Problems in the Reporting of GHG Emissions from 'Waste': Indicators and Inventories

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Executive Summary

E.1.0 What are the GHG Emissions from Waste?

E.1.1 Defra's Indicator

The indicator being used by Defra to track greenhouse gas emissions from waste is '*GG1. Territorial greenhouse gas emissions from waste management.*' GG1 is one of a number of indicators that have been developed which, in general terms, may be considered quite progressive.[1]

GG1 excludes emissions from incineration where the facility generates energy. A number of observers have asked why that is the case. After all, as is shown in Figure E - 1, emissions from incineration where energy is generated have risen from close to zero to more than 5 million tonnes CO_2e over the 1990-2019 period, with the majority of the increase happening in the last ten years.

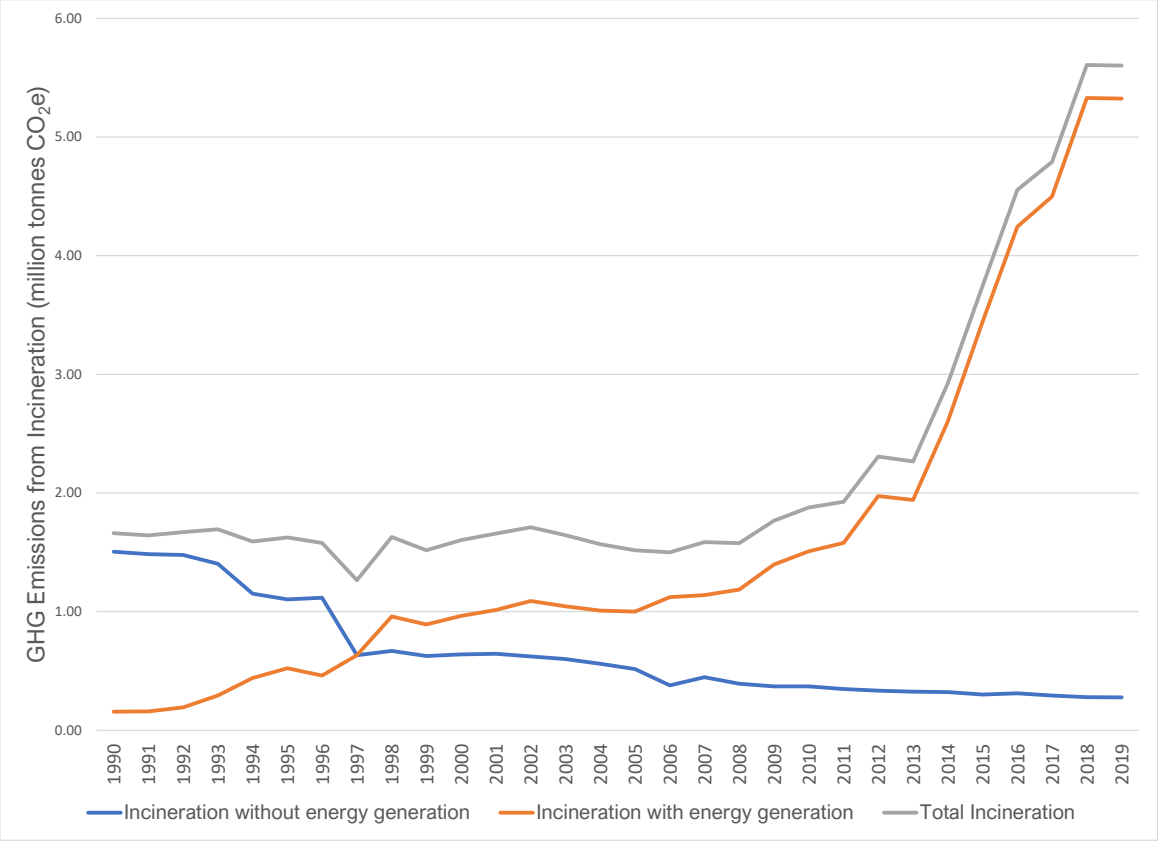
The indicator The Defra indicator uses the emissions of greenhouse gases which are reported under the 'waste' category in the National Atmospheric Emissions Inventory.

E.1.2 Guidelines and Inventories – the UN Influence

At the root of the answer to the question is the way in which the IPCC, as a body working to advise the UNFCCC, has formulated Guidelines for Parties to the UNFCCC to report their emissions of greenhouse gases. Under these Guidelines, the emissions are effectively apportioned across a range of categories. These include 'energy', 'industrial production and product use' (IPPU) and 'waste'.

[1] A feature of indicators is that sometimes, it's only once the information conveyed by a particular specification of an indicator has been reviewed that it becomes clear how that same indicator might be enhanced so as to convey more meaningful information. Some of the Defra indicators look as they might be improved through some fairly simple changes.

Figure E - 1: Evolution in GHG Emissions from Incineration in the UK, 1990-2019



Source: data are taken from the Climate Change Committee's 'Charts and Data Behind the 6th Carbon Budget Reports.

The decision was made when the Guidelines were first issued, in the mid-1990s, to assign the emissions from incinerators to the 'waste' category only in cases where no energy was generated from the process of incinerating of the waste. In cases (now, true for the majority of waste being incinerated) where energy is generated, the Guidelines specified that emissions from incinerators should be reported under the 'Energy' category. This may have reflected the fact that when the IPCC Guidelines, and approaches to reporting inventories, were first formulated, they seem to have taken, as their starting point, the already existing (at the time) system of reporting energy statistics to the IEA.

The UK's NAEI understandably follows IPCC conventions (and GHG emissions are reported in Tables using what is known as the 'common reporting format'). It follows that the Defra indicator does not include emissions from incineration where the facilities generate energy (in other words, the vast majority of UK incineration), since the NAEI follows IPCC Guidelines, and reports these under the 'energy' section.

E.2.0 Waste Sector Emissions – the UK's Climate Change Committee

In its recent Waste Sector report, the Climate Change Committee (CCC) recognised the counter-intuitive nature of this, and included, in its reporting of emissions from the waste sector, the estimated emissions from incineration. Whilst this is welcome, the fact remains that the reporting of emissions related to waste, as considered by the CCC, still give an incomplete view of the potential for the waste sector to drive reductions in emissions.

Accepting the broad approach of reporting *territorial* emissions from what happens in the UK, the remaining shortcomings relate to:

- the way in which the effects of recycling are reported, following IPCC Guidelines, a matter I have dealt with previously with former colleagues in other publications.[2] In short, the effects of recycling on territorial emissions materialise largely (if at all[3]) in the Industrial Production and Product Use (IPPU) category of the inventory;
- the way in which the time-limited sequestration of carbon in soils, associated with the land application of waste-derived soil improvers, impacts on inventories is dealt with in the inventories; and
- the fact that, in the absence of reporting emissions from direct measurements (which would be an option for incineration), there is no attempt to model, in the dynamic sense, the GHG emissions from landfill or incineration through reference to what is sent to those management methods. It follows that the NAEI's reporting of emissions from incineration under the energy section might not be expected to be especially accurate.

Other issues related to the accuracy of emissions reporting for biological treatment remain relevant.

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[2] See, for example, D. Hogg and A. Ballinger (2015) *The Potential Contribution of Waste Management to a Low Carbon Economy*, Main Report, prepared by Eunomia for Zero Waste Europe.

[3] This follows from the fact that it is territorial emissions which are being reported. If materials are being exported for recycling, and if there is no change in the domestic production of materials as a result of increasing recycling, then there will be no change in the territorial emissions being reported.

Also, the fact that only territorial emissions are being reported also means that emissions associated with, for example, incineration of waste that is exported to other countries fall outside the UK inventory.

E.3.0 Does any of this matter?

These issues mean that the reporting of GHG emissions from 'waste' under the existing inventories is both disjointed and misleading. There is a very large difference between '*the effect on climate change of managing waste*', and '*emissions of greenhouse gases reported under the waste category*'. Whilst some, by no means all, of these effects are 'picked up' in other parts of the inventory, the picture is rendered opaque. If rational decisions are to be made regarding the best way to mitigate climate change through improved management of waste, this demands a level of understanding from those coming to the issue anew which they simply may not have. There is plenty of evidence to suggest that this level of understanding is far from widespread.

Indicators and inventories might, respectively, be expected to pass the following tests:

- Where indicators are chosen as a means to highlight the extent to which 'progress' is being / has been made, movement in those indicators should be expected to reflect progress in the outcomes the indicator was intended to track; and
- The agreed configuration of inventories designed to support delivery of the objectives of the UNFCCC should meet both a 'structural' and a 'quantitative' test. The former would require that inventories are structured in such a way that they support rational decision making. This may mean that items that are recorded for the purpose of accounting in one part of an inventory are reported, though not counted, in other parts of the inventory precisely so as to avoid potentially misleading perspectives. The quantitative test would require that when emissions reported under national inventories increase or decline, this should translate into a parallel increase, or a reduction, in global emissions. If this is not the case, then countries may either a) meet their own objectives at the expense of increases in emissions in other countries; and b) avoid, or deprioritize, taking

actions which have no effect on their own reported emissions but which are beneficial on a global level. Both are counterproductive.[4]

Defra's indicator GG1 fails the indicator test. It is the wrong indicator. It does not include emissions from incineration. It ignores the beneficial impact (to the planet, if not always to the national inventory) of recycling. It is completely indifferent, for example, as to whether plastics are incinerated to generate electricity, or recycled in closed loops. Currently, the difference in these management routes amounts to around 4 tonnes CO_2e per tonne of plastic. If an indicator of the climate change impacts of waste is to be at all useful, it cannot be indifferent to such impacts, and hence, to such choices.

