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Greenhouse Gas Emissions from Waste: A Critique on the Data Inconsistencies for Reporting and Decision Making

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Abstract

Tracking and reporting greenhouse gas emissions from waste programs is a growing priority for the corporate sector. A review of the resources available for quantifying emissions finds multiple options for calculating emissions, each of which give different results. In this review two main sources for emissions factors, EPA and DEFRA, are compared. We find that similar inputs to each methodology result in differing GHG results for recycling, composting and incineration processes. The results show that increasing diversion through recycling does not always correlate to decreasing GHG emissions. It depends on the material being recycled and the alternative waste management process: landfill or incineration. Additionally, the 'standard' EPA emissions factors should not be confused with EPA's Waste Reduction Model (WARM), which is a comparative modeling system that utilizes a broader lifecycle approach. The latter is not intended to provide baseline GHG calculations, and the discrepancy is a potential source of confusion for reporting organizations.

Keywords: Recycling; GHG Emissions; Waste Audit; EPA; DEFRA; WARM

Introduction

The corporate sector is firmly committed to sustainability. Over 14,000 companies currently disclose carbon footprint to the Carbon Disclosure Project [1]. Other activities also point to growing corporate responsibility for environmental issues – self-imposed mandates on carbon neutrality, water security, and deforestation are but a few [2].

Many companies work assiduously to reduce the amount of waste hauled to landfill or incinerator. This is accomplished by increasing diversion from these final destinations through recycling, composting, and other beneficial uses. The core metric in this case is the Diversion Ratio – the amount of waste not sent to landfill or incineration as a percentage of total waste generation [3].

Another critical target for sustainable waste performance is carbon footprint reporting. How best to quantify waste in greenhouse gas emissions (GHG) reporting is a source of much confusion. Gentil et al. (2009) observed this issue looking at four types of GHG accounting in waste management: the national accounting, the corporate level, life-cycle assessment (LCA), and finally, the carbon trading methodology [17]. Even within the corporate level, problems arise. The GHG Protocol, which provides the world's most widely used greenhouse gas accounting standards, provides corporate guidance on calculating GHG emissions resulting from waste in Scope 3 Category 5. Emissions in Scope 3 are any indirect sources, other than energy, and Category 5 is descriptive of waste generated in operations [4]. However, due to the complexity in linking waste disposal to emissions, there are: (1) several methods appropriate for data collection, (2) factors that vary by governmental agency, and (3) different models for quantifying emissions from the same agency.

These complications invite reporting errors and inconsistencies. How can the public expect companies to pay attention and learn from the waste impact on climate when guidance is unclear? Untangling these complications is the subject of this publication: waste data collection methods for carbon reporting, comparison of UK's Department for Environment, Food & Rural Affairs (DEFRA) vs. the US Environmental Protection Agency (EPA) emissions factors, and distinctions between EPA Emission Factors for Greenhouse Gas Inventories (Factors Hub), EPA Waste Reduction Model (WARM), and when each is appropriate. A case study is presented which helps illustrate the varying outcomes of these tools.

We also examine the results of specific emissions factors to reflect the progression from 0% material recycled to 100% recycling for each example material presented. GHG analysis varies according to material and disposal option. In providing the same analysis for WARM, we observe the lifecycle impact of recycling two example materials compared to landfilling or combustion processes. If not examined on their own (which in municipal or business accountings is unlikely), the divergence of results will not be apparent leading to potential inconsistencies in reporting. This analysis makes apparent the benefits and shortcomings of existing emission factors.

Methodology

To determine the amount of GHG contributed by waste, the amount of waste generated at a site is converted using the appropriate emissions factors for the type of waste. The following details the variations on this process.

