The Potential Contribution of Waste Management to a Low Carbon Economy

Main Report

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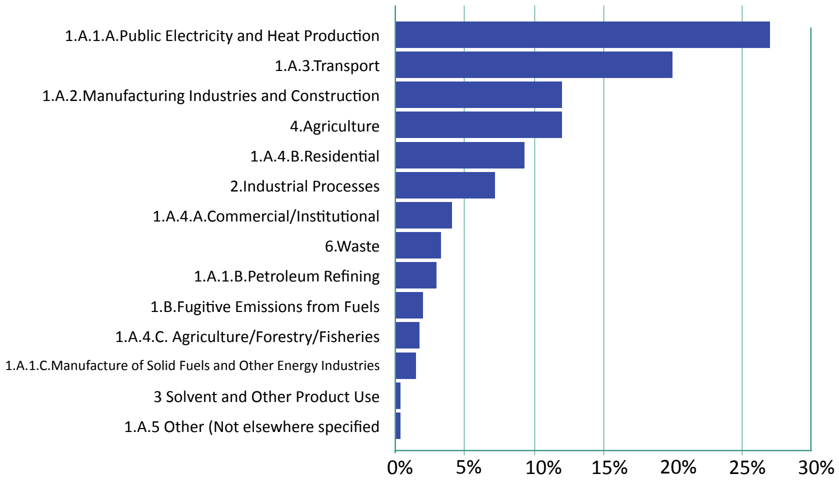
Executive Summary

Figure E- 1: Contribution to EU Emissions by 'Sector', 2012



Source: *EEA (http://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer)*

One could be forgiven for thinking, when considering the reporting of greenhouse gas (GHG) inventories, that waste management is responsible for a limited proportion of GHG emissions from Europe. The Reporting of GHG emissions from the EU-28 in 2012 suggests that the sector 'waste' accounted for just over 3% of total GHG emissions (the gases responsible for causing global climate change). Other countries tend to show similarly low contributions to their inventory from 'waste'. These low shares might lead one to believe that this is a sector which can do relatively little to contribute to reducing GHG emissions from the EU, and indeed, globally.

Yet studies by various bodies indicate that the potential contribution of waste prevention and management to GHG abatement could be far greater than the total reported emissions under the 'waste' part of the inventory reported to the UNFCCC[1]. These studies appear to indicate that the potential savings to be made from further improvements in waste management (of the order 150-200 million tonnes CO_2 equ.) exceed the level of emissions reported under the 'waste' part of the inventory (of the order 100 million tonnes CO_2 equ., and already down from a figure of the order 170 million tonnes CO_2 equ. in 1995)[2]. As this report notes, the means of reporting emissions inventories to the UNFCCC includes, under the 'waste' chapter, only a very limited representation of the extent to which improved waste management systems, reconceptualised as resource management systems, can play in greenhouse gas reduction. A range of beneficial impacts from improved resource and waste management are effectively recorded in other parts of the overall inventory.

The problems associated with properly seeing the positive role, at the global level, that can be played by improved resource and waste management are further exacerbated by the fact that the inventories for specific countries are based on activities that take place within their borders. Since both primary and secondary materials are widely traded, the way in which activities such as waste prevention, reuse and recycling reflects

1 Okopol (2008) Climate Protection Potentials of EU Recycling Targets, http://www.eeb.org/publication/documents/RecyclingClimateChangePotentials.pdf; Prognos Ifeu and INFU (2008) Resource savings and CO2 reduction potential in waste management in Europe and the possible contribution to the CO2 reduction target in 2020, Prognos in cooperation with IFEU Heidelberg, INFU Dortmund, October 2008; Günter Dehoust, Doris Schüler, Regine Vogt and Jürgen Giegrich (2010) Climate Protection Potential in the Waste management Sector – Examples: Municipal Waste and Waste Wood, Umweltbundesamt (UBA), January 2010, https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4049.pdf Projections of Municipal Waste Management and Greenhouse Gases, ETC/SCP working paper 4/2011, European Environmental Agency (EEA), August 2011; European Commission (2014) Impact Assessment Accompanying the document, Proposal for a Directive of the European Parliament and of the Council amending Directives 2008/98/EC on waste, 94/62/EC on packaging and packaging waste, 1999/31/EC on the landfill of waste, 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment, Brussels, 2.7.2014, SWD(2014) 207 final.

2 The figure comes from European Environment Agency (2014) Annual European Union Greenhouse Gas Inventory 1990–2012 and Inventory Report 2014, Submission to the UNFCCC Secretariat, Technical Report No. 09/2014.

on these inventories varies depending upon whether a country imports primary products, or whether it is a producer of those primary products: if the former, then waste recycling and prevention activities will have little or no impact on their inventories; if the latter, then the impact is potentially far more significant. The counterintuitive element in this – and arguably, this applies in greater force to end-of-life resource management than to any other field of activity – is that activities undertaken domestically with a view to addressing a global problem might have no impact, and even a counterproductive one, in domestic inventories.

For both the above reasons, the exhortation to policy makers in the IPCC's Fifth Assessment Report to have waste management policy driven by climate concerns seems to have missed the point:

> **….waste management policies are still not driven by climate concerns, although the potential for GHG emission reductions through waste management is increasingly recognized and accounted for.**

The IPCC's own report offered little by way of concrete evidence as to why any country would consider that its waste management policies should be driven by climate concerns. On the contrary, the opaque manner in which the potential upside of more positive waste management is accounted for in UNFCCC inventories and IPCC reports – it is effectively hidden - is itself an obstacle to policy makers recognizing the potential in this regard.

There are other methodological issues which are deserving of attention: the guidance from IPCC on how to develop inventories has been interpreted, erroneously, to imply that when considering alternative approaches to managing waste, emissions of CO_2 of non-fossil origin can be ignored. This issue gives rise to a misunderstanding of the extent to which some technologies can contribute positively to climate change mitigation.

Within UNFCCC inventories, the ability of the biosphere to act as a sink is, in each country's inventory, supposed to be addressed through accounting for the change in land use and forestry cover, this indicating the change in the extent to which soils and vegetation can act to sequester carbon, and through understanding the stock of harvested wood products prior to their reaching the end of their useful life. However, the extent to which this approach, when combined with the various assumptions made under the industry, energy and waste sections of the inventory, could be said to deal properly with the issue of biogenic carbon, remains problematic, and may be leading to significant underestimates of the contribution made by biogenic CO_2 to global climate change. There is a significant difference between the way in which biogenic emissions of CO_2 are generated by different waste treatment processes. Where landfills are concerned, methane which is captured, whether for energy recovery or flaring, is converted to CO_2, and some uncaptured methane may be oxidised at the cap of the landfill site. These emissions occur over an extended period of time. If the same waste is, for example, combusted, then the emissions of CO_2 occur instantaneously. These processes clearly have very different time profiles. The rate at which emissions occur might be considered to be of relevance, not least since this may have implications for how effectively they can be sequestered by the less than instantaneous growth of biomass

E.1.0 Key Findings

Our research indicates that changing waste management practices can generate significant climate change benefits. The effects of different approaches is shown in conventional terms (excluding biogenic CO_2 emissions) in Figure E- 2. As this shows, the main benefits come from waste prevention, and from recycling, particularly of dry materials.

Whilst the benefits from biowaste treatment processes such as composting and anaerobic digestion are less substantial than those relating to the recycling many of the dry materials, the benefits from food waste prevention are significant: to the extent that separate collection of food waste can give rise – in both households and in businesses - to enhanced awareness of what is thrown away (and hence, to a preventive effect), so the benefits of such an approach might be considered more effective.

Where residual waste treatment and disposal are concerned, these tend to make contributions to climate change emissions rather than helping to reduce emissions overall. Indeed, the benefits of switching from landfill to incineration are slight. Furthermore, as energy systems decarbonise, so the impact of the processes for which the net effect is more strongly determined by the amount of energy generated will tend to decline. Because it seems unlikely that climate change can be arrested without significant decarbonisation of energy sources, so it would appear that technologies such as incineration will become less attractive over time.

Figure E- 2: Indicative Climate Change Impacts of Key Waste Management Activities (excl. CO_2 from biogenic sources)

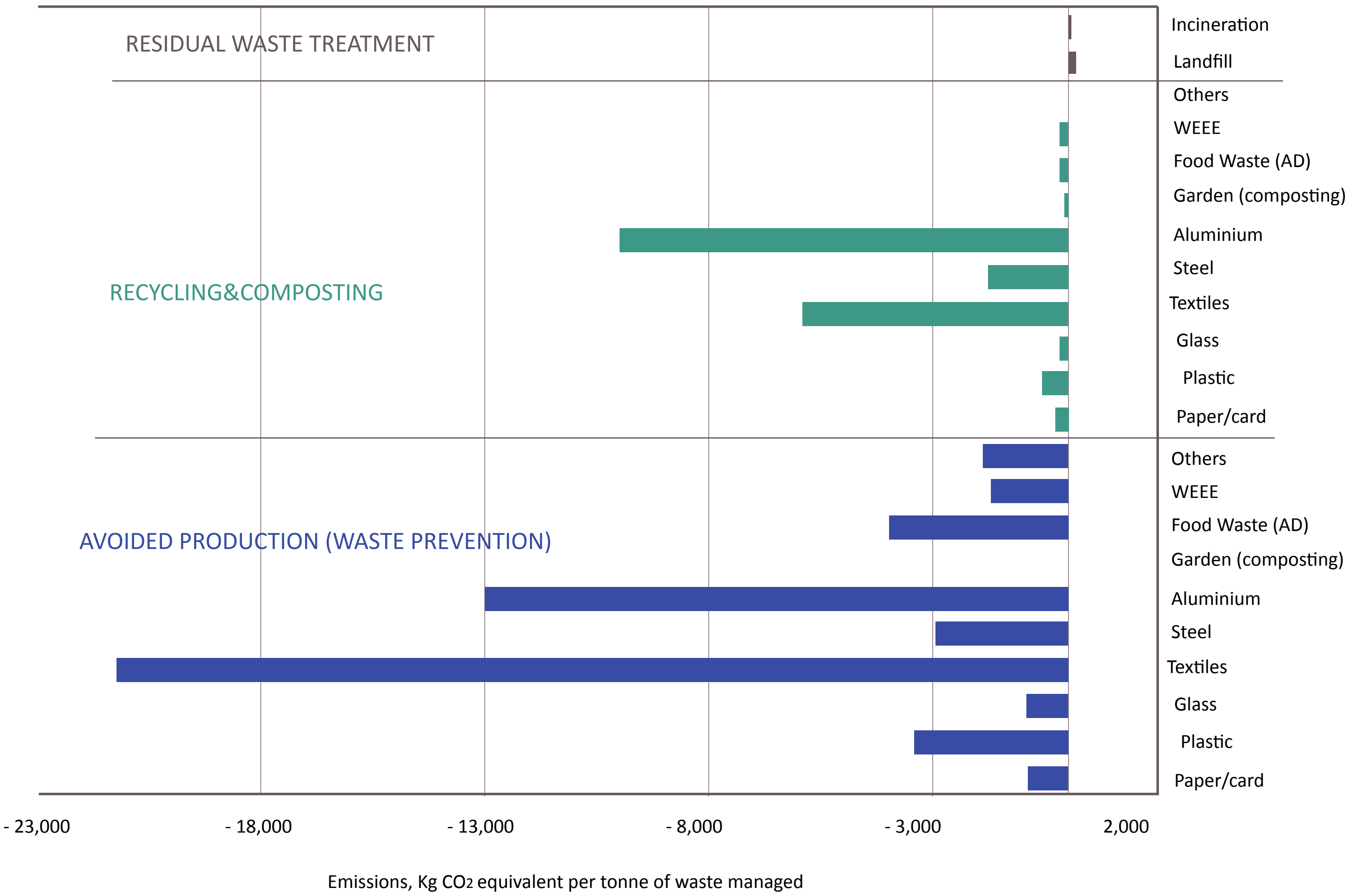


Figure E- 3: Indicative Climate Change Impacts of Key Waste Management Activities (incl. CO_2 from biogenic sources)

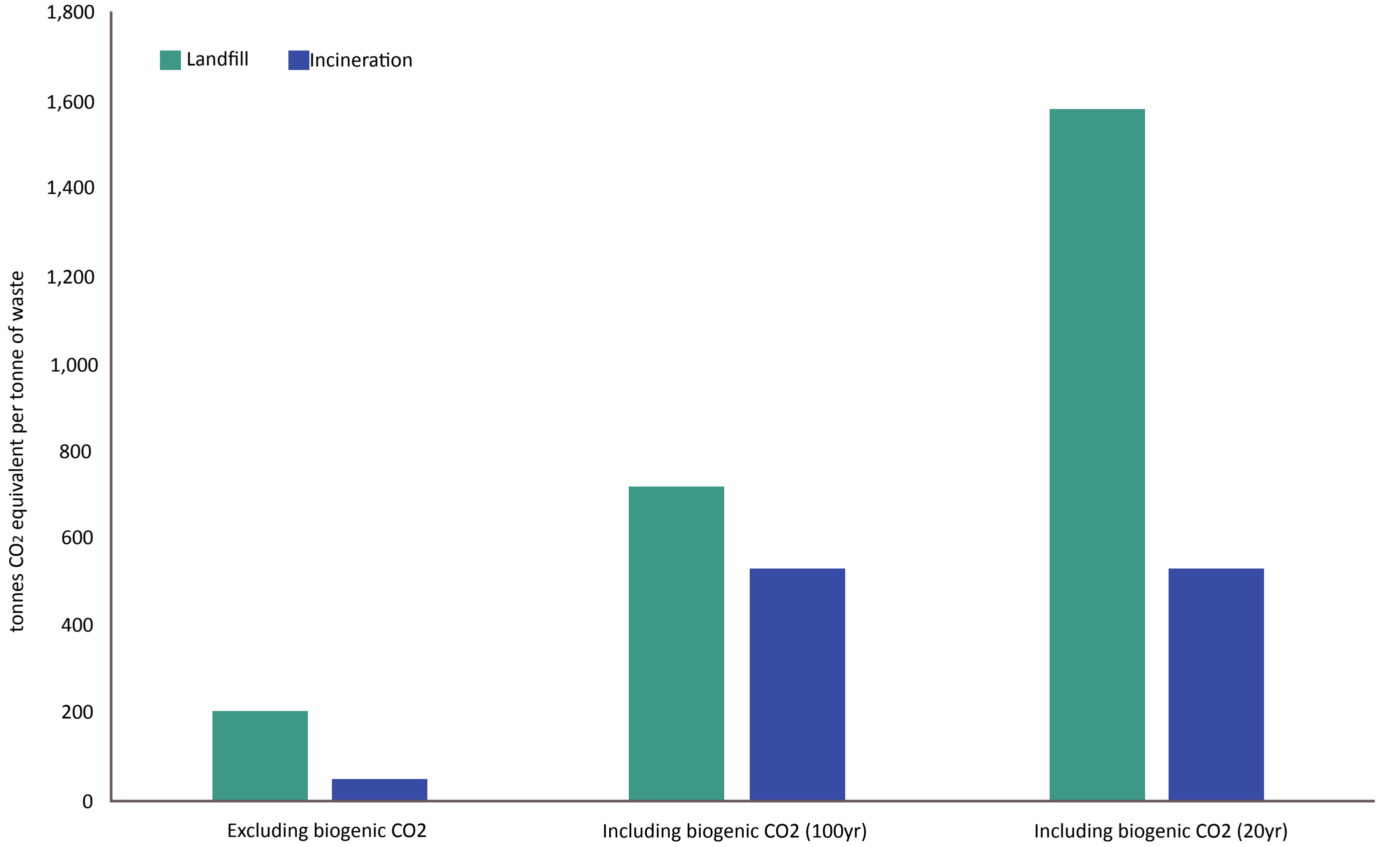


Figure E- 3 presents again the data for residual waste, this time showing results including the biogenic CO2 emissions over two time periods – the conventionally used 100 year timeframe - as well as the shorter 20 year timeframe. The relatively limited benefits associated with switching from landfill to incineration become more apparent where results over a 100 year timeframe are considered. In the Main report, we show how these benefits can be reversed as the energy supply becomes decarbonised. The benefits of anaerobic digestion (of food) relative to composting (of garden waste) also become more apparent.

Looking forward, and reflecting on the above results, it is clear that a climate friendly strategy, as regards materials and waste, will be one in which materials are continually cycling through the economy, and where the leakage of materials into residual waste treatments is minimised. Looked at from the perspective of energy, this is akin to conserving the embodied energy (and associated emissions) within materials rather than seeking to generate energy from these materials. By doing this, the energy used in making what is consumed will be reduced, and by rather more than the energy which might otherwise be generated from thermally treating the waste.

Some indication of the relative contributions associated with different waste management methods is given through consideration of scenarios where

1) Consumption of materials per capita is low or high
2) The recycling rates are low or high, and
3) Residual waste is disposed at landfills or incinerated.

The outcomes of the different scenarios are given in Figure E- 4. They clearly indicate that:

1) The dominant effect is that associated with emissions from production of the materials that become waste, illustrating the value of reducing materials consumption;
2) The effect of recycling is also strong, and

helps to reduce the emissions associated with the system;

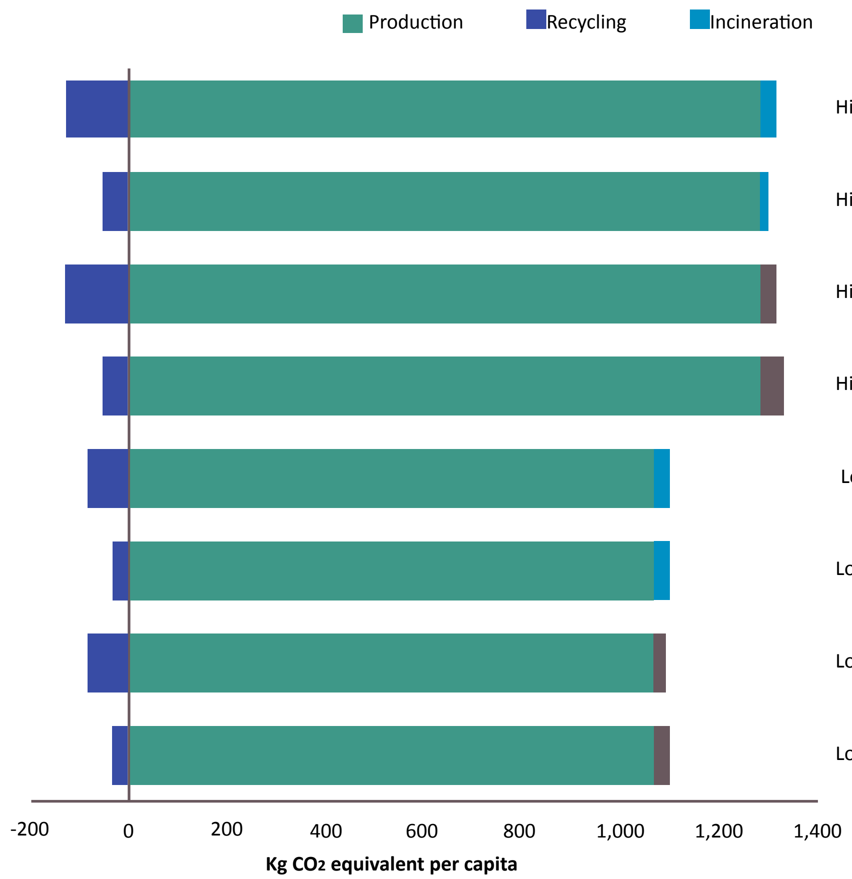
3) The management of waste as residual waste makes a net contribution to the climate change balance. There is not that much difference between the landfill and incineration scenarios.

At the higher levels of recycling under high consumption levels, more substantial benefits associated with recycling can be seen, but this is not sufficient to outweigh the larger emissions impact from the higher consumption levels.

Where policy, and the monitoring of performance, has been concerned, we find that in Europe, for the most part, policy is moving in the right direction: the withdrawal of the legislative proposal that formed part of the first so-called Circular Economy package was disappointing, but the promise of a more ambitious replacement raises prospects for gains to be made. There remain, however, contradictory messages and incentives, partly driven by the fact that the biodegradable part of waste is considered to be a source of renewable energy. This leads to unjustified support measures, and implicit subsidies, for generating energy from waste.

Furthermore, the success or failure of a Member State's waste management policy continues to be measured by European institutions in terms of how little is landfilled: yet precisely because other treatments for residual waste offer limited climate change benefits (if, indeed, they offer any in scenarios where energy systems are being decarbonised), the focus should be on how much waste 'leaks' into any form of residual waste treatment. It follows that policies such as landfill bans have the potential to be counterproductive (as well as being unjustified on grounds of costs and benefits), and that the more appropriate measure is to make all residual waste treatments less attractive relative to recycling and waste prevention through fiscal measures.

Figure E- 4: Illustrative Example - Production Emissions and Waste System Emissions (Impacts per person)



E.2.0 Recommendations

In order to ensure that the prevention and management of waste is accorded the significance it deserves from the perspective of climate change, we make the following recommendations:

Recommendation 1
Waste policies should be designed to manage waste in the upper tiers of the waste hierarchy (i.e. recycling or above)

Generally, waste policies that move waste increasingly into the upper tiers of the hierarchy are likely to be beneficial for climate change. The waste management hierarchy offers a reasonable guide to managing waste sustainably: waste prevention leads to the greatest gains, with recycling options, especially for the dry materials, following closely behind. The main issues lie with the way the hierarchy indicates that residual waste should be managed. In the EU, incineration facilities are classified as recovery where they meet a specific criterion related to energy efficiency. Although the rationale for this seems questionable, a recent study from the JRC suggests that this criterion might be further relaxed in circumstances where temperatures are generally higher. This is despite the fact that simply switching waste from landfill to incineration is likely to lead to limited climate change benefits, and even a worsening of the emissions where energy sources are becoming decarbonised.