It is not actually clear what it is that GG1 is intended to be an indicator of. It does not give a clear indication of the impact of waste management on climate change. That might be acceptable if other indicators in the set 'compensated' for this shortcoming, but there is none in the overall set. Indeed, the figures presented for 'waste landfilled' as part of indicator WD1 ('*waste landfilled or incinerated*') are closely matched, as one would expect, with GG1. It is unclear what GG1, in its current form, adds.

Since GG1's flawed formulation is itself linked to the existing reporting system, we suggest that this itself is *a* (by no means, *the best*) reason to conclude that the inventories fail the structural test. After all, the indicator seems to be evidence of the fact that the inventory is apt to mislead, and this is also reflected in the design of some of the tools which have been developed to inform solid waste management decision-making in developing countries. These focus almost exclusively on the reduction of the (mainly methane from landfills) emissions reported under the waste section of the inventory.

Inventories fail the quantitative test also. Improvements in inventories can be gained by, for example, exporting waste for incineration rather than incinerating it in the country reporting. Emissions being reported may be increased by increasing the in-country production of materials from recycled

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[4] This may incline one to the view that consumption-based inventories have more to recommend them than the territorial ones currently being reported in inventories. The difference, for the UK, would be quite profound. Depending on the data being presented, consumption-based emissions may be 50-75% higher that territorial ones (see Defra (2021) UK's Carbon Footprint 1997 - 2018, and BEIS (2021) *2019 UK Greenhouse Gas Emissions, Final Figures*, 2 February 2021; in the former, consumption emissions are around 50% more than territorial ones, whilst the figure is higher in the latter document, exceeding 75%).

inputs where they would otherwise have been imported as primary materials, even though the effect is to reduce global emissions. More perniciously, illegal exports of waste may have a beneficial impact on a country's inventory. If countries are to pursue their own targets with vigour, it will be unwise to maintain such a state of affairs.

E.4.0 Recommendations

Defra is obviously well-placed to make changes to the indicators it has chosen to reflect whatever it was intending the indicators should demonstrate. It is also well-placed to improve the accuracy of the reporting of emissions from the management of waste in England.

It is, furthermore, well-placed, currently, to initiate a process designed to correct some of the problems with the existing Guidelines for reporting greenhouse gas emissions and the associated inventories. It will be as well to do this sooner rather than later in parallel with the development of mechanisms that will make country signatories' commitments more binding in their nature in future.

Following our review, we recommend:

1) That Defra changes the scope of the indicator GG1 such that it becomes a suitable measure of performance of the waste management sector in respect of climate change. GG1 does not even achieve what its subtitle claims (there are territorial emissions from waste management which fall outside the indicator). There should be no need to tie this to greenhouse gas inventories reported to UNFCCC (and to restrict to territorial emissions). Other indicators included in the complete set are a) relevant to climate change, but b) not linked to the reporting of the inventory (such as GG2 and GG3) The indicator should, preferably, be such that it clearly tracks the impact of better management of waste from the perspective of global climate change;
2) That, using its role as Chair of COP26, the UK should initiate a review of the IPCC Guidelines and inventories used to report emissions to the UNFCCC. There are two approaches that might follow from this report:
    a. Look, specifically, at the way in which emissions from managing waste are reported under the 'waste' category. In doing so, it could (amongst other things) re-assign incineration with energy generation to the 'waste' category; consider

approaches to account for time-limited sequestration of non-fossil CO_2 in soils; and encourage reporting of reductions in emissions associated with recycling under the waste category, even if only as memorandum items;

b. Undertake a more fundamental review of the IPCC Guidelines and the reporting of emissions in the context of elaborating how it would be determined when a country had achieved 'net-zero', and whether the associated emissions reduction pathways were adequate. There is a need to set countries on the right path, with an inventory system that conveys 'the right signals'. GG1 has, as its relevant '*target/ambition/commitment: Legislative target within the Climate Change Act (2008), since updated with the aim of achieving net zero emissions by 2050 on a territorial basis*.' The misalignment between 'territorial emissions' and the fundamental objective (as expressed at Article 2) of the UNFCCC deserves to be addressed so that policy makers are not encouraged to pursue actions which are counterproductive, or which could have been far more productive, when considered from a global perspective. We will be preparing a separate report in relation to this broader issue.[5]

We note, in passing, that the inventories have not changed radically since the mid-1990s, a time when, had the world acted with a modicum of urgency, the issue of climate change could have been largely addressed by now (consider that since the early 1990s, annual global emissions of carbon dioxide have risen by around 60%, and that something close to a trillion tonnes of carbon dioxide have been emitted, giving rise to a further 0.4 degrees C or so of warming). That time has passed, and if the world is now to respond with the requisite urgency, it simply will not do to have countries making commitments, and reporting performance against these using outdated metrics and approaches that are no longer adequate to guide parties to make the best decisions for the future of mankind and other species.

[5] We welcome interest from others in this regard. Input from climate scientists and academics with an interest in these matters would be incredibly valuable.

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Report by:
Dr Dominic Hogg, Equanimator.

Citation:
D. Hogg (2022) Reporting of GHG Emissions from 'The Waste Sector': Problems with the Status Quo, Equanimator Report, February 2022.

1.0 Introduction

In November 2021, Defra published the Second Edition of its report monitoring progress on implementation of the Resources and Waste Strategy (RWS).[6] The report updates performance against a range of indicators which were set out in the RWS as the basis for tracking progress towards meeting objectives contained therein.[7] The set of indicators that were developed include some ground-breaking indicators in an attempt to highlight how the UK is doing in terms of improving resource efficiency and the management of wastes.

One of the indicators that is used for progress monitoring is 'GG1. Territorial greenhouse gas emissions from waste management'. In the latest publication, the emissions for 2019 are reported as follows:[8]

> *In 2019, the waste management sector in England generated an estimated 15.6 million tonnes CO_2e ($MtCO_2e$) of greenhouse gas emissions, 71.1% less than the equivalent figure in 1990 (53.9 $MtCO_2e$). Total emissions were at a similar level in 2019 to 2018.*

The report then goes on to say:

> *These figures exclude recycling and incineration with energy from waste (EfW), as these recovery processes are not considered waste management for the purposes of the National Atmospheric Emissions Inventory.*

Citing the Climate Change Committee's (CCC's) work on waste[9], it then states, '*The greenhouse gas emissions from EfW were around 6.2 $MtCO_2e$ in 2019.*"

A number of commentators have expressed surprise at the omission of emissions from 'incineration with energy from waste and recycling' from an

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[6] See Defra (2021) *Resources and Waste Strategy: Monitoring Progress*, Second Edition, November 2021.

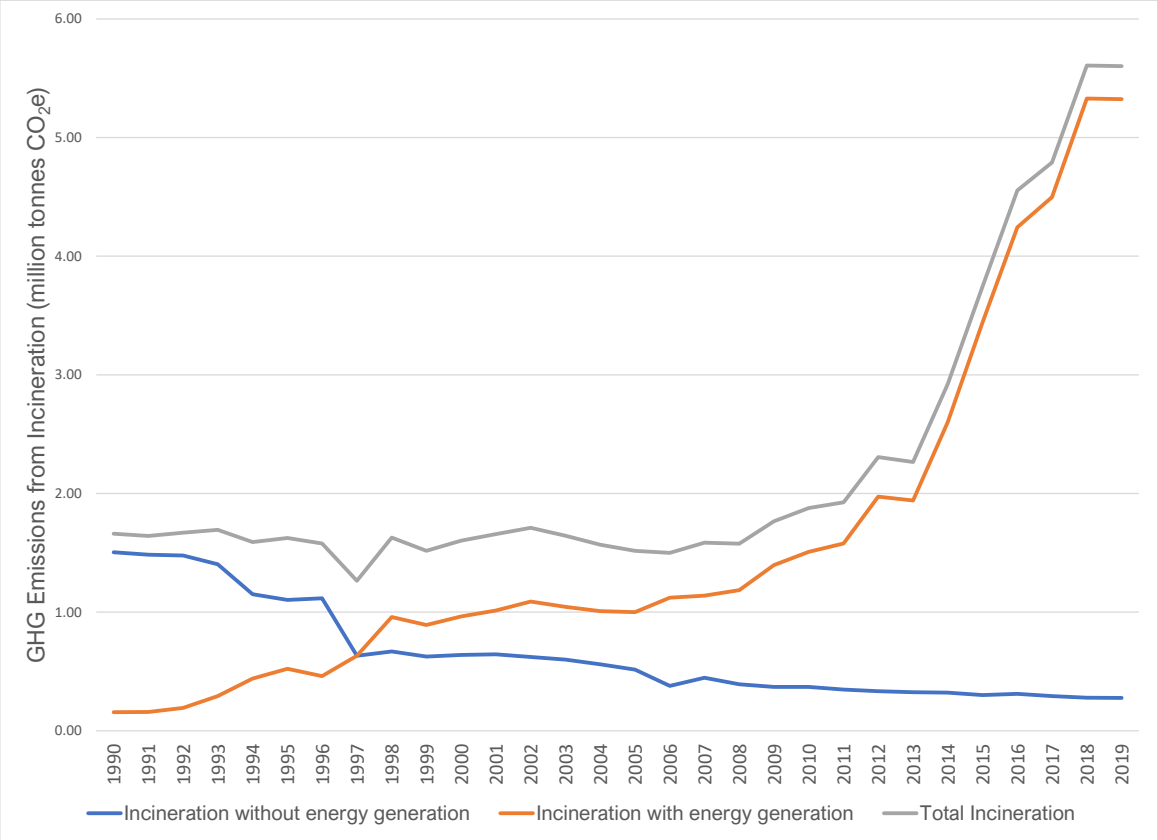
[7] See Chapter 8 in HM Government (2018) *Our Waste, Our Resources: A Strategy for England*, London: Defra.

