METHODOLOGY FOR THE QUANTIFICATION AND REGISTRATION OF ENVIRONMENTAL IMPACTS OF GREEN FINANCE FOR

DIVERSION OF ORGANIC WASTE FOR COMPOSTING PROJECTS

VERSION 1.0

July 2021

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American Carbon Registry®

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ABOUT AMERICAN CARBON REGISTRY® (ACR)

ACR is a scientific standards body for the creation of environmental assets. This includes tradable assets like carbon offset credits issued by ACR Environmental Markets and the quantification of environmental attributes of financial instruments by ACR Capital Markets. We complement decades of expertise in the development of market-making standards and project measurement methodologies with operational expertise in the verification, registration, issuance, retirement, and reporting of environmental claims.

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Rockefeller Brothers Fund
Philanthropy for an Interdependent World

ACRONYMS

ACR	American Carbon Registry
ASP	Aerated static pile
CARB	California Air Resources Board
CASP	Covered aerated static pile
CH_4	Methane
CNG	Compressed natural gas
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
eGRID	Emissions & Generation Resource Integrated Database
EPA	United States Environmental Protection Agency
GHG	Greenhouse gas
GWP	Global warming potential
IPCC	Intergovernmental Panel on Climate Change
IVC	In-vessel composting
kg	Kilogram
KPI	Key performance indicator
LFG	Landfill gas
MSW	Municipal solid waste
MT	Metric ton
N_2O	Nitrous oxide
N/A	Not applicable
RNG	Renewable natural gas
SDG	United Nations Sustainable Development Goals
SMM	Sustainable materials management
SSR	Greenhous gas source, sink, and reservoir
WARM	Waste Reduction Model

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1 METHODOLOGY DESCRIPTION

This Methodology for the Quantification and Registration of Environmental Impacts of Green Finance for Diversion of Organic Waste for Composting Projects was developed as part of ACR's Green Finance Impact Program.

This Methodology describes the approach and process for quantifying environmental key performance indicators (KPIs) for bond-funded activities related to the diversion of organic waste for composting. It calculates a project's Carbon Return and applies a benchmark to assess a project's impact relative to investments in the same category. This Methodology documents the approach used to quantify the following environmental benefits:

- Greenhouse gas (GHG) emission reductions
- Landfill diversion
- Compost production

In the United States, the total generation of municipal solid waste (MSW) in 2017 was 267.8 million tons, or 4.51 pounds per person per day. Despite advancements in sustainable materials management (SMM), 52 percent of this material ended up in landfills.[1] When organic waste decomposes in a landfill, it produces methane (CH_4) and carbon dioxide (CO_2). Where present, landfill gas (LFG) collection systems reduce such emissions, but adoption of these systems and their efficiency rates vary.[2] As a result, MSW landfills remain the third-largest source of human related methane emissions in both the United States and worldwide.[3,4]

Municipalities are increasingly taking action to promote SMM and prohibit organic materials from entering landfills, thereby creating demand for resource recovery technologies and composting operations such as the activities quantified in this Methodology.[5] SMM promotes a circular economy through the use and reuse of materials after they have been discarded and enter the waste stream. Composting is one such end-of-life management practice.

This Methodology quantifies the environmental benefits of diverting food waste, yard waste, and mixed organics from landfills for composting via windrow, aerated static pile (ASP), covered aerated static pile (CASP), and in-vessel composting (IVC). The methods for assessing the environmental impacts of a compost project apply both prior to construction/expansion and upon operation. It contains methods for assessing the environmental impacts of an organic waste diversion for composting project funded with bond proceeds, including:

[1] EPA (2020a), The Current National Picture.

[2] EPA (2019a), Section 6.2.2.3, pp. 6-11 – 6-13.

[3] EPA (2020b), p. 1-1.

[4] EPA (2011), p. 1.

[5] Lystek International (2018).

- Environmental KPIs
- Carbon Return ($MTCO_2e$ per $1,000 bond financing per year)
- Project performance relative to benchmarks, where applicable

This document provides the project eligibility requirements, quantification approach, and project data requirements. Additional resources and requirements applicable to ACR's Green Finance Impact Program are available at www.winrock.org/ms/acr-capital-markets.

2 CALCULATOR TOOL

This Methodology details the technical methods used to calculate environmental KPIs for bond-funded projects. To make these methods accessible to issuers, ACR has created an easy-to-use calculator that embeds the methods and equations found in this document. The accompanying Calculator Tool and instructions for use are available to program participants at www.winrock.org/ms/acr-capital-markets.

3 METHOD APPLICABILITY

Bond-funded activities must satisfy the following conditions for this Methodology to apply:

I. Project reduces GHG emissions through an increase in the amount of organic MSW diverted from a municipal landfill for composting by:
   A. Constructing or purchasing equipment for a compost facility;
   B. Expanding capacity of an existing compost facility;
   C. Constructing, expanding, or purchasing/installing equipment for a waste stream sorting facility; and/or
   D. Initiating or expanding a residential or commercial organics waste program (e.g., collection or source separation technologies).
II. Project diverts organic MSW from the below categories, as defined in this Methodology:
   A. Food waste;
   B. Yard waste; and/or
   C. Mixed organics.
III. Project utilizes organic MSW that would be landfilled in the absence of the project as feedstock to produce finished compost via one of the following approaches, as defined in this Methodology:
   A. Windrow composting;
   B. ASP composting;
   C. CASP composting; or
   D. IVC.
IV. Project is located in the United States.
V. Issuer supplies project data per requirements described in Chapter 10.

Project aggregation for the purpose of reporting is permitted for projects that quantify environmental impacts using this Methodology and accompanying calculator tool, provided that aggregated projects all:

I. Divert organic MSW from the same landfill or landfills that share the same attributes as input into the calculator tool;
II. Are categorized into the same compost facility types; and
III. Have identical project operational lives.

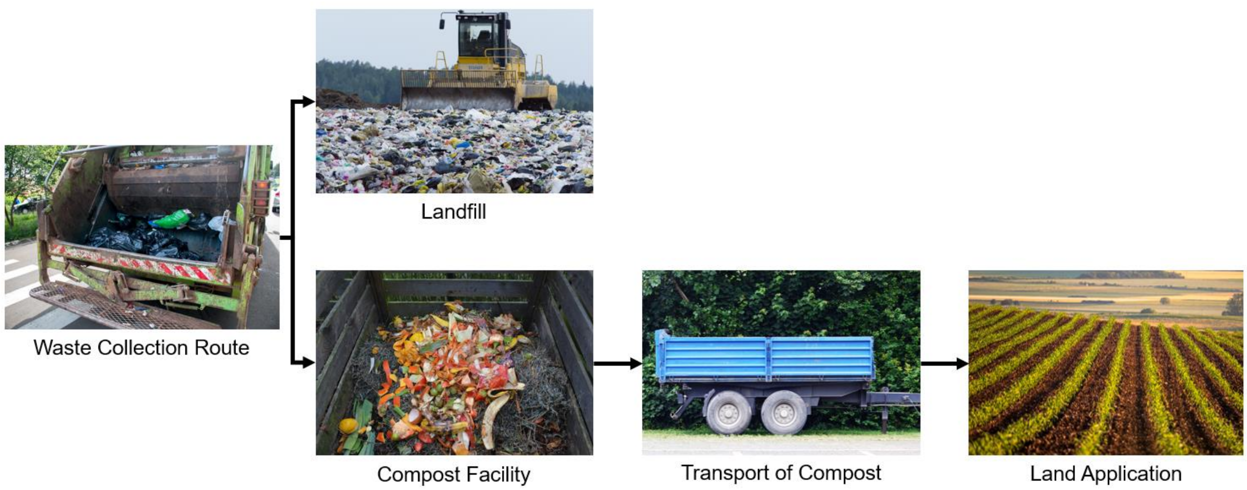
See Chapter 11 for definitions of terms used above and throughout this Methodology.

4 PROJECT BOUNDARIES

4.1 SPATIAL BOUNDARY

The spatial boundary includes the physical and geographical site where the composting takes place, the location of the landfill(s) from which organic material is diverted and at which residual material is disposed, the lands on which compost is applied, and the transportation of diverted organic waste between these sites, as depicted in Figure 1.

