GREENHOUSE GAS PROTOCOL

WORLD RESOURCES INSTITUTE

Policy and Action Standard

Waste Sector Guidance

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Introduction

This document provides sector-specific guidance to help users implement the GHG Protocol *Policy and Action Standard* in the waste sector. A wide range of low carbon options are available to mitigate GHG emissions from this sector. Collectively, these technologies can 1) directly reduce GHG emissions, for example, through landfill gas recovery, improved landfill practices, engineered wastewater management; or 2) avoid significant GHG generation, for example, through controlled composting of organic waste, state-of-the-art incineration and expanded sanitation coverage. In addition, waste minimization, recycling and re-use can indirectly reduce GHG emissions through the conservation of raw materials, improved energy and resource efficiency, and fossil fuel avoidance.

Users should follow the requirements and guidance provided in the *Policy and Action Standard* when using this document. The chapters in this document correspond to the chapters in the *Policy and Action Standard*. This document refers to Chapters 5–11 of the *Policy and Action Standard* to provide specific guidance for the waste sector. The other chapters have not been included as they are not sector-specific, and can be applied to the waste sector without additional guidance. Chapters 1–4 of the *Policy and Action Standard* introduce the standard, discuss objectives and principles, and provide an overview of steps, concepts, and requirements. Chapters 12–14 of the *Policy and Action Standard* address uncertainty, verification, and reporting. The table, figure, and box numbers in this document correspond to the table, figure, and box numbers in the standard.

To illustrate the various steps in the standard, this guidance document uses a running example of a hypothetical food waste landfill diversion policy.

We welcome any feedback on this document. Please email your suggestions and comments to David Rich at drich@wri.org.

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Chapter 5: Defining the policy or action

In this chapter, users are required to clearly define the policy or action that will be assessed, decide whether to assess an individual policy or action or a package of related policies or actions, and choose whether to carry out an ex-ante or ex-post assessment.

5.1 Select the policy or action to be assessed

Table 5.1 provides a non-exhaustive list of examples of policies and actions in the sector for which this guidance document will be useful by policy/action type.

Table 5.1 Examples of policies/actions in the sector by policy/action type

Type of policy or action	Examples
Regulations and standards	• Landfill diversion: biodegradable wastes • Food waste diversion • Required landfill gas collection and control • Accelerated collection system installation, i.e., reduce permissible delay in collection system installation • Routine landfill methane monitoring and measurement • Extended producer responsibility (EPR) based on life-cycle assessment / thinking • Waste hierarchy / sustainable waste management standards incorporating recycling (including anaerobic digestion (AD) and composting) and landfill diversion goals
Taxes and charges	• Landfill taxes / levies • Tiered tax structure based on waste hierarchy • Incorporation of recycling and AD funds from resulting revenue • Incorporate cost of future landfill GHG emissions in post-closure care bonding requirements
Subsidies and incentives	• Commodity pricing support or floors for formal and informal recycling / waste pickers • Feed-in tariffs (FIT) and renewable portfolio standards (RPS) for waste-based energy • Grants or low cost loans for renewable energy projects (e.g.,, landfill methane to compressed biogas)
Tradable permits	• Expand eligibility of recycling for methane avoidance offset project types • Allow “time of action” crediting for future landfill methane avoidance • Facility or system-wide electricity GHG performance standard incorporating co-product accounting
Voluntary agreements	• Short-lived climate pollutant reduction goals and targets • Prominent recognition programs (e.g., waste leaders) • Municipal or regional targets for source reduction, re-use, organics management (AD and/or composting), and recycling (e.g., targeting high-embedded GHG commodities)

Type of policy or action	Examples
Information instruments	• Waste management hierarchy and guidance • Policies to advance life-cycle thinking, inventories, and assessments • Public information campaigns on ‘reduce, reuse, recycle’ • Transparent short-term climate impact inventory accounting using shorter term global warming potentials • National and international waste management lifecycle databases • Direct measurement of landfill methane emissions • Lifecycle accounting, including avoided landfill methane, for electricity carbon intensity
Research and development (R&D)	• Landfill biocovers to encourage methane oxidation • Landfill cap design to minimize emissions and cap degradation • Innovative waste management grant programs • Low waste, recyclable or biodegradable product development
Public procurement policies	• Energy procurement – waste-based electricity (e.g., waste-to-energy, anaerobic digestion) • Compost procurement policies for landscaping projects • Minimum recycled content standards • Procurement of low waste, recyclable or biodegradable products
Infrastructure programs	• Fund matching programs / investment in non-landfill waste management projects (e.g., materials recovery facilities, informal processing areas, anaerobic digestion, waste-to-energy) • Informal recycling “incubator” space
Implementation of new technologies, processes, or practices	• Plant-based plastics • Dual- or tri-stream waste collection systems, including computer-aided truck routing and accelerated replacement with higher-efficiency collection equipment • Low/zero energy (passive) flares at smaller/older/closed landfill sites • “Pay as You Throw” (PAYT) or similar volume-based pricing schemes for reducing municipal waste generation • Source reduction programs: e.g., bans on “junk mail” • Performance based technology incentives
Financing and investment	• Micro-financing for informal recycling / waste pickers • Low cost financing programs • Accelerated depreciation schedules • Investment or sustainable waste management tax credits

5.2 Clearly define the policy or action to be assessed

A key step in Chapter 5 is to clearly define the policy or action. Chapter 5 in the standard provides a checklist of information users should report. Table 5.2 provides an example of providing the information in the checklist using the example of a hypothetical landfill food waste diversion policy in a country.

Table 5.2 Checklist of information to describe the landfill food waste diversion policy

Information	Example
The title of the policy or action	Food waste landfill diversion
Type of policy or action	Regulations requiring diversion of organics from landfilling
Description of the specific interventions included in the policy or action	Food waste generators (commercial and institutional) of a pre-defined size or waste generation rate (depending on the sector, as defined in the policy) have specific landfill levies imposed on the food wastes they generate. Penalty payments arise for illegal deposit of food waste outside the landfill, and the generators are also required to removal these illegal waste deposits. Additional requirements may incentivize use of generated biogas from anaerobic digestion facilities to maximize environmental benefits.
The status of the policy or action	Proposed
Date of implementation	Planned implementation date beginning 2016
Date of completion (if applicable)	No end date
Implementing entity or entities	National government
Objective(s) of the policy or action	The objective of the policy is the diversion of waste from landfills to composting, anaerobic digestion and energy recovery options further up the waste hierarchy. This will minimize landfill methane emissions, promote compost and organic fertilizer generation, and promote energy recovery.
Geographical coverage	National
Primary sectors, sub-sectors, and emission sources or sinks targeted	GHG emissions from waste disposal
Greenhouse gases targeted	• CO_2 • CH_4 • N_2O

Information	**Example**
Other related policies or actions	*Policies targeting non-organic landfill waste* A number of policies are in place that aim to encourage re-use and recycling. They target paper, glass, metal and plastic waste. New regulations on electronic waste are under consideration. *Renewable Power Obligations incentivizing energy generation from landfill gas* A renewable power obligation scheme is effective, requiring 15% of total electricity generation to come from renewable sources, including from landfill gas. There are no specific quotas for different technologies, but due to the favorable economics, electricity generation from landfill gas has increased through the scheme. The required share is planned to be increased to 20% by 2016 and 23% by 2020. *Improved waste regulation and enforcement* Regulation introduced in 2010 imposes penalties for illegal waste disposal. To enforce the policy a system of inspections and a special waste management task force were established. *Landfill engineering and gas capture standards* The standards prescribe minimum technological requirements for landfill engineering and gas capture. They were introduced in 2011 and have resulted in improved technology and increased gas capture rates.
Optional information	
Key performance indicators	• Tons of organic waste landfilled, composted, digested anaerobically, and sent for energy recovery (e.g., combustion, gasification, pyrolysis). • Tons of compost and fertilizer products generated • Energy (electricity, heat, and/or steam) generated through anaerobic digestion or combustion • Food waste transportation distances (e.g., Ton-kilometers)
Intended level of mitigation to be achieved and/or target level of other indicators	The levy would be set at a level to achieve a 50% reduction in landfilling of food waste relative to the base year 2010.
Title of establishing legislation, regulations, or other founding documents	Food waste landfill diversion policy
Monitoring, reporting, and verification (MRV) procedures	-
Enforcement mechanisms	-
Reference to relevant guidance documents	-
The broader context/significance of the policy or action	Diversion of waste from landfill is associated with a broad range of potential drivers, including public opposition to landfill operation, demand for land-space and the potential economic benefits of waste recovery opportunities further up the waste hierarchy.