Recommendation 2
Indicators of waste management performance should shift from 'how much is landfilled?' to 'how much residual waste is generated?' [3]

One of the key indicators that has been used by DG Environment, Eurostat and the EEA to assess waste management performance is the amount of waste landfilled, with lower figures being deemed indicative of superior performance. This would be a sensible indicator to use if it were true that landfill performed dramatically less well than all other options, and if all other options performed more or less equally well. This is not true: 'not landfilling' can lead to very different strategies and outcomes, and within the EU, there are countries with similarly low rates of landfilling, some of whom have high recycling rates, and low levels of incineration, and others who are in the opposite situation. The analysis in Figure E-2 shows that it will be waste prevention and waste recycling effects that are the dominant determining factors in climate change performance. The shift to a focus on residual waste would also help Member States focus their attention not on capital-intense residual waste treatments (that have the potential to lock them in to low recycling rates), but on moving waste into the upper tiers of the waste hierarchy;

Recommendation 3
The implementation of blanket bans on the landfilling of waste should be resisted. Since, for materials widely found in mixed residual waste, material-specific landfill bans are not enforceable, the focus should be on measures to encourage, or mandate, the separation of waste for preparation for reuse or recycling;

3 By 'residual waste', we mean the waste that is left over after households and businesses have sorted their waste for recycling, as well as the contraries from sorting facilities and plants for treating separately collected biowaste. This is usually a mixed waste fraction, and is typically sent for landfilling, incineration or MBT (mechanical biological treatment).

Linked to the previous recommendation, landfill bans may have counterproductive effects since at the time when they enter into force, then to the extent that they are enforced, there is a requirement to have in place sufficient treatment capacity to ensure that all residual waste can be dealt with at facilities that are not landfills. This can lead to a situation in which the country's waste strategy becomes locked in to low recycling rates. Unsurprisingly, it is Member States which have implemented bans that have excess capacity in residual waste treatment, and which are now seeking to make use of that capacity through importing waste from other Member States.

Similarly, where materials widely found in residual waste are concerned – such as plastics – material specific landfill bans are likely to be unenforceable for the material on its own, and would tend to lead to a complete ban on landfilling if the intention of regulators was to fully enforce the ban (since 100% recycling of all plastics might prove difficult). Policies should 'positively' drive waste up the hierarchy rather than simply banning resort to the lowest tier of the hierarchy, and forcing sometimes excessive investment in residual waste treatment capacity. Hence, landfill taxes, extended to other residual waste treatments, and requirements to sort waste, or to provide households with collection services of a minimum quality, will tend to deliver far superior results. The use of pay-as-you-throw systems is made more 'incentive compatible' where the costs of disposal / residual waste treatment are higher, and is to be encouraged once convenient systems for segregation of wastes are in place.

Recommendation 4

Member States should reconsider their support mechanisms for renewable energy: in particular, they should immediately discontinue support for all forms of energy from residual waste. This includes the use of implicit subsidies, such as exemptions from taxes on heating fuels, unless there are 'balancing' incineration taxes in place.

Given that part of the rationale for developing renewable sources of energy is to address climate change, it seems counterproductive to maintain support for those which might contribute to climate change. The case for supporting measures for the generation of energy from waste on the basis that waste is 'a renewable resource' makes no sense when set against the waste hierarchy. As countries improve in their prevention, reuse, and recycling, so less and less residual waste will be available. It is stretching the definition of 'renewable' beyond what is credible to argue that residual waste could be a source of 'renewable' energy;

Recommendation 5

At the same time, it would make sense to consider the withdrawal of any form of support for the utilisation, directly, of harvested biomass for renewable energy generation / renewable fuels

In a world where there will be increasing pressure on land, it must surely be questionable to use biomass directly for energy when the land used to grow it could be used for food, or for manufacturing prior to the resulting waste materials being recycled: only when waste materials are 'leaking' from the system, or when food waste is being digested, should they be used for energy generation. Currently, the use of primary biomass for energy and fuel is widely subsidised. It is intensely ironic that the waste hierarchy suggests wood wastes would only be combusted once the potential for reuse and recycling has been fully explored: yet the virgin resource can be combusted directly and be subsidies to boot. This is a fundamental misallocation of resources resulting from perverse economic incentives.

Recommendation 6
Consideration needs to be given as to how to integrate 'waste' within the framework of European policies to tackle climate change. One way would be to consider its integration within the EU-ETS. Another would be to consider reinforcing the Effort Sharing Decision, making GHG emission reduction targets with appropriate ambition for the waste sector. Particular attention would need to be paid to ensuring the benefits of recycling and reuse were adequately recognised, even where the recycling and reuse took place in other countries;

Although electricity generation is an activity for which, under the EU-ETS, (with some exceptions) no free allowances are issued, waste facilities which generate energy are not included in the EU-ETS. This is an implicit subsidy. Although the Commission has frequently urged Member States to remove environmentally harmful subsidies, the EU-ETS, as a measure for which the Commission has substantial responsibility, affords an implicit subsidy to waste facilities which generate electricity. An incinerator generating electricity might generate electricity with a carbon intensity of around 600g CO_2 per kWh, almost double the carbon intensity of a modern gas-fired power station.

Recommendation 7
In the short-term, and in the absence of a move to consumption-based inventories, it would be helpful to include:
o as an addendum to the 'waste' section of the inventory, the estimated GHG effects of recycling (including where materials collected for recycling are exported), and
o in the Industry chapter, the extent to which industries make use of recycled materials (and the implied level of emissions saving).

The focus on landfilling highlighted in Recommendation 2 is somewhat perpetuated by the structure of GHG inventories as reported to the UNFCCC. Even the IPCC's own reports, though they refer to waste as a sector, appear to confine themselves, artificially, only to measures which address the number reported under the 'waste' aspect of the inventory (in the main, ways of reducing methane emissions from landfills).[4] This gives a misleading impression as to the extent to which improved waste prevention and management can deliver emissions reductions (even though the emissions reductions might, in the round, be captured by a global inventory).

Recommendation 8
Recognising the uncertainty associated with the way in which emissions from the AFOLU (agriculture, forestry and other land use) Sector are accounted for, inventories should include emissions of biogenic CO_2 from incineration (and biomass power plants) until such time as the accounting methods have across countries been assessed in terms of the adequacy of the treatment of this matter.

Although inventories are developed with the intention, in principle, of capturing biogenic CO_2 emissions through the AFOLU Section, in practice, the manner in which this occurs is such that one cannot be confident

4 Consider that recycling metals instead of landfilling them makes no contribution to reducing landfill emissions, but a considerable one from the perspective of the emissions associated with energy used in manufacturing, as indicated in Figure E- 2.

that the CO_2 emitted from, for example, harvested wood products, is captured under the Tier 1 and other Member State methodologies. Given that, in principle, emissions of biogenic CO_2 from waste treatment plants (and biomass power plants), and to a lesser extent, landfills, are capable of being linked reasonably well to activity data, then it would seem sensible to incorporate these within inventories rather than assuming that the approaches identified by IPCC in the AFOLU Section are adequate for accounting for these.

Recommendation 9
All lifecycle studies engaged in comparative assessments of waste treatments should incorporate CO_2 emissions from non-fossil sources in their comparative assessment:

Whatever the merits of the approach to assembling inventories in IPCC Guidelines, it is a mistake to assume that ‘CO_2 from non-fossil sources doesn’t matter’ in comparative assessments of waste treatment facilities. The argument that CO_2 from such sources is all ‘short-cycle’, and so, can be ignored, is tantamount to assuming a separation in the pools of carbon dioxide from fossil and non-fossil sources. It is as though the argument runs that the climate only changes if emissions of CO_2 come from fossil sources. This is so obviously wrong that it seems genuinely surprising that this argument could ever have been considered acceptable: in a comparative assessment of the contribution of waste management alternatives to climate change, the only correct way to proceed is to account for emissions (and sinks, if this is applicable) of all greenhouse gases since they will all have ‘warming potential’, irrespective of their origin.

Recommendation 10
In the longer term, it would be preferable to move towards consumption based inventories. The information requirements might be significant (although, arguably, if other countries are gathering appropriate inventories, it should be possible to do this).

Many authors have argued reporting inventories on the basis of what is consumed by a country is superior to the existing approach, where emissions are reported based on production within the reporting country. Under the former approach, carbon leakage can occur, whereby businesses transfer their operations to other countries, or countries progressively become more reliant on imports of goods to satisfy demand.[5] Depending on the boundaries used in the inventory assessment, different mitigation options may be indicated; the approach also tends to reduce the importance of emissions contributions from developing countries.[6] Conversely, for most European countries, consumption-based inventories result in higher emissions than their production-based counterparts. One paper which carried out this analysis at a European level suggested that emissions for the EU-27 from 2009 using the production based approach to be 4,059 million tonnes CO_2 equivalent, whilst the equivalent figure using their consumption-based approach was 4,823 million tonnes CO_2 equivalent. [7]
Consumption based inventories typically have higher uncertainties, and involve a significant data collection effort.[8] In addition, countries would need to work closely together to encourage mitigation efforts, thereby reducing the impact of imported goods. Perhaps because of these last two points, policy is currently linked to production or territorial inventory, and in particular the national UNFCCC inventory produced under guidance of the IPCC which is the subject of the discussion in the next section.

5 http://ec.europa.eu/clima/policies/ets/cap/leakage/index_en.htm
6 Glen P. Peters and Edgar G. Hertwich (2008) CO2 Embodied in International Trade with Implications for Global Climate Policy, Environmental Science & Technology, Vol. 42, No.5, 2008, http://www.cepe.ethz.ch/education/EnergyPolicy/PetersHertwich.pdf
7 http://www.wiod.org/conferences/groningen/paper_Boitier.pdf
8 http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/1646/1646we12.htm

Recommendation 11
Regional funds (and funding from international financial institutions) urgently need to reconsider their funding of waste management projects.

The more capital intense waste management options lie closer to the bottom of the waste management hierarchy than the top. The tendency for those engaged in funding organisations, on the other hand, is to see disbursement of capital as a key indicator of success. In such a situation, large amounts of capital can create as many problems as it solves. Whilst it is one thing for private capital to back specific projects, those disbursing regional funds, and the international financial institutions, need to develop innovative models of funding that facilitate projects for prevention, reuse, repair, remanufacturing, and recycling rather than residual waste treatments. The lack of innovation in this regard is extremely disappointing, not least given the limited climate change benefits that are achieved through such projects (notwithstanding the claims made for them).

Fundamentally, the role that waste prevention and improved waste management can play in reducing GHG emissions risks being significantly understated. The current guidelines for preparing inventories are useful for specific purposes, but they are apt to obscure the potential role to be played by better waste and resource management in climate change mitigation. Instead of focusing on waste as a potential source of supposedly renewable energy, the focus must fall on how best to retain the energy which is embodied in (the manufacture of) materials and products, as well as reducing waste generation in the first place.

Contents

1.Introduction

In 2011, the European Commission published its Roadmap to a low-carbon economy, setting targets, which included reductions in domestic emissions of 80% by 2050 compared to 1990. [9] Along with significant reductions in the emissions generated by the power, industrial and transport sectors, the Roadmap indicated that increased resource efficiency through eco-design, waste recycling, better waste management and behavioural change could also play an important role in achieving this objective.

Several Member States have highlighted the contribution made by improved waste management to reduced greenhouse gas emissions:

• A 2008 study by Okopol noted that with 37% of the waste in the EU recycled in 2005, savings of around 158 million tonnes CO_2eq had been achieved. Increasing the recycling rate to 50% increased these savings by 89 million tonnes CO_2eq, whilst increasing the recycling rate to 65% would increase these savings by 145 million tonnes CO_2eq; [10]

37%

of the waste in the EU recycled in 2005

• A 2008 study by Prognos and IFEU found that waste management in Europe could achieve an additional reduction in CO_2 emissions of between 146 and 244 MT, thereby contributing 19-31% of the European climate reduction targets of 780 MT CO_2 equivalent for 2020; [11]

• A 2010 study for the German Umweltbundesamt similarly indicated there were annual savings of circa 140-200 million tonnes CO_2 equivalent still to be realised from improved waste management practices for Europe as a whole. [12]

• A report published by the EEA in 2010 presented a headline scenario in which the annual impact of waste management activities for European countries declined by 85 million tonnes CO_2 equivalent in 2020 when compared to 1995. [13] Although more modest than the reductions indicated by the aforementioned studies, this figure nonetheless still represents more than 10% of the total European climate reduction target for 2020.

• The European Commission's impact assessment noted that high recycling scenarios could lead to an additional 62 million tonnes CO_2 equivalent saving by 2030 over and above those that were expected to be delivered by existing legislation (which appear to be of the order 50 million tonnes CO_2 equivalent). [14]

Each of these studies makes slightly different assumptions regarding the potential benefits. Generally, though, studies in Europe suggest that, even though much progress has already been made in respect of reducing climate change emissions from waste, further savings of the order 100-200 million tonnes CO_2 equivalent could be made simply through conventional waste management approaches: conventional waste prevention measures could deliver more substantial reductions, whilst measures designed to achieve a circular eco-

9 European Commission (2011) A Roadmap for moving to a competitive low carbon economy in 2050

10 Okopol (2008) Climate Protection Potentials of EU Recycling Targets, http://www.eeb.org/publication/documents/RecyclingClimateChangePotentials.pdf

11 Prognos Ifeu and INFU (2008) Resource savings and CO2 reduction potential in waste management in Europe and the possible contribution to the CO2 reduction target in 2020, Prognos in cooperation with IFEU Heidelberg, INFU Dortmund, October 2008

12 Günter Dehoust, Doris Schüler, Regine Vogt and Jürgen Giegrich (2010) Climate Protection Potential in the Waste management Sector – Examples: Municipal Waste and Waste Wood, Umweltbundesamt (UBA), January 2010, https://www.umweltbundesamt.de/sites/default/files/medien/461/publikationen/4049.pdf

13 Projections of Municipal Waste Management and Greenhouse Gases, ETC/SCP working paper 4/2011, European Environmental Agency (EEA), August 2011

14 European Commission (2014) Impact Assessment Accompanying the document, Proposal for a Directive of the European Parliament and of the Council amending Directives 2008/98/EC on waste, 94/62/EC on packaging and packaging waste, 1999/31/EC on the landfill of waste, 2000/53/EC on end-of-life vehicles, 2006/66/EC on batteries and accumulators and waste batteries and accumulators, and 2012/19/EU on waste electrical and electronic equipment, Brussels, 2.7.2014, SWD(2014) 207 final.

nomy could further enhance emissions reduction through reuse, repair and remanufacturing.

The level of these savings compares with the reported level of emissions from waste of round 143 million tonnes in 2012 for the EU under the waste chapter.[15] Of this, around 100 million tonnes is related to solid waste management (the majority of the balance being due to waste water treatment). Consequently, it would appear that the potential for emissions reduction from waste prevention and management is likely to be of the order two times the reported level of emissions under the 'waste' inventory.

Considered through the lens of reporting inventories to the UNFCCC, however, the role of proper waste management is far less easy to discern. A report on the Mitigation of Climate Change which formed part of the IPCC's Fifth Assessment Report in 2014, highlights - in the chapter on Industry – a range of technological options that can be used to mitigate climate change impacts of waste management, including waste prevention, recycling and re-use.[16]

The main mitigation options subjected to quantitative analysis, however, were a narrow range of options: too many reports have followed the IPCC's structuring of the inventory by focusing on methane emissions from landfill when considering the potential for waste to contribute to GHG reduction. Waste management is not simply about 'not landfilling', still less, ensuring the capture of methane from landfills, important as this might be. The contribution that waste management can make to GHG emissions reduction risks being undermined by the approach which countries are being asked to take to reporting of 'waste' emissions, and this is reflected in the lack of emphasis on the most beneficial options in the Fifth Assessment Report. It is barely surprising, therefore, that the report notes:

....waste management policies are still not driven by climate concerns, although the potential for GHG emission reductions through waste management is increasingly recognized and accounted for.

The IPCC's own report offered little by way of concrete evidence as to why any country would consider that its waste management policies should be driven by climate concerns. Despite suggesting that the waste hierarchy might offer a sensible guide to managing waste, as noted above, quantitative evidence was restricted to a range of management options, mostly at the bottom end of the hierarchy. [17]

The intention of this report is to draw urgent attention to the significance of choices made in respect of preventing and managing waste materials in the battle to tackle climate change. In doing so, it also makes observations regarding some policy measures which have been used to support the development of 'renewable' energy generation. To the extent that renewable energy policies are developed in part with the intention of tackling climate change, we indicate that some such policies are likely to give rise to perverse consequences from the perspective of preventing and managing waste in the most appropriate manner.

Recognising that the existing structure of the reported GHG inventory might have had the unintentional consequence of diminishing the attention paid to waste prevention and management in the quest to combat climate change, we also comment on matters which we believe need to be considered in respect of accounting methodology.

15 European Environment Agency (2014) Annual European Union Greenhouse Gas Inventory 1990–2012 and Inventory Report 2014, Submission to the UNFCCC Secretariat, Technical Report No. 09/2014.

16 IPCC (2014) Mitigation of Climate Change: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

17 Mitigation options considered were composting, AD, Biocover, In situ aeration (at landfills), CH4 flaring (at landfills), CH4 capture plus heat / electricity generation (at landfills).

1.1 Scope

1.1.1 Geographical Scope

The study is primarily focused on the current situation in EU Member States. However, it is anticipated that the analysis of treatment technologies will also be of relevance to countries outside of Europe. This is because for most of the prevention and management methods concerned, whilst local factors such as waste composition, and the country's marginal sources of energy, may change from one place to another, the potential benefits derived from the different prevention / management routes tend to follow fairly set principles.

Furthermore, the study's recommendations in respect of the approach to assembling inventories are applicable across the board. These are important since the current approach has the potential, we believe, to mislead, both in respect of the potential gains to be made from improved prevention and management of waste, and in terms of which technologies are most beneficial from the perspective of climate change mitigation.

1.1.2 Waste Streams

The main focus in this report is on the potential for GHG reductions associated with waste typically collected, or targeted for prevention, by local authorities (and others), i.e., non-hazardous waste collected by local authorities. The term 'municipal waste' is often used in this context: within Europe, although there is a 'more or less official' definition of municipal waste, in practice, few Member States apply this definition rigidly. The IPCC Guidelines state:

Municipal waste is generally defined as waste collected by municipalities or other local authorities. However, this definition varies by country. Typically, MSW includes:

Household waste;
Garden (yard) and park waste; and
Commercial/institutional waste.

The regional default composition data for MSW is given in Section 2.3.1.

This definition, if applied as it is worded, would exclude any waste collected by private contractors. Furthermore, those familiar with this discussion will know that the quantity and composition of municipal waste is significantly influenced by factors such as:

• the extent to which the municipality, or an actor working on its behalf, consciously decides to collect waste from non-household sources;ces;

• whether the nature of the service on offer to households is effectively 'open' to others to access (such as with many road container schemes) or not (for example, with door-to-door collections).

The emphasis here is on the types of waste collected by local authorities.

2.Methodological Issues with Reporting of Emissions from Waste Management

This Section reviews some of the issues which arise in the context of the reporting to the UNFCCC of emissions associated with waste management.

2.1 The Scope of "Waste" in the UNFCCC Emissions Inventory

At present, targets being set by Member States, and by the European Commission itself, relate largely to the emissions as reported to the UNFCCC, so these, or closely related adaptations thereof, are the principle means through which progress in terms of emissions reduction is tracked.[18] Guidelines and Good Practice Guidance on the development of these inventories has been produced by the IPCC, whilst Good Practice Guidance arising from the Kyoto Protocol has also been produced. The IPCC Guidelines form the basis of most of the discussion in this sub-section.

2.1.1 General Approach

The UNFCCC inventory contains a specific chapter on waste. It covers impacts related to landfilling, incineration, organic waste treatment and MBT. For incineration and the anaerobic digestion of biowaste, once energy is generated, the impact of these treatment systems is no longer recorded under the "waste" section of the inventory, but is instead recorded under the stationary combustion section of the inventory.[19]

There is no mention of 'recycling', or 'preparation for reuse', or 'reuse' (as part of 'waste prevention') in the waste inventory. At first glance, this might seem odd given the fact that the emissions savings from these activities would seem to be the most significant ones for the management of waste. However, the emissions from materials production and from product manufacture fall under the 'industry' part of the inventory: under this approach, if industries resort to using more secondary materials in production than primary ones, this should result in the reported emissions falling under the waste section of the inventory.

Generally, the impacts recorded in the "waste" part of the inventory are limited to the recording of direct emissions from the disposal / treatment systems (other than where the treatment generates energy). This is because the inventory is concerned with gathering information on emissions generated within the country, and across all sectors: in the analysis conducted in Section 3, the perspective taken is one of the effects, in the round, of activities undertaken to manage waste in a better way.