[8] See Defra (2021) *Resources and Waste Strategy: Monitoring Progress*, Second Edition, November 2021, p.12

[9] Climate Change Committee (2020) *The Sixth Carbon Budget: Waste*,

indicator of this nature, and have queried the basis for them. This led, in turn, to questions as to the basis for these omissions, and indeed, whether it makes sense to make such omissions. After all, as is shown in Figure 1, emissions from incineration where energy is generated have risen from close to zero to more than 5 million tonnes CO2e over the 1990-2019 period, with the majority of the increase happening in the last ten years. Those concerns are what this paper sets out to explore and address. Regarding GG1, the issue is whether this indicator is helpful; if the indicator is intended to track some aspect of performance, does it do its job?

Figure 1: Evolution in GHG Emissions from Incineration in the UK, 1990-2019



Source: data are taken from the Climate Change Committee's 'Charts and Data Behind the 6th Carbon Budget Reports.

2.0 Background

It seems surprising, to many professionals involved in considering matters of sustainable production and consumption, and / or in the management of products, materials and packaging when they arise as 'wastes', that such matters receive relatively scant treatment in global discussions regarding mitigation of climate change. After all, reports indicate that the proportion of global GHG emissions associated with producing food and the materials from which we make 'stuff' are around 50% of the annual total of emissions, insofar as we have a clear picture of these. Work by Eunomia highlights the potential impact, globally, of better management of waste,[10] whilst recent work undertaken on behalf of WRAP highlights the potential benefits of improved resource efficiency.[11]

Nonetheless, policymakers can be routinely heard indicating that 'waste' is responsible for a trifling proportion of overall climate change emissions.[12] In some jurisdictions, these are reported as having sharply declined, so not only is this proportion reportedly small, but it is also reported to be in

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[10] Eunomia (2021) Waste in the Net-Zero Century: How Better Waste Management Practices Can Contribute to Reducing Global Carbon Emissions, May 2021.

[11] Norman, J., Barrett, J., Betts-Davies, S., Carr-Whitworth, R., Garvey, A., Giesekam, J., James, K., Styles, R. and Scott, K. (2021) *Resource efficiency scenarios for the UK: A Technical Report*. Centre for Research into Energy Demand Solutions. Oxford, UK

[12] Globally, the quantity reported under the waste section of inventories as reported to the UNFCCC amount to around 3% of global emissions as they are currently being assessed (see Climatewatchdata.org, based on CAIT data). The same (3%) figure applies to emissions reported at the EU level (see EEA (2021) *Annual European Union greenhouse gas inventory 1990-2019 and inventory report 2021: Submission to the UNFCCC Secretariat*, 27 May 2021), whilst in the UK, the figure is 4% (see Brown P, Cardenas L, Choudrie S, Del Vento S, Karagianni E, MacCarthy J, Mullen P, Passant N, Richmond B, Smith H, Thistlethwaite G, Thomson A, Turtle L, Wakeling D (2021) *UK Greenhouse Gas Inventory, 1990 to 2019: Annual Report for submission under the Framework Convention on Climate Change*, April 2021.. These emissions are assessed as 'CO_2 equivalent' based on global warming potentials over a 100 year period (GWP100) which assign a weighting to methane emissions (relative to CO_2) of 25. This follows a Decision made at COP19 in 2013. It seems bizarre that the basis for 'summing' contributions to global warming have not changed since then, despite well-articulated shortcomings of this approach (and even under the same approach, the 'vintage' of those figures).

fairly steep decline. The question that arises is what do the 'emissions from waste' that are being discussed actually cover?

In Defra's GG1 indicator, the breakdown of contributing sources is shown in Table 1. The report references the National Atmospheric Emissions Inventory (NAEI) as the basis for what it chooses to include, or not to include, under the indicator.

Table 1: Territorial greenhouse gas (GHG) emissions from the waste management sector, England, 1990 to 2019, million tonnes carbon dioxide equivalent ($MtCO_2e$)

Year	Landfill	Waste-water handling	Composting	Incineration (without EfW)	Anaerobic digestion	Total
1990	50.0	2.5	0	1.3	0	53.9
1995	52.4	2.5	0.2	1.0	0.0	56.0
2000	46.9	2.6	0.3	0.6	0.0	50.3
2005	36.0	2.0	0.5	0.5	0.0	38.9
2010	19.6	2.2	0.9	0.3	0.0	23.0
2015	11.7	2.2	1.3	0.3	0.1	15.6
2016	11.1	2.1	1.3	0.3	0.2	15.0
2017	11.4	2.2	1.4	0.3	0.2	15.5
2018	11.6	2.2	1.4	0.3	0.2	15.6
2019	11.5	2.2	1.4	0.3	0.2	15.6

Source: Defra (2021) Resources and Waste Strategy: Monitoring Progress, Second Edition, November 2021

The NAEI, however, especially as regards greenhouse gas emissions, is largely structured in line with what is required for the UK to fulfil its

reporting obligations to the United Nations Framework Convention on Climate Change (UNFCCC). The NAEI website states:[13]

> *The National Inventory System (NIS) is a requirement of the GHG Inventory only. However, the benefits of the system apply to the AQ inventory also. The Marrakesh Accords of the Kyoto Protocol (Decision 20/CP7) define the requirements for National Inventory Systems (NIS), including the need to establish legal, procedural and institutional arrangements to ensure that all parties to the Protocol estimate and report their GHG emissions in accordance with relevant decisions of the COP, facilitate UNFCCC Reviews and improve the quality of their inventories. Under related EU legislation set out in Decision 280/2004/EC, the UK was required to have in place it's NIS by 31st December 2005.*

It follows that the choice as to what to include or not to include in the GG1 indicator is less a matter determined by the NAEI, but rather, by extension, one which is determined by decisions in relation to the requirements established by the UNFCCC.

2.1 The UNFCCC – Inventories and Reporting Guidelines

The United Nations Framework Convention on Climate Change (UNFCCC) was drafted in 1992.[14] Through the Convention, and Decisions made at various Conferences of the Parties (COPs), the UNFCCC has effectively entrusted to the Intergovernmental Panel on Climate Change (IPCC) the task of developing guidelines, and linked methodologies, for developing inventories of greenhouse gas emissions, covering sources and removals by sinks of greenhouse gases.[15] The *IPCC Guidelines for National Greenhouse Gas Inventories* were first accepted in 1994 and were published in 1995.

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[13] https://naei.beis.gov.uk/about/national-inventory-system

[14] United Nations (1992) *United Nations Framework Convention on Climate Change*, https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf

[15] The IPCC was established in 1988 by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). It aimed to provide governments at all levels with scientific information that they can use to develop climate policies. The IPCC also developed a National Greenhouse Gas Inventories Programme, which was managed from 1991 by the IPCC's Working Group I in close collaboration with the Organisation for Economic Co-operation and Development (OECD) and the International Energy Agency (IEA). This remained the case until its transfer to the IPCC's Task Force on National Greenhouse Gas Inventories (TFI) based in Japan in 1999.

The UNFCCC's COP3, held in 1997 in Kyoto, then confirmed that the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* should be used as "*methodologies for estimating anthropogenic emissions by sources and removals by sinks of greenhouse gases*" in the calculation of legally binding targets during what was known as the first commitment period. This was referenced in the Kyoto Protocol (Article 5.2).

Decisions have been made at subsequent COPs to reaffirm the commitment to the Guidelines, as revised and updated. Major updates to the Guidelines were undertaken in 2006, and a further refinement was made in 2019. However, the structure and form of inventories has not been radically altered since the mid-1990s.