Figure 1: Spatial Boundary



A project proponent may or may not have operational control over all components within the spatial boundary. A diversion of organic waste for composting project's benefits can accrue at a site outside of the operational control – but as a direct result – of a project. This Methodology is designed to capture these benefits as long as they occur within the spatial boundary. This Methodology relies on reasonable assumptions, supported by data and literature, when assessing project impacts that occur upstream or downstream of a composting facility.

For this project type, project proponents may have limited information on downstream operations (i.e., transport of compost, carbon storage, and displaced fertilizer from the land application of compost). For this reason, and due to the potential impermanence of carbon storage, the project impacts from the transport and application of compost are less certain and therefore estimated as a secondary effect while all other impacts are categorized as primary effects (see designations in Table 1).

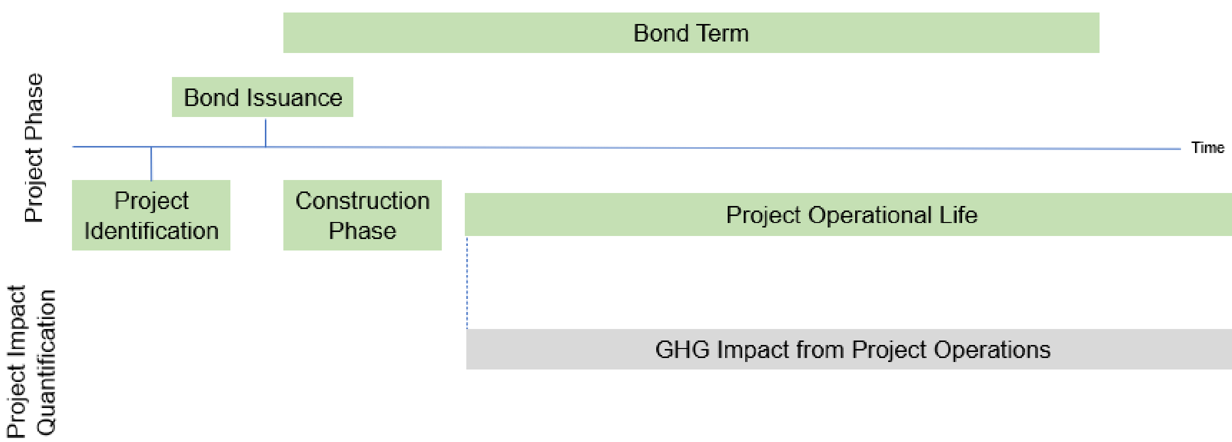
4.2 TEMPORAL BOUNDARY

The temporal boundary is designed to capture impacts associated with the project during its operational life. Figure 2 depicts the project phases, from project identification through the operational life, and how the different phases relate to the quantification of project impacts.

Construction phase emissions (e.g., emissions associated with the construction, installation, or expansion of equipment or systems) are omitted for diversion of organic waste for composting projects on account of being small relative to the overall emission reductions and the construction phase being temporary. Moreover, it is anticipated that construction emissions would still eventually occur without the project due to the material's contribution toward landfill capacity.

This Methodology assumes an operational life of 25 years for an organic waste diversion for composting project and uses this time period when establishing the benchmarks.[6] This period of time is also consistent with the expected time for food and yard waste to degrade in a landfill, which the EPA estimates at 20-30 years.[7] Individual project operational lives may vary. To apply a different operational life to the quantification of project benefits, project proponents must substantiate the alternative project duration with documentation (i.e., equipment manufacturer specifications, operator's project performance record, or organic waste processing contracts). If a project proponent substantiates a different operational life than that used in the benchmarks, that duration will be used when assessing the project against the benchmarks.

Figure 2: Project Phase Timeline



[6] Nemecek T. & Kägi T. (2007), p. 93.

[7] EPA (2019b), p. 1-21.

4.3 GHG ASSESSMENT BOUNDARY

The GHG assessment boundary, depicted by Figure 3 and Table 1 below, delineates the sources, sinks, and reservoirs (SSRs) that are included or excluded in quantifying emissions and emission reductions associated with the diversion of organic waste for composting. Table 1 also describes the SSRs used for the quantification of the project impact and the GHG benchmark.

Figure 3 illustrates the GHG assessment boundary for composting projects. All SSRs inside the grey box are included and must be accounted for under this Methodology.

Figure 3: GHG Assessment Boundary Diagram

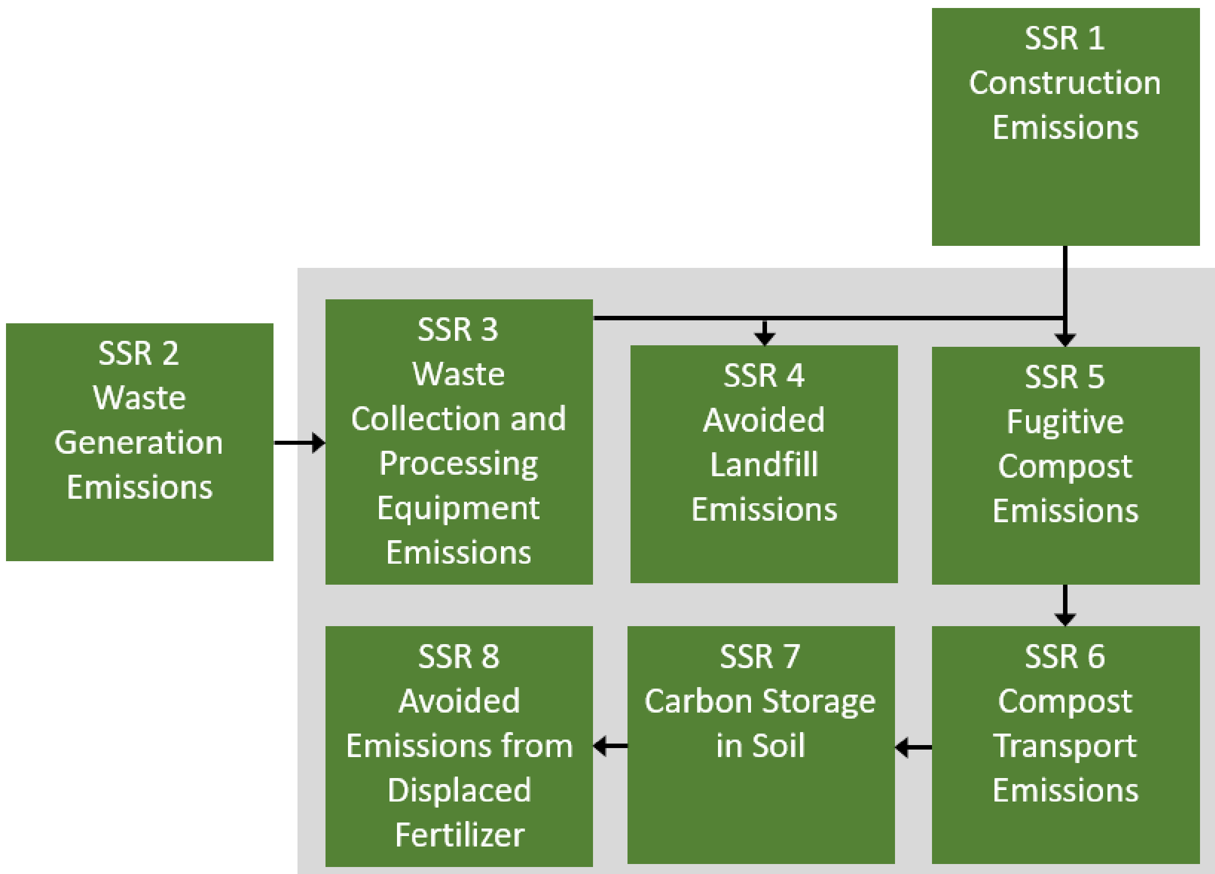


Table 1 lists the SSRs for diversion of organic waste for composting projects, indicating which gases are included in, or excluded from, the GHG assessment boundary.