A number of key impacts in emissions which arise from changes in the management of waste do not appear under the waste part of the inventory. These include:

- The benefits of targeted waste prevention activities, such as food waste prevention: these are effectively reported as reduced emissions in the industry part of the inventory;
- The benefits of extending the life of products or components thereof, notably through preparation for reuse (not to mention, repair, or remanufacturing, though these are more clearly associated with actions taken by industrial producers): these are effectively reported as reduced emissions in the industry part of the inventory;
- The benefits, from recycling, of avoiding the use of primary materials. These are effectively reported as reduced emissions in the industry part of the inventory;
- The benefits, from avoiding the use of alternative means of generating energy or fuels, of

18 See European Commission (2013) Elements of the Union greenhouse gas inventory system and the Quality Assurance and Control (QA/QC) programme, Commission Staff Working Document SWD(2013) 308 final, Brussels 12.8.2013 http://ec.europa.eu/clima/policies/strategies/progress/monitoring/docs/swd_2013_308_en.pdf

19 Note that this does not appear consistent, methodologically, with the approach taken to landfill: if energy is generated by incineration, the process emissions are recorded under "energy", whilst the emissions from landfill are reported under "waste" irrespective of whether energy is generated at the site.

various treatments and of landfilling. These are effectively reported as reduced emissions in the stationary combustion inventory;

• The benefits associated with the use of compost / digestate, including benefits associated with the reduced requirement for the manufacture of fertiliser, or the increase in soil carbon that might result from the application of compost to soil;

• Emissions associated with energy used at waste treatment facilities are not included and neither are emissions associated with the transport of waste (these being reported under the stationary combustion and mobile combustion parts of the inventory);

• The avoidance of fuels such as petcoke in the cement industry (through use of waste-derived fuels). These are effectively translated into reduced emissions from industry;

In addition, it should be noted that:

• For MBT systems, the suggested emissions factors are those relating to source segregated organic treatment systems; no specific MBT factors are provided, although Member States are also free to supply the relevant data on emissions factors specific to that country and its systems;

• Only emissions which are generated within the borders of the country are considered (see Section 2.2 below).

The waste section of the inventory therefore only considers impacts only of a very limited range of activities which would generally be regarded as being part of the waste management function, with the emissions being reported largely connected to the emissions associated with treatment at the lowest level of the hierarchy.

Additionally, for landfill, only the emissions that occur within the past year are included. This will include both impacts from previous deposition as well as current deposition. Future impacts in subsequent years, however, are not included until those years are reported (even though they are, effectively, pre-determined in a Member State's modelling).

Subject to the above limitations in scope, the methodology for estimating the landfill / incineration emissions is relatively sensible if one accepts the view adopted by the IPCC that emissions which are not of fossil origin can be ignored: it will become clear in Section 2.3 that we do not. The default factors for composting look somewhat more problematic.

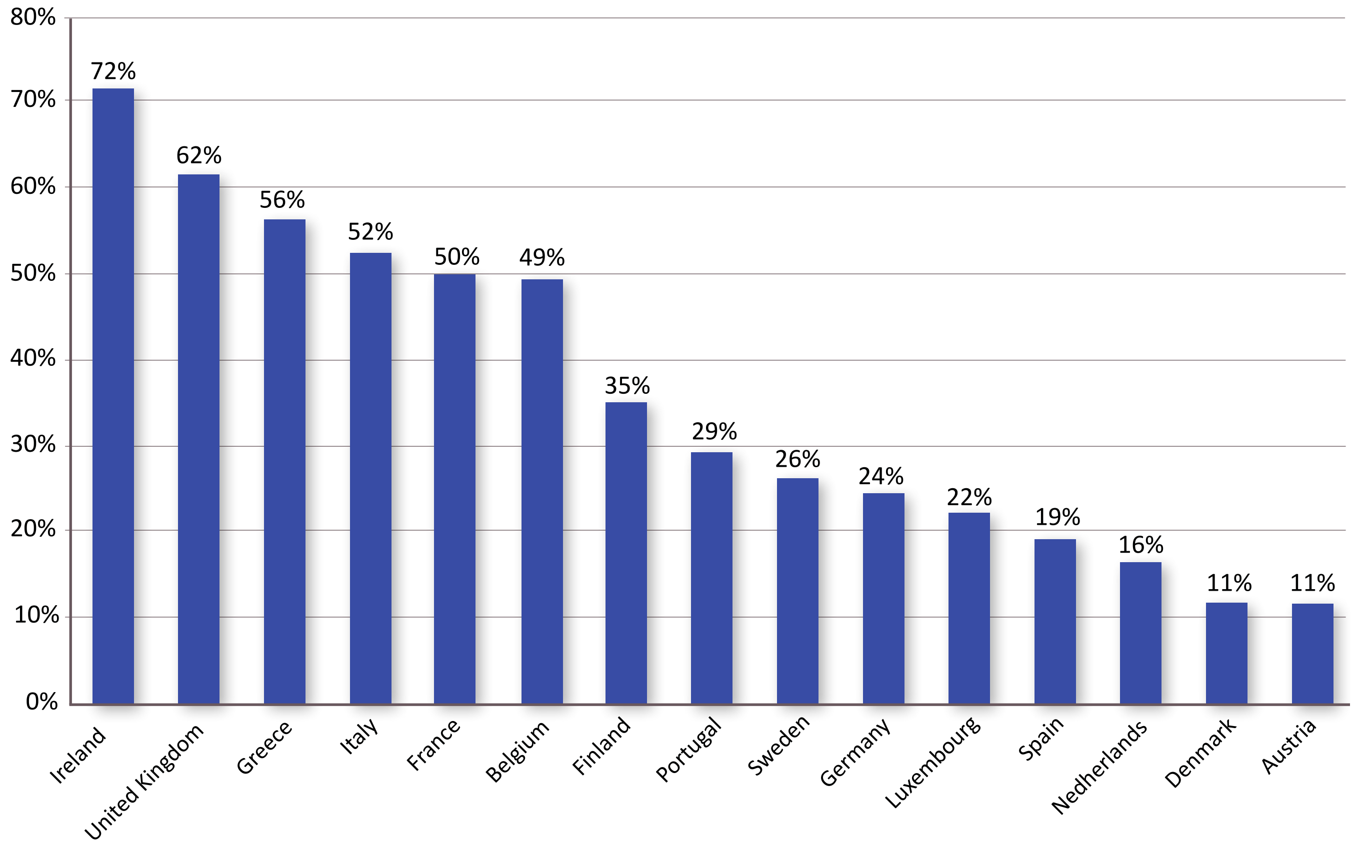
However, it is important to note that many Member States opt to use country-specific data when estimating the impacts. In the case of the landfill, there is scope for departures from the default methodology: Figure 2 -1 confirms, for example, that there are substantial differences across different member states in their implied landfill gas capture rates.

It should be noted that EU waste policy has, in the past, suffered from a similarly narrow view of the role of waste prevention and management in addressing climate change emissions. In the only mention of greenhouse gas emissions in the Directive, Paragraph 35 of the preamble to the Waste Framework Directive (2008/98/EC) states:

It is important, in accordance with the waste hierarchy, and for the purpose of reduction of greenhouse gas emissions originating from waste disposal on landfills, to facilitate the separate collection and proper treatment of bio-waste in order to produce environmentally safe compost and other bio-waste based materials. The Commission, after an assessment on the management of bio-waste, will submit proposals for legislative measures, if appropriate.

This might be interpreted as implying that only the separate collection and treatment of biowaste is being considered as important from the perspective of climate change because this contributes to reduced landfill emissions.

Figure 2 1: Methane Recovery Rates (%) for 2012



*Source: EEA (2014) Annual European Union greenhouse gas inventory 1990–2012 and inventory report 2014, Technical report No 09/2014. Note CH_4 recovery in % = CH_4 recovery in Gg/ (CH_4 recovery in Gg + CH_4 emissions 6A1 in Gg)*100. CH_4 emissions from unmanaged landfills are excluded in the calculation*

2.1.2 Critical Review of IPCC Fifth Assessment Report

It is clear that given the approach in the UNFCCC inventory, reported impacts under the 'waste' section would be very small for countries that do not send much waste to landfill. Given this, it is perhaps less surprising that the mitigation report published by the IPCC alongside the Fifth Assessment Report has very little mention of policies in respect of improved waste management. The report does note:

With a high degree of agreement, it has been suggested that urban mining (as a contribution towards a zero waste scenario) could reduce important energy inputs of material future demands in contrast to domestically produced and, even more important for some countries, imported materials, while contributing to future material accessibility.

There is a review of mitigation options and their potential. The study presents 'the potentials and costs of selected mitigation options to reduce the GHG emissions of the solid waste disposal and domestic wastewater emissions. The report looked at six mitigation options for solid waste. These were composting; anaerobic digestion; biocover; in-situ aeration; CH_4 flaring; and CH_4 capture plus heat / electricity generation.

The report notes that the reference case and the basis for mitigation potentials were derived from IPCC 2006 guidelines. It also states that: 'Abatement costs and potentials are based on EPA (2006b; 2013).' The EPA source referenced included three other options for abatement: paper recycling, mechanical biological treatment and waste to energy.[20] The way in which the calculations were conducted in the IPPC report is less than transparent, but the EPA report considered that waste to energy was the most expensive option when considered in terms of a break-even price, expressed in terms of \$/tonne CO_2 equ. abated. The EPA report appeared to focus the analysis only on the abatement of the methane emissions from landfill. The IPCC report takes the same approach:

The mitigation potential for waste is derived by comparing the emission range from a reference technology (e. g., a landfill) with the emission range for a chosen technology. The GHG coverage for solid waste is focused on methane, which is the most significant emission from landfilling; other GHG gases such as N_2O only play a minor role in the landfill solid waste sector and are neglected in this study (except for composting).

This gives an unrealistic picture of the potential for abatement of GHGs more generally. The objective of improved waste management, after all, is, as well as to reduce emissions from landfill, to reduce emissions in production (and hence, consumption), including through allowing for substitution of primary materials by secondary ones.

In our view, the IPCC reporting around the issue of 'waste' is compromised by its desire to speak, on the one hand, of the various possibilities for preventing and managing waste (as exemplified by the replication of the waste management hierarchy in the document), and on the other, by a narrow and unhelpful review of abatement potential, which focuses only on the reduction of methane from landfills. The section on waste, therefore, includes no appreciation of the reduction in CO_2 emissions which results from moving, for example, non-biodegradable materials (such as metals) out of landfills and into recycling. As Section 3.2 indicates, these are some of the largest benefits that accrue from improving waste management, but since they have no impact on methane emissions from landfills, they receive no meaningful quantitative analysis in the 'waste' part of the report.

Other comments include that:

1) The report comments, regarding landfill and waste-to-energy, note that despite higher capital costs, incineration (WTE) is 'usually more economic over its lifetime of 30 years or more'. There is no substance given to this comment (and nor does it make much sense to speak of one technology being 'more economic' than another). In our experience, in the absence of price support for energy, and before the application of taxes at landfills, incinerators are typically much more expensive than landfills to operate where emissions are controlled (as they will be). There is a concern that the analysis shades into a bias towards WTE, not least given its omission from the analysis of abatement costs and potential: had this been included in line with the EPA approach, presumably, this would have demonstrated, as the EPA work did, the very high abatement cost of the technology;

2) The assumption that because food wastes 'when composted in windrows, emit unpleasant odours' and that 'Therefore, food wastes need to be anaerobically digested in closed biochemical reactors' is technically misinformed. Even open-air windrows can be operated under negative pressure with air drawn through biofilters to address odours, but housed windrows and other enclosed composting systems will be equally valid in different situations;

20 See EPA (2013). Global Mitigation of Non-CO2 Greenhouse Gases: 2010 – 2030. United States Environmental Protection Agency, Washington, D. C., USA, 410 pp. Available at: http://www.epa.gov/climatechange/Downloads/EPAactivities/MAC_Report_2013.pdf .

3) There is a statement that: 'Source separation, collection, and anaerobic digestion of food wastes are costly and so far have been applied to small quantities of food wastes in a few cities (e. g., Barcelona, Toronto, Vienna; Arsova, 2010), except in cases where some food wastes are co-digested with agricultural residues.' This situation is changing quite quickly, and this view is beginning to look rather dated. There has, in any case, been somewhat limited separate collection of food waste in Barcelona, where MBT facilities incorporating anaerobic digestion have been used to deal with residual waste.

In short, the IPCC document does few favours for the perception that improved waste management has a major role to play in ongoing efforts to combat climate change. Sadly, therefore, it could itself be considered one more reason why countries have not based waste management policies around climate change in the manner it implies they should: perhaps if the IPCC made a better job of demonstrating the mitigation potential arising from improved waste management, then countries might be more likely to review their waste management policies from this perspective: they might also seek to do something more than simply 'not landfilling', as sometimes switching from landfill to incineration will diminish the prospects for achieving far higher levels of mitigation by committing to send materials to incineration plants.

2.2 The Use of Production-based Inventories

The climate impacts of greenhouse gas emissions are not dependent on the place from which they are emitted. In this sense, the emissions are 'democratic'. On the other hand, in the context of global negotiations regarding climate change, countries are being expected to agree to establish binding targets. These targets have focused on reducing emissions which are emitted from activities which take place within the borders of the country concerned. The UNFCC asks countries to report emissions on the basis of production, or territorial, inventories: these consider only those impacts taking place within the national boundary, although in the case of the UNFCCC inventory, this is extended to include emissions and removals " taking place within national (including administered) territories and offshore areas over which the country has jurisdiction; [21]

The emissions associated with what a country decides to do in respect of management of its own waste are not, however, necessarily confined to its own borders. Materials collected for recycling, for example, may be traded globally, so that the recycling activity occurs outside the country's borders. Consequently, the global impact of the changes which result from a country's decisions regarding its waste management behaviour might be quite different from those which are registered in the country itself, as reported under IPCC Guidelines.

This discussion has its parallels in patterns of consumption: if a country is a significant net importer of the good which it consumes, then emissions associated with the production of the consumed goods will not be recorded in the inventory of the importing country: only the emissions of what is produced domestically will be registered. In principle, this means that countries could meet their national climate change targets by, in part, relying more heavily on other countries for its production of goods. Although this would have, other things being equal, detrimental economic consequences, this could be avoided by switching to services and exporting more of these.

To give one concrete example of what this means for waste management, we noted above that the

21 Intergovernmental Panel on Climate Change. Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 3, Pg. 6.28, (Paris France 1997)

climate change benefits of waste prevention are significant. If we take food, as an example of a widely traded commodity, if campaigns on food waste prevention are successful, then from the perspective of the inventory reported to the UNFCC, the impact of this activity actually depends on where the food whose production is effectively avoided would have been produced. Only if the prevention relates to domestically produced food does the inventory register any change. Even then, if the domestic source of food from which demand has diminished is able to produce the same quantity (and, for example, compensate for reduced demand by exporting), then there is still no net effect. This is shown in Table 2 -1. If the emissions associated with food production are 3 tonnes per tonne of food consumed, then there is zero effect on the national inventory if the production which is avoided is overseas. Only where the avoided production is domestic production, and where the domestic producer cannot maintain production (by, for example, increasing sales of product overseas), does the prevention effect register in the national inventory.

Similarly, the climate change benefits of recycling are related to the emissions saved when goods are produced from secondary materials instead of primary ones. The net effect on inventories reported under IPCC is rather more complicated here since the net effect depends on:

- Whether the production of the primary and / or secondary material takes place domestically or in other countries; and
- How the domestically located producers (whether primary or / and secondary) adapt to the changes caused by an increase in domestic recycling activity.

Although the effects of recycling may be to reduce emissions at the global level, the way in which this translates into the reported inventory varies under different situations. The effect in the UNFCC inventory is zero in three of the eight scenarios considered, a net increase in emissions in two of the scenarios, and negative only for three of the scenarios, with an overstatement of the benefit at the global level being reported under two of the three scenarios. In only one of the eight scenarios does the reported effect in the UNFCC inventory reflect the global impact. This is shown in Table 2 -2.

In the global round, to the extent that they covered

Table 2-1: Effect on Inventory Reporting of Waste Prevention under Different Scenarios

Scenario		Impact (tonnes CO¬2 eq.)
Actual impact	Prevention of food waste	-3
Impacts according to inventory	Where avoided food waste is produced overseas	0
	Where avoided food waste is produced domestically, but there is no compensating increase in production	-3
	Where avoided food waste is produced domestically, and producer maintains production (and exports to compensate)	0

Table 2-2: Effect on Inventory Reporting of Waste Recycling under Different Scenarios

Scenario	Primary production	Secondary production	Scenario description	t CO_2 eq.
Actual impact	5 tonnes CO_2 eq.	1 tonne CO_2 eq.	ACTUAL GLOBAL IMPACT	-4
Inventoried impact	Domestic	Overseas	Primary Production Increases Exports to Compensate for Reduced Domestic Demand	0
	Domestic	Overseas	Primary Production Falls in Line with Reduced Domestic Demand	-5
	Overseas	Domestic	Secondary Production Increases in Line with Increased Availability of Feedstock	1
	Overseas	Domestic	Secondary Producer Reduces Demand for Foreign Feedstock	0
	Domestic	Domestic	Primary Production Falls as Secondary Production Increases	-4
	Domestic	Domestic	Primary Production Remains Constant as Secondary Production Increases	1
	Domestic	Domestic	Primary Production Remains Constant and Secondary Production Remains Constant	0
	Domestic	Domestic	Primary Production Falls and Secondary Production Remains Constant	-5

all countries, UNFCC inventories ought to capture the benefits of the changes in waste management being implemented across countries, irrespective of where activities take place. However, there is limited encouragement given, through the UNFCC mechanism for reporting inventories, to improving waste management, in particular, in those countries which are significant net importers of materials and products.

2.3 The Weaknesses in Accounting for Biogenic Carbon

A key issue in the assessment of GHG emissions from waste treatment technologies is whether or not non-fossil CO_2 (otherwise known as biogenic CO_2) should be included in the assessment of the impacts of waste management. For the IPCC, non-fossil CO_2 is considered to be part of the natural carbon balance and therefore not a contributor to atmospheric concentrations of CO_2.[22] In the Introduction to Volume 5, on Waste, the IPCC notes.[23]

Typically, CH_4 emissions from SWDS are the largest source of greenhouse gas emissions in the Waste Sector. CH_4 emissions from wastewater treatment and discharge may also be important.[24]

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 guidance given in Chapter 5 of this Volume is generally valid for waste burning with or without energy recovery. CO_2 is also produced in SWDS, wastewater treatment and burning of non-fossil waste, but this CO_2 is of biogenic origin and is therefore not included as a reporting item in this sector.1 In the Energy Sector, CO_2 emissions resulting from combustion of biogenic materials, including CO_2 from waste-to-energy applications, are reported as an information item. Nitrous oxide is produced in most treatments addressed in the Waste volume. The importance of the N_2O emissions varies much depending on the type of treatment and conditions during the treatment.

The important footnote referred to in the above citation reads as follows: [25]

CO_2 *emissions of biogenic origin are either covered by the methodologies and reported as carbon stock change in the AFOLU [Agriculture, Forestry and Other Land Use] Sector, or do not need to be accounted for because the corresponding* CO_2 *uptake by vegetation is not reported in the inventory (e.g., annual crops).*

It is important to understand whether this is, indeed, the case, or at least, whether the treatment is adequate.

2.3.1 UNFCCC Approach

The AFOLU Volume of the IPCC Guidance essentially requires that inventories consider net changes in carbon stocks over time, or that they consider GHG fluxes through direct estimation. Increases in total carbon stocks over time are equated with a net removal of CO_2 from the atmosphere and reductions in total carbon stocks (less transfers to other pools) are equated with net emissions of CO_2.

What eventually becomes 'waste of biogenic origin' is originally harvested as biomass, considered within the AFOLU section. One of the other 'pools' to which carbon is transferred is the pool of 'Harvested Wood Products' (HWP), the subject of a specific chapter under the AFOLU Section. The rationale for this is as follows: [26]

Harvested wood requires additional consideration because some of the carbon may be stored in wood products in use and in landfills for years to centuries. Thus, some of the carbon removed from the ecosystem is rapidly emitted to the atmosphere while some carbon is transferred to other stocks in which the emissions are delayed.

It is also instructive to understand why the HWP chapter was deemed necessary. The previous (1996) version of the Guidelines:[27]

22 Intergovernmental Panel on Climate Change (1997) Greenhouse Gas Inventory Reference Manual: Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, Vol. 3, Pg. 6.28
23 IPCC (2006) Volume 5: Waste, Chapter 1: Introduction, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_1_Ch1_Introduction.pdf
24 Solid Waste Disposal Sites (SWDS)
25 IPCC (2006) Volume 5: Waste, Chapter 1: Introduction, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_1_Ch1_Introduction.pdf
26 IPPC (2006) Volume 4: Agriculture, Forestry and Other Land Use, Chapter 1: Introduction, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_01_Ch1_Introduction.pdf
27 IPCC (2006) Volume 4: Agriculture, Forestry and Other Land Use, Chapter 12: Harvested Wood Products, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_12_Ch12_HWP.pdf

did not provide methods for estimating carbon held in HWP, and recommended, for the purpose of basic calculations, a default assumption expressed as "… that all carbon biomass harvested is oxidised in the removal [harvest] year". This was based on the perception that HWP stocks are not changing. That is, the annual carbon inflow and outflow for the HWP reservoir were assumed to be equal and the oxidation from pre-existing wood products stocks could be replaced (and hence omitted) by an implied oxidation directly after harvesting. More precisely therefore the IPCC default assumption was that inputs to the HWP reservoir equals outputs. Since the only significant output is oxidation, this means that the amount of oxidation equals the harvest, where the oxidation includes oxidation of some of the wood harvested in the current year and oxidation of some of the HWP placed in use in prior years. Given that inputs do not in general equal outputs and that carbon can remain stored in HWP for extended periods of time, this storage time needs to be taken into account when providing guidelines for estimating the contribution of HWP to AFOLU CO_2 emissions/ removals.

In principle, therefore, the HWP pool ought to include an estimation as to how stocks of biomass change over time. We can reason that the stocks will increase as a result of harvesting, and decline as a result of oxidation, but also, other losses, including the fate of carbon in those HWPs that enter the waste stream.

This implies that the HWP stock estimation has to take into account the way in which HWPs that enter waste stream are managed, and in particular, the emissions to which they give rise. This overlap with the other Sections of the inventory is recognised in the chapter related to HWP:[28]

Estimates of HWP Contribution are designed to be consistent with those for other sectors of these guidelines, specifically:

1. All CO_2 released from HWP is included in the AFOLU Sector;
2. CO_2 released from wood burnt for energy in the Energy Sector is not included in the Energy Sector totals (although CO_2 emissions from biofuels are reported as a memo item for QA/QC purposes). CH_4 and other gases from HWP used for energy is included in the Energy Sector;
3. CO_2 released from HWP in SWDS is not included in the Waste Sector totals although CH_4 emissions from HWP are included.