Data Collection Methods

According to the GHG Protocol, there are three methods of collecting data: Supplier-specific method, Waste-type-specific method, and Average-data method, as defined below [4]. Data collection using the Supplier-specific method requires that a third party, the waste treatment company, provide allocated emissions from their waste treatment processes. Where waste treatment companies report Scope 1 and 2 emissions, they could provide an allocation of those emissions to the waste collected from the customer. Scope 1 emissions are direct emissions from energy sources, emitted by an entity onsite, such as emissions from fuel burning. Scope 2 emissions are indirect emissions from energy sources, where emissions are generated off-site, such as electricity. Since the supplier would be providing emissions data, there is no emissions factor needed to process the information. This is the GHG Protocol's preferred method as reporting companies should reference emissions that are as specific as possible to suppliers' GHG emitting processes.

The waste-type-specific method requires a breakdown of waste by material type. This also includes how the waste was disposed, such as landfilled, combusted, recycled, etc for each waste type. This breakdown necessitates the company monitor and measure their waste profile and utilize waste type-specific and waste treatment specific emissions factors, such as those discussed in section 2.2. The Average-data method does not require a breakdown of materials but is based on the total waste going to each disposal facility (landfill, recycling, etc.). Accordingly, it is much less accurate or specific. [4]

Emission Factors for Company Reporting

When using the waste-specific method or average-data method, weights of waste material must be translated into GHG emissions by utilizing formulas provided by the GHG Protocol. (The Supplier-specific method does not require further calculations once allocations are established, because the GHG emissions are provided by the Supplier.) There are several resources available to provide factors for calculating emissions from waste. Due to the complexity of the relationship between waste disposal and emissions, these emissions factors vary, depending upon the research on which they were based.

Emissions factors are available for general reference and use from EPA's Emission Factors for Greenhouse Gas Inventories and the UK Government's GHG Conversion Factors for Company Reporting (DEFRA). The EPA Emission Factors Hub states "landfilling emissions include transport to landfill, equipment use at landfill and fugitive landfill CH4 emissions. Landfill CH4 is based on typical landfill gas collection practices and average landfill moisture conditions [5]."

Similarly, DEFRA states factors are drawn from landfill operations and the collection and transport of waste. According to DEFRA, the "landfill emissions remain within the accounting Scope of the organization producing waste materials. [...] these factors are now drawn directly from MELMod [model used to predict methane emissions from landfill], which contains information on landfill waste composition and material properties, with the addition of collection and transport emissions [6]." DEFRA does not say that emissions from other waste handling processes – recycling, composting, and combustion – remain in the accounting scope of the organization producing waste. This leads to significantly divergent reporting on all other waste handling processes as follows.

In composting, recycling and incineration, the basis for the emission factors diverges. For compost, the EPA Emission Factors Hub "include transport to composting facility, equipment use at composting facility and CH4 and N2O emissions during composting [5]." As per the most recent DEFRA Methodology Paper for Conversion factors, DEFRA made updates to the compost emission factors: "Changes to Compost: raw material factors have been updated based on peer-reviewed sources that take full account of processing emissions and nitrous oxide production [6, 7]."

DEFRA states, "emissions associated with recycling and energy recovery are attributed to the organization which uses the recycled material, or which uses the waste to generate energy. The emissions attributed to the company which generates the waste cover only the collection of waste from their site [6]." Since the DEFRA factors for the organization producing the waste materials do not include emissions from the recycling processes or energy recovery (combustion), the same emissions factor is used for all materials. In contrast, the EPA includes both the waste treatment process and transportation of waste. Recycling emissions on the EPA Factors Hub include "transport to recycling facility and sorting of recycled materials at material recovery facility [8]." Combustion emissions "include transport to combustion facility, and combustion related non-biogenic CO2 and N2O [8]." EPA emission factors are calculated from variables including but not limited to transportation, in direct contrast with DEFRA.

Emission Factors for Decision Making

EPA WARM is another means of determining GHG emissions from waste. The EPA generated all waste related emissions on data collected for WARM. The EPA adapted and modified WARM's waste emission factors to be included in the US Emission Factors Hub, which listed below GHG emissions factors from fuel and electricity. Unlike the EPA's WARM tool, the Factors Hub excludes negative or avoided emissions from materials management efforts involved in manufacturing or repurposing of products.