Information	Example
Outline of non-GHG effects or co-benefits of the policy or action	• Soil and nutrient conservation; reduced nutrient run-off through substitution of chemical-based fertilizers with slower release organic fertilizers. • Job creation as part of new waste treatment and recovery operations. • Increased value from recoverable fractions of waste. • Reduced soil, water and air pollution associated with landfill.
Other relevant information	-

5.3 Decide whether to assess an individual policy/action or a package of policies/actions

Chapter 5 also provides a description of the advantages and disadvantages of assessing an individual policy/action or a package of policy actions. Steps to guide the user in making this decision based on specific objectives and circumstances include identifying other related policies/actions that interact with the initial policy/action.

The user would need to undertake a preliminary analysis to understand the nature of these interactions and determine whether to assess an individual policy/action or a package of policy actions. This analysis can be brief and qualitative, since detailed analysis of interactions would be taken up in subsequent chapters. An illustrative example for the food waste landfill diversion policy is provided below.

Table 5.5 Mapping policies/actions that target the same emission source(s)

Policy assessed	Targeted emission source(s)	Other policies/actions targeting the same source(s)	Type of interaction	Degree of interaction	Rationale
Food waste landfill diversion	Methane generation in landfills and Fossil fuel combustion in Grid connected power plants	Policies targeting non-organic landfill waste	Neutral	-	
		Feed in Tariffs or Renewable Energy Standards incentivizing energy generation from landfill gas	Overlapping	Minor	This may have the effect of encouraging the landfilling of biodegradable wastes so as to maintain methane generation levels.
		Improved waste regulation and enforcement	Overlapping	Major	This reduces illegal tipping and open dumping, and diverts more waste to managed waste treatment and disposal routes, including composting and anaerobic digestion.
		Landfill engineering and gas capture standards	Overlapping	Moderate	This reduces the amount of fugitive methane and may reduce GHG benefits

					of landfill diversion e.g., landfill gas capture, lining and capping standards

Table 5.6 Criteria to consider for determining whether to assess an individual policy/action or a package of policies/actions

Criteria	Questions	Guidance	Evaluation
Use of results	Do the end-users of the assessment results want to know the impact of individual policies/actions, for example, to inform choices on which individual policies/actions to implement or continue supporting?	If "Yes" then undertake an individual assessment	Yes
Significant interactions	Are there significant (major or moderate) interactions between the identified policies/actions, either overlapping or reinforcing, which will be missed if policies/actions are assessed individually?	If "Yes" then consider assessing a package of policies/actions	Yes
Feasibility	Will the assessment be manageable if a package of policies/actions is assessed? Is data available for the package of policies/actions? Are policies implemented by a single entity?	If "No" then undertake an individual assessment	No
	For ex-post assessments, is it possible to disaggregate the observed impacts of interacting policies/actions?	If "No" then consider assessing a package of policies/actions	No

Recommendation for the food waste landfill diversion policy

Effective or proposed policies pertaining to energy and waste management will likely need to be assessed as a package. There are a number of interactions between the key policies identified above. In summary, there are three key related policies which may have a supporting or overlapping effect on a food waste landfill diversion program:

1. Feed-in tariff or renewables obligation schemes providing an economic incentive for energy generation from landfill gas and/or other waste treatment technologies. This presents a complex interaction between incentive levels set for landfill gas energy generation versus other waste-based energy generation technologies and could diminish the relative incentive to manage wastes through practices identified as preferential in the hierarchy.
2. Improved waste regulation and enforcement. In effect, this policy could comprise a suite of legislative instruments aimed at reducing illegal tipping of waste. As described above, reducing levels of open tipping may effectively increase the overall levels of methane generation. However, this in turn could also be influenced by the requirement for (or lack of) landfill gas capture infrastructure at landfills. Diverting more waste to managed waste treatment and disposal routes could potentially have a net overlapping effect if the policy leads to increase in diversion of waste to composting and anaerobic digestion rather than landfilling.
3. Landfill engineering and gas capture standards could include standards for the process of gathering, processing, and treating the methane gas emitted from decomposing garbage to produce electricity, heat, fuels, and various chemical compounds. If the waste deposited in

landfills is lower due to the landfill diversion policy, gas captured would be lower too, thus the overall impact of the two policies together may be considerably lower than the sum of the impact of each individually.

An assessment of a package of policies will be necessary in the majority of cases. For instance, it is likely that enhanced enforcement would need to be introduced alongside a landfill levy to control illegal tipping, an oft-cited side effect of landfill levies. It is also likely that, if not already in place, the potential for a feed-in-tariff or renewable obligation scheme which includes waste to energy in its scope, is also being considered as a key policy for reducing greenhouse gas emissions from the energy sector. If an assessment of the package a policies is not possible, then it will be necessary to make some simplifying assumptions with regard to the effect of other policies.

Chapter 6: Identifying effects and mapping the causal chain

In this chapter, users are expected to identify all potential GHG effects of the policy or action and include them in a map of the causal chain.

6.1 Identify potential GHG effects of the policy or action

Using reliable literature resources, combined with professional judgment or expert opinion and consultations, users can develop a list of all potential GHG effects of the policy or action and separately identify and categorize them in two categories: In-jurisdiction effects (and sources/sinks) and out-of-jurisdiction effects (and sources/sinks). In order to do this, users may find it useful to first understand how the policy or action is implemented by identifying the relevant inputs and activities associated with the policy or action. For the given policy example, an illustrative list of indicators and possible effects for the policy (by type) is provided below.

Table 6.1 Summary of inputs, activities, and effects for the Food Waste Landfill Diversion policy

Indicator types	Examples for Food Waste Landfill Diversion policy
Inputs	Investment in re-use/recycling, composting, anaerobic digestion, energy recovery, incineration and landfill facilities
Activities	Permission and construction of composting and AD facilities Collection of levy to promote food waste diversion from landfills Inspections and other enforcement activities
Intermediate effects	Changes in organic waste landfilled, composted, digested anaerobically, or sent for combustion with energy recovery Increase in the amount of compost and fertilizer products generated Increase in the amount of energy (electricity, heat, and/or steam) generated through anaerobic digestion or combustion Increase in levy value Revenue generated by recycling and recovery operations
GHG effects	Reduction in emissions (predominately CH_4) from landfill (in CO_2e) Increase in emissions from composting, AD operations, or waste to energy (in CO_2e) Indirect emissions reduction from offsetting electricity/heat use with energy created by AD or waste to energy facilities Indirect CO_2e emissions reduction from the use of co-products (AD fertilizer, animal bedding, compost) and displacement of conventional product use. Change in CO_2e emissions due to the change in food waste transport requirements
Non-GHG effects	Soil and nutrient conservation; reduced nutrient run-off through substitution of chemical-based fertilizers with slower release organic fertilizers Job creation as part of new waste treatment and recovery operations Increased revenue from recoverable fractions of waste Reduced soil, water and air pollution associated with reduced landfill operations

Quantitative information may not be available for all elements identified in the table at the point of assessment and not all elements are relevant for the determination of the causal chain. However, creating a comprehensive list will not only provide support for the identification of effects, but also helps to design a robust performance monitoring (see Chapter 10).

In the next step, develop a comprehensive list of expected effects, based on the understanding of the design of the policy.

Table 6.2 Illustrative example of various effects for the Food Waste Landfill Diversion policy

Type of effect	Effect
Intended effect	• Reduction in the quantity of waste landfilled, leading to reduced GHG emissions from landfilling • Increase in composting resulting in net carbon storage. • Reduced emissions from displacement of nitrogen fertilizers • Increase in incineration of food wastes with energy recovery displacing fossil fuel based grid electricity
Unintended effect	• Increase in illegal tipping of wastes • Increase in transport related emissions from additional trips to specialized food waste facilities • Reduced transport related emissions from landfill collection/delivery • Increased emissions from composting, AD, and energy recovery related operations
In-jurisdiction effect	• Landfill void space used at a slower rate thus reducing the need for additional future landfill facilities
Out-of-jurisdiction effect	• Waste sent for disposal or treatment in another jurisdiction to avoid levy[1]
Short-term effect	• See short-term effects identified above
Long-term effect	• Reduction in food waste generated as costs of disposal of waste increases • Increased investment in waste recycling and recovery infrastructure reduces long-term economic cost of these technologies, and stimulates innovation in waste recycling/recovery technologies

6.2 Identify source/sink categories and greenhouse gases associated with the GHG effects

Users are also expected to identify and report the list of source/sink categories and greenhouse gases affected by the policy or action.