3.0 Emissions from Waste in the Inventories

In this Section, we consider some key issues in the inventory in relation to waste management (and other matters). There have been three main iterations to the IPCC Guidelines for developing GHG Inventories. These have been the originally agreed version, albeit most readily available as the Revised 1996 Guidelines, the 2006 Guidelines, and the 2019 Refinement of the 2006 Guidelines. There have been other updates and refinements for, especially, emissions and reporting in relation to land use and land use change and forestry, as well as wetlands, but in the main, the three iterations mentioned provide the relevant information, especially as regards the management of waste, although there are relevant links to the land use change and forestry sectors that this author has considered previously elsewhere, but which we do not consider in this report.[16]

3.1 What is the Scope of Emissions from 'Waste'?

In the Revised 1996 Guidelines, the Waste Chapter of the Reference Manual stated:[17]

> *Disposal and treatment of industrial and municipal wastes can produce emissions of most of the important greenhouse gases (GHG). Solid wastes can be disposed of through landfilling, recycling, incineration or waste-to-energy. This chapter will deal with emissions resulting from landfilling of solid waste, treatment of liquid wastes and waste incineration. Greenhouse gas emissions from waste-to-energy, where waste material is used directly as fuel or converted into a fuel, should be calculated and reported under the Energy Chapter.*

This is the only mention in the Chapter of 'recycling'. The Chapter makes no reference to composting, or anaerobic digestion, or mechanical biological

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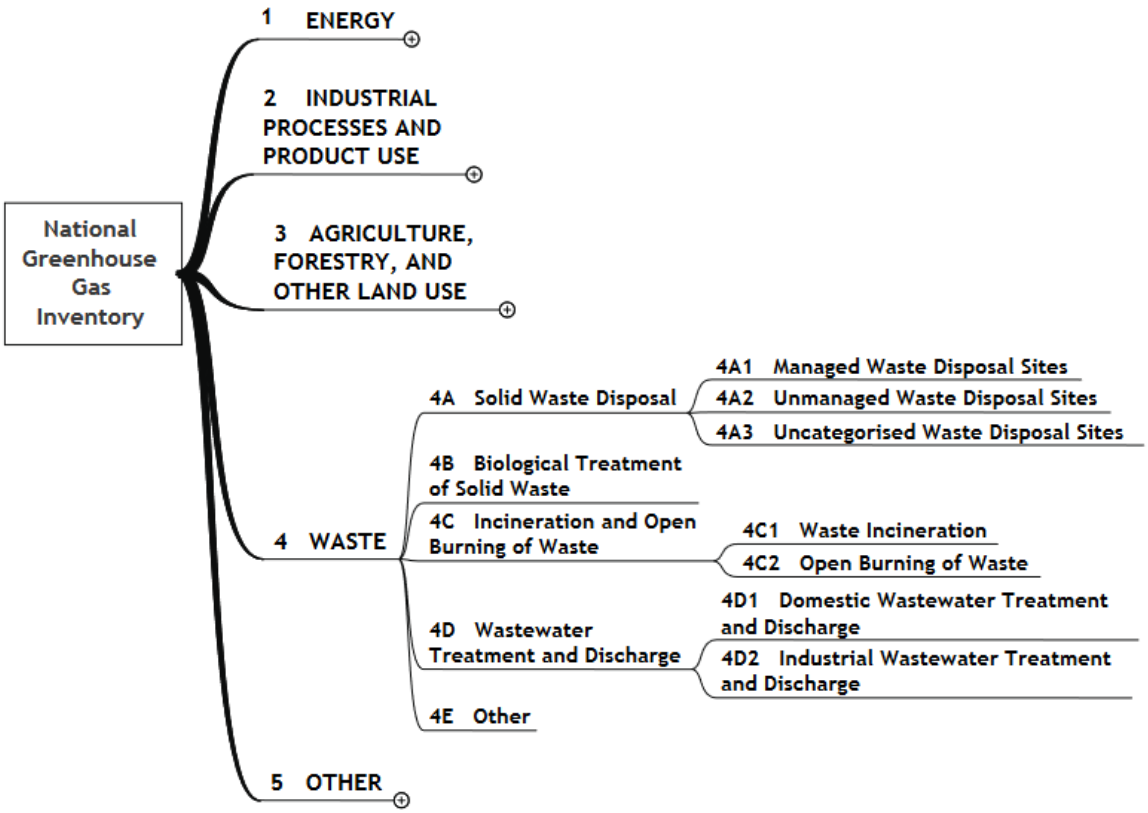
[16] See D. Hogg and A. Ballinger (2015) *The Potential Contribution of Waste Management to a Low Carbon Economy*, Main Report, prepared by Eunomia for Zero Waste Europe.
[17] IPCC (1997) *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual (Volume 3). Waste*, https://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch6ref1.pdf

treatment insofar as solid waste was concerned. Composting and digestion were mentioned in relation to sludge treatment under the section on 'Wastewater Handling'.

Where solid wastes were concerned, if incinerators were generating energy, then the only emissions considered were those from 'solid waste disposal sites' (SWDSs).

In the 2006 Guidelines, Chapter 1 of Volume 5 regarding 'Waste', the Introduction to the Waste source category, includes a Figure setting out the 'Structure of Waste Sector'. This is shown as Figure 2 below.

Figure 2: Outline of the Waste Sector



Source: IPCC (2007) 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste, IPCC, Switzerland.

Compared to the 1996 Revised Guidelines, the additional items included were 'Biological Treatment of Solid Waste' and 'Open Burning of Waste'. The Figure is still, though, intriguing more for its omissions than for what it includes. Those who appreciate how improvements in waste management can contribute to climate mitigation understand that a key contribution comes from recycling. In Figure 2, there is no reference to 'recycling' as

part of the 'Waste Sector'. Indeed, the Introduction Chapter to the Waste Section makes no reference to recycling at all.

Chapter 2 of the Waste Section does provide more information:[18]

> *Solid waste management practices include: collection, recycling, solid waste disposal on land, biological and other treatments as well as incineration and open burning of waste. Although recycling (material recovery) activities will affect the amounts of waste entering into other management and treatment systems, the impact on emissions due to recycling (e.g., changes in emissions in production processes and transportation) is covered under other sectors and will not be addressed here in more detail.*

Box 2.1 adds:

> *Recent growing recognition of the need for resource conservation and environmental protection has increased solid waste recycling and treatment before disposal in developed countries. In developing countries, recovery of valuable material at collection, during transportation and at SWDSs has been common.*

There was no explicit mention of the possible contribution that recycling might make to overall emissions of greenhouse gases, whether or not these were to be reported under the Waste Section, or indeed, anywhere else in the inventory.

The 2019 Refinement to the 2006 Guidelines concentrated mainly on updating various parameters and default values for waste generation, waste composition[19] and the modelling of landfill emissions, as well as on providing new information on '*Pyrolysis, gasification and plasma as new technologies for treating solid wastes*' (these were not included in the 2006 Guidelines). Somewhat surprisingly, given the sketchy nature of the 2006 Guidelines in this regard, no attempt was made to update the state of knowledge in relation to biological treatment, notwithstanding the

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[18] Page 2.4 in Chapter 2: Waste Generation, Composition and Management Data, in IPCC (2007) *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste*, IPCC, Switzerland, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf

[19] At least as regards these two aspects, many of these parameters, whilst they are no doubt designed to be helpful, are of dubious provenance and value, and some are almost certainly out of date as soon as they are published.

considerable amount of research effort devoted to understanding better the emissions from these processes in the intervening years.

The status of recycling was unchanged. In the Refinement to the Guidelines, it is stated:[20]

> *Although recycling (material recovery) activities will affect the amounts of waste entering into other management and treatment systems, the impact on emissions due to recycling (e.g., changes in emissions in production processes and transportation) is covered under other sectors and will not be addressed here in more detail.*

In summary, the scope of the Waste section of the inventory does not lead to reporting on emissions from 'waste management', and reporting on these emissions as though they represent the sum total of emissions linked to management of waste is rather misleading.

3.2 How are Emissions from Incineration (and Other Thermal Treatment) Reported?

3.2.1 Revised 1996 Guidelines

The revised 1996 IPCC Guidelines, published in 1997, state, as regards the chapter on 'Waste': [21]

> *This chapter will deal with emissions resulting from landfilling of solid waste, treatment of liquid wastes and waste incineration. Greenhouse gas emissions from waste-to-energy, where waste material is used directly as fuel or converted into a fuel, should be calculated and reported under the Energy Chapter.*

The reasons for this appear linked to the fact that the development of inventories by the IPCC appears to have followed, fairly closely, the approach already utilised by the IEA for the regular collection of energy

[20] Page 2.5 in Chapter 2: Waste Generation, Composition and Management Data, in in IPCC (2019) *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste*, IPCC, Switzerland, https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/5_Volume5/19R_V5_2_Ch02_Waste_Data.pdf

[21] Chapter 6: Waste, p.6.1, in IPCC (1997) Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Reference Manual (Volume 3).

data from OECD member countries.[22] The Revised 1996 Guidelines reflect, largely, discussions that had been ongoing regarding classes of fuels. Box 1 in the Energy Section sets out the 'main fuel groups':

- *coal*
- *natural gas*
- *oil*
  - *gasoline for transport;*
  - *diesel oil for transport;*
  - *other oil products.*
- *biomass*
  - *wood / wood waste;*
  - *charcoal;*
  - *other biomass and wastes (includes dung, agricultural, municipal and industrial wastes, bagasse and agricultural residues).*

The IPCC Guidelines, therefore, note that:

> *At least five aspects of energy data presentations need to be checked prior to using data for greenhouse gas inventories: […]*
>
> *[…] Are wood waste, agricultural wastes or waste-derived fuels included if combusted for energy production? These fuels should be accounted for in the IPCC methodology, but are included with biomass fuels.*

In part, the desire to retain consistency with 'energy' statistics may have been a key reason why emissions from waste installations are not reported under the 'waste' chapter, even when they are obviously more closely linked with the management of waste that the generation of energy.