WARM is designed to provide the EPA and the waste industry insight on the waste industry's climate change impact by enabling comparisons of waste treatment methods using lifecycle GHG emissions and energy factors by material. The WARM tool takes into account avoided emissions in order to quantify the GHG emission tradeoffs between different management choices. The EPA has taken substantive steps toward understanding a wide variety of materials and their lifecycle environmental impact by each waste treatment process, enabling companies in a wider range of industries to utilize it [9].

WARM reflects GHG impact for materials utilizing a whole life cycle approach. It accounts for a variety of waste disposal methods and materials and includes GHG incurred in the manufacture of the product, as well as its disposal. In this way, the benefit of recycling is weighed not only by the energy used to recycle a material but also by the energy saved by the end product replacing a virgin material made product. WARM is also a comparative tool, calculating differences in GHG output from a defined starting point, rather than an absolute GHG footprint from a specific set of circumstances.

Case Study

To understand how different emission factors impact results, we compared the emission factors issued by EPA and DEFRA. Then, using those factors, we took two waste materials, paper and plastic, and created a range of scenarios to simulate how significantly the results are impacted.

Figures 1-4 show how the EPA emission factors from its Factors Hub align with the factors from DEFRA on landfill waste but diverge significantly on other waste processes. Emissions from landfill (Figure 1) are not an exact match but are much the same, reflecting the similar types of inputs used in creating these models, despite different source inputs: WARM for EPA Factors Hub and MELMod for DEFRA. Emissions related to the composting process (Figure 2), combustion (Figure 3) and recycling (Figure 4) show the significant divergence between the two models. The discrepancy between EPA and DEFRA emissions factors for recycling, and combustion follows the larger number of inputs from the EPA, including transportation and processing. DEFRA emission factors for all materials recycled and materials combusted are the same: 21.317 kg CO_2e per metric ton/ 0.023 Metric tons CO_2e per metric ton, reflecting only the transportation of the waste material.

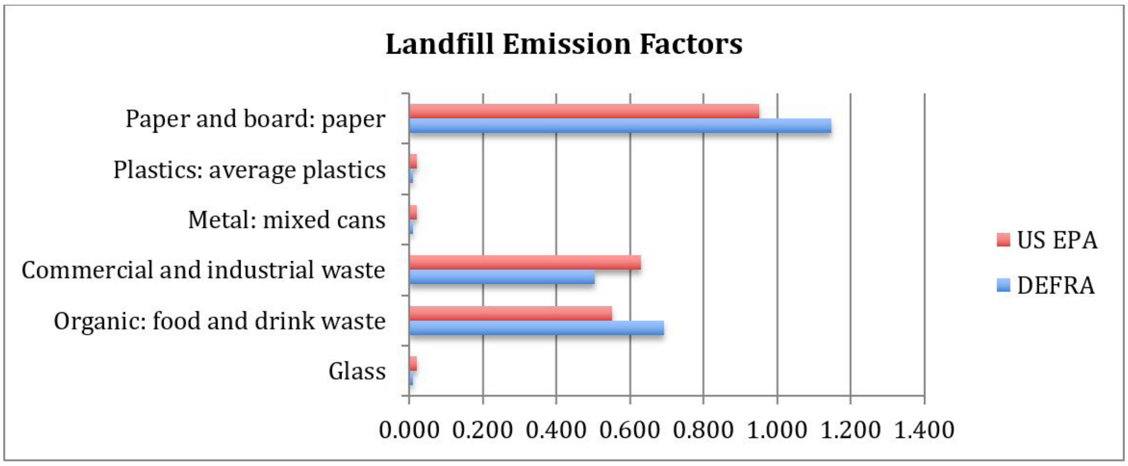

Figure 1: Emission factors from material sent to landfill (metric ton CO_2e per metric ton waste) (EPA Center for Corporate Climate Leadership 2020, Department for Business, Energy & Industrial Strategy 2020)

