.1	24.7	3.8	1.2	1.5
2015	1.48	31.1	24.7	3.8	1.2	1.5
2016	1.48	31.1	24.7	3.8	1.2	1.5
2017	1.48	31.1	24.7	3.8	1.2	1.5
2018	1.48	31.1	24.7	3.8	1.2	1.5
2019	1.48	31.1	24.7	3.8	1.2	1.5
2020	1.48	31.1	24.7	3.8	1.2	1.5
2021	1.48	31.1	24.7	3.8	1.2	1.5
2022	1.48	31.1	24.7	3.8	1.2	1.5
2023	1.48	31.1	24.7	3.8	1.2	1.5
2024	1.48	31.1	24.7	3.8	1.2	1.5
2025	1.48	31.1	24.7	3.8	1.2	1.5
2026	1.48	31.1	24.7	3.8	1.2	1.5
2027	1.48	31.1	24.7	3.8	1.2	1.5
2028	1.48	31.1	24.7	3.8	1.2	1.5
2029	1.48	31.1	24.7	3.8	1.2	1.5
2030	1.48	31.1	24.7	3.8	1.2	1.5
2031	1.48	31.1	24.7	3.8	1.2	1.5
2032	1.48	31.1	24.7	3.8	1.2	1.5

Year	kT CH_4	kT CO_2 eq	kT CO_2 eq	kT CO_2 eq	kT CO_2 eq	kT CO_2 eq
	UK	UK	England	Scotland	Wales	NI
2033	1.48	31.1	24.7	3.8	1.2	1.5
2034	1.48	31.1	24.7	3.8	1.2	1.5
2035	1.48	31.1	24.7	3.8	1.2	1.5

Appendix 13 – Summary of consultees for industrial wastewater data

Table 21: Summary of Industrial Wastewater Data Sources and Consultees

Data Sources Review	Consultees
• Other reporting parties • EU Commission BAT reference documents • Office for National Statistics • Department for Business, Innovation and Skills • UNFCCC and IPCC • UK Water Industry Research • Waste Resources Action Programme (WRAP) • Anaerobic Digestion and Biogas Association	• The Chemical Industries Association • The Food and Drink Federation • The Scotch Whisky Association • Severn Trent Water • The Environment Agency • Northern Ireland Environment Agency • Natural Resources Wales • Scottish Environmental Protection Agency

Appendix 14 - Comparative data for other countries (industrial wastewater)

Table 22: Industries for which estimates of activity have been made

Australia	**Canada**	**Germany**	**USA**
Food & beverage: Beer Dairy processing Fruit Meat & poultry Sugar Vegetables Wine	Food & beverage	Food & beverage	Food & beverage: Fruit, vegetables & juices Meat & poultry
Paper and pulp	Paper and pulp	Paper and pulp	Paper and pulp
Organic chemicals	Chemicals/chemical products	Chemicals	
	Petroleum & coal products		Petroleum refining
	Plastic products		
	Rubber products		
	Textiles		
		Iron and steel	
			Ethanol milling

Note: no information is available for France

Appendix 15 – Office of National Statistics production data

Table 23: ONS index of production selected sectors (2009-12)

Sector	2009	2010	2011	2012
Milk-processing	94	100	109	110.9
Manufacture of fruit and vegetable products	100	100	88.2	82.1
Potato-processing	100	100	88.2	82.1
Meat industry	88	100	98	99.5
Breweries	92	100	133.3	116.1
Production of alcohol and alcoholic beverages	92	100	133.3	116.1
Manufacture of animal feed from plant products	97	100	102	96.5
Manufacture of gelatin and of glue from hides, skin and bones	100	100	100	100
Malt-houses	92	100	133.3	116.1
Fish-processing industry	94	100	103.7	104.2
Chemical Industry	104	100	105.7	99.5

Appendix 16: Industrial sector discharges not to sewer in the UK

Table 24: Industrial sector discharges to sewer

INFOBOX

Table of industrial sector discharges not to sewer in the UK

Industrial sector	Total organic load (in PE)	Number of plants	Total organic load meeting required standards at 31.12.2000 (in PE)	Full compliance
Milk-processing	1,464,380	30	644,880	Dec-2003
Manufacture of fruit and vegetable products	1,144,564	9	1,144,564	Dec-2000
Manufacture and bottling of soft drinks	–	–	–	–
Potato-processing	302,037	3	302,037	Dec-2000
Meat industry	623,348	18	573,348	Dec-2001
Breweries	94,000	1	94,000	Sep-1997
Production of alcohol and alcoholic beverages	1,930,727	23	1,930,727	Dec-2000
Manufacture of animal feed from plant products	476,000	3	476,000	Dec-2000
Manufacture of gelatin and of glue from hides, skin and bones	13,315	1	13,315	Dec-2000
Malt-houses	206,666	9	206,666	Dec-2000
Fish-processing industry	18,000	2	5,000	Feb-2001
Total	**6,273,037**	**99**	**5,390,537**	

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