Methods in this chapter estimate release of carbon: this carbon may also be counted as methane emissions in the Waste Sector. This potential double counting of carbon release to the atmosphere can be corrected by subtracting the carbon emitted in the methane emissions from HWP in landfill from the carbon emissions estimated in this chapter (see guidance on how to make an optional correction in Section 12.2.1.5).

There are problems with this approach, however. For example, as the Chapter on HWP itself notes, emissions occur over different time profiles: [29]

The time carbon is held in products will vary depending on the product and its uses. For example, fuelwood and mill residue may be burned in the year of harvest; many types of paper are likely to have a use life in uses less than 5 years which may include recycling of paper; and sawnwood or panels used in buildings may be held for decades to over 100 years.

Newsprint is typically cycled through recycling systems and back into newsprint in a period of weeks. Whether it is recycled back into newsprint depends critically on whether it is recycled. Recycling has the effect, therefore, of not only reducing the energy

28 IPCC (2006) Volume 4: Agriculture, Forestry and Other Land Use, Chapter 12: Harvested Wood Products, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_12_Ch12_HWP.pdf
29 IPCC (2006) Volume 4: Agriculture, Forestry and Other Land Use, Chapter 12: Harvested Wood Products, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_12_Ch12_HWP.pdf

used to manufacture paper (see Section 3 below), but it also has the effect of slowing down the rate at which HWP stocks are diminished, the more so as the recycling rate increases. The same is true of wood, which can be reused or recycled. Given that data regarding the level of harvesting is likely to come from a completely different source to that which is used to estimate the loss of carbon in HWP stocks, then these parameters – reuse and recycling rates – ought to have an influence on how country estimates the rate at which losses take place from HWPs unless compensating estimates are made in other parts of the inventory.

The HWP Tier 1 approach seeks to specify changes in stocks through essentially positing half-lives of types of products (paper and solid wood), which is an opaque way of representing something that is potentially significant. Tier 3 methods allow for alternative approaches. However, what is at issue here is whether or not the inventories can be sure to have taken into account the non-fossil emissions of CO_2 from incineration plants (and from plants using harvested biomass to generate energy). In our view, this is far from clear, not least since cross checks of this nature would be rather difficult to undertake.

In the stationary combustion section, it is stated that CO_2 from biomass is to be reported as an information item: [30]

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 biomass fuels, the comment is made:

Emissions of CO_2 from biomass fuels are estimated and reported in the AFOLU sector as part of the AFOLU methodology. In the reporting tables, emissions from combustion of biofuels are reported as information items but not included in the sectoral or national totals to avoid double counting. In the emission factor tables presented in this chapter, default CO_2 emission factors are presented to enable the user to estimate these information items.

It is less than clear that these emissions are being appropriately accounted for in the AFOLU Section of the inventory.

The significance of this issue can perhaps be appreciated from the way in which emissions from the EU have changed over time. For the EU-15, emissions from solid waste disposal on land reportedly fell from 143 million tonnes CO_2 equ. in 1990 to 77 million tonnes CO_2 equ. in 2012, a reduction of 66 million tonnes.[31] The same source reports that:[32]

In 2012, the share of CO_2 emissions from other fuels amount to 4 % of total greenhouse gas emissions from public electricity and heat generation. Emissions increased by 190% at EU-15 level between 1990 and 2012 and increased in all countries where 'other fuels' are used in heat and power generation. Other fuels cover mainly the fossil part of municipal solid waste incineration where there is energy recovery, including plastics (Table 3.10).

30 IPCC (2006) Volume 2: Energy, Chapter 2: Stationary Combustion, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

31 European Environment Agency (2014) Annual European Union Greenhouse Gas Inventory 1990–2012 and Inventory Report 2014, Submission to the UNFCCC Secretariat, Technical Report No. 09/2014.

32 European Environment Agency (2014) Annual European Union Greenhouse Gas Inventory 1990–2012 and Inventory Report 2014, Submission to the UNFCCC Secretariat, Technical Report No. 09/2014.

33 In landfills, not all carbon is assumed to be dissimilable within the landfill. Furthermore, around half of the carbon that does degrade is converted to methane. Hence, only around a quarter of the non-fossil carbon in landfills is converted directly to CO2. Of the fraction that is converted to methane, some will be captured for energy generation and converted to CO2 (EU Member States take different views on how effective gas capture systems are, or have been). A further fraction of the methane generated may be converted into CO2 through oxidation as the gas passes through the landfill cap. In essence, therefore, the lower the assumed gas capture rate, the lower, other things being equal, will be the proportion of biogenic carbon being emitted as CO2. By contrast, more or less 100% of all biogenic carbon entering an incinerator will be emitted as CO2.

For this category of stationary combustion, for the EU15, emissions increased from 12.9 million tonnes CO_2 equ. 1990 to 37.4 million tonnes CO_2 equ. in 2012, an increase of 24.5 million tonnes. This is 37% of the drop in emissions from landfill.

Neither the landfill figures nor the incineration figures account for the biogenic CO_2 emissions over the same period: these are much higher, on a tonne-for-tonne basis, for incinerators than for landfill.[33]

If one assumes that on average, of carbon assumed to be dissimilable, 50% was converted to methane, and that on average, 45% was captured and converted to CO_2, whilst a further 10% was oxidised, this would leave around three times as much carbon being emitted in the form of CO_2 than is emitted as methane. In CO_2 equivalent terms, therefore, the fall in landfill emissions would be from 163 million tonnes CO_2 equ. to 88 million tonnes CO_2 equ., or a reduction of around 75 million tonnes CO_2 equ. Most of our analyses indicate that the carbon content of residual waste is reasonably evenly split between the fossil and non-fossil elements (though the UK inventory, for example, assumes that 75% of the carbon in waste which is incinerated is of non-fossil origin, a completely unsupportable assumption, and one that is completely at odds with the waste composition data which was commissioned by the environment department of the UK Government) [34], so that the increase in all CO_2 emissions from 'other fuels' might be closer to 49 million tonnes CO_2 equ., or even greater.[35] This suggests that if biogenic emissions are included, then it may be that as much as 65% of the reported reduction in emissions from waste disposal have been effectively offset by increases in emissions from 'other energy sources', including incineration.

Other issues relate to the treatment of soils, and the lack of apparent read across from the Waste Section of the inventory to the AFOLU Section. In principle, the application of compost to soils should be taken into account within inventories, with the effects on reservoirs of soil carbon taken into account.

It is clear that the lack of clarity in the inventory process around how biogenic CO_2 emissions should be accounted for is a fundamental issue, and potentially of genuine significance. There appears to be potential for significant gaps and errors in the reporting process. It should be noted that the US EPA has also seen it appropriate to launch a body of research on how carbon dioxide emissions associated with bioenergy and other biogenic sources should be accounted for.[36]

2.3.2 The Treatment of Biogenic CO2 in Comparative Studies of Waste Treatment Methods

Many studies have sought to understand the pros and cons of different waste management methods from the perspective of climate change. They have often done so using principles of life cycle assessment, though focused on the impact assessment category related to climate change.

Currently, the convention in most studies in respect of the accounting for greenhouse gas impacts using the life cycle assessment methodology appears to be shaped by IPCC's approach to dealing with non-fossil

34 The assumption is made clear in UK Greenhouse Gas Inventory 1990 - 2012: Annexes, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/310791/UK_National_Inventory_Report_Annexes_1990-2012.pdf . For composition studies of relevance, see, for example, Resource Futures (2012) National compositional estimates for local authority collected waste and recycling in England, 2010/11, Defra Research Report EV0801, file:///C:/Users/dominic.hogg/Downloads/11715_EV0801ReportFINALSENT05-12-13.pdf

35 Eurostat notes, for example, that in 2012, in the EU15, 92.6 million tonnes of waste were incinerated (see the Table which can be accessed from http://ec.europa.eu/eurostat/web/waste/waste-generation-and-management/management/incineration): the figure of 37.4 million tonnes of emissions of non-fossil origin for this, as well as other sources, seems low (a figure of 403 kg per tonne of waste is implied). Equally, for the emissions including CO_2 of fossil origin, we would expect a figure of the order 90-100 million tonnes, and possibly more. Such a level of emission from incineration would suggest that the reduction in emissions from landfill are almost completely counterbalanced by an increase in emissions from incineration.

36 See http://www3.epa.gov/climatechange/ghgemissions/biogenic-emissions.html

37 This is also dependent upon proper accounting of the impacts in the land use sector. The extent to which this is the case is further discussed in the Appendix

carbon in the reporting of greenhouse gas inventories by different countries. Biogenic CO_2 emissions from incineration and landfill are generally excluded from the calculation of the climate change impacts, whilst biogenic methane emissions are included.

In comparative assessments between waste management processes, it cannot be considered valid to ignore biogenic CO_2 emissions if the different processes deal with biogenic CO_2 in different ways.[37] This point was made some years ago by some of those involved in life cycle assessments, and has also been the subject of a number of more recent papers.[38]

Fundamentally, unless there are impacts on sources and sinks for CO_2 related to the different management approaches (in which case, these should be accounted for), then the contribution which different management methods make to climate change should take into account all emissions which give rise to climate change, including CO_2 from biogenic sources. A number of authors have suggested that can be appropriate to ignore the biogenic CO_2 in LCA studies if the methodology also accounts for the storage of biogenic carbon in waste management systems through application of a credit for the unemitted carbon.[39] It would also be appropriate and consistent in such an approach to reduce the global warming effect attributed to methane from biogenic carbon by an amount equivalent to the figure that would have arisen had the same biogenic carbon been converted to carbon dioxide. Even if LCAs undertake to incorporate this perspective, however, the fact that life-cycle assessments are generally insensitive to the time profile of emissions means that the often arbitrary decision regarding the time-period over which emissions will be counted (or not) becomes an important determinant of the outcome of the study. The majority of analyses of waste management systems undertaken using the life cycle assessment methodology in recent years, however, have not applied such a credit, and have generally not counted the CO_2 associated with biogenic carbon. This has to be considered a mistake, and generally leads to the emissions of a number of waste treatment technologies being understated, and an overstatement of the benefits of switching waste from landfill and into incineration (see above).[40]
The main source of this error appears to be the view that assumptions made in specific parts of the UNFCCC inventory are applicable to more specific comparative analyses of processes. This was well understood in the USEPA's work on developing a framework for the treatment of biogenic CO_2 sources. One of the Appendices, regarding the IPCC inventory approach makes the point that:[41]

Application of the IPCC classification system to CO_2 emissions from the consumption of biologically based feedstocks for an individual stationary source would lead to an outcome that excludes impacts on land-based emissions and sequestration. Stationary source emissions (fossil fuel emissions) are captured in one IPCC sector (Energy) and terrestrial fluxes (biomass fuels, such as fuelwood, and related emissions, along with other terrestrial biogenic carbon and carbon-based gases) in the Agriculture, Forestry and

38 G. Finnveden, J. Johansson, P. Lind and A. Moberg (2000) Life Cycle Assessments of Energy from Solid Waste, FMS: Stockholm; Rabl A, Benoist A, Dron D, Peuportier B, Spadaro J V and Zoughaib A (2007) How to Account for CO2 Emissions from Biomass in an LCA, Int J LCA, 12(5) p 281; Searchinger T D, Hamburg S P, Melillo J, Chameides W, Havlik P, Kammen D M, Likens G E, Lubowski R N, Obersteiner M, Oppenheimer M, Robertson G P, Schlesinger W H and Tilman G D (2009) Fixing a Critical Climate Accounting Error, Science, 326, pp527-528

39 Gentil, E., Christensen, T. and Aoustin, E. (2009) Greenhouse Gas Accounting and Waste Management, Waste Management & Research, 27(8), pp696-706; Laurent, A., Clavreul, J., Bernstad, A., Bakas, I., Niero, M., Gentil, E., Christensen, T. and Hauschild, M. (2014b) Review of LCA studies of solid waste management systems – Part II: Methodological Guidance for a Better Practice, Waste Management, 34, pp589-606

40 This issue is further discussed in the Appendix.

41 USEPA (2014) Revised Framework for Assessing Biogenic Carbon Dioxide (CO2) Emissions From Stationary Sources: Appendix A: IPCC Inventory Approach to Accounting for All Anthropogenic Greenhouse Gas Emissions, downloadable from http://www3.epa.gov/climatechange/ghgemissions/biogenic-emissions.html

Other Land Use sector (AFOLU). In essence, if there is no corresponding accounting (i.e., of both the Energy and AFOLU sectors) or only incomplete accounting of land-based fluxes, then application of the IPCC national inventory approach to stationary source emissions estimation does not provide a complete picture of the true net atmospheric contribution associated with the biogenic CO_2 emissions from the stationary source (Pena et al., 2011).

Similarly, a specific Appendix on waste derived biogenic feedstocks notes: [42]

Materials in the waste stream represents material that has been discarded, where final disposition of the material must be managed in some fashion (EPA, 2011b). As a result, if waste-derived feedstocks had not been processed or used by a stationary source, the material would have been managed through an alternative strategy with an alternative emissions pathway. Whatever the waste management strategy, it would result in biogenic CO_2 emissions and likely some amount of CO_2e GHG emissions (e.g., CH_4 emissions as a result of anaerobic decomposition). Evaluating the carbon cycle effects of waste management at a stationary source involves a comparison of the biogenic CO_2 and CH_4 emissions at the stationary source against an alternative emissions pathway that would have resulted under an alternate management strategy.
Evaluating these alternate waste management GHG emissions pathways does not require an analysis of the carbon cycle effects that transpired during the growth and harvest of the primary biogenic materials on the landscape. As a result, many of the biogenic attributes related to the carbon cycle effects of the growth, harvest, and use of other biogenic feedstocks are not relevant for waste-derived biogenic feedstocks.

What this effectively means is that whilst it might be acceptable for an inventory approach – which seeks to capture changes in sources and sinks of GHGs in agriculture, forestry and land-use, and also, changes in stocks of carbon in harvested wood products, as well as emissions from the stationary combustion sector, in various ways – to ignore biogenic emissions from incineration and landfill if these are being properly accounted for elsewhere, it is not appropriate to overlook them in any comparative assessment.

This appears to be the source of errors in comparative analyses of waste management, but also, in how emissions from biomass fuels and energy plants have been accounted for. It should be added that, as noted above, it is not actually clear that the inventory approach is dealing with this approach adequately.

Finally, the dimension of time deserves to mentioned at this juncture. There are significant differences in the way in which biogenic emissions of CO_2 are generated by different waste treatment processes. Where landfills are concerned, methane which is captured, whether for energy recovery or flaring, is converted to CO_2, and some uncaptured methane may be oxidised at the cap of the landfill site. In composting processes, there are emissions of various GHGs, mainly of CO_2, and after the intensive phase, and the application of the material on land, the emissions generally slow down somewhat. In both cases, emissions occur over an extended period of time. If the same waste is, for example, combusted, then the emissions of CO_2 occur instantaneously. These processes clearly have very different time profiles.

The rate at which emissions occur might be considered to be significant. First, the different rates of emissions have implications for how effectively emissions can be sequestered by the less than instantaneous growth of biomass. The significance of this is hinted at in the IPCC Guidelines for the AFOLU emissions,

42 USEPA (2014) Revised Framework for Assessing Biogenic Carbon Dioxide (CO2) Emissions From Stationary Sources: Appendix N: Assessing Emissions from Waste-derived Biogenic Feedstocks, downloadable from http://www3.epa.gov/climatechange/ghgemissions/biogenic-emissions.html

where Chapter 2, regarding Generic Methodologies, speaks of the significance of the synchrony of emissions and removals: nothing about the process of incineration, for example, is likely to affect the way in which forests are managed, and the rate at which they grow. Second, and following on from this, in the context of strategies to combat climate change, there may be some merit in seeking to delay some emissions if, for example, sink capacities can be built up, whilst at the same time, emissions are being reduced.

3. The Carbon Impacts of Waste Prevention and Management Activities

This chapter focuses on the impacts of prevention and other ways of managing materials in respect of emissions of greenhouse gases. More detail regarding these, as well as other emissions to air, are offered in the Appendix to this report. In subsequent discussions, we consider how methodological issues might prevent these impacts from being properly considered (and hence, why countries might have been less inclined than we argue they should be to consider waste policy as a central element of the battle to reduce GHG emissions).

3.1 Approach to Accounting for Impacts

3.1.1 Waste Prevention

In considering the climate change impacts of waste prevention initiatives, a distinction is made between:

- Activities that reduce the amount of material consumed without increasing the consumption of another type of material, such as light-weighting of single use packaging, or avoiding the wastage of food through judicious purchasing decisions. Benefits of these activities can be considered through data on the impacts of producing the materials that are the target of the activity, which typically comes from life cycle analysis studies.
- Initiatives where the reduction in the consumption of one type of material results in the increased consumption of another type of material. Here, emissions reductions may still be seen, but are often more difficult to quantify. Examples include swapping from single use plastic carrier bags to long life plastic bags, bags made from textiles, or single use paper bags.

Given the difficulties in quantifying the second type of impact, this section predominantly focuses on the first type of impact. Data on both types of activities is, however, provided in the Appendix.

3.1.2 Re-use and Preparation for Re-use

The re-use of some items – such as furniture, textiles, and electrical items - where there is no need for repair work constitutes another type of waste prevention activity. Since such items may not enter the waste stream in the first place, it is often difficult to fully capture this type of activity (goods may be sold informally through internet sites such as Ebay and Preloved, for example).

Preparation for re-use sites, however, are part of the waste management system: here, items are sorted, and cleaned and/or repaired prior to being resold. The benefits associated with this type of activity are highly dependent on the scope of the preparation for re-use activity, the type of material being reused, and the extent to which the resold item avoids the production of a new item.[43]

3.1.3 Dry Recycling

The climate change impacts of recycling are typically calculated from the impact associated with manufacturing the material entirely from primary sources, minus the impact associated with producing the same item from recycled materials. Data again typically comes from life cycle analysis studies; sources are detailed in the Appendix.

3.1.4 General Considerations for Modelling Treatment Systems

Emissions from treatment systems are accounted for taking into account both direct and indirect impacts. The former relate to emissions directly emitted from the process, such as emissions from plastics combusted at an incinerator. In accounting for climate change impacts, the latter typically relate to credits applied to the system to account for beneficial effects, such as the generation of energy (electricity or heat) or the recovery of materials for recycling.

43 See further discussion in the Appendix

There are a number of factors to consider when accounting for the impacts of waste treatment systems, which are here taken to include both those applied to source segregated biowaste as well as those used for residual waste:

- **Approach to dealing with the biogenic CO_2 emissions:** these emissions are typically ignored in the majority of life cycle analyses, as was previously discussed in Section 2.3. Where data in this section is presented excluding the biogenic CO_2 emissions, we also apply a credit to account for sequestered biogenic carbon (this applies to landfill and composting systems). We also show key results including the biogenic CO_2 emissions for comparison purposes (in this case no credit for sequestered biogenic carbon is applied).
- **Energy generation:** where waste treatment systems generate energy, the system is given a credit to account for this benefit. In the default case, it is assumed that electricity generated by waste treatment plant would otherwise be generated by gas CCGT power plant. We also show results, however, for the incinerator indicating the impact where the energy would otherwise have been generated using other sources.
- **Recycling:** waste treatment systems that recycle materials are given a further credit, to account for the associated climate change benefits (using the data indicated in Section 3.1.3).

3.1.5 Treatment of Source Segregated Biowaste

Separately collected food and garden waste can be treated using a range of processes, including composting and anaerobic digestion (AD). The climate change impacts of these different processes vary according to the feedstock being treated (i.e. food or garden waste), and on the management of the treatment system – impacts will vary depending on, for example, the type of composting process (e.g. enclosed or open), or the type of energy generated at the AD plant.

To simplify the analysis, we have focused in this section on the treatment of garden waste at open air windrows, and the treatment of food waste at an AD plant generating only electricity using a gas engine. Variation in the impacts according to feedstock and treatment method is discussed in the Appendix. The data is derived from Eunomia's in-house models of treatment facilities; sources are also detailed in the Appendix.

3.1.6 Treatment of Residual Waste

Although a wide range of methods can be used to treat residual waste, the use of landfill and incineration still predominates. As such, the discussion on residual waste in this section focusses on these two methods of treatment. The appendix, however, also considers impacts associated with Mechanical Biological Treatment (MBT) and gasification.

The impacts per tonne of waste of residual waste are discussed in this section, and as such the composition of residual waste has some bearing on the analysis. The composition changes as consumption levels and recycling rates change, although it is difficult to apply definitive rules in this respect. As was indicated above in Section 3.1.4, the analysis applies credits to the emissions totals associated with the generation of energy and the recovery of materials for recycling. Assumptions are discussed in the Appendix.

As was indicated in the discussion on AD, impacts vary according to the type of energy generated. Results for incineration are presented assuming the incinerator generates only electricity (data in the appendix also considers the generation of heat). In the discussion that follows, we also consider the impact of some other key sensitivities – the extent to which landfill gas is captured at landfill sites, and the impact on the results for the incinerator when assumptions regarding the avoided source of electricity are changed.