Table 6.3 Sources/sinks and greenhouse gases affected by the food waste landfill diversion policy

Source category	Description	Examples of emitting equipment or entity	Relevant greenhouse gases
Food waste degradation	Emissions from landfilling of food waste	Landfill	CH_4
Landfill construction processes	Emissions due to construction of landfills	Construction equipment	CO_2, CH_4, N_2O
Illegal dumps	Emissions from dumping food wastes at illegal dumps	Illegal dumps	CH_4
Power generation units	Fuel combustion	Power plant	CO_2, CH_4, N_2O
Combustion of fuel for transportation	Emissions due to transportation of food wastes	Transport vehicles	CO_2, CH_4, N_2O

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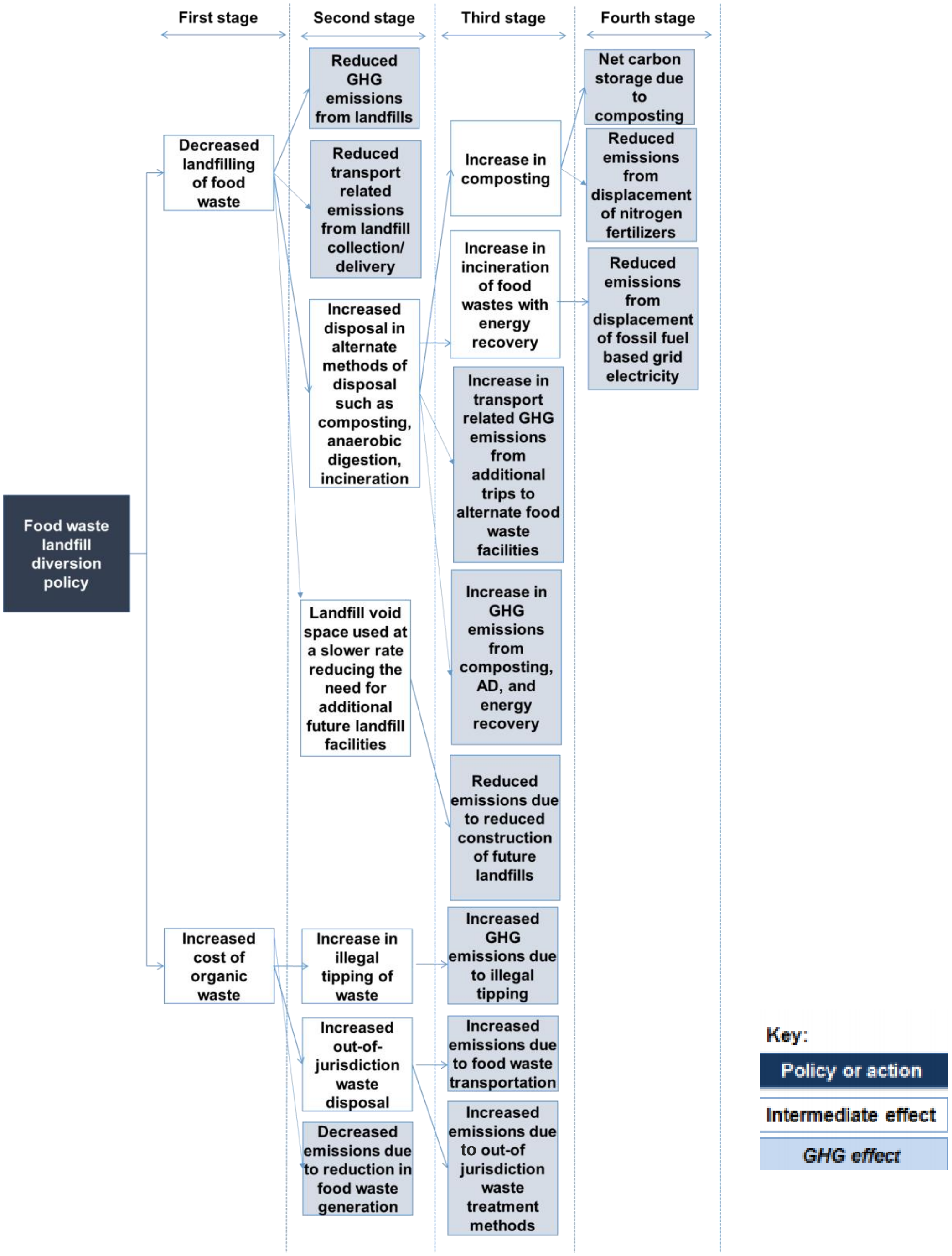
[1] Note that the Basel Convention seeks to prevent the inter-national transfer of residual wastes.

6.3 Map the causal chain

Once effects have been identified, developing a map of the causal chain allows the user and relevant stakeholders to understand in visual terms how the policy or action leads to changes in emissions. Figure 6.3 presents a causal chain for the example policy based on the effects identified above.

Figure 6.3 Mapping GHG effects by stage for a Food Waste Landfill Diversion policy



For this chapter, there are a number of sector-specific resources such as guidance documents, tools, databases of projects etc. that can be referred to while brainstorming possible effects of policies in the sector, however the extent of available literature and resources varies by policy type and geography. Some examples of these resources are provided in the methods and tools database on the GHG Protocol website, which can be filtered by sector. Most of these resources will not be applicable in their entirety; however select sections of these resources could provide a preliminary basis for further brainstorming and analysis.

Chapter 7: Defining the GHG assessment boundary

Following the standard, users are required to include all significant effects in the GHG assessment boundary. In this chapter, users determine which GHG effects are significant and therefore need to be included. The standard recommends that users estimate the likelihood and relative magnitude of effects to determine which are significant. Users may define significance based on the context and objectives of the assessment. The recommended way to define significance is "In general, users should consider all GHG effects to be significant (and therefore included in the GHG assessment boundary) unless they are estimated to be either minor in size or expected to be unlikely or very unlikely to occur".

7.1 Assess the significance of potential GHG effects

Changes in waste policies are likely to change the amount of wastes generated, recycled, sent for energy recovery, incinerated without energy recovery, or landfilled. In general, reduced landfill methane generation, avoided grid connected fossil based electrical generation, avoided fossil based transportation fuel associated with the generation of renewable biofuels (e.g., biogas from anaerobic digestion of food waste), and incremental soil carbon storage and avoided fertilizer production associated with composting and anaerobic digestion are likely to be the most significant common effects in the sector.

Transportation effects are generally not significant, although long-haul transport, particularly by truck, warrants some review and estimation, depending on the specific local circumstances. Short-term effects from the construction of the facilities, including landfills and compost, anaerobic digestion, and energy recovery facilities are unlikely to be significant relative to the operation of these facilities. Fugitive emissions aside from landfill methane, including fugitive emissions of methane and nitrous oxide from compost and anaerobic digestion facilities may be significant, depending on how well the operation is controlled and monitored.

Effects beyond the jurisdiction must also be considered. At the sub-national and national levels, there can be significant movement into and out of the jurisdiction where the policy originates or is in effect. It is important to consider not only the mass of material movement across boundaries but also the effect of waste management policies in the jurisdiction the waste is moved to. This has a strong impact on the sign and magnitude of out-of-jurisdiction effects. This could impact the GHG emissions reductions from the policy assessed either negatively or positively.

The figure below shows the U.S. EPA's waste management hierarchy depicting the approaches to consider, based on environmental outcomes. Policies/actions high on the waste management hierarchy (source reduction, re-use and recycling) serve to lessen demand for new production. Emissions associated with that new production often occur outside of the jurisdiction that implements the policy/action. Still, those upstream reductions are often much higher than any associated downstream waste management emissions (e.g., landfill methane, GHGs from waste combustion).

Source: U.S EPA: http://www.epa.gov/osw/nonhaz/municipal/hierarchy.htm

For the landfill diversion example, an illustrative assessment boundary is described below.