Table 1: GHG Sinks, Sources, and Reservoirs

SSR	DESCRIPTION	GAS	INCLUDED (I) OR EXCLUDED (E)	JUSTIFICATION / EXPLANATION OF CHOICES
1 Construction Emissions	Stationary and mobile combustion emissions from construction/ expansion of a sorting or compost facility or installation of equipment at such facilities	CO_2	E	Construction emissions are omitted for diversion of organic waste for composting projects on account of being small relative to the overall emission reductions and the construction phase being temporary. Moreover, it is anticipated that, construction emissions would still eventually occur without the project due to the material's contribution toward landfill capacity.
		CH_4	E	
		N_2O	E	
2 Waste Generation Emissions	Stationary and mobile combustion emissions from the generation of waste	CO_2	E	Emissions are assumed to be equivalent with and without the project
		CH_4	E	
		N_2O	E	
3 Waste Collection and Processing Equipment Emissions	Mobile combustion emissions from fossil fuel consumed by equipment to collect and process waste at landfills and compost facilities	CO_2	I	Primary activity of the project
		CH_4	I	
		N_2O	I	

SSR	DESCRIPTION	GAS	INCLUDED (I) OR EXCLUDED (E)	JUSTIFICATION / EXPLANATION OF CHOICES
4 Avoided Landfill Emissions	Net fugitive, stationary combustion, and mobile combustion, emissions avoided from the decomposition of organic material at a landfill, including avoided methane emissions, avoided carbon storage in landfills, reduced bioenergy production from LFG capture systems (if applicable), and landfill equipment emissions	CO_2	I/E	CO_2 emissions from stationary and mobile sources are included Fugitive biogenic CO_2 emissions are excluded[8]
		CH_4	I	Primary activity of the project
		N_2O	I/E	N_2O emission from stationary and mobile sources are included There is insufficient data on fugitive landfill N_2O emissions and this source is conservatively omitted[9]
5 Fugitive Compost Emissions	Fugitive emissions from the composting of diverted organic material	CO_2	E	Biogenic CO_2 emissions are excluded[10]
		CH_4	I	Primary activity of the project
		N_2O	I	
6 Compost Transport Emissions	Mobile combustion emissions from fossil fuel consumed to transport finished compost	CO_2	I	Secondary effect of project
		CH_4	I	
		N_2O	I	
7 Carbon Storage in Soil	Carbon stored in soils from the land application of compost	CO_2	I	Secondary effect of project

[8] IPCC (2006), Volume 5, Chapter 3, p. 3.6.
[9] CARB (2017), p. 6.
[10] IPCC (2006), Volume 5, Chapter 3, p. 3.6.

SSR	DESCRIPTION	GAS	INCLUDED (I) OR EXCLUDED (E)	JUSTIFICATION / EXPLANATION OF CHOICES
8 Avoided Emissions from Displaced Fertilizer	Net fugitive, stationary combustion, and mobile combustion emissions avoided from the production and application of synthetic fertilizer displaced by compost	CO_2	I	Secondary effect of the project
		CH_4	I	
		N_2O	I	

5 PERIODIC REVIEWS

ACR may periodically update (or decide to retire) this Methodology. Such updates occur when significant changes to accounting best practices or the legislative and/or regulatory context justify an update; when sufficient new data is available to revise eligibility requirements, benchmarks, or emission factors; when ACR becomes aware of clarifications that should be made; or for other reasons. Before assessing a project's impacts against the benchmarks contained in this document, the project proponent should ensure that they are using the latest version of the Methodology.

6 QUANTIFICATION OF GHG IMPACT

GHG emission reductions from diverting organic waste for composting are quantified using the methods and equations in the following sections. This chapter describes how to establish the Carbon Return of the project and compare performance relative to the GHG benchmark for composting projects.

GHG emissions are converted to carbon dioxide-equivalent (CO_2e) using the 100-year global warming potential (GWP) in the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report.[11] This methodology may be adjusted to updated GWPs in the future.

6.1 QUANTIFICATION OF NET PROJECT GHG IMPACT & CARBON RETURN

A diversion of organic waste for composting project's GHG emission reductions are assessed using the methods and equations in Subsections 6.1.1 – 6.1.8 below. Each subsection covers a different SSR and the net project GHG impact is calculated in Subsection 6.1.9.

6.1.1 CONSTRUCTION EMISSIONS

Construction emissions refers to the stationary and mobile combustion emissions from construction/expansion of a sorting or compost facility or installation of equipment at such facilities. This emission source is excluded from the GHG assessment boundary on account of it being small relative to the overall emission reductions and the construction phase being temporary. Moreover, it is anticipated that, without the project, construction emissions would still eventually occur without the project due to the material's contribution toward landfill capacity.

6.1.2 WASTE GENERATION EMISSIONS

Waste generation emissions refer to the stationary and mobile combustion emissions from the generation of waste. This emission source is excluded from the GHG assessment boundary on account of waste generation emissions being assumed to be equivalent with and without the project.

[11] IPCC (2018), Table 2.14.

6.1.3 WASTE COLLECTION AND PROCESSING EQUIPMENT EMISSIONS

Waste collection and processing emissions refer to the mobile combustion emissions from fossil fuel consumed by equipment to collect and process waste at landfills and compost facilities.

Transportation emission factors vary by fuel type, as displayed in Table 2, and electric vehicle emissions vary by grid carbon intensity, as displayed in Appendix A. The diesel ton-mile emission factor is sourced from WARM[12] and the emission factors for alternative fuel types are reduced proportionally based on ACR analysis using fuel economies, energy densities, energy economy ratios and, for electric vehicles, data from the EPA's Emissions & Generation Resource Integrated Database (eGRID).[13] The difference in transportation emissions for waste collection and delivery between the project and no project scenarios is calculated using Equations 1 and 2.

Table 2: Vehicle Emission Factor

FUEL TYPE	$MTCO_2e$/SHORT TON-MILE
Diesel	0.00016
Biodiesel	0.00004
Compressed Natural Gas (CNG)	0.00016
Renewable Natural Gas (RNG)	0.00006
Hydrogen	0.00009
Electric	See Appendix A

[12] U.S. EPA (2019b), Exhibit 5-1.
[13] U.S. EPA (2021), column DE in the ST19 tab.

Equation 1: Weighted Vehicle Emission Factor

$$\mathbf{VEF} = \mathbf{VEF_{dsl}} \times (\mathbf{1} - \mathbf{Biodsl} - \mathbf{CNG} - \mathbf{RNG} - \mathbf{Hyd} - \mathbf{EV}) + \mathbf{VEF_{biodsl}} * \mathbf{Biodsl} + \mathbf{VEF_{CNG}} * \mathbf{CNG} + \mathbf{VEF_{RNG}} * \mathbf{RNG} + \mathbf{VEF_{hyd}} * \mathbf{Hyd} + \mathbf{VEF_{EV}} * \mathbf{EV}$$

WHERE	
VEF	Weighted vehicle emission factor
VEF_{dsl}	Vehicle emission factor for diesel from Table 2 ($MTCO_2e$/short ton-mile)
$Biodsl$	Percentage of waste collection fleet that operates on biodiesel (%)
CNG	Percentage of waste collection fleet that operates on CNG (%)
RNG	Percentage of waste collection fleet that operates on RNG (%)
Hyd	Percentage of waste collection fleet that operates on hydrogen (%)
EV	Percentage of waste collection fleet that operates on electricity (%)
VEF_{biodsl}	Vehicle emission factor for biodiesel from Table 2 ($MTCO_2e$/short ton-mile)
VEF_{CNG}	Vehicle emission factor for CNG from Table 2 ($MTCO_2e$/short ton-mile)
VEF_{RNG}	Vehicle emission factor for RNG from Table 2 ($MTCO_2e$/short ton-mile)
VEF_{hyd}	Vehicle emission factor for hydrogen from Table 2 ($MTCO_2e$/short ton-mile)
VEF_{EV}	Vehicle emission factor for electric vehicles from Appendix A ($MTCO_2e$/short ton-mile)

Equation 2: Waste Collection Vehicle Emissions

$$\mathbf{WCV} = \left\{ \sum_t [(\mathbf{TONS}_t + \mathbf{RML}_t) \times \mathbf{YEARS}_t] \times (\mathbf{VMTF} - \mathbf{VMTL}) + \sum_t (\mathbf{RML}_t \times \mathbf{YEARS}_t) \times \mathbf{VMTR} \right\} \times \mathbf{VEF}$$

WHERE	
WCV	Waste collection vehicle emissions (or emission reductions) ($MTCO_2e$)
t	Time interval (initial start-up period or remainder of operational life)
$TONS_t$	Organic material diverted and composted over time interval *t* (short tons feedstock/year)
RML_t	Residual material initially diverted but later landfilled over time interval *t* (short tons/year)
$YEARS_t$	Duration of time interval *t* (years)
VMTF	Average vehicle miles traveled to transport diverted waste from curb to compost facility (miles)
VMTL	Average vehicle miles traveled to transport waste from curb to landfill (miles)
VMTR	Average vehicle miles traveled to transport residual material from compost facility to landfill (miles)
VEF	Vehicle emission factor from Equation 1 ($MTCO_2e$/short ton-mile)

According to WARM, emissions from equipment used to process waste at a landfill or compost facility are the same. While equivalent with and without the project, WARM includes these waste processing emissions when estimating landfill emissions avoided by a project (see Subsection 6.1.4) and so they must also be accounted for in the composting scenario using Equation 3.