The 2006 Guidelines reaffirm the exclusion of incineration, where energy is generated, from the 'Waste source' category:[23]

> *Incineration and open burning of waste containing fossil carbon, e.g., plastics, are the most important sources of CO_2 emissions in the Waste Sector. All greenhouse gas emissions from waste-to-energy, where waste material is used directly as fuel or converted into a fuel, should be estimated and reported under the Energy Sector. The*

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[22] See IPCC (1997) *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual (Volume 3). Chapter 2: Energy*, https://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/ch1ref1.pdf

[23] Introduction, p. 1.5, in IPCC (2006) *2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste*, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_1_Ch1_Introduction.pdf

guidance given in Chapter 5 of this Volume is generally valid for waste burning with or without energy recovery.

In Volume 2, concerning Energy, the mirror paragraph states:[24]

When energy is recovered from waste combustion, the associated greenhouse gas emissions are accounted for in the Energy sector under stationary combustion. Waste incineration with no associated energy purposes should be reported in the Waste source category; see Chapter 5 (Incineration and Open Burning of Waste) of Volume 5. It is good practice to assess the content of waste and differentiate between the part containing plastics and other fossil carbon materials from the biogenic part and estimate the associated emissions accordingly. The CO_2 emission from the fossil-carbon part can be included in the fuel category Other fuels, while the CO_2 emissions from the biomass part should be reported as an information item. For higher tier estimations, inventory compiler may refer to Chapter 5 of the Waste Volume.

This clarifies that although all emissions should be reported, those from biomass are to be reported as an information item.

The position is again re-stated in the 2019 Refinement to the 2006 Guidelines, which also states:[25]

Consistent with the 1996 Guidelines (IPCC, 1997), only CO_2 emissions resulting from oxidation, during incineration and open burning of carbon in waste of fossil origin (e.g., plastics, certain textiles, rubber, liquid solvents, and waste oil) are considered net emissions and should be included in the national CO_2 emissions estimate. The CO_2 emissions from combustion of biomass materials (e.g., paper, food, and wood waste) contained in the waste are biogenic emissions and should not be included in national total emission estimates. However, if incineration of waste is used for energy purposes, both fossil and biogenic CO_2 emissions should be estimated. Only fossil CO_2 should be included in national emissions under Energy Sector while biogenic CO_2 should be reported as an information item also in the Energy Sector. Moreover, if combustion, or any other factor, is causing long term decline in the total carbon

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[24] Page 2.33 in Chapter 2: Stationary Combustion in IPCC (2007) *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy*,

[25] Page 5.8 in Chapter 5, Incineration and Open Burning of Waste, in IPCC (2019) *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste*, IPCC, Switzerland.

embodied in living biomass (e.g., forests), this net release of carbon should be evident in the calculation of CO_2 emissions described in the Agriculture, Forestry and Other Land Use (AFOLU) Volume of the 2006 Guidelines.

The biogenic sources of CO_2 are considered irrelevant to national emission estimates, but somewhat oddly, they are to be reported as an information item, but only if energy is generated (not if energy is not generated). The paragraph is also ambiguous regarding impact on carbon in living biomass. Whether combustion contributes to long-term decline in total embodied carbon in living biomass depends partly on what one considers the counterfactual to be – is it a system where paper, for example, would otherwise have been recycled, or of wood might otherwise have been reused? If so, then it might well be the case there is an associated net release implied, at the margin, by combusting biogenic wastes (whether or not the combustion process is associated with the generation of energy).

Regarding the new thermal treatments, the Guidelines state:[26]

Since gas products generated from the new technologies are usually collected and used mostly as fuel or chemical feedstock, direct emissions of CH_4 and N_2O from the new technologies are expected to be quite low unless gas products containing CH_4 and N_2O are intentionally vented to the atmosphere. If the gas products would be combusted to supply energy to inside processes, the emissions of CH_4 and N_2O are reported under the Energy Sector. On the other hand, the emissions of CH_4 and N_2O in gas products are reported under the Waste Sector provided that the gas products would be released to the atmosphere. If gas, liquid, and solid products generated from the new technologies would be exported outside for their use or disposal, the emissions of greenhouse gases are not reported as those from the new technologies themselves, but at the point of their use or disposal.

In short, whether the emissions are reported under the waste, energy, or other parts of the inventory depends on what happens to the gases which are derived from the process. It might be stated that this is the parallel interpretation of what happens to incineration with regard to whether the heat is, or is not, utilized to generate energy.

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[26] Page 5.5-5.6 of Chapter 5: Incineration and Open Burning of Waste, in IPCC (2019) *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, . Volume 5: Waste*, IPCC, Switzerland.

3.3 Emissions from Biological Treatment

As noted above, the biological treatment methods were not addressed in the Revised 1996 Guidelines but were addressed in the 2006 Guidelines. No updates were made in respect of the 2019 refinement. Hence, the principal text of interest is that of the 2006 Guidelines.

Regarding composting, the Guidelines are interested only in methane emissions and nitrous oxide emissions from the composting process itself.[27] There is no consideration of the time-profile of emissions of CO_2 of biogenic origin which, where composting (and landfill) are concerned, takes place over an extended period of time. Compared with the emissions of biogenic CO_2 from incineration, where the biogenic CO_2 is emitted instantaneously, no benefit is accorded to the slowing in the profile of emissions. To some extent, this might be considered a side-effect of other decisions made in relation to inventories, notably the way in which biogenic sources of CO_2 are reported – or, rather, not reported – under the Guidelines for inventories. There are ways of adapting the reporting to account for this, but these do not seem to have been considered. The consequence of this is that the implications of what this author has referred to elsewhere as the 'time-limited carbon sequestration' of carbon in soils following the application of compost is underplayed.[28] The potential magnitude of this has been explored recently by the ISWA Working Group on Biological Treatment.[29]

Regarding anaerobic digestion, the Guidelines state:[30]

> *Anaerobic treatment is usually linked with methane (CH_4) recovery and combustion for energy, and thus the greenhouse gas emissions from the process should be reported in the Energy Sector. […]*

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[27] Page 4.4 in Chapter 4: Biological Treatment of Solid Waste, in IPCC (2007) *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste*, IPCC, Switzerland.
[28] E. Favoino and D. Hogg (2008) The potential role of compost in reducing greenhouse gases, *Waste Management Research* 2008; 26. pp.61-69. Note that there may also be other effects of applying organic matter to soils in relation to reducing the emissions of methane from soils (see Ho, A., Reim, A., Kim, S., Meima-Franke, M., Termorshuizen, A., de Boer, W., van der Putten, W. & Bodelier, P. (2015) Unexpected stimulation of soil methane uptake as emergent property of agricultural soils following bio-based residue application. *Global Change Biology*, Volume 21, Issue 10, October 2015, Pages 3864-3879).
[29] Jane Gilbert, Marco Ricci-Jürgensen and Aditi Ramola (2021) *Quantifying the Benefits to Soil of Applying Quality Compost*. ISWA, Rotterdam.
[30] Page 4.4 in Chapter 4: Biological Treatment of Solid Waste, in IPCC (2007) *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste*, IPCC, Switzerland.

Further detail is given on where to report various emissions from anaerobic digestion, depending on the way methane is used:[31]

> *When CH_4 emissions from anaerobic digestion are reported, the amount of recovered gas should be subtracted from the amount CH_4 generated. The recovered gas can be combusted in a flare or energy device. The amount of CH_4 which is recovered is expressed as R in Equation 4.1. If the recovered gas is used for energy, then also the resulting greenhouse gas emissions from the combustion of the gas should be reported under Energy Sector. The emissions from combustion of the recovered gas are however not significant, as the CO_2 emissions are of biogenic origin, and the CH_4 and N_2O emissions are very small so good practice in the Waste Sector does not require their estimation. However, if it is wished to estimate such emissions, the emissions from flaring should be reported under the Waste Sector. A discussion of emissions from flaring and more detailed information are given in Volume 2, Energy, Chapter 4.2. Emissions from flaring are not treated at Tier 1.*

This is not straightforward, and arguably, rather complicated. Nonetheless, the Guidelines are, at least consistent in that anything related to energy generation falls under the Energy part of the inventory. What is not clear is whether non-fossil CO_2 emissions from anaerobic digestion should be reported, if only as an information item.