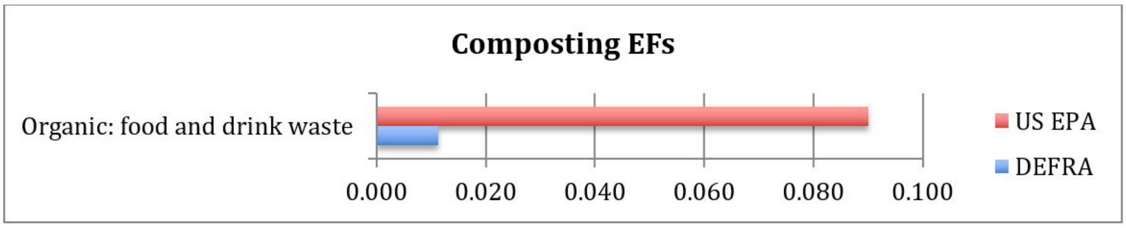

Figure 2: Emission factors from material sent to composting facility (metric ton CO2e per metric ton waste) (EPA Center for Corporate Climate Leadership 2020, Department for Business, Energy & Industrial Strategy 2020)

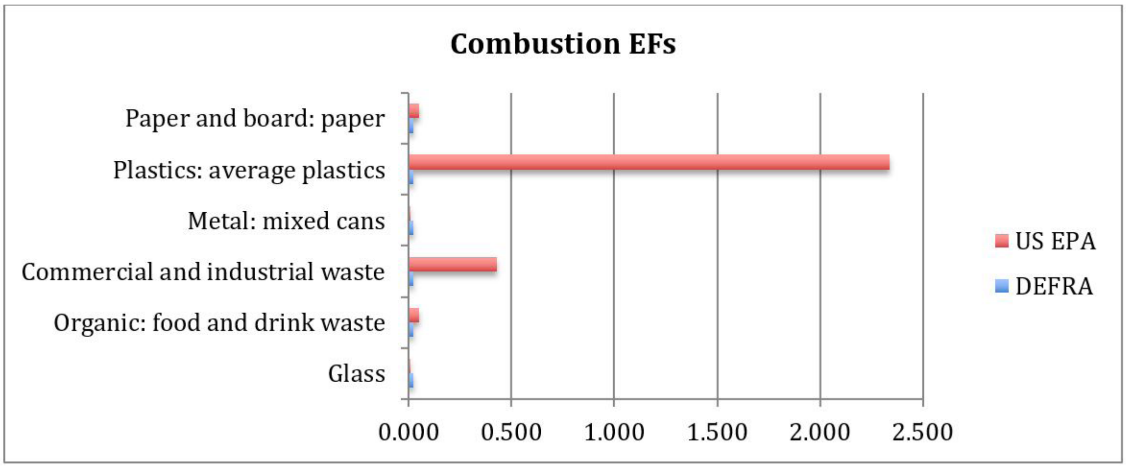

Figure 3: Emission factors from material sent to combustion facility (incineration) (metric ton CO2e per metric ton waste) (EPA Center for Corporate Climate Leadership 2020, Department for Business, Energy & Industrial Strategy 2020)