Equation 3: Waste Processing Equipment Emissions

$$\mathbf{WPE} = \sum_{t} [(\mathbf{TONS}_t + \mathbf{RML}_t) \times \mathbf{YEARS}_t] \times \mathbf{0.02}$$

WHERE	
WPE	Waste processing equipment emissions ($MTCO_2e$)
t	Time interval (initial start-up period or remainder of operational life)
$TONS_t$	Organic material diverted and composted over time interval *t* (short tons feedstock/year)
RML_t	Residual material initially diverted but later landfilled over time interval *t* (short tons/year)
$YEARS_t$	Duration of time interval *t* (years)
0.02	Processing emission factor from WARM[14] ($MTCO_2e$/short ton)

6.1.4 AVOIDED LANDFILL EMISSIONS

Avoided landfill emissions refer to the net fugitive, stationary combustion, and mobile combustion, emissions avoided from the decomposition of organic material at a landfill, including avoided methane emissions, avoided carbon storage in landfills, reduced bioenergy production from LFG capture systems (if applicable), and landfill equipment emissions. Avoided methane emissions from the decomposition of organic material at a landfill is the primary GHG benefit of organic waste diversion. Organic waste diversion also impacts the use of landfilling equipment, the amount of carbon stored at a landfill, and the energy production from LFG recovery. These factors depend on the type of material disposed based on the material's amount of degradable carbon and anaerobically degradable carbon and its decay rate. Landfill conditions such as climate and the existence and efficiency of an LFG gas capture system also impact a landfill's emission profile.

This Methodology incorporates the United States Environmental Protection Agency's (EPA) Waste Reduction Model (WARM)[15] to determine the landfill emissions avoided by a diversion of

[14] EPA (2019a), Exhibit 4-2.
[15] EPA (2019c).

organic waste for composting project. The emission factors derived from WARM capture reductions in fugitive methane emissions, equipment emissions, biogenic carbon storage, and LFG recovery for energy, if applicable. The accompanying Calculator Tool translates basic landfill management and diverted waste characteristics into WARM emission factors used in Equation 4 to determine the avoided landfill emissions.

Equation 4: Avoided Landfill Emissions

$$\mathbf{ALE} = \sum_{t} \left[\left(\mathbf{TONS}_{\mathbf{mo},t} \times \mathbf{WARM}_{\mathbf{mo}} + \mathbf{TONS}_{\mathbf{fw},t} \times \mathbf{WARM}_{\mathbf{fw}} + \mathbf{TONS}_{\mathbf{yw},t} \times \mathbf{WARM}_{\mathbf{yw}} \right) \times \mathbf{YEARS}_{t} \right]$$

WHERE	
ALE	Avoided landfill emissions ($MTCO_2e$)
t	Time interval (initial start-up period or remainder of operational life)
$TONS_t$	Organic material diverted and composted by waste type: mixed organics (mo), food waste (fw), or yard waste (yw) over time interval *t* (short tons feedstock/year) If composition of diverted waste is unknown, material is aggregated together as mixed organics.
WARM	WARM GHG emission factor for MSW management in a landfill by waste type: mixed organics (mo), food waste (fw), or yard waste (yw) ($MTCO_2e$/short ton feedstock)
$YEARS_t$	Duration of time interval *t* (years)

6.1.5 FUGITIVE COMPOST EMISSIONS

Fugitive compost emissions refer to the small amounts of CH_4 and N_2O emitted during the composting of diverted organic material. These fugitive emissions can vary based on aeration, density, feedstock composition, turning frequency, climate, and size of compost piles. Fugitive emissions from composting are calculated using Equation 5 and, depending on the type of composting, the emission factors in Tables 3 through 5.

WARM assumes windrow composting and provides material type-specific fugitive emission values based on scientific literature[16] as displayed in Table 3.

Table 3: Fugitive Windrow Composting Emission Factors

FOOD WASTE FUGITIVE EMISSIONS	0.0451 $MTCO_2e$/short ton feedstock
YARD WASTE FUGITIVE EMISSIONS	0.0748 $MTCO_2e$/short ton feedstock
MIXED ORGANICS FUGITIVE EMISSIONS	0.0724 $MTCO_2e$/short ton feedstock

ASP composting produces less fugitive emissions than windrow composting (49 percent CH_4 and 48 percent N_2O).[17] When assessing the GHG impact of an ASP composting project, the fugitive emissions rates displayed in Table 4 apply.

Table 4: Fugitive ASP Composting Emission Factors

FOOD WASTE FUGITIVE EMISSIONS	0.0217 $MTCO_2e$/short ton feedstock
YARD WASTE FUGITIVE EMISSIONS	0.0360 $MTCO_2e$/short ton feedstock
MIXED ORGANICS FUGITIVE EMISSIONS	0.0349 $MTCO_2e$/short ton feedstock

Composting operations that use a biofilter layer, IVC, or CASP composting result in 95 percent less fugitive emissions than windrow composting.[18] When assessing the GHG impact of these types of composting operations, the fugitive emissions rates displayed in Table 5 apply.

Table 5: Fugitive IVC, CASP, or Biofilter Layer Composting Emission Factors

FOOD WASTE FUGITIVE EMISSIONS	0.0023 $MTCO_2e$/short ton feedstock
YARD WASTE FUGITIVE EMISSIONS	0.0037 $MTCO_2e$/short ton feedstock
MIXED ORGANICS FUGITIVE EMISSIONS	0.0036 $MTCO_2e$/short ton feedstock

[16] EPA (2019a), Exhibit 4-5.

[17] CARB (2020), Compost ERF tab.

[18] CARB (2014a), pp. 39-41.

Equation 5: Fugitive Compost Emissions

$$\mathbf{FUG} = \sum_{t} \left[\left(\mathbf{TONS}_{\mathbf{mo},t} \times \mathbf{EF}_{\mathbf{mo}} + \mathbf{TONS}_{\mathbf{fw},t} \times \mathbf{EF}_{\mathbf{fw}} + \mathbf{TONS}_{\mathbf{yw},t} \times \mathbf{EF}_{\mathbf{yw}} \right) \times \mathbf{YEARS}_{t} \right]$$

WHERE	
FUG	Fugitive compost emissions ($MTCO_2e$)
t	Time interval (initial start-up period or remainder of operational life)
$TONS_t$	Organic material diverted and composted by waste type: mixed organics (mo), food waste (fw), or yard waste (yw) over time period *t* (short tons feedstock/year) If composition of diverted waste is unknown, material is aggregated together as mixed organics.
EF	Emission factor by composting type: windrow, ASP, IVC, CASP, or biofilter layer, and waste type: mixed organics (mo) food waste (fw), or yard waste (yw) from Tables 3 through 5 ($MTCO_2e$/short ton)
$YEARS_t$	Duration of time period *t* (years)

6.1.6 COMPOST TRANSPORT EMISSIONS

Compost transport emissions refer to the mobile combustion emissions from fossil fuel consumed to transport finished compost to the site upon which it is land applied. The additional emissions from transportation of the compost are calculated using Equation 6.