Table 7.3 Example of assessing each GHG effect separately by gas to determine which GHG effects and greenhouse gases to include in the GHG assessment boundary for the example policy

GHG effect	Likelihood	Relative magnitude	Included?
Reduced emissions from landfills (diversion to composting, AD, and energy recovery)			
CO_2	Very likely	Minor	Excluded
CH_4	Very likely	Major	**Included**
N_2O	Very likely	Minor	Excluded
Net carbon storage from compost production			
CO_2	Possible	Moderate	**Included**
CH_4	Very unlikely	Minor	Excluded
N_2O	Very unlikely	Minor	Excluded
Reduced emissions from displacement of nitrogen fertilizers			
CO_2	Very unlikely	Minor	Excluded
CH_4	Very unlikely	Minor	Excluded
N_2O	Possible	Moderate	**Included**
GHG reductions from displaced fossil grid electricity			
CO_2	Very likely	Major	**Included**
CH_4	Very likely	Minor	Excluded
N_2O	Very likely	Minor	Excluded
GHG reductions due to reduced transport emissions from landfill collection/delivery			
CO_2	Very likely	Major	**Included**

CH_4	Very likely	Minor	Excluded
N_2O	Very likely	Minor	Excluded
Increased emissions from illegal dumps			
CO_2	Possible	Minor	Excluded
CH_4	Possible	Moderate	**Included**
N_2O	Possible	Minor	Excluded
Reduced emissions from landfilling (reduced food waste generation)			
CO_2	Possible	Minor	Excluded
CH_4	Possible	Minor	Excluded
N_2O	Possible	Minor	Excluded
Increased GHG emissions from transport due to additional trips to alternate food waste facilities			
CO_2	Likely	Minor	Excluded
CH_4	Likely	Minor	Excluded
N_2O	Likely	Minor	Excluded
Increased emissions from composting, AD, and energy recovery[2]			
CO_2	Very likely	Minor	Excluded
CH_4	Possible	Minor	Excluded
N_2O	Possible	Minor	Excluded
Reduced GHG emissions from future landfill construction			
CO_2	Possible	Minor	Excluded
CH_4	Possible	Minor	Excluded
N_2O	Possible	Minor	Excluded
Increased emissions from out-of-jurisdiction waste treatment facilities including landfills			
CO_2	Very likely	Moderate	**Included**
CH_4	Very likely	Moderate	**Included**
N_2O	Very likely	Moderate	**Included**
Increased emissions from transport to out-of-jurisdiction landfills			
CO_2	Very likely	Minor	Excluded
CH_4	Very likely	Minor	Excluded
N_2O	Very likely	Minor	Excluded

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[2] The decision to exclude increased short-term biogenic CO_2 generation from composting, AD, and energy recovery is in line with the requirements outlined in the GHG Protocol Policy and Action Standard for minor effects. Additionally, there is considerable scientific consensus that waste forms of biomass are carbon neutral or nearly carbon neutral over the 100 year time-scale consistent with the selection of the 100 year global warming potentials.

Figure 7.3 Assessing each GHG effect to determine which GHG effects to include in the GHG assessment boundary for the example policy

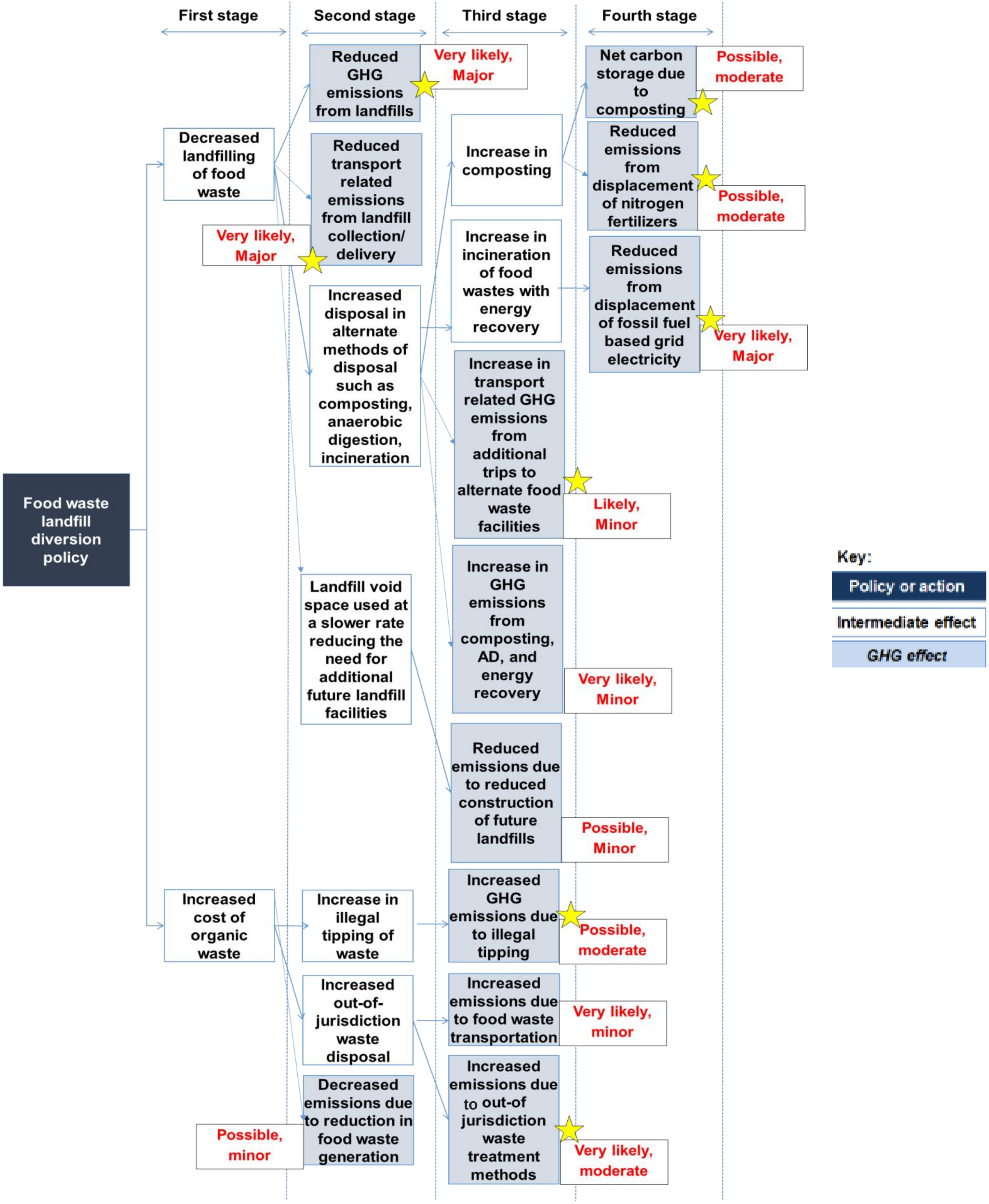

Table 7.4 List of GHG effects, GHG sources and sinks, and greenhouse gases included in the GHG assessment boundary for the example policy

	GHG effect	GHG sources	GHG sinks	Greenhouse gases
1	Reduced emissions from landfills (diversion to composting, AD, and energy recovery)	Landfills	N/A	CH_4
2	Net carbon storage from compost production	Composting processes	N/A	CO_2
3	Reduced emissions from displacement of nitrogen fertilizers	Agricultural processes	N/A	N_2O
4	GHG reductions from displaced fossil grid electricity	Fossil fuel combustion for Grid electricity generation	N/A	CO_2
5	GHG reductions from displaced transportation fuels	Fossil fuel combustion for transportation	N/A	CO_2
6	Increased emissions from illegal dumps	Illegal waste dumps	N/A	CH_4
7	Increased emissions from out-of-jurisdiction waste treatment facilities	Landfill waste management processes	N/A	CH_4

Lifecycle tools and published literature will likely be the most appropriate sources for determining significance of effects in the waste management sector. Lifecycle tools can either be used directly, or the accompanying technical documentation consulted to access appropriate defaults and emission factors.

Another significant resource for default factors is the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5: Waste. The document provides emission factors and other parameters with background documentation or technical references that can be used for estimating greenhouse gas emissions and removals for various sectors such as Waste.[3]

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[3] See http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf.

Chapter 8: Estimating baseline emissions

In this chapter, users are expected to estimate baseline emissions over the GHG assessment period from all sources and sinks included in the GHG assessment boundary. Users need to define emissions estimation method(s), parameter(s), driver(s), and assumption(s) needed to estimate baseline emissions for each set of sources and sinks.

8.3 Choose type of baseline comparison

In most cases, the scenario method will be the most appropriate for determining baseline emissions in the waste management sector. The comparison group method is difficult to apply because of the potential significant differences between any two groups with regard to the composition of waste generated and remaining after baseline recycling and reuse efforts; waste generation rates; climate differences which affect the generation and emission of methane from landfills; and influential waste management policies, including landfill levies and bans. Since several waste management practices are able to generate energy from waste materials, differences in the emissions intensity of grid-connected electrical generation, electricity price, and renewable energy policies may result in significant differences between comparison groups. Finally, finished products markets, particularly for compost and digestive products from anaerobic digestion can be impacted by local demand for these products. For example, the existence of agricultural demand in one comparison group may not only create a demand for compost and fertilizer products, it may also present an opportunity for co-digestion of post-consumer food wastes with agricultural and food processing wastes.

The comparison approach may have some value with the evaluation of limited trial programs, where the geographical reach is small enough such that a similar group can be found. However, the above complicating factors should be considered to ensure a comparable assessment of the two groups. In addition, the comparison approach may be useful in determining reasonable activity outcomes associated with policies. For example, the relationship with higher landfill levies and higher recycling rates exhibited in the European Union member states may be helpful in determining the expected outcome from landfill levies applied in other jurisdictions, particularly in other developed economies.