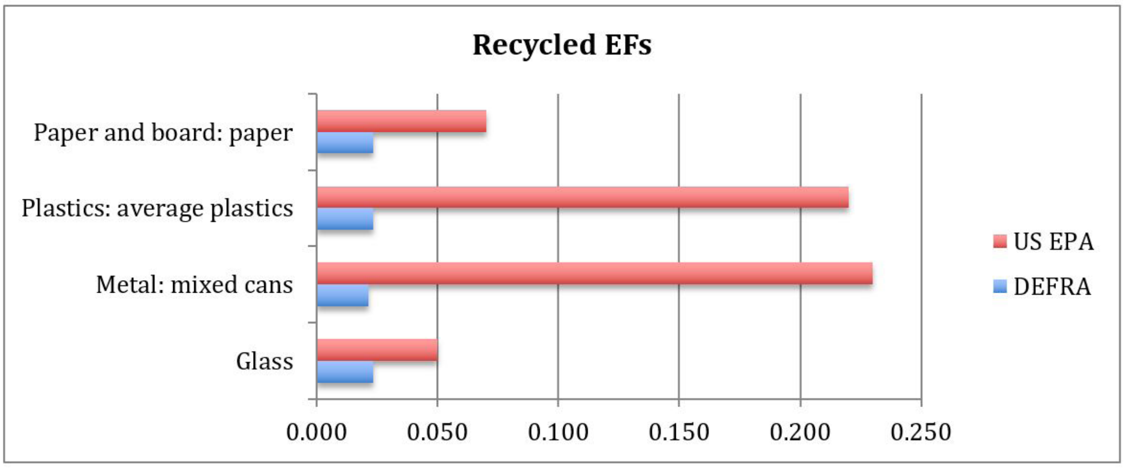

Figure 4: Emission factors from material sent to material recovery facility (metric ton CO2e per metric ton waste) (EPA Center for Corporate Climate Leadership 2020, Department for Business, Energy & Industrial Strategy 2020)

Below we have examined the results of using these emission factors on the same type and amount of waste, (1) mixed paper and (2) plastics, where 10 short tons of a material is recycled, with rates of diversion varying from 0-100%. The remaining material is then either landfilled or combusted, so that in all scenarios the same total amount of material is disposed, but the amount of material recycled varies. The variable of whether the non-diverted material is landfilled or combusted can change the GHG impact of recycling significantly (Figure 5).