Equation 6: Compost Transport Emissions

$$CTE = \sum_t (TONS_t \times YEARS_t) \times 0.58 \times VMTC \times 0.00016$$

WHERE	
CTE	Compost transport emissions ($MTCO_2e$)
t	Time interval (initial start-up period or remainder of operational life)
$TONS_t$	Organic material diverted and sent to anaerobic digester over time interval *t* (short tons feedstock/year)
$YEARS_t$	Duration of time interval *t* (years)
0.58	Conversion of feedstock to tons of compost (ton compost/ton feedstock)[19]
$VMTC$	Average vehicle miles traveled to transport compost from facility to land application site (miles)
0.00016	Transportation emission factor from WARM[20] ($MTCO_2e$/short ton-mile)

6.1.7 CARBON STORAGE IN SOIL

Carbon storage is soil refers to the potential secondary effect of carbon stored in soils from the land application of compost. The composting process stabilizes the carbon in the diverted waste, enabling a slow decomposition and uptake by soils when land applied.[21] Despite recognition that compost is often used for non-agricultural purposes, the carbon storage factor used in WARM is based only on application to agricultural lands.[22] Consistent with WARM, this Methodology also applies the WARM carbon storage factor for agricultural lands to alternative land application end-uses of compost. Studies show that benefits observed from agricultural land application would also be expected for various uses in other settings and that this approach is likely to result in conservative soil carbon storage values.[23] The amount of carbon stored in soils is calculated using Equation 7.

[19] CARB (2017), Table 9.

[20] U.S. EPA (2019b), Exhibit 5-1.

[21] This Methodology applies the soil carbon storage factors used in WARM based on EPA modeling and studies of the fraction of carbon stored in soil after 10 years. Additional information about the soil carbon storage values can be found in WARM Management Practices Chapter (EPA 2019a).

[22] EPA (2019a), p. 4-16.

[23] Brown and Beecher (2019), p. 227-239.

Equation 7: Carbon Storage in Soil from Land Application of Compost

$$\mathbf{CS} = \sum_{t} (\mathbf{TONS}_t \times \mathbf{YEARS}_t) \times \mathbf{PLA} \times \mathbf{0.24}$$

WHERE	
CS	Carbon stored in soil from land application of compost ($MTCO_2e$)
t	Time interval (initial start-up period or remainder of operational life)
$TONS_t$	Organic material diverted and composted over time interval *t* (short tons feedstock/year)
$YEARS_t$	Duration of time interval *t* (years)
PLA	Percentage of finished compost distributed for land application (%)
0.24	Carbon storage factor from WARM[24] ($MTCO_2e$/short ton feedstock)

6.1.8 AVOIDED EMISSIONS FROM DISPLACED FERTILIZER

Avoided emissions from displaced fertilizer refers to the potential secondary effect of avoiding net fugitive, stationary combustion, and mobile combustion emissions from the production and application of synthetic fertilizer displaced by compost. When finished compost is land applied, it may lead to the use of less synthetic fertilizer. Avoided emissions associated with the production and application of displaced fertilizer uses an emission factor obtained from the WARM model scenario of applying the finished compost resulting from the curing of the digestate byproduct of anaerobic digestion[25] and is calculated using Equation 8.

[24] EPA (2019a), Exhibit 4-1.

[25] EPA (2019a), Exhibit 3-13.

Equation 8: Avoided Emissions from Displaced Fertilizer

$$\mathbf{DF} = \sum_{t} (\mathbf{TONS}_t \times \mathbf{YEARS}_t) \times \mathbf{PLA} \times \mathbf{0.01}$$

WHERE	
DF	Avoided emissions from displaced fertilizer ($MTCO_2e$)
t	Time interval (initial start-up period or remainder of operational life)
$TONS_t$	Organic material diverted and composted over time interval *t* (short tons feedstock/year)
$YEARS_t$	Duration of time interval *t* (years)
PLA	Percentage of finished compost distributed for land application (%)
0.01	Displaced fertilizer emission factor ($MTCO_2e$/short ton feedstock)

6.1.9 NET PROJECT GHG IMPACT & CARBON RETURN

The following subsection describes how to calculate the net GHG impact of the project, which includes primary and potential secondary GHG emission reductions, and how to calculate the Carbon Return, cost-effectiveness, and the social cost of carbon for the bond issuance.

The primary GHG emission reductions from diversion of organic waste for composting projects are calculated using Equation 9.

Equation 9: Primary GHG Emission Reductions from Project Operations

$$\mathbf{GHG_P} = \mathbf{ALE} - (\mathbf{WCV} + \mathbf{WPE} + \mathbf{FUG})$$

WHERE	
GHG_P	Primary GHG emission reductions from project operations ($MTCO_2e$)
ALE	Avoided landfill emissions from Equation 4 ($MTCO_2e$)
WCV	Waste collection vehicle emissions (or emission reductions) from Equation 2 ($MTCO_2e$)
WPE	Waste processing equipment emissions from Equation 3 ($MTCO_2e$)
FUG	Fugitive compost emissions from Equation 5 ($MTCO_2e$)

The potential secondary GHG emission reductions from diversion of organic waste for composting projects are calculated using Equation 10.

Equation 10: Potential Secondary GHG Emission Reductions from Project Operations

$$GHG_S = CS + DF - CTE$$

WHERE	
GHG_S	Secondary GHG emission reductions of project ($MTCO_2e$)
CS	Carbon stored in soil from land application of compost from Equation 7 ($MTCO_2e$)
DF	Avoided emissions from displaced fertilizer from Equation 8 ($MTCO_2e$)
CTE	Compost transport emissions ($MTCO_2e$) from Equation 6

The net project GHG impact, which is based on the primary and secondary GHG emission reductions from a diversion of organic waste for composting project, is equal to the GHG emission reductions from project operations, as calculated using Equation 11.

Equation 11: GHG Emission Reductions from Project Operations

$$GHG_{PO} = GHG_P + GHG_S$$

WHERE	
GHG_{PO}	GHG emission reductions from project operations ($MTCO_2e$)
GHG_P	Primary GHG emission reductions of project from Equation 9 ($MTCO_2e$)
GHG_S	Secondary GHG emission reductions of project from Equation 10 ($MTCO_2e$)

The Carbon Return of a diversion of organic waste for composting project is the GHG benefit per thousand dollars of bond financing per year of project operation. Carbon Return is calculated using Equation 12.

Equation 12: Carbon Return of Project

$$CR = GHG_{PO} / \$ / YEARS$$

WHERE	
CR	Carbon Return of the project ($MTCO_2e$/$1,000/year)
GHG_{PO}	GHG emission reductions from project operations from Equation 11 ($MTCO_2e$)
$\$$	Total bond financing for the diversion of organic waste for composting project (dollars, in thousands)
$YEARS$	Operational life (years)

The overall cost effectiveness of GHG emission reductions of a diversion of organic waste for composting project is the GHG benefit per thousand dollars of bond financing. GHG cost effectiveness is calculated using Equation 13.

Equation 13: GHG Cost Effectiveness of Project

$$GHG_{\$} = GHG_{PO} / \$$$

WHERE	
$GHG_{\$}$	GHG cost effectiveness of the project ($MTCO_2e$/$1,000)
GHG_{PO}	GHG emission reductions from project operations from Equation 11 ($MTCO_2e$)
$\$$	Total bond financing for the diversion of organic waste for composting project (dollars, in thousands)

The social cost of carbon benefit of a project is calculated using the current social cost of carbon rate and Equation 14.

Equation 14: Social Cost of Carbon Benefit

$$\mathbf{SCC = GHG_{PO} \times \frac{51}{1,000}}$$

WHERE	
SCC	Social cost of carbon benefit ($, in thousands)
GHG_{PO}	GHG emission reductions from project operations from Equation 11 ($MTCO_2e$)
51	Social cost of carbon ($ per $MTCO_2e$)[26,27]
1,000	Conversion ($ per $1,000)

[26] Chemnick (2021).
[27] Whitehouse.gov (2021).

6.2 QUANTIFICATION OF GHG BENCHMARK

A benchmark is a representative standard of performance that facilitates measurement and comparison of impacts across investments in the same category. The analysis contained in this Methodology results in a benchmark for GHG emission reductions expected from the typical compost project based on common practice and a comparison of average landfill and composting emissions.

Windrow composting is by far the most common technique for composting beyond home scale[28] and is therefore used for the GHG benchmark. The GHG benchmark uses the mixed organics category, which is a weighted average of both food and yard waste, as the default feedstock.

The GHG benchmark for organic waste diversion for composting projects was determined using the methods and equations in Subsections 6.2.1 – 6.2.8 below. Each subsection covers a different SSR and they are summarized in Subsection 6.2.9.