8.4 Estimating baseline emissions using the scenario method

8.4.1 Define the most likely baseline scenario

Users may use a baseline developed by an external party or from published data sources or develop new baseline values. Data requirements depend on the target of the policy and may include:

Waste generation, composition and disposition

- Tons of waste generated or tons of waste generated per capita
- Population
- Fraction of waste managed by management method (e.g., recycling, composting, energy recovery, anaerobic digestion, landfill)
- Subdivision of waste management method (e.g., fraction of waste landfilled managed in a landfill equipped with landfill gas to energy)
- Waste composition based on national input/output data or waste characterization analyses

Recycling

- Tons of material recycled by material type and recycling method
- GHG savings per ton of material recycled (average static value, or dynamic value)

Composting

- Amount of compost generated
- Amount of chemical fertilizer displaced
- Default GHG emissions savings per ton of material composted

- Specific factor based on available technologies, considering energy consumption, pile fugitive emissions, avoided emissions associated with displaced commercial fertilizer consumption, soil carbon storage

Anaerobic digestion

- Fraction of material managed in AD facility with compost reuse versus no compost reuse (e.g., digestion of food wastes in wastewater treatment plant with landfilling of biosolids or use as landfill daily cover)
- Fraction of AD systems generating electricity, transportation fuels, renewable natural gas for direct pipeline injection
- Efficiency of electrical generation or renewable natural gas (RNG) production
- GHG intensity (g CO_2 / MWh) of displaced electricity
- GHG intensity (g CO_2 / MJ) of displaced transportation fuels

Energy recovery

- Stack emissions of biogenic and fossil CO_2 (may also be estimated based on waste composition, and default fossil and biogenic carbon content of individual components)
- Efficiency of electrical and/or steam generation (net of parasitic load)
- GHG intensity of displaced electricity (g CO_2 / MWh) and steam (g CO_2 / MJ)
- Presence and efficiency of ferrous and non-ferrous metal recovery systems

Data quality will vary significantly. Where possible, waste generation and disposition data based on actual receipts from receiving facilities is the most reliable but it generally requires an organized central system of reporting.

Many of the other data may be obtained from published sources or through the use of life-cycle tools. Life-cycle tools typically contain documented default values which can be used; however, care should be taken with regard to the age and the geographical applicability of the defaults and a literature review is advisable to ensure the use of the most appropriate data.

More care should generally be taken with data that is directly impacted by the policy or suite of policies being reviewed. For example, when establishing a baseline for a policy aimed at increasing the efficiency of landfill gas collection systems, it is essential that the estimates of collection efficiency accurately reflect the group of landfills subject to the policy.

When practical, it is advisable to validate parameters or calculated GHG emissions through more than one calculation approach. For example, energy recovery stack emissions of biogenic and fossil CO_2 can be deduced from waste composition and default carbon contents of individual waste components. In addition, actual emissions data may be available from facilities from continuous emissions monitoring systems and regular testing of stack gases for the fraction of biogenic carbon via radiocarbon analysis.

Users should identify other policies and non-policy drivers that affect emissions in the absence of the policy or action. Examples of other policies and non-policy drivers are provided in Table 8.3 and Table 8.4.

Table 8.2 Examples of other policies or actions that may be included in a baseline scenario

Other policies	Sources of data for developing assumptions
Low carbon fuel standard, renewable fuel standard	Regulatory background documents Peer reviewed literature, NGO whitepapers, environmental commodity exchanges & brokerage houses
Renewable portfolio standard, feed-in tariffs	Local and national regulatory agencies
Carbon offsets	Voluntary and regulatory programs for eligible project

	types; offset brokers for current, historic sales prices and futures prices (if applicable), CDM registry, other registries
Non-GHG emissions regulations (e.g., compost fugitive emissions standards, NOx emissions restrictions, energy recovery stack limits, landfill fugitive and stack emissions requirements)	Local and national regulatory agencies
Government purchasing directives (e.g., renewable electricity or fuels, waste management services, compost, organic fertilizers)	Local and national regulatory agencies

Table 8.4 Examples of non-policy drivers that may be included in a baseline scenario

Non-policy drivers	Sources of data for developing assumptions
Waste composition	Local, regional, or national waste characterization data; input / output analyses
Physical constraints	Certain areas (e.g., islands) may have more limited waste management options. Local regulatory agency responsible for waste management may be able to provide information.
Macroeconomic conditions	Waste generation and economic conditions often are related. Studies on the relationship can be found in peer reviewed literature
Microeconomic conditions (costs of technology and management options)	Vendor data, public records of bidding and project costs
Product development & retirement, changes in consumer preferences (i.e., changes in available products can result in changes in the waste stream)	Trade magazines, peer reviewed journal articles, waste management regulatory agency, facility operators (e.g., changes in recovery at materials recovery facilities)
Population	Census data and projections, UN population projections
Energy (e.g., electricity, natural gas) prices	Government and private forecasts
Waste management tip fees	Industry trade publications and surveys, facility operators, local governments

8.4.2 Select a desired level of accuracy

There are different methodological choices related to the level of accuracy of an assessment. Simplified methods can be used, such as IPCC Tier 1 methods, or more complex methods, such as IPCC Tier 3. The methods by which the parameter values of the selected method are derived also impacts the accuracy of the analysis. A further important factor is the source of data, where internationally applicable default values constitute lower levels of accuracy than jurisdiction or source specific data.

Further, emission factors can be static (calculated upfront and applied for the duration of the assessment) or dynamic (updated over time to reflect changes in recycling, compost, or electricity markets) and that can be another means of making the distinction. A low accuracy method could have the option of applying a static emission factor and higher accuracy methods could update emission factors on a regular basis to maintain accuracy.

For the example of the landfill food waste diversion policy, examples for different levels of accuracy for selecting the method and determining parameter values are provided below.

Low accuracy

Under a low accuracy approach, the mass of food waste sent for landfilling is assumed to continue along historical trends on a per capita basis. Population change projections are used to calculate total food waste generation from per capita factors. The fraction of food waste sent to landfills with no control, flaring, or landfill gas to energy is assumed to remain constant and is determined based on national defaults. Soil oxidation factors and lifetime collection efficiencies are assumed to remain constant and based on regulatory agency defaults and a review of current regulatory proposals which revealed no new requirements.

Intermediate accuracy

Simple economic modeling could augment the process for estimating baseline emissions outlined under the low accuracy method. A basic economic model is developed based on anticipated increases in electricity and compost prices that could make composting, anaerobic digestion, and energy recovery more economically viable thereby increasing their market share in absence of specific food waste landfill diversion policies. However, the amount of food waste *generated* is assumed to remain constant. In addition, state level information on the relative amounts of food waste sent to landfills with no gas control, flaring, or landfill gas to energy is substituted for national values; these values are assumed to remain constant.

High accuracy

Under a high accuracy approach, more sophisticated modeling and local data is used. The amount of food waste generated *and* the fraction thereof sent for disposal at landfills with no gas control, flaring, and landfill gas to energy is modeled based on expected changes in tip fees, compost value, electricity and renewable energy credit (REC) prices and transportation fuel prices over time, starting with state-level data. The lifetime collection efficiency value for landfills equipped with landfill gas to energy systems is also modeled based on projected electricity and REC prices which could make landfill gas more valuable and therefore incentive more efficient collection and for longer periods of time. Furthermore, the lifetime collection efficiency is calculated specifically for food waste: different waste components may have different lifetime collection efficiencies as different decay rates may lead to changes in methane generation relative to the installation of landfill gas collection and control systems and cap materials, and therefore, changes in landfill gas emissions.

There are many sector-specific emissions estimation algorithms, equations, models, tools, and methodologies that are available for estimating baseline emissions for the sector. Source documentation should be reviewed for transparency, completeness, and applicability to the standard. Users should refer to the corresponding websites of the resources to review source documentation and additional information.

8.4.3 Define the emissions estimation method(s) and parameters needed to calculate baseline emissions

The baseline calculation method for emissions associated with in-jurisdiction landfill waste management is illustrated below for the example of the food waste landfill diversion policy. We only show calculations for effect 1 ‘Reduced emissions from landfills’:

Emissions from landfilling can be calculated using the following equation:

Equation 1 Estimating baseline emissions for reduced emissions from landfills

$$Baseline\ emissions_y = L_{0,FW} \times M_{FW} \times [X_{NC} + X_{FL}(1 - OX)(1 - LCE_{FL}) + X_{LFGTE}(1 - OX)(1 - LCE_{LFGTE})] \times GWP$$

Where:

$L_{0,\,FW}$ = Methane generation potential of food waste (Mg CH_4 / Mg food waste)
M_{FW} = Mass of food waste landfilled (Mg)
X = Fraction of food waste managed in landfill (%)
NC = Landfills with no gas collection (%)
FL = Landfills with flares (%)
LFGTE = Landfills with landfill gas to energy systems (%)
OX = Landfill cover soil oxidation fraction
LCE = Lifetime collection efficiencies at landfills
GWP = Global Warming Potential

Changes in methane emissions from landfills associated with MSW can be calculated by substituting MSW methane generation potential, L_0 in place of the one for food waste described above. The equation presented above calculates GHG emissions on a life-cycle basis; however, emissions inventories are generally completed annually so that the emission reductions achieved by the policy will actually be achieved over a series of inventory years. A life-cycle approach better reflects the overall emissions reductions achieved by a policy change, and better reflects the impacts achieved in any given year that the policy is in effect.