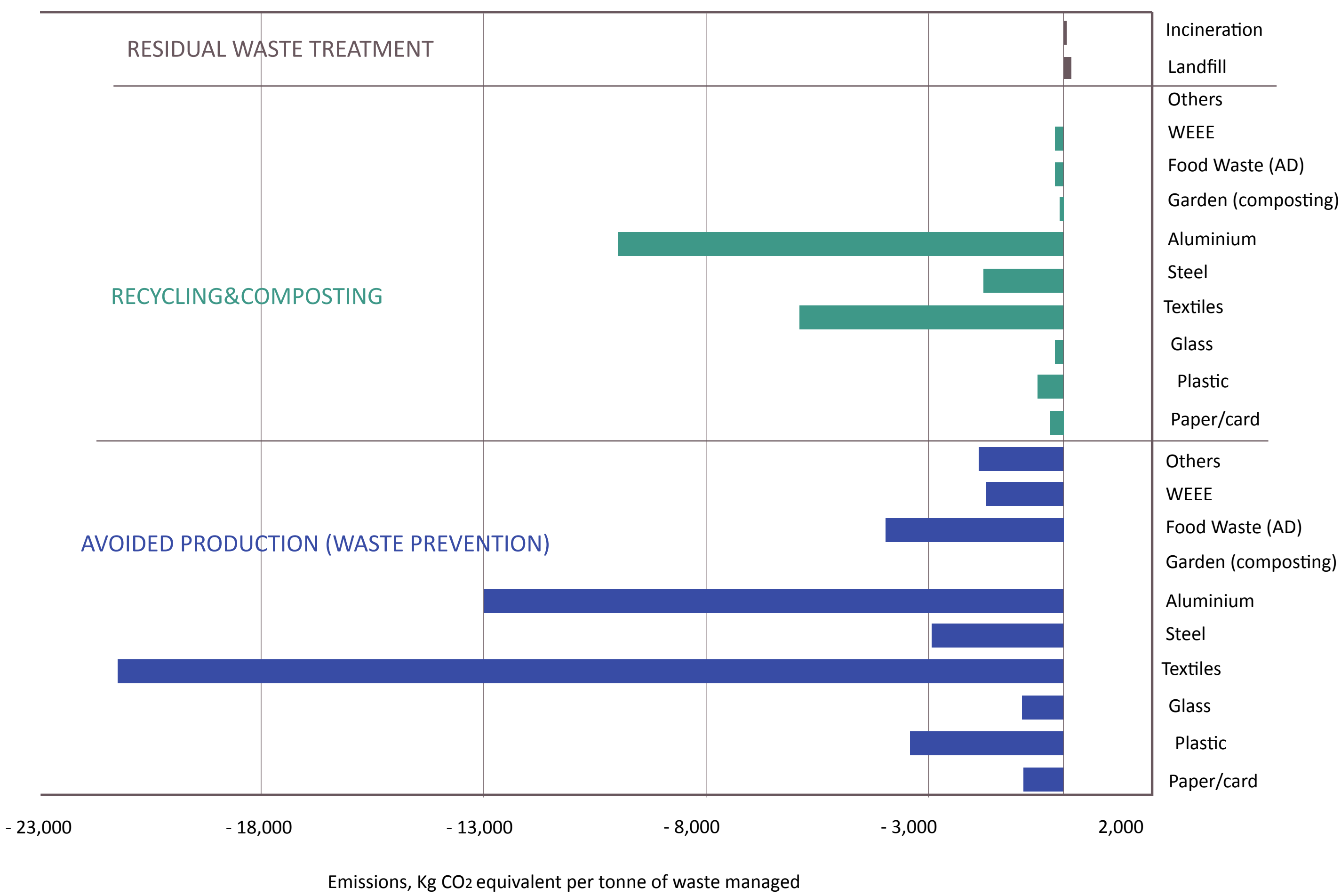
3.2 Quantifying the Impacts per Tonne of Waste

3.2.1 Results and Discussion

The IPCC reports present little in the way of clear evidence as to the climate change impacts associated with the different waste management activities. Many other authors, however, have considered this in much greater detail, and in the Appendix to this report, we therefore review and discuss key elements of this work. The discussion in the Appendix confirms that the various authors and bodies undertaking this work often differ in their approach when assessing these impacts, and it is also clear that various factors and assumptions will influence the results. As such, obtaining truly representative numbers for assessing the relative climate change impacts of undertaking various waste prevention and management activities is no straightforward task.

Although precise numbers may be rather difficult to determine, however, there is a reasonable level of agreement in the literature on the impacts at the various levels of the waste hierarchy for a given material. The difference in performance between the various activities is strikingly illustrated in Figure 3 -2 which shows the indicative climate change impacts of the key waste management activities excluding the biogenic CO_2 emissions, over a 100 year time period – the period conventionally used in life cycle assessments. The analysis includes a credit for biogenic carbon sequestered after 100 years in landfill and biological treatment processes.

Figure 3.2: Climate Change Impacts of Waste Activities excluding Biogenic CO2 – 100 year time period



The data is taken from life cycle analyses (for the production and dry recycling impacts) and from Eunomia's in-house treatment models; sources and assumptions are detailed in the Appendix.

The figures shows the impact of treating or disposing of residual waste alongside the impacts associated with recycling and waste prevention, in each case, showing the impact relating to one tonne of material.[44] The incinerator and AD treatment (used to treat source segregated food waste) are assumed to generate only electricity; where processes generate electricity, this energy is assumed to avoid the generation of electricity from sources with the same carbon intensity as that from combined-cycle gas turbines.[45]

The graph confirms with regard to waste prevention activities that the benefit associated with using one tonne less plastic packaging can be a saving in the order of 3 tonnes CO_2 equivalent, whilst recycling the same type of material might result in a benefit of around 500 kg CO_2 equivalent per tonne of plastic.

The figure shows that the climate change benefits are greater for dry recycling than for treating organic material (food waste and garden waste). However, the Figure also shows that for food waste there are considerable climate change benefits associated with waste prevention activities: for food waste, the difference between the recycling benefit and the prevention benefit is particularly substantial. Some research in the UK has indicated that the introduction of separate collection schemes has resulted in a waste-prevention effect, as those using the scheme become more aware of how much food is being wasted.[46] To the extent that such an effect does occur, it substantially improves the overall climate change benefit associated with introducing source segregated food waste collection schemes (this effect is not included in the depiction shown in the Figure).

Until recently, the benefits of treating source segregated organic materials have not been so well understood; in particular, authors have not always fully comprehended the benefits of using compost, or the potential for generating biogas from source segregated food waste, although more recent work has improved this situation somewhat. The data presented here reflects the more recent thinking on these issues.[47] To this effect the analysis includes the biogenic carbon sequestered through composting over a 100 year period, as well as the benefits from displacing synthetic fertilisers.

Figure 3 -2 shows that the activity of treatment or disposal of residual waste generally increases climate change emissions, whilst recycling and waste prevention are activities which contribute to emissions reduction. Furthermore, the difference in the impacts between landfill and incineration is almost trivial when compared with the benefits which might be achieved from recycling, or preventing the use of, dry materials, and preventing food waste.

Figure 3 -3 shows the data for residual waste only, and also shows the data including the CO_2 biogenic emissions as well as the impact excluding biogenic CO_2. Results here also show on the same axis the impacts calculated over a 20 year time period. Other authors have noted that there is no scientific rationale for the choice of the 100 year period; rather, the decision is a subjective one, driven for the most part by the widespread use of the 100-year GWP in

44 Whilst this graph considers only the impacts of treating residual waste using either incineration or landfill, the discussion in the Appendix also considers the impacts of other residual treatments such as MBT and gasification. It can be seen from this discussion that impacts of these treatment systems are not substantially different from those of incineration and landfill.

45 See Appendix 1 for more information on the assumptions used to model these impacts

46 A review of the literature is presented in: WRAP (2011) Literature Review – Relationship between Household Food Waste Collection and Food Waste Prevention, August 2011

47 To this effect the analysis includes the biogenic carbon sequestered in composting, as well as the benefits from displacing synthetic fertilisers

48 Brandao, M., Levasseur, A., Kirschbaum, M., et al. (2013) Key issues and options in accounting for carbon sequestration and temporary storage in life cycle assessment and carbon footprinting, Int.J LCA, Vol.18, pp.230–240

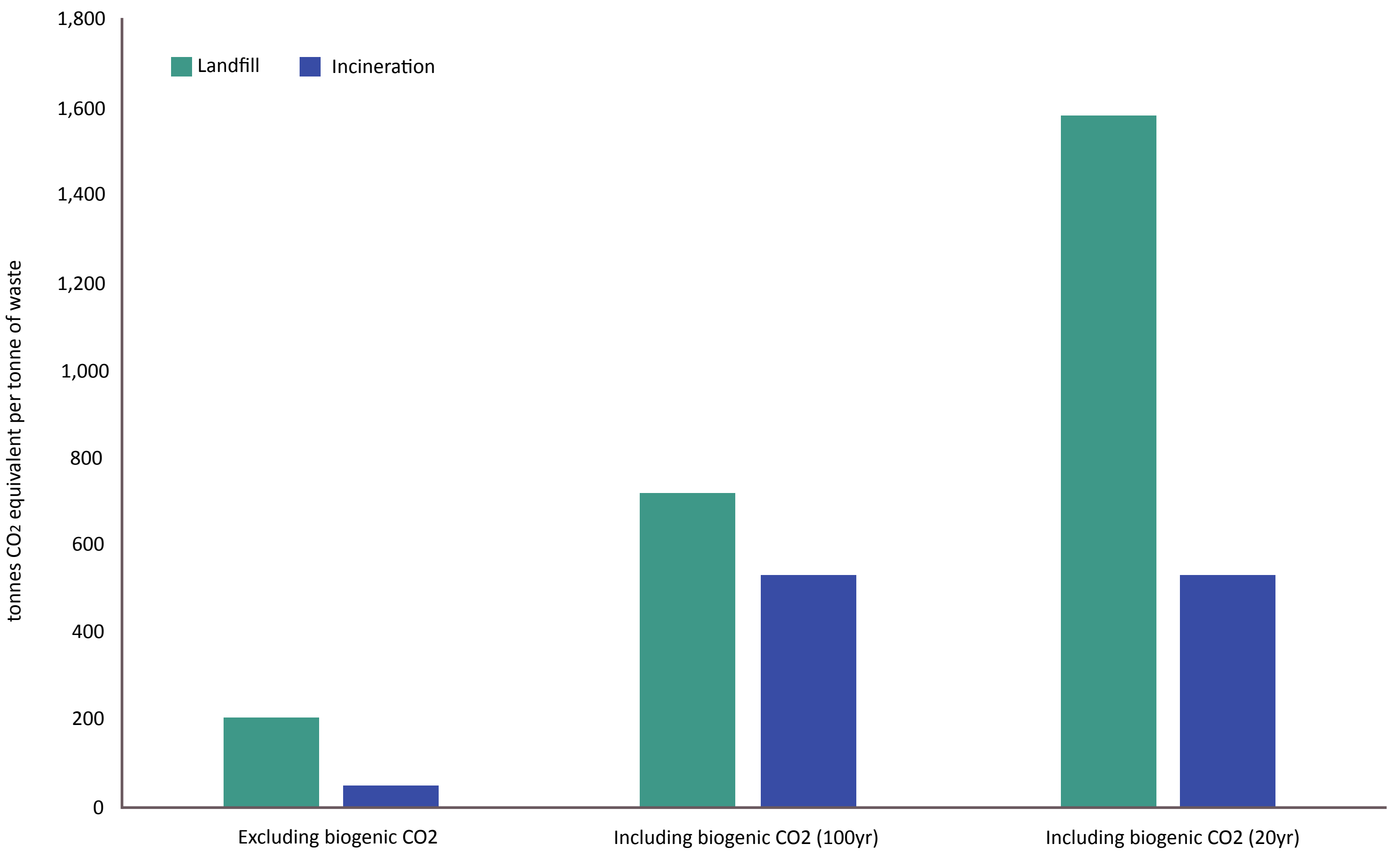
policies and accounting related to the Kyoto protocol.[48]

Methane persists in the atmosphere for a much shorter time period than carbon dioxide, and this is reflected in markedly different GWP values over different time scales. Where the climate change impacts are using the much higher 20-year GWP for methane, this results in much higher emissions from landfill.[49]

In all instances shown on the graph, landfill results in higher emissions than incineration, although the inclusion of the biogenic CO_2 emissions closes the gap between the two approaches over a 100-year timeframe. However, this situation can be reversed where the electrical supply is decarbonised; this is discussed further in Section 3.2.2.2.

It is important to note that waste management activities result in other emissions to air alongside the climate change impacts. Landfill results in emissions of ammonia, incineration in emissions of NOx; both have human health impacts and impacts on eco-systems. On the other hand, air pollution impacts from composting and AD facilities are typically much less significant. Although dry recycling results in a net reduction in air pollution impacts overall, emissions typically arise from both the primary production and the secondary production facilities, and these will not necessarily be located in the same place. Where the location of the two differs, an increase in recycling could bring about an increase in local air pollution within the locality of the recycling plant, whilst at the same time resulting in a net decrease in air pollution impacts in aggregate. For this reason, "avoided production" or waste prevention activities

Figure 3 3: Residual Waste Impacts Including Biogenic CO_2 Emissions



49 Uses a GWP of 72 for methane (the 100 year results use a GWP of 25). The variation in GWP values over the different time periods is discussed in more detail in the Appendix

are again likely to bring about the biggest benefits, particularly where production is largely based on the use of raw materials rather than recyclate.

3.2.2 Sensitivities for Residual Waste Treatment Results

3.2.2.1 Impact of Decarbonising Energy Sources

Modelling residual waste treatment impacts is particularly challenging given the range of materials included within the stream, and the fact that the composition of residual waste changes as recycling rates change. Activities undertaken at both incineration and landfill facilities aimed at mitigating the worst environmental effects of the impacts also affect performance. In addition, both types of facilities usually generate energy, and this results in climate change benefits relating to a reduction in energy that would otherwise need to be generated by other sources. These benefits can vary considerably depending on what source of energy is being displaced.

As countries shift away from more carbon-intensive forms of electricity generation, such as coal, towards a mix that is more strongly based on renewable sources, the benefits associated with an incinerator generating electricity are expected to decline. The potential impact of such a switch can be seen in Figure 3 -4. The data presented on this chart compares the performance of an incinerator generating electricity with that of a landfill where gas is captured and used for electricity generation. Three different levels of gas capture are considered for the landfill. The lowest performance is in line with the default capture rate assumption given by the IPCC. The figure is intended to be applicable to global performance of facilities: performance guidelines contained within the European Landfill Directive are designed to improve performance such that sites compliant with the directive would be expected to perform rather better than this. As such, a 50% figure is likely to be more representative of reasonable European performance. The inventories of some countries, such as the UK, suggest higher capture levels, so we also consider the impacts of such landfills. Alongside the variations in gas capture, we also show the performance of the incinerator taking into account the variations in benefit seen from electricity generation, depending on the carbon intensity of the avoided electricity source.

The graph shows results both including and excluding the biogenic CO_2 emissions, the latter following the approach outlined in Section 3.1.4 (in both cases, results are shown over the 100 year time period). Impacts here are shown per tonne of residual waste, and with performance from worst (on the left) to best (on the right). Waste incineration leads to climate change benefits where coal is the avoided source of electricity generation (if biogenic CO_2 emissions are excluded from the analysis), but leads to relatively significant climate change impacts where the avoided fuel source for electricity generation is wind generation.[50] A similar pattern is seen for results irrespective of whether the biogenic CO_2 emissions are included.

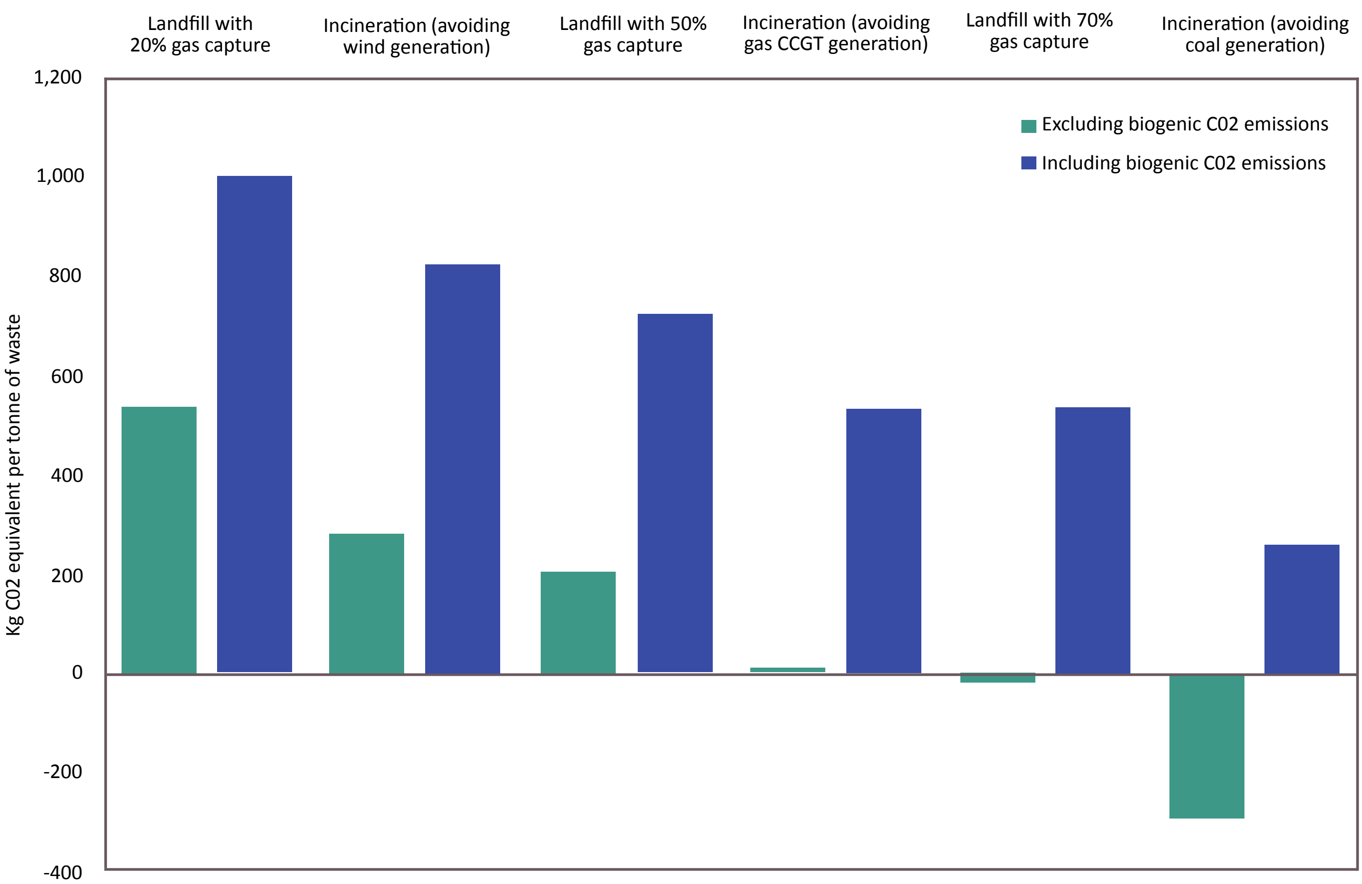
Although the benefit relating to the switch from a poorly performing landfill to an incinerator offsetting electricity generation from coal is relatively significant, such a switch is not, generally, representative of the situation in most European countries. Typical performance is probably more closely represented by the two bars in the middle of the chart. This suggests there is usually a (relatively modest) benefit associated with moving waste away from landfill and into incineration, as is also reflected in Figure 3 -2. However, under the assumptions used here, at high levels of gas capture, landfill outperforms the incinerator where the avoided electricity source is that generated using natural gas in a combined cycle gas turbine – likely to be the avoided source of generation for many European countries. Landfill also outperforms incineration even at 50% gas capture where the displaced electricity source has a

50 Similar impacts would be seen for other renewables such as solar generation, or for generation using nuclear power.

low carbon intensity. It is important to note that the graph here has been developed using a composition that is reflective of the European situation. Results presented here are therefore not necessarily representative of the global situation. In economically less well developed countries, the proportion of food waste in the waste stream is often much higher than shown here. Although this will result in higher landfill emissions, it also affects the performance of incineration facilities. Since food waste contains a significant amount of water, such facilities must use much higher quantities of additional fuel (e.g. coal, oil) to ensure the effective combustion of the waste, significantly increasing the emissions from the incinerator. [51]

In all cases where waste treatment systems are compared, it is important to understand what source of electricity is effectively being replaced when incinerators are operated. Two general approaches are possible when considering the climate change impacts of generating energy from waste. The average mix of generation in the electricity grid is commonly used where the carbon footprint of an individual facility is concerned. Where, however, the consequences of a decision are being modelled – as is the case where the development of a new facility is concerned - a number of authors have indicated it is appropriate to use marginal energy data in waste management LCA. [52]

Figure 3.4: Performance Differentials - Landfill and Incineration (100 years)



51 Previous research by the World Bank suggested that up to 20% of the input mass to some Chinese incinerators is coal: see World Bank (2005) Waste Management in China: Issues and Recommendations, May 2005

52 Ekvall.T, and Weidema, B.P. (2004) System Boundaries and Input Data in Consequential Life Cycle Inventory Analysis, International Journal of LCA, Vol.9, No.3, pp.161–171; Gentil, E., Christensen, T., and Aoustin, E. (2009) Greenhouse Gas Accounting and Waste Management, Waste Management & Research, Vol.27, No.8, pp.696–706

More generally, marginal data reflects the consequences of infinitesimal or small changes in the quantity produced of a good or service. Where assumptions for the marginal generation source are concerned, this principally relates to the estimate of the next generation facility to be built, given economic, political and resource constraints.[53]

Where countries are seeing to reduce emissions from electricity generation, then at the margin, they require these new energy sources to have a low carbon intensity. In these circumstances, it can be argued that the source of electricity which is avoided is one with a low carbon intensity. UK government departments have set out the carbon intensity of the marginal source of electricity which is assumed to be displaced over time as the electricity supply is progressively decarbonised.[54] Under these assumptions, an incinerator constructed today to generate electricity will, over a 20 year life, perform better than a landfill in the early years of its operation, but will perform worse in the later years.[55]

The review of the literature included in the Appendix confirms that there is a lack of firm agreement for many of the assumptions used when modelling the relative performance of both treatment systems. Depending on the assumptions used, then, there may be performance losses or gains for either landfill or incineration: effectively, under other analytical approaches, the bars on Figure 3 -4 might thus appear in a different order. This type of effect was also considered in recent work undertaken in the UK by Defra, which considered a range of factors and the consequent climate change impacts for incineration and landfill. The conclusion in that study was that, notwithstanding these performance variations, given the country's trajectory for decarbonising electricity generation, there would nonetheless come a point – likely to be within the lifetime of a facility currently under construction - at which incineration facilities generating only electricity would perform worse than landfill in climate change terms. The impact of the performance variations (relating to the different assumptions) served only to change the point in time at which such an outcome might be expected to occur. None would be expected to change the impact attributed to either system to a significant extent.