6.2.1 CONSTRUCTION EMISSIONS

Construction emissions refer to the stationary and mobile combustion emissions from construction/ expansion of a sorting or compost facility or installation of equipment at such facilities. This emission source is excluded from the GHG assessment boundary on account of it being small relative to the overall emission reductions and the construction phase being temporary. Moreover, it is anticipated that construction emissions would still eventually occur without the project due to the material's contribution toward landfill capacity.

6.2.2 WASTE GENERATION EMISSIONS

Waste generation emissions refer to the stationary and mobile combustion emissions from the generation of waste. This emission source is excluded from the GHG assessment boundary on account of waste generation emissions being assumed to be equivalent with and without the project.

6.2.3 WASTE COLLECTION AND PROCESSING EQUIPMENT EMISSIONS

Waste collection and processing emissions refer to the mobile combustion emissions from fossil fuel consumed by equipment to collect and process waste at landfills and compost facilities. Emissions result from fossil fuel combustion by trucks used to collect and deliver waste and by the equipment used to process the material at a landfill or compost facility. For this GHG

[28] Highfields Center for Composting and the Institute for Local Self-Reliance (2014), p. 13.

benchmark, transportation emissions from waste collection and delivery are assumed to be equivalent with and without the composting project (i.e., whether delivered to a landfill or compost facility) and are therefore excluded.

According to WARM, average emissions from equipment used to process waste at a landfill or compost facility is 0.02 $MTCO_2e$/short ton.[29] While equivalent with and without the project, WARM includes these waste processing emissions when estimating landfill emissions avoided by a project. They must therefore also be included in the composting GHG benchmark, as displayed in Table 6.

Table 6: Fuel for Waste Processing

FUEL FOR WASTE PROCESSING AT COMPOST FACILITY	**0.02 $MTCO_2e$/short ton**

6.2.4 AVOIDED LANDFILL EMISSIONS

Avoided landfill emissions refer to the net fugitive, stationary combustion, and mobile combustion, emissions avoided from the decomposition of organic material at a landfill, including avoided methane emissions, avoided carbon storage in landfills, reduced bioenergy production from LFG capture systems (if applicable), and landfill equipment emissions. As organic waste decomposes in landfills, some of the carbon portion of these materials does not completely decompose and is stored in the landfill. The portion that does decompose is emitted as LFG, composed of CO_2 and CH_4. The CO_2 portion of the gas is biogenic and therefore not accounted for, consistent with IPCC guidance,[30] while the methane emissions are accounted for. Most methane generated at municipal landfills is from landfills with LFG recovery and electricity generation[31] so avoided emissions from fossil fuel-based energy displaced by the biogas is also accounted for.

WARM identifies the national average net GHG emissions from landfilling based on the typical LFG collection practices, average landfill moisture conditions, and U.S.-average non-baseload electricity grid mix,[32] as displayed in Table 7.

[29] EPA (2019a), Exhibits 4-2 and 6-11.

[30] IPCC (2006), Volume 5, Chapter 3, p. 3.6.

[31] EPA (2019a), Exhibit 6-1.

[32] EPA (2019a), Exhibit 6-16.

Table 7: Avoided Landfill Emissions

LANDFILL COMPONENT	MIXED ORGANICS ($MTCO_2e$/SHORT TON)
Collection and Processing Fuel Emissions	-0.02
Landfill CH_4 Emissions	-0.53
Landfill Carbon Storage	0.30
Avoided CO_2 from Energy Recovery	0.04
AVOIDED LANDFILL EMISSIONS	**-0.21 $MTCO_2e$/short ton feedstock**

6.2.5 FUGITIVE COMPOST EMISSIONS

Fugitive compost emissions refer to the small amounts of CH_4 and N_2O emitted during the composting of diverted organic material. These fugitive emissions can vary based on aeration, density, feedstock composition, turning frequency, climate, and size of compost piles. WARM provides the emission factor for windrow composting of mixed organics based on scientific literature[33] as displayed in Table 8.

Table 8: Fugitive Windrow Composting Emissions

FUGITIVE COMPOST EMISSIONS	**0.0724 $MTCO_2e$/short ton**

6.2.6 COMPOST TRANSPORT EMISSIONS

Compost transport emissions refer to the mobile combustion emissions from fossil fuel consumed to transport finished compost to the site upon which it is land applied. This GHG benchmark assumes a transport distance of 40 miles[34] and uses the same ton-mile emission factor applied to waste collection and delivery in a diesel vehicle.[35] The resulting emission factor for transport of the compost, as assumed for this GHG benchmark, is displayed in Table 9.

Table 9: Digestate or Compost Transport Emissions

COMPOST TRANSPORT EMISSIONS	**0.0034 $MTCO_2e$/short ton feedstock**

[33] EPA (2019a), Exhibit 4-5.
[34] CARB (2014b), p. 29.
[35] U.S. EPA (2019b), Exhibit 5-1.

6.2.7 CARBON STORAGE IN SOIL

Carbon storage is soil refers to the potential secondary effect of carbon stored in soils from the land application of compost. The composting process stabilizes the carbon in the diverted waste, enabling a slow decomposition and uptake by soils when land applied. The carbon storage factor used in WARM[36] and for this benchmark is displayed in Table 10.

Table 10: Carbon Storage in Soil

CARBON STORAGE IN SOIL	**-0.24 MTCO$_2$e/short ton**

6.2.8 AVOIDED EMISSIONS FROM DISPLACED FERTILIZER

Avoided emissions from displaced fertilizer refers to the potential secondary effect of avoiding net fugitive, stationary combustion, and mobile combustion emissions from the production and application of synthetic fertilizer displaced by compost. The avoided fertilizer emission factor for this benchmark is obtained from the WARM model scenario of applying the finished compost resulting from the curing of the digestate byproduct of anaerobic digestion[37] and displayed in Table 11.

Table 11: Avoided Emissions from Displaced Fertilizer

AVOIDED EMISSIONS FROM DISPLACED FERTILIZER	**-0.01 MTCO$_2$e/short ton feedstock**

[36] EPA (2019a), Exhibit 4-1.
[37] EPA (2019a), Exhibit 3-13.

6.2.9 SUMMARY OF GHG BENCHMARK

The GHG benchmark for a project that diverts organic waste from a landfill for composting is summarized in Table 12 below. The GHG benchmark represents both primary and secondary effects of the project.

Table 12: GHG Benchmark

SSR	EMISSIONS (+)/ EMISSION REDUCTIONS (-)
1 Construction Emissions	N/A
2 Waste Generation Emissions	N/A
3 Waste Collection and Processing Equipment Emissions	0.02 $MTCO_2e$/short ton feedstock
4 Avoided Landfill Emissions	-0.21 $MTCO_2e$/short ton feedstock
5 Fugitive Compost Emissions	0.0724 $MTCO_2e$/short ton feedstock
GHG Benchmark for Primary Effects	-0.1176 $MTCO_2e$/short ton feedstock
6 Compost Transport Emissions	0.0034 MTCO2e/short ton feedstock
7 Carbon Storage in Soil	-0.24 $MTCO_2e$/short ton feedstock
8 Displaced Fertilizer	-0.01 $MTCO_2e$/short ton feedstock
GHG Benchmark for Potential Secondary Effects	-0.2466 $MTCO_2e$/short ton feedstock
GHG BENCHMARK FOR DIVERSION OF ORGANIC WASTE FOR COMPOSTING PROJECTS	**-0.3642 $MTCO_2e$/short ton feedstock**

A project's emission reductions, quantified per Section 6.1, will be assessed against this GHG benchmark using the methods in Section 6.3.

6.3 COMPARISON OF PROJECT GHG IMPACT TO BENCHMARK

This Section describes how project performance is assessed relative to the GHG benchmark. After calculating the total project emission reductions from the diversion of organic waste for composting in Section 6.1, the project GHG emission reductions are compared to the GHG benchmark determined in Section 6.2. To do this, the GHG benchmark must first be converted from the $MTCO_2e$/short ton unit to $MTCO_2e$ using project-specific inputs and Equation 15.