Table A[4] Examples of determining baseline values from published data sources

Parameter	Sources of published data for baseline values
Food waste methane generation potential $L_{0,\,FW}$	Levis & Barlaz, *Environ. Sci. Technol.* 2011, 45, 7438-7444.
Shares of food waste managed by different landfill types X_{NC}, X_{FL}, X_{LFGTE}	U.S. EPA Waste Reduction Model WARM tool background document – Landfilling. State and/or local data may be substituted for more accurate projections.
Landfill cover soil oxidation fraction OX	U.S. EPA Emission Factor Database, AP-42, Chapter 2 *Solid Waste Disposal*, Section 2.,4 Municipal Solid Waste Landfills
Component-specific lifetime collection efficiencies LCE_{FL}, LCE_{LFGTE}	U.S. EPA Waste Reduction Model WARM tool background document – Landfilling

Table 8.2 List of typical other policies and actions, and related data sources for developing assumptions (for developing new baseline values) for each parameter

Parameter	Relevant polices	Sources of data for developing assumptions
M_{FW} X_{NC}, X_{FL}, X_{LFGTE}	• Feed-in tariffs or renewable energy standards • Landfill levies • Statutory or voluntary waste recycling and energy recovery targets • Tradable permits for landfill GHG emissions	• Regulatory goals or modeling • Market models

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[4] Table numbering differs, as there is no corresponding table included in the standard. The table is adapted from Table 8.7 in the standard.

Parameter	Relevant polices	Sources of data for developing assumptions
OX LCE_{FL}, LCE_{LFGTE}	• Landfill engineering and gas capture standards	• Peer-reviewed literature demonstrating performance of new rules • Regulatory background documentation

Table 8.4 List of typical non-policy drivers and related data sources for developing assumptions (for developing new baseline values) for each parameter

Parameter	Typical non-policy drivers	Sources of data for developing assumptions
M_{FW} X_{NC}, X_{FL}, X_{LFGTE}	• Householder and business behavior • Compost and electricity markets • Economic viability of alternatives to landfill	• Survey data • Historical trends
OX LCE_{FL}, LCE_{LFGTE}	• Electricity markets • Best practices	• Trade publications • Historical data • Energy agency / independent system operator projections

8.4.4 Estimate baseline values for each parameter

The following table provides an overview of the parameter values used for the baseline calculation. For simplification, we assume that only one type of landfill is used and all are equipped with gas to energy technology.

Table 8.7 Example of reporting parameter values and assumptions used to estimate baseline emissions for the food waste diversion policy

Parameter	Baseline value(s) applied over the GHG assessment period	Methodology and assumptions to estimate value(s)	Data sources
Parameters required for reduced emissions from landfills			
Mass of food waste landfilled	500,000 Tons (t) (2012) 520,000 t (2015) 590,000 t (2020)	Increase proportional to population growth, based on historic trend[5] of per capita food waste	Government statistics division, UN population projections
Food waste methane generation potential	0.07168 $MgCH_4/Mg$	Product of: • Methane generation potential (m^3/Mg): 100	Default Data for MSW Landfills from US EPA

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[5] If assumptions are based on historic trends, the underlying data that were used to determine the trend should be provided in additional material, e.g. as annex.

		- Density of Methane ($MgCH_4/m^3$): 0.0007168	IPCC default value
Landfill cover soil oxidation fraction	0.1	Review of published literature	IPCC default value
Component-specific lifetime collection efficiencies	50%	Based on technical specifications of the landfill gas capture systems installed; Default value of 50%	IPCC default value
Fraction of food waste managed in landfill	NC: 80% FL: 10% LFGTE: 10%	Based on landfill gas systems being installed	Government statistics division
Examples for parameters required for other identified effects			
Tons of compost generated from food wastes	10,000 t (2012) 10,400 t (2015) 11,800 t (2020)	Constant share of compost generation at 2%, i.e. increase proportional to mass of food waste	Government statistics division
Grid electricity generated from food waste	15,000 MWh (2012) 16,500 MWh (2015) 21.500 MWh (2020)	Stepwise increase based on renewable obligation scheme	National energy institute study
Transportation fuels generated from food waste	0 (2012) 0 (2015) 0 (2020)	No generation of transport fuels foreseen without the policy	Market survey

8.4.5 Estimate baseline emissions for each source/sink category

The final step is to estimate baseline emissions by using the emissions estimation method identified in Section 8.4.3 and the baseline values for each parameter identified in Section 8.4.4.

Baseline emissions$_{2020}$ = $L_{0,\,FW}$ x 590,000 t x [X_{NC} + X_{FL}(1 - OX)(1 - LCE_{FL}) + X_{LFGTE}(1 - OX)(1 - LCE_{LFGTE}) x GWP = X t CO_2e

Baseline emissions$_{2020}$ = 0.07168 tCH_4/t x 590,000 t x [80% + 10%*(1 – 0.1)*(1 – 50%) + 10%*(1 – 0.1)*(1 – 50%) x 25 = 940,979.2 t CO_2e

In a full analysis this calculation would need to be repeated for each year within the assessment period.

8.6 Aggregate baseline emissions across all source/sink categories

Table 8.9 provides an illustrative example of the results of the analysis for all effects included in the assessment boundary, assuming the calculation steps outlined in section 8.4 that were illustrated with effect 1, were carried out for each of the effects.

Table 8.9 Example of aggregating baseline emissions for the food waste diversion policy[6]

GHG effect included in the GHG assessment boundary	Affected sources	Baseline emissions
1 Reduced emissions from landfills (diversion to composting, AD, and energy recovery)	Landfills	940,979 tCO_2
2 Net carbon storage from compost production	Composting processes	100,000 tCO_2
3 Reduced emissions from displacement of nitrogen fertilizers	Agricultural processes	20,000 tCO_2
4 GHG reductions from displaced fossil grid electricity	Fossil fuel combustion for Grid electricity generation	500,000 tCO_2
5 GHG reductions from displaced transportation fuels	Fossil fuel combustion for transportation	20,000 tCO_2
6 Increased emissions from illegal dumps	Illegal waste dumps	50,000 tCO_2
7 Increased emissions from out-of-jurisdiction landfills	Landfill waste management processes	100,000 tCO_2
Total baseline emissions		**1,730,979 t CO_2**

Note: The table provides data for the end year in the GHG assessment period (2020).

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[6] Numbers for effects 2 to 7 are illustrative.

Chapter 9: Estimating GHG effects ex-ante

In this chapter, users are expected to estimate policy scenario emissions for the set of GHG sources and sinks included in the GHG assessment boundary based on the set of GHG effects included in the GHG assessment boundary. Policy scenario emissions are to be estimated for all sources and sinks using the same emissions estimation method(s), parameters, parameter values, GWP values, drivers, and assumptions used to estimate baseline emissions, except where conditions differ between the baseline scenario and the policy scenario, for example, changes in activity data and emission factors.

9.2 Identify parameters to be estimated

In the waste management sector, many of the data requirements for ex-ante assessments will be similar to those required for the baseline. However, there will also likely be a need to develop some estimates, particularly with regard to those parameters or GHG emissions that may change with the policy or suite of policies.

Policies which set a goal for a certain outcome (e.g., recycling rate target, waste portfolio standard) will be easier to evaluate; however, not all commodities in the waste stream may be impacted equally. For example, mass based recycling targets or requirements can create a disproportionate incentive to recycle heavier materials such as glass or steel. Therefore, in order to assess the impact of the policy, it may not be appropriate to assume that recycling of all waste components will increase uniformly. In these cases, it may be helpful to look at examples in other jurisdictions to understand what types of materials are more widely recycled in programs with an overall recycling rate similar to the target or requirement set by the policy. In addition, the relationship between the recycling rate of a waste component and its GHG benefit is not necessarily linear, especially at higher recycling rates. This non-linearity may be reasonably ignored in low accuracy assessments but should be considered in higher accuracy assessments.