3.2.2.2 Diversion from Landfill

In the context on the above discussion, it should be considered that for many years, 'diversion from landfill' has often been used in the EU as a key indicator to determine the performance of a country's waste management system. However, Figure 3 -4 clearly shows that the performance gains to be made from shifting waste out of landfill and into incineration are for the most part relatively minor, when these are weighed against the much bigger gains to be made from undertaking prevention activities and increasing recycling. Consequently, the use of measures such as 'the proportion of waste being landfilled' as an indicator of waste management performance (the less landfilled, supposedly, the better the system) is a completely unreliable one since landfill can be avoided through simply switching to other residual waste treatments. What seems clear is that countries should seek to bear down on the amount of residual waste being generated, irrespective of how it is treated or disposed of.

3.2.3 Minimising Leakage

Looking to the future, in a truly circular economy, production processes will generate fewer GHG emissions as they are based increasingly on secondary materials, effectively reducing the climate change

53 Weber C, Jaramillo P, Marriott J and Samaras C (2010) Life cycle assessment and grid electricity: What do we know and what can we know? Environ Sci Technol, Vol 44, pp1895-1901

54 DECC and HM Treasury (2013) Appraisal Guidance: Energy Use and GHG Emissions: Supporting tables 1-20, Supporting the Toolkit and the Guidance, HM Treasury, London

55 Defra (2014b) Energy Recovery for Residual Waste: A Carbon Based Modelling Approach, Defra, London

impact of production, and energy source are expected to decarbonise. The leakage of materials that currently occurs from the system into landfill, incineration (including the combustion of RDF at incineration and co-incineration plants) and other treatments would be significantly reduced: leakage being the term used by influential figures in this field - such as the Ellen MacArthur Foundation - to describe waste being sent to incineration or landfill.[56]

At present, manufacturing activity is still significantly reliant on the use primary materials, although this varies by material and by specific product: this, in turn, is reflected in the climate change benefits associated with waste prevention.

As levels of recycling increase on a global scale, however, the climate change benefits associated preventing the use of a given material or product would be expected to decline, since the GHG-intensity of its production would fall if greater use was made of secondary materials. The benefits from recycling, on the other hand, might remain constant, since this benefit is based on the difference between the emissions associated with producing the material from primary sources and the emissions associated with producing the same material using recycled feedstocks.

Table 3-3: Changing Impacts of Production at Different Levels of Recycling

Typical recycled content	Production impacts taking into account recycled content, kg CO2 equivalent per tonne material	Net benefits of recycling (100% primary - 100% secondary), kg CO2 equivalent per tonne material
0%	5,000	3,000
20%	4,400	3,000
50%	3,500	3,000
90%	1,800	3,000

Notes: Hypothetical example calculated assuming the material manufactured with 100% primary content results in emissions of 5,000 kg equivalent per tonne of material, whilst that manufactured 100% secondary content leads to emissions of 2,000 kg equivalent per tonne of material

The impact of this can be illustrated with an example, as shown in Table 3 -3. This shows impacts relating to the manufacture of a hypothetical material – product X, say – which results in emissions of 5,000 kg CO_2 equivalent when produced from 100% primary materials, and emissions of 2,000 kg CO_2 equivalent if produced from 100% recycled materials. This shows the declining impact of consumption over time, as the levels of recycling increase.

3.3 Some Illustrative Examples – Impacts per Person

In this section, we provide some examples to provide additional context to the numerical data presented in Section 3.2. In contrast to the data in the previous section, which looked at the impacts per tonne of material, in the examples that follow, we consider the amount of waste produced per person in a given year. In this case, both the amount and the composition of materials produced by the individual affect the outcome, as can be seen with reference to the results presented in the previous section.

56 See Ellen MacArthur Foundation (2013) Towards the Circular Economy Vol.1: Economic and Business Rationale for an Accelerated Transition, January 2013, www.ellenmacarthurfoundation.org/business/reports/ce2012.

Table 3-4: Cases Considered within the Analysis

Case	Level of consumption / waste production	Level of recycling	Residual waste treatment
1	High[1]	High[3]	Incineration
2	High[1]	Low[4]	Incineration
3	High[1]	High[3]	High[3]
4	High[1]	Low[4]	Low[4]
5	Low[2]	High[3]	Incineration
6	Low[2]	Low[4]	Incineration
7	Low[2]	High[3]	Landfill
8	Low[2]	Low[4]	Landfill

Notes
[1] Assumes the total waste production is 470 kg per capita per annum (similar to UK)
[2] Assumes the total waste production is 300 kg per capita per annum (similar to Latvia)
[3] Equivalent to a 17% recycling rate under the low consumption composition, and 21% under the high. Based on a country that just meets the current packaging directive targets for recyclables.
[3]Equivalent to a 45% recycling rate under the low consumption composition, and 57% under the high. Data based on a relatively high performing UK authority.

Source: Eurostat

Our accounting method here again considers the waste that is recycled as well as that which is disposed, looking at:

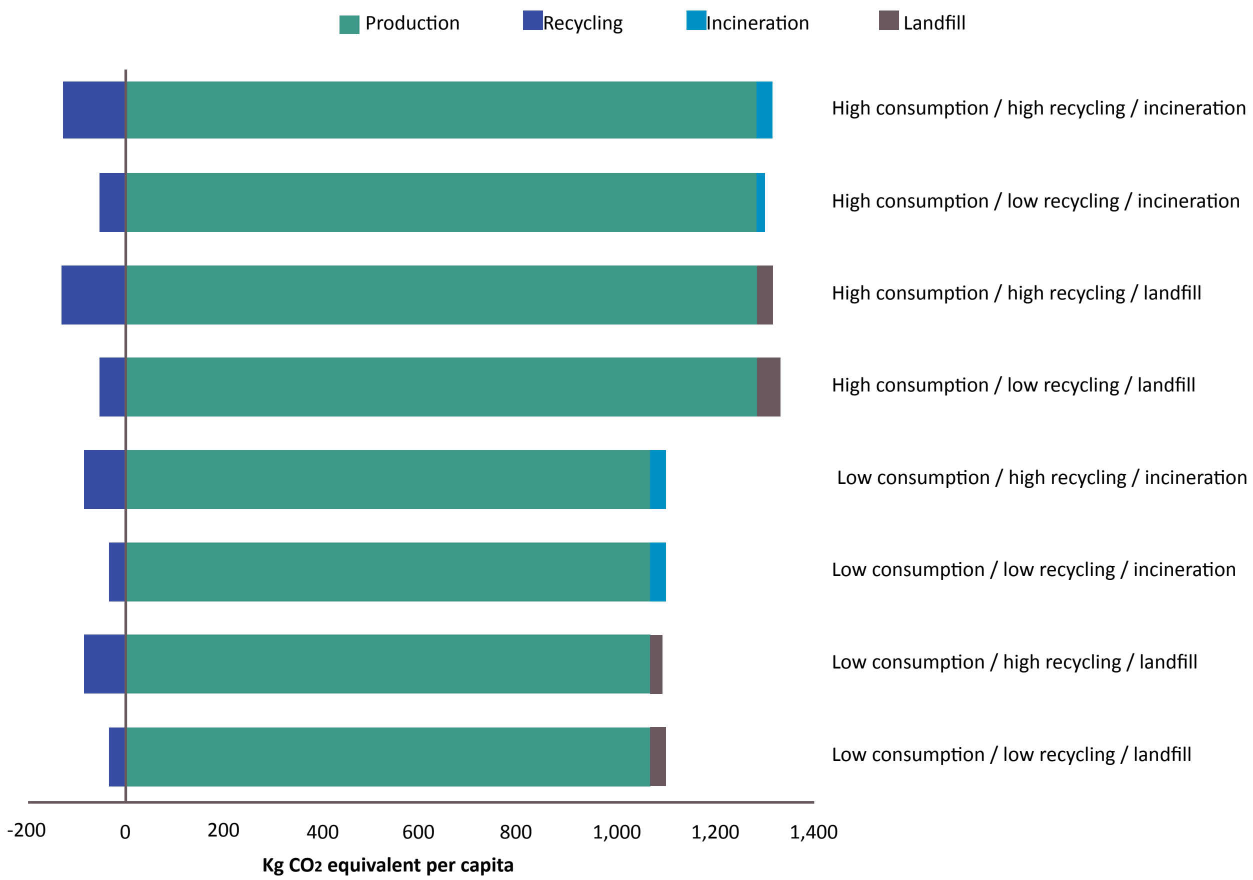
- Emissions associated with the production of the materials that subsequently become waste;
- Benefits associated with recycling and/or composting/anaerobically digesting the materials;
- Impacts associated with landfilling or incinerating the waste that is not recycled.

The analysis here is based on the impacts excluding the biogenic CO_2 emissions.
Details of the examples included within this section are shown in Table 3 -4. Data on composition has been chosen here for illustrative purposes but is nonetheless largely taken from Eurostat from specific countries. It is clear that some countries are already achieving rates of recycling in excess of that seen here under the "high" recycling scenarios, whilst higher targets may also be imposed in the future. As such, these examples should not be taken as indicative of the best performance that could be achieved by a given region.
Climate change impacts are modelled using the data presented in Section 3.2 for production impacts, recycling, organic waste treatment, incineration and landfill.[57]

The analysis uses the same approach to modelling the performance of the different waste treatment systems - landfill, incineration, biowaste treatment - on a per tonne basis as was previously outlined in Section 3.2 (further information is also provided in the Appendix).
The results from the scenarios are shown in Figure 3 -5. This shows the impacts – or embodied emissions – per person associated with the production of the waste materials alongside the benefits of recycling and the impact of landfilling or incinerating the non-recycled materials. The composition changes at

57 For incineration, impacts assume the generation of electricity only; average emissions factors are used for landfill. In both cases the displaced electricity generation source is assumed to be gas CCGT. More information on this and other assumptions is presented in the Appendix.

Figure 3-5: Case Study Production Emissions and Waste System Emissions



different levels of consumption, and as recycling rate changes, and this has an effect on all the bars shown in the chart, which show the per-tonne impacts multiplied by the amount of material in each part of the waste system.

Consistent with this data, the graph here shows that the production related emissions are far greater than those associated with waste treatment or the benefits associated with recycling. It is these impacts that are being addressed through initiatives designed to prevent or reduce waste: actions at the top of the waste hierarchy. The graph also shows there is greater potential for recycling to impact on emissions reduction than through changes in residual treatment method. The latter, by contrast, brings about very little change in emissions.

At the higher levels of recycling under high consumption levels, more substantial benefits associated with recycling can be seen, but this is not sufficient to out-weigh the larger emissions impact from the higher consumption levels.

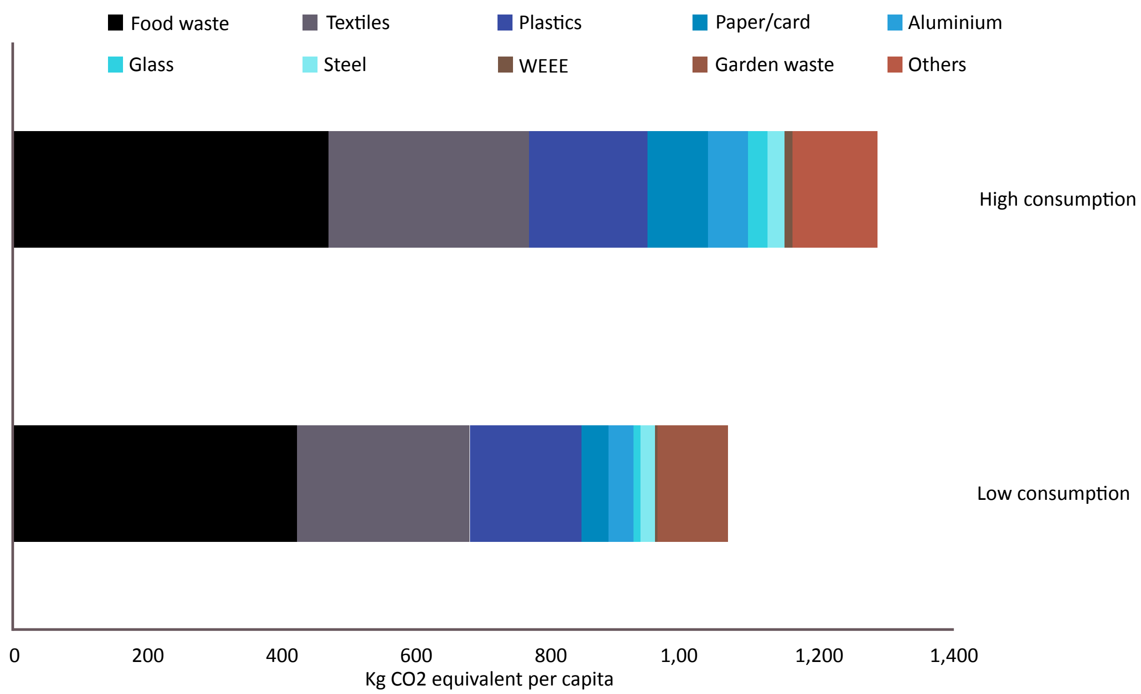
Figure 3 -2 showed that impacts vary on a per-tonne basis across the different materials, and this is also true for the materials that constitute residual waste. The household waste stream contains relatively large amounts of paper and food waste, for example, but only relatively small amounts of non-ferrous metals. The latter has a very high impact on a per-tonne basis, but has less of an influence when the impacts per person are examined.

The influence of composition on the results can also be seen with reference to Figure 3 -6 which provides a breakdown of the production related emissions associated with the waste produced by each person (excluding the biogenic CO_2 impacts). This shows that food waste and textiles dominate the impacts. Production emissions for packaging items - paper, plastics, metals and glass – have been reduced to some extent through the increased use of recycled content. Food waste, on the other hand accounts for a significant proportion of the total waste stream (assumed to be 35% in the low consumption scenarios and 25% in the high consumption scenarios). Textiles make a relatively modest contribution to overall arisings (assumed to be 3-4% in the model), but the production impacts are highly significant, at over 20 tonnes CO_2 equivalent per tonne.

Impacts associated with food waste are being tackled in some quarters - the UK's Love Food Hate Waste campaign includes a strong educational element aimed at reducing household food waste. The picture for textiles is rather more complicated; re-used textiles resold through charity shops may not formally enter the waste stream, whilst the articles that are do enter the waste stream and which are re-used may not displace the purchase of a new item (see Appendix).

Figure 3 -7 and Figure 3 -8 shows the waste system emissions excluding the consumption-related impacts, excluding and including the biogenic CO_2 emissions respectively. This confirms that even at relatively low recycling rates and low consumption, recycling affords opportunities to offset much of the contribution to climate change resulting from landfilling or incinerating residual waste. The graphs also confirm that, depending on the composition of waste, impacts from incineration may increase as the level of recycling increases. This occurs as increased levels of biogenic materials are removed from the residual waste stream at the higher rates of the recycling. At lower recycling levels, these materials mitigate the emissions impact of the fossil-carbon plastics. As recycling increases, the amount of biogenic CO_2 decreases (principally because more food waste and paper are assumed to be captured), and this mitigation effect is therefore reduced.[58]

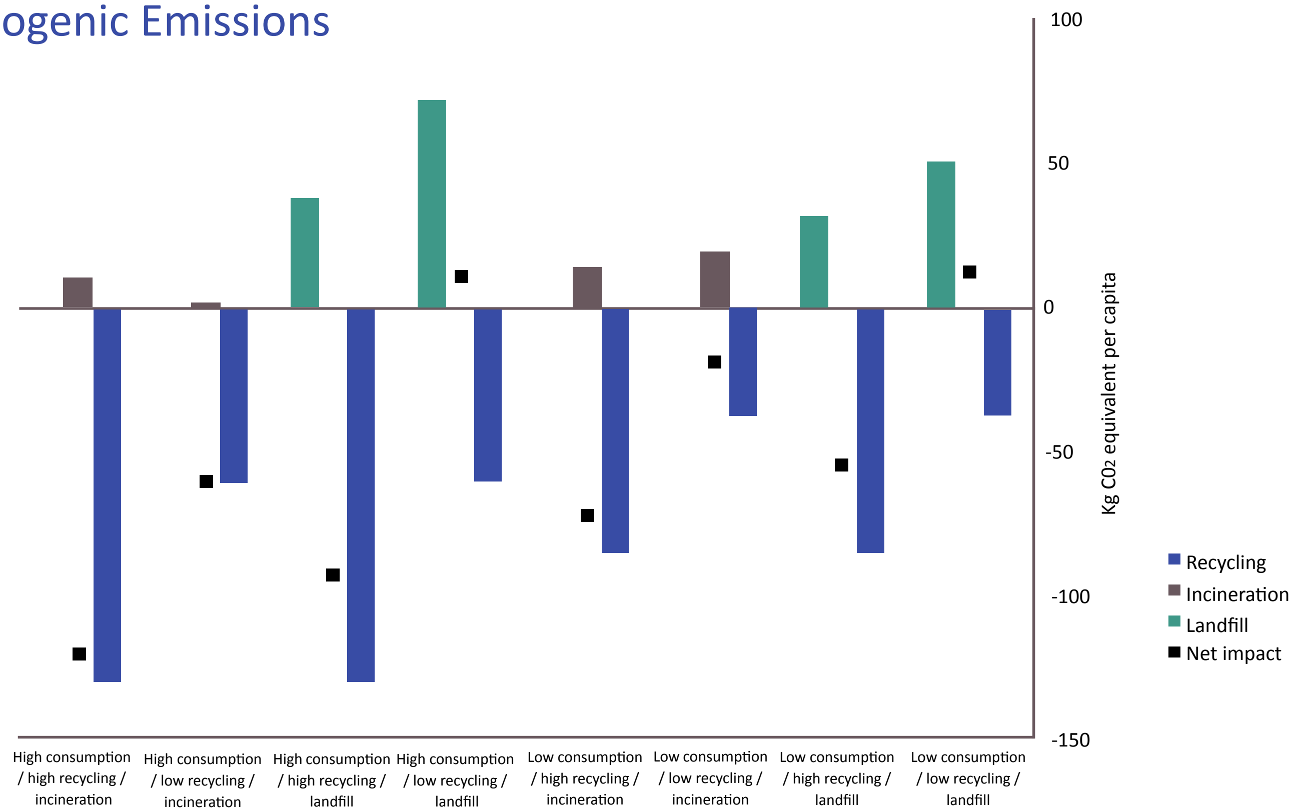
Figure 3-6: Breakdown of Production Related Emissions



Sources: Eunomia; Eurostat (see Appendix for details)

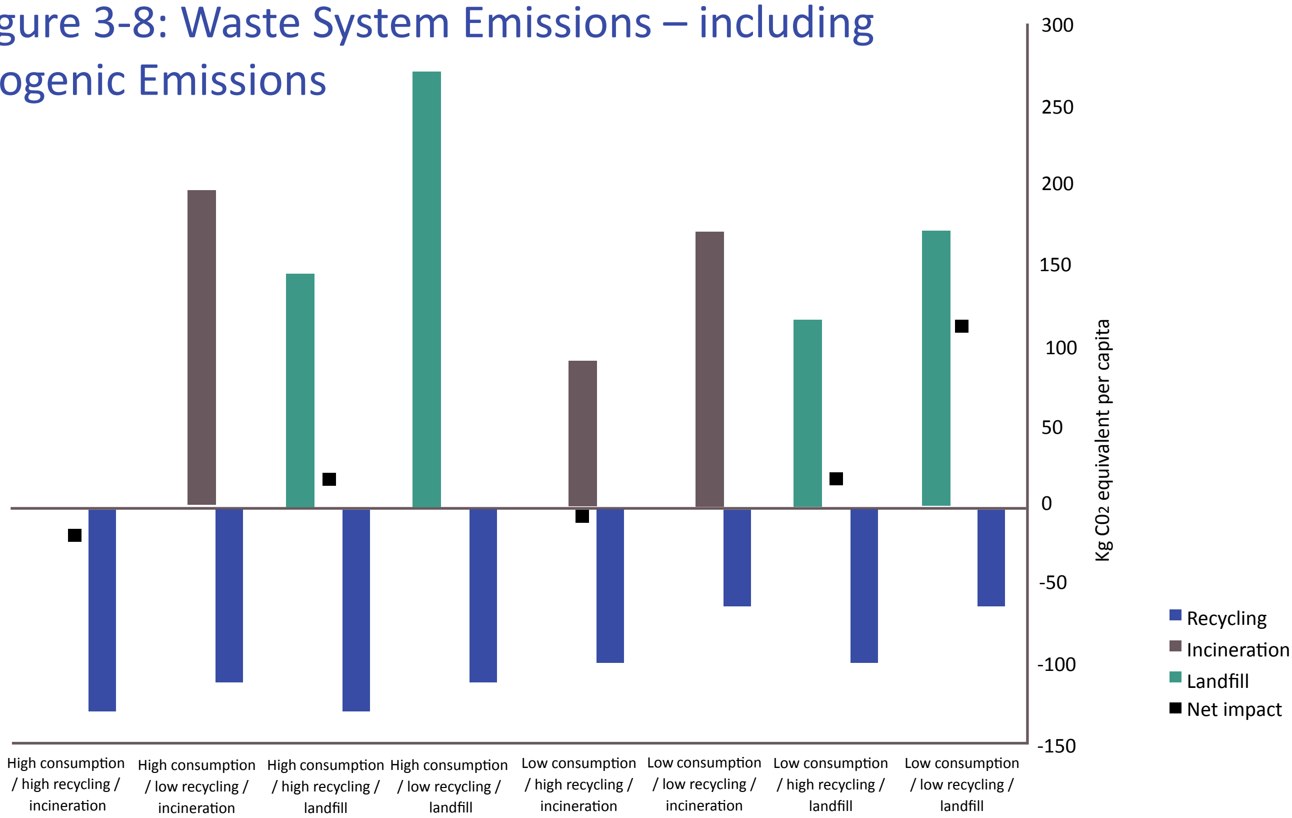
58 As was discussed earlier in this section, the climate change contribution from incineration facilities is likely to increase in the future as energy systems are decarbonised.