Equation 15: GHG Benchmark Unit Conversion

$$\mathrm{GHG_B} = \left[\frac{\sum_t (\mathrm{TONS}_t \times \mathrm{YEARS}_t)}{\sum_t \mathrm{YEARS}_t}\right] \times 0.3642 \times 25$$

WHERE	
$\mathrm{GHG_B}$	Benchmark GHG emission reductions ($MTCO_2e$)
t	Time interval (initial start-up period or remainder of operational life)
TONS_t	Organic material diverted and composted over time interval *t* (short tons feedstock/year)
YEARS_t	Duration of time interval *t* (years)
0.3642	Benchmark GHG emission reduction rate ($MTCO_2e$/short ton)
25	Operational life assumed for benchmark (years)

The resulting calibrated GHG benchmark is then compared to the project GHG impact to determine the project's relative performance. The project's emission reductions are compared to the GHG benchmark using Equation 16.

Equation 16: Comparison of Project GHG Impact to Benchmark

$$\mathbf{GHG_C = GHG_{PO} - GHG_B}$$

WHERE	
GHG_C	Project GHG impact compared to benchmark ($MTCO_2e$)
GHG_{PO}	GHG emission reductions from project operations from Equation 11 ($MTCO_2e$)
GHG_B	Benchmark GHG emission reductions from Equation 14 ($MTCO_2e$)

The project's emission reductions are also compared to the GHG benchmark on a percentage basis (e.g., project performance is X% relative to benchmark) using Equation 17.

Equation 17: Percentage Comparison of Project GHG Impact to Benchmark

$$\mathbf{GHG_{\%} = \frac{GHG_{PO}}{GHG_B}}$$

WHERE	
$GHG_{\%}$	Project GHG impact compared to benchmark (%)
GHG_{PO}	GHG emission reductions from project operations from Equation 11 ($MTCO_2e$)
GHG_B	Benchmark GHG emission reductions from Equation 14 ($MTCO_2e$)

7 QUANTIFICATION OF LANDFILL DIVERSION IMPACT

In addition to GHG emission reductions, composting projects reduce the amount of waste entering landfills, thereby avoiding tipping fees and reducing pressure on limited land. Net material diverted from landfills is calculated using Equation 18.

Equation 18: Net Material Diverted from Landfills

$$\text{NMD} = \sum_t \text{TONS}_t \times \text{YEARS}_t$$

WHERE	
NMD	Net material diverted by the project (short tons)
t	Time interval (initial start-up period or remainder of operational life)
TONS_t	Organic material diverted and composted over time interval *t* (short tons feedstock/year)
YEARS_t	Duration of time interval *t* (years)

The waste diversion per thousand dollars of bond financing invested in the project is calculated using Equation 19.

Equation 19: Landfill Diversion per $1,000 Invested

$$\text{NDD} = \frac{\text{NMD}}{\$}$$

WHERE	
NDD	Net material diverted per $1,000 invested (short tons/$1,000)
NMD	Net material diverted by the project from Equation 18 (short tons)
$	Total bond financing for the diversion of organic waste for composting project (dollars, in thousands)

8 QUANTIFICATION OF COMPOST PRODUCTION

In addition to diverting organic material from landfills, composting projects produce compost for land application. The quantity of compost produced is calculated using Equation 20.

Equation 20: Compost Produced

$$\mathrm{CP} = \mathrm{NMD} \times 0.58$$

WHERE	
CP	Compost produced by project (short tons)
NMD	Net material diverted by the project from Equation 18 (short tons)
0.58	Conversion of feedstock to tons of compost (ton compost/ton feedstock)[38]

The compost produced per thousand dollars of bond financing invested in the project is calculated using Equation 21.

Equation 21: Compost Produced per $1,000 Invested

$$\mathrm{CPD} = \frac{\mathrm{CP}}{\$}$$

WHERE	
CPD	Compost produced per $1,000 invested (short tons/$1,000)
CP	Compost produced by project from Equation 20 (short tons)
$	Total bond financing for the diversion of organic waste for composting project (dollars, in thousands)

[38] CARB (2017), Table 9.

9 KEY PERFORMANCE INDICATORS

The KPIs resulting from this Methodology are shown in Table 13. Projects funded with bond proceeds may align with the United Nations Sustainable Development Goals (SDGs).[39] Diversion of organic waste for compost project KPIs map to particular SDGs, as signified by their icons.[40]

Table 13: Key Performance Indicators

<table>
<tr><th>KEY PERFORMANCE INDICATOR</th><th>EQUATION REFERENCE</th><th>SDG[41]</th></tr>
<tr><td>GHG Emission Reductions from Project Operations ($MTCO_2e$)</td><td>Equation 11</td><td rowspan="8">
</td></tr>
<tr><td>Primary GHG Emission Reductions from Project Operations ($MTCO_2e$)</td><td>Equation 9</td></tr>
<tr><td>Potential Secondary GHG Emission Reductions from Project Operations ($MTCO_2e$)</td><td>Equation 10</td></tr>
<tr><td>Carbon Return ($MTCO_2e$/$1,000/year)</td><td>Equation 12</td></tr>
<tr><td>GHG Cost Effectiveness ($MTCO_2e$/$1,000)</td><td>Equation 13</td></tr>
<tr><td>Social Cost of Carbon Benefit ($, in thousands)</td><td>Equation 14</td></tr>
<tr><td>Project GHG Impact Compared to Benchmark ($MTCO_2e$)</td><td>Equation 16</td></tr>
<tr><td>Project GHG Impact Compared to Benchmark (%)</td><td>Equation 17</td></tr>
<tr><td>Net Organic Material Diverted from Landfills (short tons)</td><td>Equation 18</td><td rowspan="2">


</td></tr>
<tr><td>Net Material Diverted per $1,000 Invested (short tons/$1,000)</td><td>Equation 19</td></tr>
</table>

[39] United Nations (2015).

[40] Nordic Public Sector Issuers (2020), p. 17.

[41] A compost project may contribute to the following individual SDG targets: 11.6, 12.5, 13.3, and 15.3.

KEY PERFORMANCE INDICATOR	EQUATION REFERENCE	SDG[41]
Compost Produced (short tons)	Equation 20	15 LIFE ON LAND
Compost Produced per $1,000 Invested (short tons/$1,000)	Equation 21	

10 DATA REQUIREMENTS

In order to assess the impacts of a diversion of organic waste for composting project against the benchmarks contained in this Methodology, project-specific data is required. Data requirements fall into two categories: data required at the time of ex-ante reporting prior to the project becoming operational and data required for ex-post reporting once the project is operational. These data are necessary inputs to quantify environmental impacts using this Methodology and the accompanying tool.

10.1 EX-ANTE REPORTING

The project-specific data required to quantify the environmental impacts of a diversion of organic waste for composting project prior to the project becoming operational are displayed in Table 14. Metrics with an asterisk (*) after them have default values available for use if project-specific data is unavailable.

Table 14: Data Requirements for Ex-Ante Quantification and Reporting

METRIC	UNIT	REFERENCE
GENERAL PROJECT INFORMATION		
Total bond financing for the diversion of organic waste for composting project	Dollars	Equations 12, 13, 19 & 21
LANDFILL INFORMATION		
Location of landfill from which material is diverted	State	Subsection 6.1.4
Existence of LFG capture system at the landfill from which material is diverted.	Yes or No	
• If yes, moisture conditions at location of landfill from which material is diverted. Select from: ◈ Dry: <20 inches of precipitation/year ◈ Moderate: 20-40 inches of precipitation/year ◈ Wet: >40 inches of precipitation/year ◈ Bioreactor: Water is added until the moisture content reaches 40 percent moisture on a wet weight basis	N/A	

METRIC	UNIT	REFERENCE
• If yes, select gas collection efficiency, as defined in WARM: ◈ Worst-case scenario ◈ Typical operation ◈ Aggressive gas collection ◈ California regulatory collection	%	
• If yes, select primary and, if applicable, secondary end-use for gas: ◈ Gas is recovered for energy ◈ Gas is flared	N/A	
• If yes, percentage of gas sent to: ◈ Primary end-use for gas ◈ Secondary end-use for gas, if applicable	%	
COMPOSTING INFORMATION		
If different from 25 years assumed by this Methodology,[42] project operational life*	Years	Section 4.2 Equations 2, 3, 4, 5, 6, 7, 8, 12, 15, & 18
Duration of initial start-up period prior to full operation	Years	
Composting operation type. Select from: • Windrow composting • ASP composting • CASP • Biofilter layer • IVC	N/A	Equation 5

[42] To apply a different operational life to the quantification of project benefits, project proponents must substantiate the alternative project duration with documentation (i.e., equipment manufacturer specifications or organic waste processing contracts).