Policies which work through economic and market forces (e.g., landfill levies, feed-in tariffs) will be more difficult to model as an outcome is not set or guaranteed by a given policy signal. In these cases, financial modeling assessing both capital and operating expenses will need to be considered. As an alternative, solid waste management “tip fees,” or the fee required to manage a given mass of waste, can serve as a stand-in for a levelized cost of service to determine if a given policy signal (e.g., tax or levy rate) is sufficient to overcome existing financial barriers. Then, information from other jurisdictions can be consulted to determine how much additional “signal” is needed beyond economic parity to change behavior. For example, the extent of the landfill levy applied within a member state of the European Union is a reasonably good predictor of the recycling rate attained within that member state.

Table A in chapter 8 forms the basis for determining which parameters are affected by the policy. In case the determination of affected parameters is not straight forward, the methodology to determine significance outline in chapter 7 can be used. For the example of the selected effect ‘reduced emissions from landfills’, the only parameter from equation 1 affected by the policy is the mass of food waste landfilled.

9.4 Estimate policy scenario values for parameters

Once the affected parameters are determined the parameter values for the policy scenario can be determined. All other parameters remain as in the baseline scenario. Table 9.2 provides an example.

Table 9.2. Example of reporting parameter values and assumptions used to estimate ex-ante policy scenario emissions for the food waste landfill diversion policy

Parameter	Baseline Value	Policy Scenario Values	Trend over time for scenario value(s)	Time period of effect	Source(s) used	Comments / Explanation
Parameters required for reduced emissions from landfills						
Mass of food waste landfilled	500,000 Tons (t) (2012) 520,000 t (2015) 590,000 t (2020)	450,000 Tons in 2015 350,000 Tons in 2020	Discrete step changes of 50k Ton in 2014, 2016, and 2018	Full GHG assessment period	Staff review of AD, combustion, and compost technologies and associated capacities	None
Landfill cover soil oxidation fraction	0.1	Same as baseline values	Not affected			
Component-specific lifetime collection efficiencies	50%	Same as baseline values	Not affected			
Fraction of food waste managed in landfill	NC: 80% FL: 10% LFGTE: 10%	Same as baseline values	Not affected			
Examples for parameters required for other identified effects						
Tons of compost generated from food wastes	10,000 t (2012) 10,400 t (2015) 11,800 t (2020)	20,000 Tons in 2015 30,000 Tons in 2020	Initial proportional change associated with utilization of current compost capacity, followed by discrete step changes associated with compost & AD facility construction	Full GHG assessment period	Compost and AD yield data based on similar operations and technologies	None
Grid electricity generated from food waste	15,000 MWh (2012) 16,500 MWh (2015) 21.500 MWh (2020)	18,000 MWh in 2015 33,000 MWh in 2020	Proportional change associated with diversion to existing energy recovery facility up to available capacity. Discrete step changes dependent on AD facility construction	Full GHG assessment period	Peer reviewed literature and project reports	Baseline considers combustion of food waste in existing 1,200 Ton per day combustion facility generating ~200 kWh / Ton of food waste
Transportation fuels generated from food waste	0 (2012) 0 (2015) 0 (2020)	0 litres in 2015; 2 million m3 compressed natural gas (CNG) in 2020	Discrete steps changes dependent on construction of AD facility combined with biogas	Full GHG assessment period	Peer reviewed literature and project reports, economic analysis	Extent of CNG production will depend on CNG pricing & other incentives

			processing and CNG fueling station			

9.5 *Estimate policy scenario emissions*

Once parameter values have been determined, the same equations as used for the calculation of baseline values can be used to derive the policy scenario values:

Policy scenario emissions$_{2020}$ = $L_{0,\ FW}$ x 350,000 t x [X_{NC} + X_{FL}(1 - OX)(1 - LCE_{FL}) + X_{LFGTE}(1 - OX)(1 - LCE_{LFGTE}) = X t CO_2e

Policy emissions$_{2020}$ = 0.07168 tCH_4/t x 350,000 t x [80% + 10%*(1 – 0.1)*(1 – 50%) + 10%*(1 – 0.1)*(1 – 50%) x 25 = 558,208 t CO_2e

9.6 *Estimate the GHG effect of the policy or action (ex-ante)*

After determining the GHG emissions for the policy scenario for each source category, the change resulting from the policy can be determined. Table 9.3 provides an overview of the results.

Table 9.3 Example of estimating the GHG effect of the food waste diversion policy[7]

GHG effect included	Affected sources	Policy scenario emissions	Baseline emissions	Change
1 Reduced emissions from landfills (diversion to composting, AD, and energy recovery)	Landfills	558,208	940,979	**- 382,771**
2 Net carbon storage from compost production	Composting processes	50,000	1,00,000	-50,000
3 Reduced emissions from displacement of nitrogen fertilizers	Agricultural processes	0	20,000	-20,000
4 GHG reductions from displaced fossil grid electricity	Fossil fuel combustion for Grid electricity generation	0	5,00,000	-5,00,000
5 GHG reductions from displaced transportation fuels	Fossil fuel combustion for Grid electricity generation	0	20,000	-20,000
6 Increased emissions from illegal dumps	Illegal waste dumps	50,000	25,000	25,000
7 Increased emissions from out-of-jurisdiction landfills	Landfill waste management processes	1,00,000	50,000	50,000
Total emissions /		7,58,208	16,55,979	-8,97,771

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[7] Numbers for effects 2 to 7 are illustrative.

Total change in emissions			

Note: The table provides data for the end year in the GHG assessment period (2020).

Box B.1 Addressing policy interactions

In general, when assessing waste management sector GHG policies, it is often important to assess the potential impacts of policies within the manufacturing, land-use, and energy sectors. For example, policies designed to incentivize certain manufacturing industries which use recycled inputs can help increase the demand for these products, and therefore, increase financial incentives to recycle. Energy policies also must be carefully scrutinized, particularly when they are set without consideration of waste management facilities which generate electricity as a co-product. For example, a generation intensity standard in terms of t CO_2 emitted per MWh electrical generation set to encourage combined cycle natural gas generation may inappropriately penalize the use of waste resources for energy generation because the significant benefit of avoiding methane emissions from landfills may not necessarily be included.

For the food waste landfill diversion policy example, the amount of electricity generated from food waste will depend to a large degree on what types of diversion technologies are implemented. In this particular example, the food waste landfill diversion policy is technology neutral between composting, anaerobic digestion, and energy recovery (i.e. combustion, gasification, pyrolysis). Theoretically, the types of diversion implemented will depend on available capacity and the economics of the various technologies. Initially, food waste diversion is likely to occur to existing facilities, which in this particular example, includes compost facilities and a combustion energy recovery facility. As excess capacity is absorbed, additional composting and anaerobic digestion (AD) facilities will likely be built, the type of which is dependent on economics and siting considerations including permitting, land availability, and land cost. Economics will be driven by electricity and finished product (e.g., compost, liquid digestate fertilizers) markets. It is very unlikely that additional energy recovery facilities designed to operate on mixed MSW will be constructed on the basis of a food waste diversion policy. The food waste stream is a relatively minor portion of the waste stream and composting and anaerobic digestion are likely to be more cost effective solutions when the cost of capital is taken into account.

Several policies, including renewable portfolio standards, low carbon fuel standards, and renewable energy tax incentives may significantly impact project economics, and therefore, the types of facilities that may be built. For example, the establishment of a robust low carbon fuel standard program with a reliable market incentive may result in more anaerobic digestion project developers turning toward the sale of compressed renewable natural gas at the expense of electricity generation. While this will also reduce GHG emissions by displacing the combustion of fossil based natural gas, it will reduce the amount of electricity generated as a result of the primary policy. Additional potential policy interactions are outlined in Figure B.1 below.

Figure B.1 Example policy interaction matrix

	Parameter- Electricity Generation from Food Waste			
	Food Waste Diversion	Renewable Portfolio Standard	Low Carbon Fuel Standard	Renewable Energy Tax Credits
Food Waste Diversion	N/A			
Renewable Portfolio	+	N/A		

Standard				
Low Carbon Fuel Standard	+	- - -	N/A	
Renewable Energy Tax Credits	+	++	++	N/A

One possible manner to address policy interactions in this example is to assess mandatory and market-based drivers separately, assuming a basic amount of decreased food waste managed at landfill resulting from the mandatory requirement. The waste landfill diversion requirement will achieve a change in the amount of food waste landfilled determined by the fraction of the waste stream covered by the diversion requirement (e.g., commercial organics of a certain size), multiplied by the amount of food waste in that waste stream, multiplied by a compliance rate. Incremental food waste diverted from landfills may occur as a result of spillover effects into other non-regulated portions of the overall waste stream, the diversion of other organic materials from landfill because of the increasing availability of other management options (e.g., composting, anaerobic digestion, energy recovery), and higher compliance rates. The incremental food waste diversion may be largely assumed to be driven by market forces. For example, if the additional policy measures reduce the cost of alternative measures relative to landfilling, then incremental GHG savings may occur. If there is pricing parity, incremental GHG savings may still occur, but may not be as extensive. If, however, alternative measures are more costly than landfilling, these additional policy drivers are unlikely to have an impact on reducing GHG emissions from food waste managed in landfills.