The Guidance also considers mechanical biological treatment (MBT), albeit in a perfunctory (and, apparently, incorrect) manner.[32]

3.4 Climate Change Committee's 'Waste' Sector Report

One body that appreciated that the 'waste' chapter of the UK's GHG inventory does not faithfully represent the impact of waste management on emissions is the Climate Change Committee (CCC). The CCC sector report

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[31] Page 4.5 in Chapter 4: Biological Treatment of Solid Waste, in IPCC (2007) *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste*, IPCC, Switzerland.

[32] The Guidance states that '*Emission from MB treatment can be estimated using the default values in Table 4.1 for the biological treatment.*' This is misleading and likely to be wrongly applied (because the default values (in the Table referred to) relate to inputs of waste which are entirely of biogenic origin, whereas the inputs to MBT facilities will not generally be of purely biogenic origin, and the biogenic content may include significant quantities of material, such as paper and card, which behaves very differently to more commonly composted waste fractions).

on waste included GHG emissions from energy from waste incineration. Hence, it states[33]

> *Note that with the CCC's current sector classifications, a major change from previous reports is the inclusion of energy-from-waste power generation facilities emissions within the CCC's Waste sector boundary.* This reclassification has been carried out due to the interdependencies of landfill and waste reduction & recycling policies on EfW emissions, and given the increasing importance of EfW emissions that would otherwise have been subsumed within power sector emissions data. These EfW facilities generate electricity and, in some cases, also heat.*

Elsewhere, it states:

> *Based on the most recent year of official UK emissions data, total waste sector emissions (including energy-from-waste) increased by 3.7% from 2017 to 32.9 $MtCO_2e$ in 2018. Emissions from landfill increased by 2% to 19.6 $MtCO_2e$, emissions from wastewater were flat, and emissions from EfW plants increased 18% to 5.3 $MtCO_2e$. The waste sector, including energy-from-waste facilities, therefore comprised 6% of UK GHG emissions in 2018 (Figure M10.1). Landfill methane comprised the majority of waste sector emissions in 2018, followed by wastewater treatment and EfW plants.*

There are two things worthy of note here:

- First, the omission of any impact associated with recycling persists: a fuller correction would have considered the impact on emissions of recycling processes. No note of, or reference to, the impact of recycling on greenhouse gas emissions is made other than to the extent that recycling reduces the quantity of waste managed through other means. Hence:

  > *Waste sector emissions are primarily driven by the volumes of residual waste that end up in landfill or EfW facilities, which is in turn driven by UK consumption of products and food, combined with waste reduction programmes and reuse & recycling infrastructure.*

  As in the IPCC Guidelines, the significance accorded to waste composition, and the impact of recycling on this, is not mentioned.
- Second, the figures which the CCC derived in their report appear to be somewhat at odds with those in Defra's Indicator report.

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[33] Climate Change Committee (2021) *The Sixth Carbon Budget: Waste*.

Notwithstanding the omission in Defra's figures (see Table 1 above) of energy from waste incineration, and recognising also that the Defra figures represent emissions in relation only to England (whereas the CCC figures are for the whole of the UK), the Defra figure of 15.6 million tonnes is lower than would be expected to retain consistency with the CCC figures (or, equivalently, the CCC figures seem too high). What appears to be the case here is that the CCC and UK Government are each using different figures for the global warming potential of the different greenhouse gases. This gives rise to a much wider discussions to what these 'should' be for the purpose of countries' reporting to the UNFCCC: they almost certainly should not be as they are (using a GWP for methane of 25, reflecting the convention that GWPs over a 100 year horizon should be used), and whilst the CCC has made a move 'in the right direction' (by using figures which appear more representative of the current state of science), it is doubtful, given the shortening time horizon which appears to be available to us, that even the CCC figures are adequate to guide future decision making.

Notwithstanding the inclusion of energy from waste within the waste sector, there is a sense on 'one-step-forward, one-step-back'. The CCC has made nods in the right direction, but its approach still ignores the impact of recycling. Indeed, there is no consideration of, for example, the potential for mixed waste sorting (to remove plastics) to reduce emissions from incineration plants (and reduce emissions that might otherwise have been higher under the IPPU chapter of the inventory).

4.0 Summary Comments

4.1 What Tests Should Indicators and Inventories Pass?

Indicators and inventories might, respectively, be expected to pass the following tests:

- Where indicators are chosen as a means to highlight the extent to which 'progress' is being / has been made, movement in those indicators should be expected to reflect progress in the outcomes the indicator was intended to track. If they do not do so in isolation, then they should do so as part of 'a dashboard'; and
- The agreed configuration of inventories designed to support delivery of the objectives of the UNFCCC should meet both a 'structural' and a 'quantitative' test. The former would require that inventories are structured in such a way that they support rational decision making. This may mean that items that are recorded for the purpose of accounting in one part of an inventory are reported, though not counted, in other parts of the inventory precisely so as to avoid potentially misleading perspectives. The quantitative test would require that when emissions reported under national inventories increase or decline, this should translate into a parallel increase, or a reduction, in global emissions. If this is not the case, then countries may either a) meet their own objectives at the expense of increases in emissions in other countries; and b) avoid, or deprioritize, taking actions which have no effect on their own reported emissions but which are beneficial on a global level. Both are counterproductive.[34]

There are, no doubt, more elegant ways of formulating the above principles, but it seems to me that if either is untrue, we are in problematic territory. Regarding a), if the statement is untrue, then we have

[34] This may incline one to the view that consumption-based inventories have more to recommend them than the territorial ones currently being reported in inventories. The difference, for the UK, would be quite profound. Depending on the data being presented, consumption-based emissions may be 50-75% higher that territorial ones (see Defra (2021) UK's Carbon Footprint 1997 - 2018, and BEIS (2021) *2019 UK Greenhouse Gas Emissions, Final Figures*, 2 February 2021; in the former, consumption emissions are around 50% more than territorial ones, whilst the figure is higher in the latter document, exceeding 75%).

the wrong indicator. Regarding b), if the inventories do not always support 'the right action', then we should revise the form of the inventories.

4.2 The Current State of Affairs

The management (and mismanagement) of wastes can lead to a range of different impacts in relation to climate change. The emissions reported under the 'waste' part of the inventories reported to the UNFCCC do not, though, give an accurate representation of the contribution that the management of waste makes to the emissions of greenhouse gases, whether one takes a global perspective of the impact of waste management, or a territorial perspective. In this respect, there are four main issues:

1) The first is that the development of the reporting guidelines, and the associated guidelines for developing inventories, appear to have been heavily shaped by existing reporting in respect of energy. Consequently, any activity in relation to waste management that gives rise to the generation of energy is considered to be – for the purpose of the inventory - a process that generates energy, and is reported under the 'Energy' section of the inventory. So, instead of emissions from incineration and other thermal treatments being reported under 'waste', they are reported under 'energy'. The same applies to anaerobic digestion. Whilst this might have been logical from the perspective of understanding how much energy is generated from which sources, it has the effect of rendering the full impact of changes in waste management opaque;
2) The second is that the impacts of recycling are also not attributed to 'waste' other than to the extent that they should (whether they do or not is another matter) lead to changes in emissions from downstream treatments of wastes through SWDSs, incineration, and thermal treatment (and accurate reporting might also enable more accurate estimation of emissions of CH_4 and N_2O from biological treatment processes[35]). The emissions from, and benefits associated with (in terms of reducing emissions from production) recycling are registered in either or both of the energy / industrial processes and

[35] A good example here – and a matter still not addressed by the IPCC Guidelines – would be how ammonia is treated, if at all, at composting sites. There are good reasons to believe that whether or not a scrubber is fitted prior to a biofilter (where exhaust air is subject to biofiltration) will influence N_2O emissions.

product use (IPPU) chapters. Furthermore, even if the global impact of the recycling is to reduce greenhouse gas emissions (through reducing demand for energy in production), whether or not the impact of recycling affects territorial inventories in a positive manner will depend on where the material is recycled, and from where, at the margin, the recycling process could be said to displace primary production;

3) The third impact follows from both of these. Currently, the waste chapter of the IPCC Guidelines is clear that activities such as recycling should impact upon '*the amounts of waste entering into other management and treatment systems*'. It is far less explicit than it should be about the links between recycling and the composition of what enters various waste management and treatment systems, notably, SWDSs and thermal treatment plants (irrespective of which chapter the emissions are ultimately reported under). It would logically follow that there ought to be processes by which 'waste flow data' are generated each year to indicate what types of waste material are consigned to each of the different treatment processes. The partitioning of the emissions resulting from waste management activities across 'energy' and 'waste' seems, however, to lead to a separation in the way in which they are considered. There is no coherent approach for understanding what processes receive wastes of what composition, a simple fact that means that the data reported are not reliable, and not even responsive to changes in recycling of different materials (which the IPCC Guidelines loosely implies they should be). This problem was highlighted in previous work regarding the model used in the UK to report emissions from landfills (which are based on modelled outputs, and hence, rely on accurate inputs):[36]

> *insufficient use has been made of the empirical data which has been generated over the past ten to fifteen years or so, especially in respect of municipal waste (much of which is discussed in Appendix A.2.0). This was also highlighted by AEA in their review of the data in the national assessment model (which was adopted for MELMod). Similar comments can be made in respect of waste composition. The data in MELMod for local authority collected waste is outdated, and*

[36] Dominic Hogg, Ann Ballinger and Hans Oonk (2011) *Inventory Improvement Project - UK Landfill Methane Emissions Model*, Final Report to Defra and DECC, January 2011.

has been for some time (again, sources in Appendix A.2.0 highlight the availability of relevant data over the period during which various revisions to the model were made). Since emissions of methane in MELMod are related back to waste composition, then how waste composition changes over time becomes important. This ought to be based upon empirical data rather than assumption.