METRIC	UNIT	REFERENCE
DIVERTED MATERIAL INFORMATION		
Quantity of organic material annually diverted from a landfill and composted If known, quantity by material type* • Mixed organics • Food waste • Yard trimmings	Short tons feedstock/year	Equations 2, 3, 4, 5, 6, 7, 8. 15 & 18
Quantity of residual material initially diverted but later landfilled	Short tons/year	Equations 2 & 3
FINISHED COMPOST INFORMATION		
Percent of compost distributed for land application	%	Equations 7 & 8
TRANSPORTATION INFORMATION		
Average distance traveled to transport waste, from curb to: • Compost facility* • Landfill* For each location, select from: ◈ ≤50 miles ◈ 51-100 miles ◈ 101-150 miles ◈ 151-200 miles ◈ >200 miles	Miles	Equation 2
Average distance traveled to transport residual material from compost facility to landfill* Select from: ◈ ≤50 miles ◈ 51-100 miles ◈ 101-150 miles ◈ 151-200 miles ◈ >200 miles	Miles	Equation 2

METRIC	UNIT	REFERENCE
Average distance traveled to transport compost from facility to land application site Select from: ◈ ≤50 miles ◈ 51-100 miles ◈ 101-150 miles ◈ 151-200 miles ◈ >200 miles	Miles	Equation 6
Existence of alternative fueled vehicles for waste collection and delivery. • If yes, percentage of fleet that is biodiesel • If yes, percentage of fleet that is CNG • If yes, percentage of fleet that is RNG • If yes, percentage of fleet that is hydrogen • If yes, percentage of fleet that is electric	Yes/No %	Equation 1

10.2 EX-POST REPORTING

The project-specific data required to quantify the environmental impacts of a diversion of organic waste for composting project once the project becomes operational are displayed in Table 15. Metrics with an asterisk (*) after them have default values available for use if project-specific data is unavailable.

Table 15: Data Requirements for Ex-post Quantification and Reporting

METRIC	UNIT	REFERENCE
Quantity of organic material annually diverted from a landfill and composted If known, quantity by material type* • Mixed organics • Food waste • Yard trimmings	Short tons feedstock/year	Equations 2, 3, 4, 5, 6, 7, 8, 15 & 18
Quantity of residual material initially diverted but later landfilled	Short tons/year	Equations 2 & 3

METRIC	UNIT	REFERENCE
Percent of compost distributed for land application	%	Equations 7 & 8
UPDATED INFORMATION (ONLY IF DIFFERENT FROM INFORMATION USED FOR EX-ANTE REPORTING)		
Total bond financing for the diversion of organic waste for composting project	Dollars	Equations 12, 13, 19 & 21
Duration of initial start-up period prior to full operation	Years	Equations 2, 3, 4, 5. 6, 7, 8, 12, 15, & 18
Average distance traveled to transport waste, from curb to: • Compost facility* • Landfill* For each location, select from: ◈ ≤50 miles ◈ 51-100 miles ◈ 101-150 miles ◈ 151-200 miles ◈ >200 miles	Miles	Equation 2
Average distance traveled to transport residual material from compost facility to landfill* Select from: ◈ ≤50 miles ◈ 51-100 miles ◈ 101-150 miles ◈ 151-200 miles ◈ >200 miles	Miles	Equation 2

METRIC	UNIT	REFERENCE
Average distance traveled to transport compost from facility to land application site Select from: ◈ ≤50 miles ◈ 51-100 miles ◈ 101-150 miles ◈ 151-200 miles ◈ >200 miles	Miles	Equation 6
Existence of alternative fueled vehicles for waste collection and delivery. • If yes, percentage of fleet that is biodiesel • If yes, percentage of fleet that is CNG • If yes, percentage of fleet that is RNG • If yes, percentage of fleet that is hydrogen • If yes, percentage of fleet that is electric	Yes/No %	Equation 1

11 DEFINITIONS

Aerated static pile (ASP) composting	Compost operation that involves forced aeration using pumps to push or pull air through static piles. Systems may use positive or negative aeration. Positive aeration uses pumps to force air into the pile and may rely on beneficial microbes living just under the cover. Negative aeration uses pumps to suck air through the pile and typically route the pulled air through a device such as a biofilter or a furnace.
Benchmark	A representative standard of performance that facilitates measurement and comparison of impacts across investments in the same category.
Biofilter layer	A cover layer, frequently of compost and woodchips, sufficient to oxidize CH_4 and N_2O used as an emission control technology
Carbon Return	A project's GHG benefit ($MTCO_2e$) per unit of investment (thousand dollars) per year of project operation.
Composting	A waste management strategy in which aerobic microbial decomposition transforms organic material into a stable, humus-like material (compost).
Covered aerated static pile (CASP) composting	Compost operation that adds an impermeable cover to an ASP compost system to capture and control emissions.
Food waste	Uneaten food from residences, commercial establishments such as grocery stores and restaurants, institutional sources such as school cafeterias, and industrial sources such as factory lunchrooms.
GHG source, sink, or reservoir (SSR)	• GHG Source: Physical unit or process that releases a GHG into the atmosphere. • GHG Sink: Physical unit or process that removes a GHG from the atmosphere. • GHG Reservoir: Physical unit or component of the biosphere, geosphere or hydrosphere with the capability to store or accumulate a GHG removed from the atmosphere by a GHG sink or captured from a GHG source.
In-vessel composting (IVC)	Compost operation confined within a building, container, tank, or other vessel in which air flow and emissions are controlled.

Mixed organics	Mixed food and yard waste, weighted as 53 percent food waste and 47 percent yard waste.
Municipal solid waste (MSW)	Waste materials from households, commercial, institutional, and light industrial facilities collected and managed by a municipality. MSW generally includes metals and glass, plastics, paper and wood, organics, mixed categories, and composite products. MSW does not include construction and demolition, industrial, or agricultural waste.
Residual material	Solid waste material initially diverted for composting and later sent for disposal at a landfill.
Windrow composting	Compost operation that involves forming organic waste into rows of long piles maintained under aerobic conditions. Periodic aeration occurs by either manually or mechanically turning the piles.
Yard waste	Yard trimmings from residential, institutional, and commercial sources weighted as 50 percent grass, 25 percent leaves, and 25 percent tree and brush trimmings.

APPENDIX A: ELECTRIC VEHICLE EMISSION FACTORS

The table below provides the emission factors used in Equation 1 for quantifying emissions from electric vehicles used for waste collection and delivery.

STATE	ELECTRIC VEHICLE ($MTCO_2e$/SHORT TON-MILE)
Alabama	0.00004
Alaska	0.00004
Arizona	0.00005
Arkansas	0.00005
California	0.00003
Colorado	0.00005
Connecticut	0.00002
Delaware	0.00003
District of Columbia	0.00002
Florida	0.00003
Georgia	0.00005
Hawaii	0.00005
Idaho	0.00003
Illinois	0.00006
Indiana	0.00006
Iowa	0.00006
Kansas	0.00007
Kentucky	0.00006
Louisiana	0.00004
Maine	0.00002

STATE	ELECTRIC VEHICLE ($MTCO_2e$/SHORT TON-MILE)
Maryland	0.00005
Massachusetts	0.00003
Michigan	0.00006
Minnesota	0.00005
Mississippi	0.00003
Missouri	0.00006
Montana	0.00007
Nebraska	0.00007
Nevada	0.00003
New Hampshire	0.00003
New Jersey	0.00003
New Mexico	0.00006
New York	0.00003
North Carolina	0.00005
North Dakota	0.00007
Ohio	0.00006
Oklahoma	0.00004
Oregon	0.00003
Pennsylvania	0.00004
Rhode Island	0.00003
South Carolina	0.00004
South Dakota	0.00005
Tennessee	0.00005
Texas	0.00004
Utah	0.00005

STATE	ELECTRIC VEHICLE ($MTCO_2e$/SHORT TON-MILE)
Vermont	0.00001
Virginia	0.00003
Washington	0.00004
West Virginia	0.00007
Wisconsin	0.00005
Wyoming	0.00007

APPENDIX B: REFERENCES

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