Chapter 10: Monitoring performance over time

In this chapter, users are required to define the key performance indicators that will be used to track performance of the policy or action over time. Where relevant, users need to define indicators in terms of the relevant inputs, activities, intermediate effects and GHG effects associated with the policy or action.

10.1 Define key performance indicators

Monitoring performance indicators can be achieved through:

- Measuring (estimating) activity with and without the policy: tons of food waste
- Measuring (estimating) impact with and without the policy: emissions from food waste landfilling, amount of compost produced, etc.

Some typical indicators for common policies in the sector are shown in the table below.

Table 10.1 Examples of indicators

	Landfill Levy / Biodegradable Waste Ban	Feed-in Tariffs and Renewable Portfolio Standards	Carbon Offset Credits	Waste Portfolio Standard
Input indicators	• Infrastructure investment	• Amount spent on FIT payments	• Registration fees • Investment in personnel with sufficient expertise	• Investment and HR expenditure for operation of WPO management departments
Activity indicators	• Tons of MSW managed at landfill, compost, energy recovery, etc.; • Number of inspections / enforcement activities	• Number of developers availing benefits • Number of eligible installations connected to grid • Number of Power Purchase Agreements signed	• Number of projects in the carbon offset pipeline	• Number of obligated entities
Intermediate effect indicators	• Waste generation per capita; • Waste composition; • Landfill diversion rate	• Number, capacity, and generation of installations of each waste based power plant • Tons MSW managed	• Number of projects registered • Carbon credits issued and transacted • Waste composition • Change in biodegradable waste landfilled	• Waste generation rate per capita • Recycling, landfill diversion rates • Waste composition
GHG effects	• GHG reduction per landfill	• GHG reduction per installation	• GHG reduction per project	• GHG reduction
Non-GHG	• Cost savings	• Employment	• Revenue	• Sector wide

effects	achieved	generated	generated	cost savings achieved

10.4 Create a monitoring plan

Taking the example of a high accuracy ex-post GHG assessment, an illustrative example of a monitoring plan for the example policy is provided below. One central government entity needs to be defined to collect, aggregate and process the data in a useful way.

Table 10.5. Example of information to be contained in the monitoring plan

Indicator or parameter (and unit)	Source of data	Monitoring frequency	Measured/ modeled/ calculated/ estimated (and uncertainty)	Responsible entity
Landfill waste characterizations	Waste characterization studies of MSW landfilled, with a particular focus on food waste.	At a minimum every three years, including the selected baseline year	Estimated Low uncertainty	Landfill operators/ management
Electricity generation from new facilities	Prorate electrical generation by feedstock throughput as well as measure net methane generation per mass of feedstock, such as volatile solids destruction percentage.	Annual	Modeled Low uncertainty	Anaerobic digestion facilities operators/ management
Food waste processed at AD, compost, and energy recovery facilities	Collect data on the amount of food waste processed at anaerobic digestion and compost facilities using flow meters. Determine the incremental amount of food waste processed at energy recovery facilities by subtracting the annual amount of food waste processed at AD and compost facilities from the decrease in food waste accepted at landfills. If possible, verify the amount of incremental food waste managed at energy recovery facilities through a waste characterization study at in-region energy recovery facilities	Annual	Measured Low uncertainty	AD, compost, and energy recovery facility operators/ management
MSW processes at landfill	Collect annual MSW landfilled figures from in-region landfills	Annual	Measured Low uncertainty	Landfill operators/ management

Chapter 11: Estimating GHG effects ex-post

A number of ex-post assessment methods have been described in this chapter, which can be classified into two broad categories i.e. Bottom-up methods and top-down methods.

11.2 Select an ex-post assessment method

With reference to the example policy, bottom-up methods involving the direct collection of waste management data will likely be most applicable to quantifying GHG effects ex-post in the policy region. Waste throughput information will likely be available from facilities in region as will net electrical generation data. Engineering models may be required to apportion outputs associated with food waste streams at facilities that process other waste streams in addition to food wastes.

Table 11.1 Applicability of ex-post assessment methods

Bottom up methods	**Applicability**
Collection of data from affected participants/ sources/other affected actors	• **High applicability.** Collection of parameter data (e.g., tons processed through AD, composting, and landfilling; net electrical generation; tons of MSW landfilled) will be the most likely source of data that would aid in GHG emissions quantification. • Activity data will need to be used together with emission factors and/or models to calculate emissions. Direct measurement of landfill gas emissions is possible (e.g., flux boxes, optical remote sensing), but it is very difficult to correlate the entire emissions of a landfill, which come from the total sum of waste deposited over the year that the landfill has been in operation, to changes in the landfilling of food wastes. In addition, monitoring emissions today does not allow for the determination of future emissions from food waste deposited in a landfill today.
Engineering estimates	• **Moderate applicability.** A more detailed consideration of sample of landfills to understand the interactions between GHG emissions and other variables such as landfill engineering, waste composition and landfill size can be helpful to refine top-down estimates of emissions and also assist in understanding the effects of other related policies, such as recycling targets.
Deemed estimate	• **Moderate applicability.** As above.
Methods that can be bottom-up or top-down depending on the context	**Applicability**
Stock modeling	• Low applicability
Diffusion indicators	• Low applicability
Top down methods	**Applicability**
Monitoring or indicators	• **High applicability.** Monitoring of quantities of waste landfilled using an appropriate information system represents an effective way of monitoring the effect of the policy.
Economic modeling	• **Low applicability.** Input-output would likely be more difficult than using monitoring or indicators of waste flows. Input-output data may be useful to determine national level waste composition; however, it is important to validate such analyses

	wherever possible. For example, the amount of biogenic carbon content predicted by input-output analyses can be compared against radiocarbon analysis data from energy recovery facilities.

11.3 Select a desired level of accuracy

Examples of how to implement ex-post quantification methods using low to high accuracy level approaches for the policy example are described below:

Low accuracy

Under a low accuracy approach, data could be collected on the amount of food waste processed at anaerobic digestion and compost facilities from facility owners and operators and the incremental amount of waste managed at energy recovery facilities, assuming that all of the incremental waste is food waste. A review of any other drivers for increased tonnage at energy recovery facilities should be undertaken. The sum of the incremental food waste at anaerobic digestion, compost, and energy recovery facilities is equal to the decrease in food waste landfilled.

The GHG reductions associated with the grid connected electricity displaced by the incremental amount of food waste managed is determined by summing the incremental food-waste related electrical generation at AD and energy recovery facilities multiplied by a suitable grid electrical intensity factor (e.g., average grid factor, average fossil-fuel fired grid factor, marginal grid factor). AD facilities that co-digest other materials will need to prorate electrical generation by feedstock throughput and, potentially, a measure of net methane generation per mass of feedstock, such as volatile solids destruction percentage. Incremental electrical generation from food waste at energy recovery facilities can be determined based on the incremental tonnage managed at these facilities multiplied by a default heat content of food waste and a default thermal efficiency.

Intermediate accuracy

A source of uncertainty in the low accuracy approach outlined above will be the incremental amount of food waste processed at energy recovery facilities. Under an intermediate accuracy approach, the change in food waste landfilled could be at least partially determined with the aid of waste composition studies performed at either landfills or energy recovery facilities. In addition, displaced grid electricity may be determined using a marginal grid-connected electricity GHG intensity factor from the regional grid, utility, or independent system operator.

High accuracy

Under a high accuracy approach, specific lifetime collection efficiency values could be used as described in the baseline calculations above. In addition, the amount of incremental electricity generated at energy recovery facilities associated with food waste could be based on actual facility efficiency information. For those countries using higher heating values, the efficiency calculations should account for the heat of vaporization of water in food waste. This is not a requirement for countries where efficiency and food waste heat content values are based on lower heating values.

Example: Sourcing of aggregate data on EG_y from annual update reports of government agencies
Assumption of EF_{aux} based on the most common source of auxiliary generation in wind installations in the country (for example, 0.8 tCO_2e/MWh default value for Diesel Generator sets)
Assumption of EG_{aux} based on default values (for example, 1% of gross generation)

Policy interactions are also important to assess in an ex-post assessment. The policy interaction matrix in Figure B.1 presented several different policies which may interact with the food waste landfill diversion requirement, including a Renewable Portfolio Standard (RPS), a Low Carbon Fuel Standard (LCFS), and

Renewable Energy Tax Credits. While the RPS and LCFS may serve to counteract each other, each of the three additional policies reinforce the food waste landfill diversion policy.