Figure 3-7: Waste System Emissions – excluding Biogenic Emissions



Sources: Eunomia; Eurostat (see Appendix for details)

Figure 3-8: Waste System Emissions – including Biogenic Emissions



Sources: Eunomia; Eurostat (see Appendix for details)

4. The Effect of Key Policies

At the European level, waste management policy has been largely successful in driving forward improvements in the management of waste that is being generated. There are reasons to believe that policy may not have been as successful at restricting the growth of waste.

Within Europe, there has been much discussion about the potential for 'decoupling' of waste from economic indicators. This has given rise, in turn, to a distinction between 'absolute' and relative' decoupling, the former implying that whilst the economic indicator may be growing, the waste indicator is in decline, and the latter implying that whilst the economic indicator might be increasing, the waste indicator is increasing at a lower rate. This distinction is not at all helpful: not only is it difficult to translate the concepts into situations where the economy is not growing (but in decline), but it is quite obvious that the prospects for achieving absolute (as opposed to relative) decoupling are greater if the rate of economic growth is lower. In short, whether one is in the 'absolute' or the 'relative' state depends as much on the rate of economic growth as on anything to do with the management of waste. Finally, the concept of 'decoupling' lends itself to a presumption that 'coupling' has been demonstrated as a natural law that defines the order of things. Insofar as we are aware, no such clear and immutable link between indicators of economy progress and waste generation has been demonstrated, not least over all levels of economic growth, and recognising also that there are competing indices of economic progress.
One problem with the way in which some analyses of the climate change impact of waste have been conducted is that they take no account for the emissions associated with the consumption of goods and services which may lead, subsequently, to the generation of waste. So, for example, most life-cycle assessment and cost benefit studies are conducted from the perspective of how waste that is generated can best be managed, rather than on changing the nature and quantity of waste that is generated in the first place.

One reason for this is that waste managers have not always felt empowered to intervene upstream in the supply chain to influence production patterns and product design. Equally, however, product designers tend to make decisions with little or no reference to how their products might be managed at the end of their (first) life: they are unlikely to be so concerned with these matters unless policy (for example, extended producer responsibility, or voluntary commitments backed by credible sanctions), corporate sustainability objectives, or consumer demand (or a combination of these) pushes them in this direction. This section considers, first, the extent to which existing European policy, as opposed to various thematic strategies, seems to demonstrate appreciation of the relevance of improved waste management performance for the reduction in climate-relevant emissions. Following this, we consider situations where policies appear to be at odds with the performance ranking in respect of climate change considered in Section 3.2.

4.1 Waste Framework Directive

The over-arching piece of legislation regarding waste in the EU is the Waste Framework Directive, which was last revised in 2008. A key change in the latest version of the Directive was the greater emphasis placed on aligning policy with the waste hierarchy. Whilst previous versions of the Directive had encouraged Member States to follow the hierarchy, Article 4 of the 2008 Directive reads as follows: [59]

"1. The following waste hierarchy shall apply as a priority order in waste prevention and management legislation and policy:

a) prevention;

59 Directive 2008/98/EC of the European Parliament and the Council of 19 November 2008 on Waste and Repealing Certain Directives, Official Journal of the European Union, L 312/3, 22.11.2008.

b) preparing for re-use;
c) recycling;
d) other recovery, e.g. energy recovery; and
e) disposal.

2. When applying the waste hierarchy referred to in paragraph 1, Member States shall take measures to encourage the options that deliver the best overall environmental outcome. This may require specific waste streams departing from the hierarchy where this is justified by life-cycle thinking on the overall impacts of the generation and management of such waste.

The above suggests that other than where life-cycle thinking suggests otherwise, prevention and preparing for re-use should be considered priority areas for waste management policy in future. Indeed, the WFD sets out a requirement for Member States to develop Waste Prevention Programmes under Articles 29 to 31, with possible measures for inclusion in these set out in Annex IV. [60]

Article 8 of the WFD, on Extended Producer Responsibility, allows Member States considerable freedom to develop measures to encourage producers to take responsibility for their products. There is encouragement to go beyond the daughter directives covering packaging and packaging waste, batteries and accumulators, end-of-life vehicles, and waste electrical and electronic equipment, each of which encourages producer responsibility.

Article 10 states that:

1. Member States shall take the necessary measures to ensure that waste undergoes recovery operations, in accordance with Articles 4 and 13.

2. Where necessary to comply with paragraph 1 and to facilitate or improve recovery, waste shall be collected separately if technically, environmentally and economically practicable and shall not be mixed with other waste or other material with different properties.

The second sub-paragraph above has not been given the significance that it deserves, this suggesting that, in order to comply with the waste hierarchy, Member States should collect waste separately subject to specific criteria.

Targets are included within the Directive (Article 11) for preparing for re-use and recycling key materials - paper, plastics, metals and glass – from municipal waste. Subsequent to the Directive being passed into law, a Communication from the Commission made clear that 4 different methods could be used to measure performance against these targets, each with different implications for actual waste management performance.

Article 22 encourages Member States to take measures to support the separate collection of biowaste with a view to it being composted and digested.

On the basis of the above, there is much to admire in the existing Waste Framework Directive. If Member States were to pursue the hierarchy as per Article 4, and if they were to implement the requirements of Article 10, then arguably, the targets under Article 11, and the encouragement to separately collect biowaste under Article 22 might be considered unnecessary.

4.1.1 Existing Waste Policy

We noted above that there has been some concern that waste policy has tended to develop from the base of the hierarchy, moving incrementally upwards over time. In the existing legislation, there is no target directly addressing waste prevention (or reuse as part of waste prevention). Member States are encouraged to develop waste prevention programmes, but the extent to which these will generate results is less than clear at present.[61] The setting of targets across 28 countries is not without its problems: yet in the absence of specific targets, mandating the im-

60 Directive 2008/98/EC of the European Parliament and the Council of 19 November 2008 on Waste and Repealing Certain Directives, Official Journal of the European Union, L 312/3, 22.11.2008.
61 See http://www.eea.europa.eu/publications/waste-prevention-in-europe-2014

plementation of specific measures may have provided the means to achieve the desired end.

Also of note is that fact that one position above 'disposal' in the hierarchy outlined in Article 4, is 'other recovery, e.g. energy recovery'. The definition of 'recovery' has undergone some change over recent years. In the revised Waste Framework Directive, the list of recovery operations includes those incineration facilities that exceed a threshold of efficiency in terms of energy generation, the latter being calculated on the basis of a formula set out in an Annex to the Directive - the so-called "R1" formula. Prior to this revision, all incinerators (other than some linked to district heating networks) were formally classified as disposal facilities.

The non-legally binding guidance published by the Commission on the formula confirms that energy used within the facility can also be taken into account when calculating performance against the R1 criterion. As a result it is now relatively easy for facilities to meet the threshold designated for recovery: facilities with a gross electrical generation efficiency as low as 22.5% could achieve it (the net generation efficiency figure would typically be several percentage points lower than this). Despite this, the JRC has recently undertaken work to consider whether there is a case for allowing for a climate correction factor to be applied to the R1 criterion, thereby making it easier still for facilities located in warmer climates, where efficiency of electricity generation is lower, and the demand for heat is weaker, to achieve recovery status. [62]

The latter approach should take into account that the intention of the R1 criterion appears to have been to allow incinerators to be classified as recovery where they were highly efficient. There is already a requirement (Article 44) within the Industrial Emissions Directive, which states that applications for permits should include a description of measures intended to guarantee, inter alia, that: [63]

the heat generated during the incineration and co-incineration process is recovered as far as practicable through the generation of heat, steam or power

Taken in conjunction with Article 11 of the same Directive, which obliges Member States to take the necessary measures to provide that installations use energy efficiently, then it appears to be a condition of being granted a permit that energy is used efficiently, and the heat generated is recovered as far as practicable. The JRC work moves towards a position whereby virtually all new facilities that meet their requirements in respect of permitting would be designated as recovery facilities (raising the question as to what was the point of differentiating facilities on the basis of some measure of efficiency).

Evidence presented in this report in Section 3 confirms that the climate change benefit attributable to moving waste out of landfill and into an incinerator generating only electricity are unlikely to be substantial for most European countries. Other studies – such as that undertaken by COWI on behalf of the European Commission in 2000 – that have considered the externalities of landfill compared to incineration have reached similar conclusions, namely, that only if the assumption was that all energy generated was derived from coal would the benefits of incineration be obviously better than landfill.[64] The lack of a meaningful justification for classifying some incineration facilities as recovery rather than disposal remains problematic.

It should be noted that whilst, based on the above, one would expect that Member States would work to implement the waste hierarchy in waste policy

62 See JRC (2014) Report on the impact of R1 climate correction factor on the Waste-to-Energy (WtE) plants based on data provided by Member States, http://iet.jrc.ec.europa.eu/remea/sites/remea/files/r1reportfinal_online_.pdf
63 Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on Industrial Emissions (integrated pollution prevention and control), http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02010L0075-20110106&from=EN
64 COWI (2000) A Study on the Economic Valuation of Environmental Externalities from Landfill Disposal and Incineration of Waste, Report for the European Commission, http://ec.europa.eu/environment/waste/studies/pdf/econ_eva_landfill_report.pdf

and law, the varied performance of Member States (and the slow pace of change in some of the countries lagging behind) suggests very uneven adherence to Article 4. Nonetheless, the priority ordering in the Directive is reasonably well-aligned with the ordering of preference from a climate change perspective. The main issues relate to the preference for 'recovery' over disposal, especially as energy systems within the Member States are progressively decarbonised.

4.2 Landfill Directive

Article 5 of the Landfill Directive contains targets for the diversion of biodegradable municipal waste from landfill. The Directive entered into force in 1999, and makes no mention of climate change as a motivating factor.

It is important to note, however, that the Directive itself does not specify where the diverted waste should go, and so this is likely to be dictated by the relative influence of other policy instruments.

The IPCC's Fifth Assessment Report considers the Directive has been successful in reducing emissions from waste management in the EU, suggesting this to be largely responsible for the 20% reduction in waste emissions from 2000 to 2009. The problem with this observation is that it is not possible to say, on the basis of the figures relied upon by the Fifth Assessment Report that emissions from waste management as a whole have fallen at all. This is because the 'waste' part of the inventory only covers a subset of activities which make up waste management, and if waste is managed through simply switching from landfill to incineration, then the climate change impacts might, overall, be negative.

4.3 Renewable Energy Directive

The EU Policy for Renewable Energy and Directive on Renewable Energy Sources RES 2001/77 (amended by Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market and by Directive 2009/28/EC) establishes targets for total Renewable Energy Sources.
The Renewable Energy Directive (RED) sets out the framework for Europe to achieve a target of 20% of its energy from renewable sources by 2020. The most recent version of the Directive replaces the first Directive, which entered into force in 2001.[65]
The Directive includes, as a source of renewable energy, biomass, which is defined as:

'biomass' means the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste;
Landfill gas is included in the definition of renewable energy.

The Directive does not define the term 'renewable'. It seems to stretch the logic of the term 'renewable', however, to include 'waste', whatever its origin, as a renewable resource. The framework legislation on waste make the prevention of waste the priority in terms of how to manage waste. If the priority for waste is its prevention, then the rationale for including it as a renewable source of energy seems completely misguided. This is already being highlighted in discussions in the UK regarding the tension between using food waste for renewable energy generation, or using it to feed humans, or animals.[66]

65 The more recent 2030 Energy Strategy published in 2014 includes further, higher targets for 2030, including an emissions reduction target of 40% and an energy reduction target of 27%. See: https://ec.europa.eu/energy/node/163

66 See also Fusions (2015) Review of EU legislation and policies with implications on food waste. Final Report, 15 June 2015, downloadable from http://www.eu-fusions.org/index.php/publications. As the report notes, 'Directive 2009/28/EC encourages the use of anaerobic digestion to treat food waste. This could be a potential disincentive for the prevention of food waste, which could be partly justified by its use for energy production.'

4.3.1 The Perverse Effects of Renewable Energy Support Mechanisms

Because the part of waste derived from biomass is considered as renewable, so it has become the case that measures to support the meeting of targets set under the RED have often included various forms of energy generation from waste, including landfill gas, incineration, and other thermal treatments (such as gasification and pyrolysis), as well as anaerobic digestion.

Across the EU, a variety of 'positive support' measures is used, the main ones being:

a) Feed in tariffs, under which sources of renewable energy benefit from higher prices for the energy they generate in accordance with an agreed schedule; and

b) Tradable credits (or renewable portfolio standards, or tradable quotas), under which energy generators, for example, are required to meet a specified target for generation from renewables, and where generation of renewable energy entitles the generator to a credit, which may be tradable in the market place.

Taking into account that climate change benefits associated with recycling, not to mention, waste prevention, are generally rather better than for processes generating energy (see Section 3.2), then where incentives for renewables reduce the gate fees paid for treating waste, this appears to be problematic. This is as true for anaerobic digestion as it is for treatments for residual waste and disposal, but the issue is of particular concern where the residual waste treatments are concerned. The reasons are highlighted below.

For municipal waste managers, or for those who are waste generators, the financial incentive to prevent, or to recycle, waste is significantly shaped by the costs that will be avoided by the waste not being generated in the first place, or by not having it dealt with as 'residual waste'. For the municipal waste manager, a key variable is the cost of collecting and treating / disposing of residual waste, and whilst this is also true for businesses generating waste, there are likely to be additional benefits to them from waste prevention. Even so, the avoided cost of managing waste as residual waste is a driver for moving waste up the hierarchy.

What renewable energy incentives do is that they work in the opposite direction. Because they increase the revenues associated with energy generation, the fees that operators need to charge to achieve a given level of return will fall. This reduces the costs which are avoided through waste prevention and recycling, thereby reducing the incentive to move waste up the hierarchy.

It is worth considering what happens in thermal facilities generating energy from residual waste: there is a biomass fraction of waste, but residual waste is rarely, if ever, solely biomass. Much of the calorific content comes from the non-fossil content of waste. Electricity generation at a typical residual waste incineration facility (such as that presented in Section 3.2 has a carbon intensity of approximately 600 kg CO_2 eq. per MWh of electricity where biogenic CO_2 emissions are excluded, and in excess of 1,000 kg CO_2 where these emissions are included in the total. [67] This compares with a figure of 380 kg CO_2 per MWh of electricity for electricity generated at an efficient natural gas power station using Combined Cycle Gas Turbine (CCGT) technology. [68] It is clear that

67 Assuming a net generation efficiency of 24% and a typical residual waste composition for the waste incinerator.

68 The figure comes from Ricardo AEA (2013) Current and Future Lifecycle Emissions of Key "LowCarbon" Technologies and Alternatives, Report for the Committee on Climate Change, April 2013, https://www.theccc.org.uk/wp-content/uploads/2013/04/Ricardo-AEA-lifecycle-emissions-low-carbon-technologies-April-2013.pdf

69 The relatively poor performance occurs by virtue of the low generation efficiency and the high fossil carbon content of the non-biogenic part of the residual waste stream. Whilst a CCGT plant can generate electricity at efficiencies up to 50%, the net electrical generation efficiency of a MSW incinerator is typically around 25%

these facilities are not a source of low-carbon electricity.[69] However, the generation of electricity from food waste using anaerobic digestion has a carbon intensity of less than 1 kg CO_2 eq. per kWh where biogenic CO_2 emissions are excluded.

It should also be noted that the preference ordering of incentives for different renewable energy sources do not seem consistent. In the UK, for example, the incentives for using biogas as a vehicle fuel are much weaker than those for using biogas for electricity and heat. In practice, at the margin, biogas tends to displace gas in heating applications, and the marginal electricity source is one with a carbon intensity slightly below that of a combined cycle gas turbine. In vehicle use, however, the typical displacement is with respect to diesel, a far more carbon intense fuel. The carbon benefits of using biogas in vehicle fuel would appear to justify higher, not lower, support.

The problem here is that 'waste', which ought not to be considered as a renewable resource at all, is, by virtue of support mechanisms in place, being made more readily available to the facilities being supported. There may, for some technologies, be good reasons to believe that they are more favourable than others, but to classify the biomass fraction of waste as a renewable resource is to fly in the face of everything that waste management policies should be seeking to achieve: at the very basic level, it conveys all sorts of wrong messages.

4.3.2 Implicit Subsidies for Incineration

Similar problems arise where waste facilities benefit from implicit subsidies: included within this class of subsidy are exemptions from taxes which should be applied to a given technology. In some Member States where heating fuels are taxed, for example, energy from waste facilities are exempt from the tax (examples are Denmark and Sweden). This effectively acts to increase the price received for the generation of heat, thereby having a similar effect, in the local market, to the renewable energy support mechanisms from the standpoint of the treatment. Denmark counters this effect with an incineration tax based on the carbon content of the waste being combusted. Sweden does not (an incineration tax that had been in place was withdrawn).

4.4 EU Emissions Trading Scheme

One of the most high-profile policies to address climate change in the EU has been the EU's Emissions Trading Scheme (ETS), the key tool for reducing greenhouse gas emissions from industry, the aim of the trading mechanism being to do this at the lowest cost.[70] Emissions from the waste sector - including landfills and incineration facilities - are not included within the ETS.[71] The EU's key tool for addressing climate change thus exerts no pressure on waste treatment / disposal facilities to reduce their emissions of greenhouse gases.

The Effort Sharing Decision includes targets for those sectors that are not included in the ETS, including waste facilities. However, the target here has been set at a 10% reduction of emissions by 2020 against 2005 levels; this is expected to be overachieved by some 8% and has therefore been criticised as showing a lack of ambition.[72]

It is noted that the packaging materials (such as metals, paper, plastics and glass) will fall under the scope of ETS, and so for European manufacturers of these products, there may exist through this policy some incentive to increase the proportion of recycled content, where climate change benefits result

70 See: http://ec.europa.eu/clima/policies/brief/eu/index_en.htm

71 An exception is made for emissions from the co-incineration of waste – this may happen in the power sector, or, for example, at cement kilns, both of which are included within the ETS.

72 See, for example, http://carbonmarketwatch.org/the-eus-effort-sharing-decision/

from such an approach. However, given that these are globally traded commodities, a significant proportion of the production of the material which is consumed within the EU occurs outside of its geographical boundaries. Since there is no mechanism – and nor is there likely to be – for border adjustment to levy a fee on imports equivalent to that which domestic producers pay, so there is likely to be a tendency for leakage to occur in these sectors. Indeed, whilst producers in the EU will have an incentive to switch to secondary materials to reduce their emissions, those exporting to the EU will be affected only by domestic measures, and in some cases, these means there is no equivalent treatment of these non-EU producers.

The revised ETS makes provision for listing sectors at risk of carbon leakage where one of the provisions of Articles 10(15) and 10(16) apply, and subject to Articles 10(17) and 10(18). [73] The Commission has addressed this potential for leakage in a Commission Decision (COM 2010/2/EC). This recognises that the direct costs of the EU ETS pose a potential risk to certain industries and allows the Union to allocate allowances free of charge to sectors deemed to be exposed to a significant risk of carbon leakage.[74] With regards to indirect costs, higher electricity prices are included in the methodology to determine the list of sectors eligible for assistance. These sectors can therefore be compensated for the passing down of these costs from utilities companies. The proposed list of sectors includes several raw material sectors.[75] Because the sectors are compensated for the direct / indirect costs of allowances, their incentive to reduce emissions through using less energy, a key means of doing which may be through using secondary materials from recycling (see Section 3.2), is diminished.

In principle, tax based measures would be preferable to the approach based on emissions trading where the issue of carbon leakage is concerned. A tax based measure is amenable to the application of border tax adjustments, as long as the relevant body of information is available. This would help to address the issue of carbon leakage since imports would be treated in the same way as EU production, and the need to allocate allowances free to those sectors deemed to be at risk of leakage would be largely eliminated. Because of this, sectors which are identified as being at risk of leakage would still have an incentive to engage in the use of secondary materials.

Evidently, there seems little prospect of the EU-ETS changing quickly. On the other hand, there has already been discussion of a hybrid scheme, as is already applied in the UK (albeit with some exemptions and supplementary measures to assist heavy users of energy, once again, related to competitiveness issues), where a floor price for allowances is set. In principle, this could allow for the application of border tax adjustment, albeit only at the level of the floor price: given the historic tendency for allowance prices to remain at low levels, however, such a strategy might still lead to equal treatment of EU producers and those abroad.

4.5 Use of Regional Funds

Funding support is available from the European Regional Development Fund (ERDF) and the Cohesion Fund for the waste sector. The Regulations setting out the conditions for funding confirm that the Cohesion Fund is intended to support, preserve and protect the environment, and promote resource efficiency by: [76]

"…investing in the waste sector to meet the requirements of the Union's environmental acquis and to address needs, identified by the Member States, for investment that goes beyond those requirements"

Article 4(a) indicates support for the shift towards a

73 Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC (OJ L 275, 25.10.2003, p.32).