It is clear, given the lack of use made of recent data, that both the quantitative figures and the composition data are in need of updating. Data in MELMod reveal that municipal waste composition data is still based upon data gathered in the early 1990s, and which was superseded almost ten years ago.

It remains, therefore, difficult to have any confidence in the way the emissions from waste management activities are currently being derived. At one level, it could be argued that this is unimportant (in the UK). Yet we have already highlighted that a) emissions from waste incineration (whether energy is generated or not) have increased several hundred percent, and b) reporting the effect of methane emissions with a GWP100 figure of 25 is unlikely to provide a sensible guide as to how the world should deal with methane emissions over the next thirty years. Given that the impact of carbon dioxide emissions (from incineration) are cumulative over time, and given that the pace of global warming in the coming decades will be influenced by the success or failure in reducing (shorter-lived) methane emissions, and its concentration in the atmosphere, then it seems fair to say that the current reporting approach leaves us unclear as to how important these emissions are (and will be);[37]

4) The fourth issue is that there appears to be no means of accounting for the benefits that might be offered by applying compost or digestate (or biochar derived from wastes) to land. The way in which biogenic carbon emissions are accounted for, and reported, in inventories could accommodate this, not least as they are being updated to reflect carbon capture approaches, but little

[37] In the global context, the impact of burning waste on emissions of black carbon is also likely to be more relevant. It is not *irrelevant* in the UK, but the scale and frequency of waste burning is likely to be (proportionately) lower, albeit that for fairly obvious reasons, knowledge of the extent of waste burning is far from exact.

acknowledgement of the beneficial role of time-limited sequestration is given in the inventories. There are a number of ways in which this could be rectified, even within the existing reporting framework, though if clarity is to be given to how, and when, a country might be said to have achieved 'net zero' might open up the space for more sensible reporting of non-fossil carbon dioxide emissions than is currently required.

These issues mean that the reporting of GHG emissions from 'waste' under the existing inventories is both disjointed and misleading.

There is a very large difference between 'the effect on climate change of managing waste', and 'emissions of greenhouse gases reported under the waste category'. Whilst some, by no means all, of these effects are 'picked up' in other parts of the inventory, the picture is rendered opaque.

4.3 Does This Matter?

All of this matters because policy makers – whether in the UK, or in any of the Parties to the UNFCCC – are being given a wholly misleading view of the impact that better management of wastes can have on greenhouse gas emissions. This might matter less if the same personnel who made decisions regarding the overall emissions from the UK were the same people as those who make decisions regarding improved management of waste. However, they are not in the UK, and they are unlikely to be in other countries.

Indeed, various Excel tools developed for use by cities by, or on behalf of, the World Bank entrench this focus on emissions from landfills that stems from the IPCC guidelines, with the recycling benefits being acknowledged only in terms of 'less material landfilled'.[38] The handling of the problem merely serves to deepen the problems associated with the

[38] See, for example, Solid Waste Emissions Estimation Tool (SWEET) version 4.0, developed by Abt Associates and SCS Engineers, and funded by the US EPA for the Climate and Clean Air Coalition, now hosted at the Global Methane Initiative; see also the CURB Tool, which has been designed to support cities understand their climate change. The 'waste' related emissions that are reviewed reflect the UNFCCC Waste Chapter reporting, so that the only materials considered of interest are paper, food and yard waste, other organic waste, and plastic waste. This reflects the focus on landfills / dumps, composting, anaerobic digestion and incineration (the recycling of plastics is given no credit – plastics are of interest in CURB because if they are burned at incineration plants, there will be fossil-derived greenhouse gas emissions). Recycling metals, for example, is made to appear irrelevant.

financing of aspects of waste management in developing countries, where some a significant proportion of the world's population still have no meaningful waste collection apart from that offered by informal collectors (usually for more valuable recyclable materials only). The benefits of waste management, from the perspective of climate change, are about more than just 'not landfilling', or 'landfilling in better ways'.

It would not be so bad if the relevant officials and authorities were aware of their omissions, but it is less than clear that they are. Our own experience of this is sobering. It took many years to convince the UK authorities that incineration facilities, which were recovering energy, were potentially no better than landfills from the perspective of climate change under certain, entirely plausible, assumptions and conditions (which largely now prevail).[39] The reality is that the greenhouse gas implications of different waste management options remain incredibly poorly understood beyond a rather narrow community of experts. Although the US EPA has funded tools for use in developing countries which focus on methane and black carbon, in the US itself, its own WARM tool provides a much better-informed view of what can be achieved through upstream measures.[40] The tool provides a basis for waste managers to evaluate or report the greenhouse gas impacts reductions associated with their systems, or to consider the impacts of changing such systems. The tool allows waste managers to understand these impacts in terms of both CO_2 and energy use, and it covers a range of waste management practices, including source reduction. The effects associated with source reduction also reflect the typical recycled content of the waste that is being avoided, this being

[39] For an early attempt at this, see D. Hogg (2006) *A Changing Climate for Energy from Waste?* Final Report for Friends of the Earth, May 2006. Further work was undertaken for Defra in 2014 (ERM (2014) Energy Recovery for Residual Waste - A Carbon based Modelling Approach, Report for Defra, February 2014). More recently, reviews which have used higher 'global warming potential' figures than are used in reporting inventories include Eunomia (2020) Gas and Air Quality Impacts of Incineration and Landfill, Report for Client Earth, December 2020; Zero Waste Europe (2021) *Building a Bridge Strategy for Residual Waste: Material Recovery and Biological Treatment to Manage Residual Waste within a Circular Economy*, Policy Briefing, January 2021, https://zerowasteeurope.eu/wp-content/uploads/2020/06/zero_waste_europe_policy-briefing_MRBT_en_with-annex.pdf; and Zero Waste Scotland (2021) The Climate Change Impacts of Burning Municipal Waste in Scotland, June 2021.

[40] https://www.epa.gov/warm

a factor which affects this level of benefit.[41] In the UK, also, there are two examples of note:

- The Scottish Government intended, for some time, to introduce a 'carbon metric' to replace a quantitative recycling target. Although formally, the target remains a tonnage based one, Zero Waste Scotland still reports annually on the performance of waste management using the carbon metric. The carbon metric essentially considers the GHG impacts of consumption, net of the effect of the different ways in which waste is being managed in Scotland. The approach is similar, in many respects, to the WARM tool in that it enables performance to be tracked at the level of the system, and ZWS uses the tool to highlight changes in performance over time.[42]
- In London, the Greater London Authority has developed an Emissions Performance Standard (EPS) as a means for constituent municipalities to improve the greenhouse gas emissions performance of their waste management systems. The EPS was first published in 2011 as part of the Mayor of London's Municipal Waste Management Strategy, and sets targets for London's local authorities to reduce the emissions associated with waste management. The approach in London includes, separately, a Carbon Intensity Floor for emissions from incineration. The latter reflects concerns that, as energy systems decarbonise, a reducing proportion of the direct emissions from combusting waste will be 'offset' in the form of avoided emissions associated with alternative forms of energy generation. Taken together, these are being used, effectively, to challenge municipalities to improve their GHG performance as they seek to meet recycling targets that have been set, as in Scotland, on a percentage basis by weight.

A more encompassing approach – than what is set out in the indicator GG1 – could, and should, be taken to understanding the impact of 'waste management' on climate change. The impact of waste management on

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[41] The US EPA has also developed the ReCon tool which is oriented more towards corporates, and individual citizens, who want to understand the implications of buying materials with different levels of recycled content (see https://www.epa.gov/warm/recycled-content-recon-tool).

[42] See, for example, ZWS (2020) The Carbon Footprint of Scotland's Waste: Carbon Metric Technical Report (2017 & 2018), September 2020, https://www.zerowastescotland.org.uk/sites/default/files/2017-18%20ZWS%20Carbon%20Metric%20Technical%20Report%20V02.00.pdf

greenhouse gas emissions is clearly very different to what would be observed by simply tracking the emissions of greenhouse gases being reported under the 'waste' chapter of the IPCC Guidelines (which is what Defra is currently doing with its indicator).