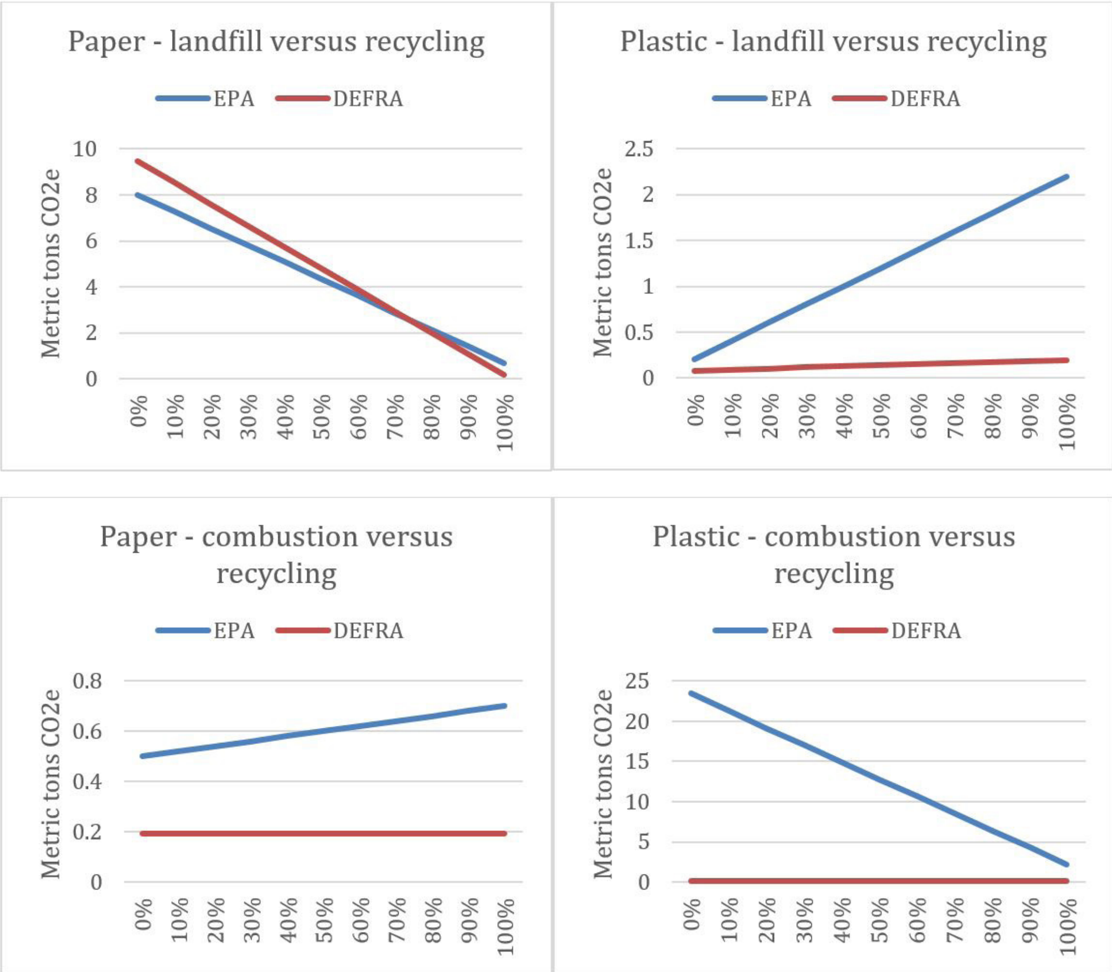

Figure 5: Diversion rate vs GHG Emissions (USEPA and DEFRA) Metric tons CO2e for 10 short tons material disposed (paper, plastic) with a range of material recycled

When WARM is used as the method for calculating GHG emissions, both positive and negative CO2e result for a combination of recycling and landfilling or recycling and incineration. The point here is to show the comparison of how emissions are impacted by the full life cycle in comparison to the direct emissions, provided by EPA Factors Hub and DEFRA emission factors.

The differences between EPA Factors Hub and WARM are consistent with the addition of the environmental benefits WARM includes in the model. A full life cycle takes into consideration the emissions avoided in the manufacturing of new material from recycled versus virgin sources. Figure 6 shows what happens using the WARM model for increasing diversion of paper and plastic from either landfill or combustion. For both paper and plastic, WARM results show a decrease in emissions the higher the amount of material is recycled.