74 Article 10a (1) of Directive2003/87/EC

75 See Annex to the Commission Decision on determining, pursuant to Directive 2003/87/EC of the European Parliament and of the Council, a list of sectors and subsectors which are deemed to be exposed to a significant risk of carbon leakage for the period 2015 to 2019, http://ec.europa.eu/clima/policies/ets/cap/leakage/docs/20140502_annex_en.pdf

76 European Commission (2013) Regulation (EU) No 1300/2013 of the European Parliament and of the Council of 17 December 2013 on the Cohesion Fund and repealing Council Regulation (EC) No 1084/2006

low-carbon economy in all sectors is an investment priority. However, beyond these general statements, there is no indication as to what activities within the waste sector should be prioritised for funding.
The European Commission has, elsewhere, confirmed in 2013 that this is a decision to be made by individual Member States, although it also indicated any such decisions should respect the waste hierarchy when allocating funds, and that the Commission would seek to ensure that the budget allocations of Member States reflect this.[77] Some authorities have applied for this fund to support the development of incineration plant; for example, in 2010, Poland submitted proposals for nine such projects to be funded by the Cohesion Fund.[78] Others have since called for a block on funding of incineration and landfill from this source.[79]

More generally, the Commission has expressed its concerns at the way in which Regional Funds are utilised. There is now in place a system of ex-ante conditionality for waste in respect of the use of Regional funds for the next programming period 2014-2020.

The following 4 conditions have to be met:

1) Report submitted to the Commission on progress towards targets of Article 11 of Directive 2008/98/EC,

2) Existence of one or more waste management plans as required by Article 28 of Directive 2008/98/EC.

3) Existence of one or more waste prevention programmes, as required by Article 29 of the Directive.

4) Necessary measures to achieve the target on re-use and recycling by 2020 consistent with Article 11(2).

Notwithstanding these measures, partly because the targets under Article 11(2) can be met through one of four different methods, and because the waste prevention programmes are not required to achieve any specific outcomes, then these conditions might be met through the development of a relatively weak waste management plan and associated waste prevention programme. As a result, the effectiveness of this form of conditionality in ensuring there is not over-investment in residual waste treatment capacity remains to be demonstrated: in addition, as noted above in respect of Poland, this might be too little too late in the case of some countries.

It is clear that many financial backers of waste-related projects have failed to come to terms with a fundamental reality: where waste management is concerned, the availability of, and the desire to commit, large sums of capital tends to lead to investments at the lower end of the hierarchy. Financial backers have failed to innovate to enable projects in the upper tiers of the hierarchy to be made viable and interesting for investors. This is true within the EU, and outside it. Not only from the perspective of climate change, but on the basis of a sound appraisal of costs and benefits, large scale residual waste treatment ought to be the last resort for projects seeking to help countries with a shortage of funds to develop their waste management capability.

4.6 Roadmaps on Carbon and Resource Efficiency

The European Commission's Roadmap to a low-carbon economy is one of several that set out the long term policy plans of the Commission. [80] As was indicated in Section 1, it indicates that increased resource efficiency through waste recycling, better waste management and behavioural change could play an important role in achieving domestic emissions reductions of 80% by 2050 compared to 1990.
Alongside this Roadmap, the Commission developed scenarios showing how the emissions reductions could be met. Perhaps reflecting the structure of the

77 http://www.europarl.europa.eu/sides/getAllAnswers.do?reference=P-2013-006735&language=FR
78 http://wtert.eu/default.asp?Menue=26&NewsPPV=8453
79 http://www.ciwm-journal.co.uk/archives/7519
80 European Commission (2011) A Roadmap for moving to a competitive low carbon economy in 2050

existing GHG inventories, the impact of waste management activities is discussed with respect to the industrial sector emissions. Beyond this statement, there is little other detail provided in the Roadmap on the activities that might occur to achieve this ambition.

Published at a similar time to the low-carbon Roadmap, the Roadmap to a Resource Efficient Europe outlines milestones intended to ensure Europe's economy is sustainable by 2050.[81] Noting that some Member States are already recycling more than 80% of waste, the roadmap sets out a series of actions to be undertaken by the Commission to ensure that, amongst other things, energy recovery is limited to non-recyclable materials, and high quality recycling is ensured. Elsewhere, the Roadmap sets out actions intended to reduce by 50% the disposal of edible food waste.

Furthermore, the Roadmap also confirms that the Commission will seek to measure progress through the development of indicators, including a carbon indicator. More detail on this is set out in the staff working paper, which confirms that a carbon indicator of consumption from a global supply chain perspective will be considered alongside the territorial inventory of emissions.[82] However, the data subsequently presented in the annex appears to be derived from the territorial-based inventories, which do not account for all the impacts of consumption occurring outside the specified geographical boundary.

4.7 Eco-Design Directive

The Ecodesign Directive (Directive 2009/125/EC)[83] establishes a framework for setting out minimum mandatory requirements on the efficiency of energy-using products (such as boilers, lightbulbs, TVs and fridges) and energy-related products (such as windows, insulation materials and certain water using products) sold in the EU28. Its scope is broad in that currently covers more than 40 product groups which are responsible for around 40% of all EU greenhouse gas emissions. The Directive results in the banning of non-compliant products sold in the EU28, as was the case with incandescent light bulbs, which have being phased out gradually since 2009.

The rules within the Ecodesign Directive govern which products may be placed on the market; and as such, since its launch, the Directive has banned the least efficient products from the market, where cost effective. It is intended that the product groups featuring in these working plans are those which will result in the largest saving potentials (from an energy and/or water perspective, and in resulting carbon emissions) at low cost, through reduced energy demand.

Although the potential for savings is significant, a recent review of both the Eco-design and Energy labelling Directives indicated that both had failed to reach their full potential as the level of ambition within many product groups had been set far too low, and the levels of enforcement were relatively weak. In addition, the directives largely fail to tackle the potentially significant emissions reductions benefits that could result from improved recyclability.[84] The Waste Framework Directive anticipated that the scope of eco-design criteria would broaden beyond 'energy efficiency in use', as had been the case with energy-using products, and shift towards design for repair / reusability / recyclability, and the extent of use of secondary materials in the products covered.[85] There is much discussion about this at present, though progress has been limited thus far. [86]

81 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0571&from=EN
82 Approaches to inventorying emissions are discussed further in Section 2
83 Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products (OJ L 285 of 31.10.2009)
84 Ecofys (2014) Final Technical Report: Evaluation of the Energy Labelling Directive and Specific Aspects of the Eco-design Directive
85 See for example, JRC (2012) Integration of resource efficiency and waste management criteria in European product policies – Second phase, November 2012,).
86 See Okopol (2015) Delivering Resource-efficient Products: How Ecodesign can Drive a Circular Economy in Europe, Report for the European Environmental Bureau,

5. Conclusions and Recommendations

Waste management activity is far broader in scope than treating residual waste through landfill or incineration. This report confirms that actions at the top of the waste hierarchy – including waste prevention initiatives and recycling - have considerable scope to reduce climate change emissions – as is also recognised by the Fifth assessment report on mitigating emissions published by the IPCC, albeit only briefly in the chapter devoted to waste, and without any specific reference to the magnitude of these benefits. The Roadmaps aimed at transforming Europe into a low-carbon and resource efficient economy are also an indication that policy is starting to move in the right direction, with both documents recognising that improvements in waste management could make a contribution to GHG emissions reductions: this is explicitly modelled in the Impact Assessment which accompanied the now withdrawn legislative proposal within the so-called Circular Economy package.

However, the focus on territorial emissions does not allow the benefits of recycling and waste prevention initiatives to be easily quantified. Impacts attributed to the waste sector in the inventories submitted to the UNFCCC cover only a very narrow part of the waste management system – all of which is at the bottom of the hierarchy.

Other aspects of European policy appear to be counterproductive for mitigating the climate change impacts of waste management. As waste facilities are not included in the EU ETS, there is no incentive through this mechanism to reduce GHG emissions from waste treatment. The Waste Framework Directive allows relatively poorly performing incineration plant to be classified as "recovery" facilities, and the Renewable Energy Directive allows for energy generation from residual waste to be subsidised, despite this being a relatively carbon-intensive form of energy generation. In addition, biogenic carbon is typically not correctly accounted for in life cycle assessments, and this has resulted in an overestimation of the benefits of diverting waste from landfill to incineration.

The combined effect is that there has far too much emphasis on the bottom layers of the waste hierarchy, where the climate change benefits from changes are relatively insignificant, and will become increasingly so as energy systems decarbonise. The need to focus attention at the higher levels of the hierarchy will become yet more acute in the future, as efforts by Member States to decarbonise energy generation start to bear fruit (since this will lead to a reduction in the benefits of generating energy from waste), and if – as seems eminently sensible – we seek to reduce the energy intensity of production and consumption.

The above discussion suggests there a need to re-define what is meant by renewable energy as far as generation from residual waste is concerned: the focus here should not just be on the biomass element of the fuel, to the exclusion of the fossil carbon element of the feedstock where emissions are substantial. Alongside this, waste facilities should be included within the EU ETS, or, alternatively, the targets within the Effort Sharing Decision increased so that they incentivise change.

The increased use of consumption-based approaches to inventorying emissions would undoubtedly help to highlight the role that waste prevention and recycling can have to mitigate climate change impacts for globally traded commodities. The development of a fully integrated global GHG emissions trading system could also assist. However, both are likely to prove challenging to develop and can only therefore be considered as long-term objectives.

For many of the most widely recycled materials, this report confirms that data is available with which to estimate the benefits of recycling for these globally traded commodities. At the very least, this data could be combined with the Eurostat data returns to estimate the emissions benefits of recycling to give some headline figures. In the medium term, an alternative solution might be to include information items in the waste section of the inventory confirming the emissions reductions occurring in other countries through recycling, developed using similar life cycle datasets.

5.1 Recommendations

On the basis of the observations in the main report, the following recommendations are made:

Recommendation 1: Waste policies should be designed to manage waste in the upper tiers of the waste hierarchy (i.e. recycling or above)

Generally, waste policies that move waste increasingly into the upper tiers of the hierarchy are likely to be beneficial for climate change. The waste management hierarchy offers a reasonable guide to managing waste sustainably: waste prevention leads to the greatest gains, with recycling options, especially for the dry materials, following closely behind. The main issues lie with the way the hierarchy indicates that residual waste should be managed. In the EU, incineration facilities are classified as recovery where they meet a specific criterion related to energy efficiency. Although the rationale for this seems questionable, a recent study from the JRC suggests that this criterion might be further relaxed in circumstances where temperatures are generally higher. This is despite the fact that simply switching waste from landfill to incineration is likely to lead to limited climate change benefits, and even a worsening of the emissions where energy sources are becoming decarbonised.

Recommendation 2:
Indicators of waste management performance should shift from ‘how much is landfilled?’ to ‘how much residual waste is generated?’[87]

One of the key indicators that has been used by DG Environment, Eurostat and the EEA to assess waste management performance is the amount of waste landfilled, with lower figures being deemed indicative of superior performance. This would be a sensible indicator to use if it were true that landfill performed dramatically less well than all other options, and if all other options performed more or less equally well. This is not true: ‘not landfilling’ can lead to very different strategies and outcomes, and within the EU, there are countries with similarly low rates of landfilling, some of whom have high recycling rates, and low levels of incineration, and others who are in the opposite situation. The analysis in Figure E-2 shows that it will be waste prevention and waste recycling effects that are the dominant determining factors in climate change performance. The shift to a focus on residual waste would also help Member States focus their attention not on capital-intense residual waste treatments (that have the potential to lock them in to low recycling rates), but on moving waste into the upper tiers of the waste hierarchy;

87 By ‘residual waste’, we mean the waste that is left over after households and businesses have sorted their waste for recycling, as well as the contraries from sorting facilities and plants for treating separately collected biowaste. This is usually a mixed waste fraction, and is typically sent for landfilling, incineration or MBT (mechanical biological treatment).

Recommendation 3:
The implementation of blanket bans on the landfilling of waste should be resisted. Since, for materials widely found in mixed residual waste, material-specific landfill bans are not enforceable, the focus should be on measures to encourage, or mandate, the separation of waste for preparation for reuse or recycling;

Linked to the previous recommendation, landfill bans may have counterproductive effects since at the time when they enter into force, then to the extent that they are enforced, there is a requirement to have in place sufficient treatment capacity to ensure that all residual waste can be dealt with at facilities that are not landfills. This can lead to a situation in which the country's waste strategy becomes locked in to low recycling rates. Unsurprisingly, it is Member States which have implemented bans that have excess capacity in residual waste treatment, and which are now seeking to make use of that capacity through importing waste from other Member States.
Similarly, where materials widely found in residual waste are concerned – such as plastics – material specific landfill bans are likely to be unenforceable for the material on its own, and would tend to lead to a complete ban on landfilling if the intention of regulators was to fully enforce the ban (since 100% recycling of all plastics might prove difficult). Policies should 'positively' drive waste up the hierarchy rather than simply banning resort to the lowest tier of the hierarchy, and forcing sometimes excessive investment in residual waste treatment capacity. Hence, landfill taxes, extended to other residual waste treatments, and requirements to sort waste, or to provide households with collection services of a minimum quality, will tend to deliver far superior results. The use of pay-as-you-throw systems is made more 'incentive compatible' where the costs of disposal / residual waste treatment are higher, and is to be encouraged once convenient systems for segregation of wastes are in place.

Recommendation 4
Member States should reconsider their support mechanisms for renewable energy: in particular, they should immediately discontinue support for all forms of energy from residual waste. This includes the use of implicit subsidies, such as exemptions from taxes on heating fuels, unless there are 'balancing' incineration taxes in place.

Given that part of the rationale for developing renewable sources of energy is to address climate change, it seems counterproductive to maintain support for those which might contribute to climate change. The case for supporting measures for the generation of energy from waste on the basis that waste is 'a renewable resource' makes no sense when set against the waste hierarchy. As countries improve in their prevention, reuse, and recycling, so less and less residual waste will be available. It is stretching the definition of 'renewable' beyond what is credible to argue that residual waste could be a source of 'renewable' energy;

Recommendation 5
At the same time, it would make sense to consider the withdrawal of any form of support for the utilisation, directly, of harvested biomass for renewable energy generation / renewable fuels

In a world where there will be increasing pressure on land, it must surely be questionable to use biomass directly for energy when the land used to grow it could be used for food, or for manufacturing prior to the resulting waste materials being recycled: only when waste materials are 'leaking' from the system, or when food waste is being digested, should they be used for energy generation. Currently, the use of primary biomass for energy and fuel is widely subsidised. It is intensely ironic that the waste hierarchy suggests wood wastes would only be combusted once the potential for reuse and recycling has been fully explored: yet the virgin resource can be combusted directly and be subsidies to boot. This is a fundamental misallocation of resources resulting from perverse economic incentives.

Recommendation 6

Consideration needs to be given as to how to integrate 'waste' within the framework of European policies to tackle climate change. One way would be to consider its integration within the EU-ETS. Another would be to consider reinforcing the Effort Sharing Decision, making GHG emission reduction targets with appropriate ambition for the waste sector. Particular attention would need to be paid to ensuring the benefits of recycling and reuse were adequately recognised, even where the recycling and reuse took place in other countries;

Although electricity generation is an activity for which, under the EU-ETS, (with some exceptions) no free allowances are issued, waste facilities which generate energy are not included in the EU-ETS. This is an implicit subsidy. Although the Commission has frequently urged Member States to remove environmentally harmful subsidies, the EU-ETS, as a measure for which the Commission has substantial responsibility, affords an implicit subsidy to waste facilities which generate electricity. An incinerator generating electricity might generate electricity with a carbon intensity of around 600g CO_2 per kWh, almost double the carbon intensity of a modern gas-fired power station.

Recommendation 7

In the short-term, and in the absence of a move to consumption-based inventories, it would be helpful to include:

- **o as an addendum to the 'waste' section of the inventory, the estimated GHG effects of recycling (including where materials collected for recycling are exported), and**
- **o in the Industry chapter, the extent to which industries make use of recycled materials (and the implied level of emissions saving).**

The focus on landfilling highlighted in Recommendation 2 is somewhat perpetuated by the structure of GHG inventories as reported to the UNFCCC. Even the IPCC's own reports, though they refer to waste as a sector, appear to confine themselves, artificially, only to measures which address the number reported under the 'waste' aspect of the inventory (in the main, ways of reducing methane emissions from landfills). [88] This gives a misleading impression as to the extent to which improved waste prevention and management can deliver emissions reductions (even though the emissions reductions might, in the round, be captured by a global inventory).

88 Consider that recycling metals instead of landfilling them makes no contribution to reducing landfill emissions, but a considerable one from the perspective of the emissions associated with energy used in manufacturing, as indicated in Figure E- 2 and Figure E- 3.d.

Recommendation 8:
Recognising the uncertainty associated with the way in which emissions from the AFOLU (agriculture, forestry and other land use) Sector are accounted for, inventories should include emissions of biogenic CO_2 from incineration (and biomass power plants) until such time as the accounting methods have across countries been assessed in terms of the adequacy of the treatment of this matter.

Although inventories are developed with the intention, in principle, of capturing biogenic CO_2 emissions through the AFOLU Section, in practice, the manner in which this occurs is such that one cannot be confident that the CO_2 emitted from, for example, harvested wood products, is captured under the Tier 1 and other Member State methodologies. Given that, in principle, emissions of biogenic CO_2 from waste treatment plants (and biomass power plants), and to a lesser extent, landfills, are capable of being linked reasonably well to activity data, then it would seem sensible to incorporate these within inventories rather than assuming that the approaches identified by IPCC in the AFOLU Section are adequate for accounting for these.

Recommendation 9
All lifecycle studies engaged in comparative assessments of waste treatments should incorporate CO_2 emissions from non-fossil sources in their comparative assessment:

Whatever the merits of the approach to assembling inventories in IPCC Guidelines, it is a mistake to assume that 'CO_2 from non-fossil sources doesn't matter' in comparative assessments of waste treatment facilities. The argument that CO_2 from such sources is all 'short-cycle', and so, can be ignored, is tantamount to assuming a separation in the pools of carbon dioxide from fossil and non-fossil sources. It is as though the argument runs that the climate only changes if emissions of CO_2 come from fossil sources. This is so obviously wrong that it seems genuinely surprising that this argument could ever have been considered acceptable: in a comparative assessment of the contribution of waste management alternatives to climate change, the only correct way to proceed is to account for emissions (and sinks, if this is applicable) of all greenhouse gases since they will all have 'warming potential', irrespective of their origin.

Recommendation 10
In the longer term, it would be preferable to move towards consumption based inventories. The information requirements might be significant (although, arguably, if other countries are gathering appropriate inventories, it should be possible to do this).

Many authors have argued reporting inventories on the basis of what is consumed by a country is superior to the existing approach, where emissions are reported based on production within the reporting country. Under the former approach, carbon leakage can occur, whereby businesses transfer their operations to other countries, or countries progressively become more reliant on imports of goods to satisfy demand.[89] Depending on the boundaries used in the inventory assessment, different mitigation options may be indicated; the approach also tends to reduce the importance of emissions contributions from developing countries.[90]

89 http://ec.europa.eu/clima/policies/ets/cap/leakage/index_en.htm
90 Glen P. Peters and Edgar G. Hertwich (2008) CO2 Embodied in International Trade with Implications for Global Climate Policy, Environmental Science & Technology, Vol. 42, No.5, 2008, http://www.cepe.ethz.ch/education/EnergyPolicy/PetersHertwich.pdf

Conversely, for most European countries, consumption-based inventories result in higher emissions than their production-based counterparts. One paper which carried out this analysis at a European level suggested that emissions for the EU-27 from 2009 using the production based approach to be 4,059 million tonnes CO_2 equivalent, whilst the equivalent figure using their consumption-based approach was 4,823 million tonnes CO_2 equivalent. [91]

Consumption based inventories typically have higher uncertainties, and involve a significant data collection effort.[92] In addition, countries would need to work closely together to encourage mitigation efforts, thereby reducing the impact of imported goods. Perhaps because of these last two points, policy is currently linked to production or territorial inventory, and in particular the national UNFCCC inventory produced under guidance of the IPCC which is the subject of the discussion in the next section.

Recommendation 11

Regional funds (and funding from international financial institutions) urgently need to reconsider their funding of waste management projects.

The more capital intense waste management options lie closer to the bottom of the waste management hierarchy than the top. The tendency for those engaged in funding organisations, on the other hand, is to see disbursement of capital as a key indicator of success. In such a situation, large amounts of capital can create as many problems as it solves. Whilst it is one thing for private capital to back specific projects, those disbursing regional funds, and the international financial institutions, need to develop innovative models of funding that facilitate projects for prevention, reuse, repair, remanufacturing, and recycling rather than residual waste treatments. The lack of innovation in this regard is extremely disappointing, not least given the limited climate change benefits that are achieved through such projects (notwithstanding the claims made for them).

Fundamentally, the role that waste prevention and improved waste management can play in reducing GHG emissions risks being significantly understated. The current guidelines for preparing inventories are useful for specific purposes, but they are apt to obscure the potential role to be played by better waste and resource management in climate change mitigation. Instead of focusing on waste as a potential source of supposedly renewable energy, the focus must fall on how best to retain the energy which is embodied in (the manufacture of) materials and products, as well as reducing waste generation in the first place.

91 http://www.wiod.org/conferences/groningen/paper_Boitier.pdf
92 http://www.publications.parliament.uk/pa/cm201012/cmselect/cmenergy/1646/1646we12.htm

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The Potential Contribution of Waste Management to a Low Carbon Economy

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