It is of interest to note, in light of the lack of any update on emissions from biological treatment processes in IPCC Guidance (no account has been taken of the last two decades' research in this regard) that the NAEI, regarding waste, states:[43]

- *Emissions from waste incineration are estimated from a combination of data reported to the Environment Agency's Pollution Inventory, supplemented with the use of literature based emission factors.*
- *Emissions from composting are estimated using activity data from annual organics recycling reports and IPCC 2006 default emission factors.*
- *Emissions of GHGs from anaerobic digestion are calculated from industry compilations of anaerobic digestion facility capacity and throughput. IPCC default emission factors are used to calculate CH_4 and N_2O emissions from this sector*

From this, it seems clear that default factors are relevant, and also that emissions from incineration appear not to be based on empirical measurement. This appears to be confirmed in the UK's latest inventory report which states:[44]

> *Power stations - MSW: The activity data reported in the UK inventory is a combination of non-biodegradable (fossil) and biodegradable wastes and we apply IPCC default carbon factors for each type of waste.*

The same report notes that one aspect of quality assurance and control is to cross-check against EU ETS data. UK incineration plants were not covered by the EU ETS, and neither are they covered now by the UK ETS. There are good reasons to question the CO_2 emissions from incineration as they are currently being reported in the inventory. Table 6.6 in the Digest of UK Energy Statistics (DUKES), to which the NAEI cross-

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[43] https://naei.beis.gov.uk/resources/Sector_Summary_Factsheet_2020-v2.html

[44] Brown P, Cardenas L, Choudrie S, Del Vento S, Karagianni E, MacCarthy J, Mullen P, Passant N, Richmond B, Smith H, Thistlethwaite G, Thomson A, Turtle L, Wakeling D (2021) *UK Greenhouse Gas Inventory, 1990 to 2019: Annual Report for submission under the Framework Convention on Climate Change*, April 2021, https://uk-air.defra.gov.uk/assets/documents/reports/cat09/2105061125_ukghgi-90-19_Main_Issue_1.pdf

refers, states, in footnote 8, '*Around half of waste is non-biodegradable, 72 per cent of tyres, and all hospital waste*'. This does not exactly inspire confidence, and whilst at one stage these emissions might not have seemed a major component of emissions associated with energy generation, as energy systems decarbonize, and as the quantity of waste being incinerated increases, so this proportion has increased (and seems likely to continue to do so over the medium-term).

The UK's inventory report now contains the following statement which is apt to confuse and mislead policymakers:

> *2.5.2.3 Waste incineration*
>
> *Waste incineration is a minor source of GHG emissions in the UK. The emissions from clinical and chemical waste incineration show a gradual decline across the time series, partly driven by the decline in the UK chemical industry, and partly through improvements in waste management practices.*
>
> *The most notable impact on the UK GHGI trend arises from the ban on the incineration of MSW without energy recovery in 1996; this regulatory change led to all UK MSW incinerators either closing or retro-fitting boilers to raise electricity, and therefore from 1997 onwards all "energy from waste" plant emissions from the incineration of MSW are reported in the power generation sector of the inventory, in 1A1a.*
>
> *2.5.2.4 Biological treatment of solid waste*
>
> *Since 1990 emissions from the biological treatment of waste sector has sharply grown from almost exclusively small-scale composting to a widespread and large-scale alternative practice for the treatment of biodegradable wastes, the generation of energy and the efficient generation of biogas as an alternative fuel. The continued increase in emissions from this source is part of the reason why emissions from the waste sector have flattened out in recent years.*

The underlined extracts above amount to an opaque statement that the most notable change in emissions from incineration is the steady movement of emissions from incineration under the waste category, to emissions from incineration under the energy category: it is an artifice of the reporting methodology. The paragraph fails to comment on the fact that the emissions from incineration of waste, wherever they may be reported (irrespective of whether energy is generated from them or not), have increased several times over since 1990, and are a growing source or emissions. Policy makers who are less familiar with this might easily misunderstand the implications of these paragraphs.

4.4 Do Indicators and Inventories Pass Muster?

At the start of this Section, we set out some tests against which to assess indicators and inventories as regards GHG emissions from waste.

Defra's indicator GG1 fails the indicator test. It is the wrong indicator. It does not include emissions from incineration. It ignores the beneficial impact (to the planet, if not always to the national inventory) of recycling. It is completely indifferent, for example, as to whether plastics are incinerated to generate electricity, or recycled in closed loops. Currently, the difference in these management routes amounts to around 4 tonnes CO_2e per tonne of plastic. If an indicator of the climate change impacts of waste is to be at all useful, it cannot be indifferent to such impacts, and to such choices.

It is not actually clear what it is that GG1 is intended to be an indicator of. It certainly does not give a clear indication of the impact of waste management on climate change. That might be acceptable if other indicators in the set 'compensated' for this shortcoming, but there are none. Indeed, the figures presented for 'waste landfilled' as part of indicator WD1 ('*waste landfilled or incinerated*') closely correspond, as one might expect (albeit a time lag could be expected), with GG1. It is unclear what GG1, in its current form, adds since it is effectively dominated by the evolution in GHG emissions from landfilling.

Since GG1's flawed formulation is itself linked to the existing reporting system, we suggest that this itself is *a* (by no means, *the best*) reason to conclude that the inventories fail the structural test. After all, the indicator seems to be evidence of the fact that the inventory is apt to mislead, and this is also reflected in the design of some of the tools which have been developed to inform solid waste management decision-making in developing countries (see footnote 38). These focus almost exclusively on the reduction of the (mainly methane from landfills) emissions reported under the waste section of the inventory.

Inventories fail the quantitative test also. Improvements in inventories can be gained by, for example, exporting waste for incineration rather than incinerating it in the country reporting. Emissions being reported may be increased by increasing the in-country production of materials from recycled inputs where they would otherwise have been imported as primary materials, even though the effect is to reduce global emissions. More perniciously, illegal exports of waste may have a beneficial impact on a country's inventory. If countries are to pursue their own targets with vigour, it will be unwise to maintain such a state of affairs.

5.0 Recommendations

Defra is obviously well-placed to make changes to the indicators it has chosen to reflect whatever it was intending the indicators should demonstrate. It is also well-placed to improve the accuracy of the reporting of emissions from the management of waste.

It is, furthermore, well-placed, currently, to initiate a process designed to correct some of the problems with the existing Guidelines for reporting greenhouse gas emissions and the associated inventories. It will be as well to do this sooner rather than later in parallel with the development of mechanisms that will make country signatories' commitments more binding in their nature in future.

Following our review, we recommend:

1) That Defra changes the scope of the indicator GG1 such that it becomes a suitable measure of performance of the waste management sector in respect of climate change. GG1 does not even achieve what its subtitle claims (there are territorial emissions from waste management which fall outside the indicator). There should be no need to tie this to greenhouse gas inventories reported to UNFCCC (and to restrict to territorial emissions). Other indicators included in the complete set are a) relevant to climate change, but b) not linked to the reporting of the inventory (such as GG2 and GG3) The indicator should, preferably, be such that it clearly tracks the impact of better management of waste from the perspective of global climate change;
2) That, using its role as Chair of COP26, the UK should initiate a review of the IPCC Guidelines and inventories used to report emissions to the UNFCCC. There are two approaches that might follow from this report:
    a. Look, specifically, at the way in which emissions from managing waste are reported under the 'waste' category. In doing so, it could (amongst other things) re-assign incineration with energy generation to the 'waste' category; consider approaches to account for time-limited sequestration of non-fossil CO_2 in soils; and encourage reporting of reductions in emissions associated with recycling under the waste category, even if only as memorandum items;

b. Undertake a more fundamental review of the IPCC Guidelines and the reporting of emissions in the context of elaborating how it would be determined when a country had achieved 'net-zero', and whether the associated emissions reduction pathways were adequate. There is a need to set countries on the right path, with an inventory system that conveys 'the right signals'. GG1 has, as its relevant '*target/ambition/commitment: Legislative target within the Climate Change Act (2008), since updated with the aim of achieving net zero emissions by 2050 on a territorial basis*.' The misalignment between 'territorial emissions' and the fundamental objective (as expressed at Article 2) of the UNFCCC deserves to be addressed so that policy makers are not encouraged to pursue actions which are counterproductive, or which could have been far more productive, when considered from a global perspective. We will be preparing a separate report in relation to this broader issue.[45]

We note, in passing, that the inventories have not changed radically since the mid-1990s, a time when, had the world acted with a modicum of urgency, the issue of climate change could have been largely addressed by now (consider that since the early 1990s, annual global emissions of carbon dioxide have risen by around 60%, and that something close to a trillion tonnes of carbon dioxide have been emitted, giving rise to a further 0.4 degrees C or so of warming). That time has passed, and if the world is now to respond with the requisite urgency, it simply will not do to have countries making commitments, and reporting performance against these using outdated metrics and approaches that are no longer adequate to guide parties to make the best decisions for the future of mankind and other species.

[45] We welcome interest from others in this regard. Input from climate scientists and academics with an interest in these matters would be incredibly valuable.