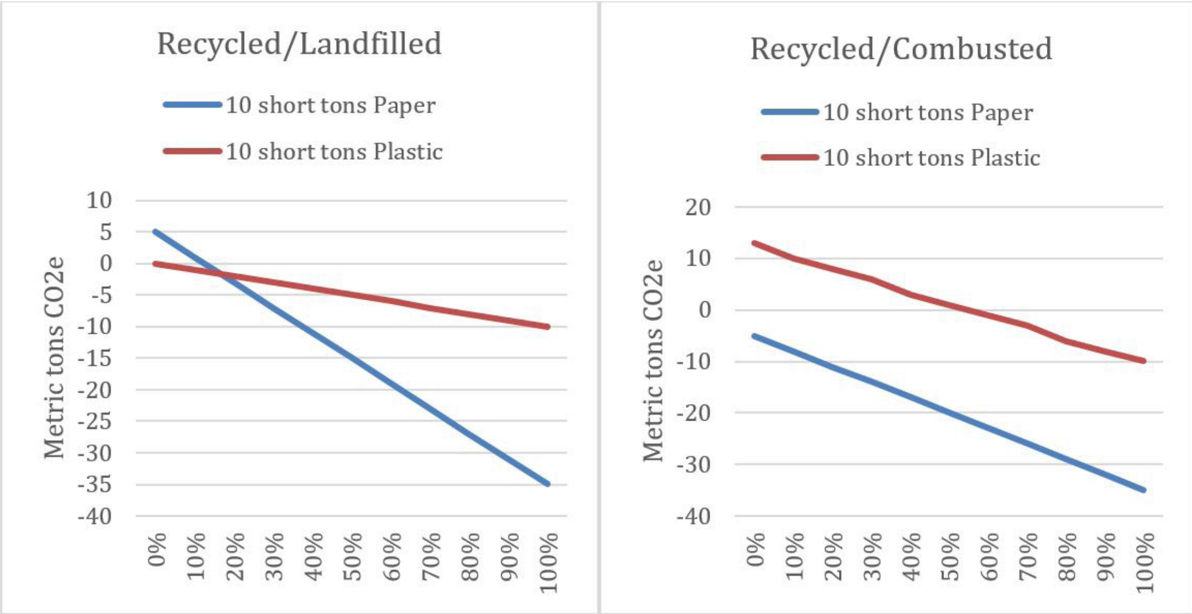

Figure 6: WARM analysis of changes in GHG Emissions as diversion to increases. Metric ton CO2e for 10 short tons material disposed (paper, plastic) against the percentage of material recycled, with remainder going to the landfill

In both scenarios, the WARM results show a decrease in emissions the higher the amount of material is recycled. For plastic recycled and combusted, WARM shows a change from +CO2e to -CO2e at just past 50% recycled. For paper recycled and landfilled, there is a change from +CO2e to -CO2e just passed 10% recycled. Landfilling plastic and combusting paper both start at or below 0 metric tons CO2e without any material being recycled.

In comparison, the same scenario using direct emission factors shows the opposite picture. Emissions increase when paper diverted away from combustion for recycling increases. Likewise direct emissions increase when plastic is diverted away from landfilling for recycling. This paradox is further explored under section 4.2.

Discussion

Data Collection

Regardless of the method used, source data needs to be as accurate as possible if reporting is to be consistent over time, and reliable. To most accurately represent a facility's GHG footprint, waste-type specific methods will give the most granular and accurate data. This method is accessible to most facilities. For this method, a breakdown by waste-type may be provided by a waste hauler, but usually this is only a rough estimate. For accuracy, a waste audit of the facility's waste stream ensures that waste is sorted and weighed by waste-type and by waste treatment method [10].

The accuracy of the supplier-specific method depends on the supplier. Waste companies who own and operate their own recycling facilities, incinerators, or landfills, may be able to provide allocations from their Scope 1 and 2 emissions, but this information is typically sparse, if available at all. The accuracy of their allocations depends on the size of the reporting company's waste stream and the waste treatment company's ability to provide accurate estimates of the reporting organization's waste volume or tonnage.

Although the average-data method does not require a breakdown by waste-type, it does necessitate actual weights of all waste streams to be meaningful. For locations that do not have compactors weighed by a hauler, a waste audit is valuable in determining the actual weights of each waste stream. If a company does not have weight-based data, it will need to convert volume of waste into weight, which is variable, leading to issues in accuracy and actionability when completing the ultimate GHG emissions calculation. The number of assumptions made in this scenario produces less than useful results.

If GHG emissions from waste are significant to the organization or relevant to business goals, the recommendation is to tightly measure the company's waste profile by weight (metric tons), through a waste audit, a review of the weight or volume of a facility's waste stream, which often includes a breakdown of the waste by generator source and/or material. If the waste treatment company has the capability to provide allocated Scope 1 and 2 emissions, one can review their allocation assumptions against the waste audit and coordinate any necessary adjustments with the waste treatment company (supplier-specific method). If the waste treatment company is unable to provide emissions data, one can utilize waste type-specific emissions factors with the breakdown of the materials in the waste stream (waste-type-specific method) making use of waste audit results and available hauler data to understand the total waste by weight going to each waste disposal facility. If possible, we recommend against using the Average-data method. If using this method, it is possible to improve the data with a waste audit, where weights of each waste stream can be calculated.

Emission Factors

The emissions factors presented by the EPA Factors Hub and by DEFRA for all but those from landfill processes are not compatible. This discrepancy can lead to confusion and/or inconsistency in reporting. For the organization producing the waste and seeking to report accurate environmental impacts, the EPA emission factors would portray a more holistic view of Scope 3 waste compared to those of DEFRA. By including both transportation and processing of the waste generated, the organization takes full responsibility for waste processing.

Regardless of method used, paper reduces GHG footprint as recycling diversion increases against landfill. Plastics recycling does not show a similar reduction when using the DEFRA or EPA emission factors. EPA's emission factors effectually penalize recycling plastic versus landfilling it, since it does not take into account a life cycle analysis of the material, as WARM does.

Incineration and recycling impact paper and plastic differently in resulting emissions. As paper diversion increases, the amount emissions increases when using EPA emissions, since their model indicates a slightly larger emissions factor for paper recycling (0.07 metric tons CO2e per short ton) versus paper incineration (0.05 metric tons CO2e per short ton). The inverse is the case with plastic, where plastic recycling reduces GHG emissions against incineration, since the EPA factors for plastic incineration (2.34 metric tons CO2e per short ton) is so much higher than paper incineration (0.22 metric tons CO2e per short ton). However, when the material's life cycle is taken into account, as seen with WARM, recycling against both landfill and combustion reduces GHG emissions.

The way DEFRA has modelled recycling and combustion, by removing all inputs except transportation, DEFRA effectively is removing the reporting penalty for these two processes. By limiting the inputs to transportation, the model ensures that a reporting entity's absolute emissions will not increase when switching from landfill or incineration to recycling of any materials.

WARM shows improvement in GHG as diversion increases but is not intended as the absolute GHG footprint as EPA Factors Hub or DEFRA. This extended methodology means that the resulting GHG emissions from WARM are incompatible with GHG data reporting per the GHG Protocol [4]. Instead, it is useful as a modeling tool to estimate the impact of possible changes in waste management practices.

Conclusion

From the case study above, it makes clear that using the EPA's WARM is superior to the US EPA Factors Hub in comparing waste management strategies with potential alternatives. However, given GHG Protocol guidelines, it cannot and should not be used as a reporting tool for organizational GHG inventories. The EPA clearly notes in the Factors Hub: "These factors are intended for use in the waste-type-specific method or the average-data method defined in the Scope 3 Calculation Guidance for category 5 and category 12 [5]." While necessary for reporting, these factors cannot replace WARM for decision making. Likewise, WARM results should not be presented as part of an organization's Scope 3 GHG emissions inventory because the GHG Protocol does not allow accounting to include avoided emissions.

However, equally important in the exercise of reporting is providing transparency of an organization's programs as well as their data. The lifecycle analysis of materials and avoided emissions can be utilized to provide explanation for decision making on waste treatment processes. Providing these details shows specificity to the company, its activities and programs, as well as projections for the future based on these activities, providing the most complete picture of an organization's waste management activities and their climate impact.

One key factor in GHG reporting on waste that can trip up companies include the different methods of data collection and the disparities in emissions factors. The GHG Protocol is clear about the boundary of Scope 3 Category 5 for reporting and the options available. It is up to organizations to provide consistency in collecting and reporting data in a way that best reflects the organization's waste management activities.

In reporting its GHG emissions resulting from waste to organizations like CDP (via the GHG protocol), Great Forest recommends companies do the following to make the process as accurate as possible. For waste data collection, use the supplier specific method if such data is available, but most likely the waste-type-specific method will be used. In both cases, it is important to conduct a waste audit to either verify reporting from haulers or appropriately sort waste by type.

For emissions factors, employ the waste emissions factors in the EPA Factors Hub or local guidance that shows a complete view of Scope 3 emissions from waste, including both transportation and processing of the waste generated by a business. For reporting, calculate emissions based on these emissions factors. Waste management decisions can be made using the EPA's WARM model but the actual results reported need to be calculated using emissions factors and waste collection data, ideally backed up with regular audits.

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