METHODOLOGY FOR AVOIDING GREENHOUSE GAS EMISSIONS BY KEEPING FOOD IN THE HUMAN SUPPLY CHAIN

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Title	Avoiding greenhouse gas emissions by keeping food in the human supply chain
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Type	Methodology
Sectoral Scope	13 Waste handling and disposal

Relationship to Approved or Pending Methodologies

Approved and pending methodologies under the VCS Program and approved GHG programs, that fall under the sectoral scope 13 and related sectoral scopes 3 were reviewed to determine whether an existing methodology could be reasonably revised to meet the objective of this proposed methodology. Eight methodologies were identified and are set out in Table 1 below. None were found to meet the objective of the proposed methodology.

Table 1: Similar Methodologies

Methodology	Title	GHG Program	Comments
VM0018	Energy efficiency and solid waste diversion activities within a sustainable community	VCS	This methodology provides a procedure to determine the net CO_2, N_2O and CH_4 emissions reductions associated with grouped projects that focus on energy efficiency and solid waste diversion activities for an assortment of facilities within a set territory.
[under development]	Methodology for the avoidance of greenhouse gas emissions through composting of food waste using insects	VCS	The methodology applies to food waste that is diverted from a landfill. The proposed methodology demonstrates the accounting procedure for the reduction in methane emissions from landfills by diverting food waste to a composting facility that uses compositing by an insect-based process to produce a usable compost for other applications such as fertilizer for local gardens and landscaping. Composting using an insect-based process is more efficient than traditional composting processes using windrows. The insect-based process takes less time to convert food waste to compost, using less area for the process, and can be operated indoors on a year-round basis.
AM0083	Avoidance of landfill gas emissions by in-situ aeration of landfills – version 1.0.1	CDM	This methodology comprises measures to avoid the emissions of methane to the atmosphere from biomass or other organic matter that would have otherwise been left to decay anaerobically in a landfill. In the project activity, ambient air is sucked into the landfilled waste.

			Limited to sites with waste depth lower than 10m.
AMS-III.AO	Methane recovery through controlled anaerobic digestion – Version 1.0	CDM	This methodology comprises measures to avoid the emissions of methane to the atmosphere from biomass or other organic matter that would have otherwise been left to decay anaerobically in a solid waste disposal site (SWDS), or in an animal waste management system (AWMS), or in a wastewater treatment system (WWTS). In the project activity, controlled biological treatment of biomass or other organic matters is introduced through anaerobic digestion in closed reactors equipped with biogas recovery and combustion/flaring system
AMS-III.F	Avoidance of methane emissions through composting	CDM	This methodology comprises measures to avoid the emissions of methane to the atmosphere from biomass or other organic matter that would have otherwise been left to decay anaerobically in a solid waste disposal site (SWDS), or in an animal waste management system (AWMS), or in a wastewater treatment system (WWTS). In the project activity, controlled aerobic treatment by composting of biomass is introduced.
AMS-III.G	Landfill methane recovery – version 10.0	CDM	This methodology comprises measures to avoid methane emissions through capture and combustion from landfills used for disposal of residues from municipal, industrial and other solid wastes containing biodegradable organic matter.
-	Organic Waste Composting Project Protocol - Version 1.1	CAR	The Reserve Organic Waste Composting Project Protocol provides guidance to account for, report, and verify GHG emission reductions associated with the diversion of eligible organic wastes away from anaerobic landfill disposal systems and to composting operations where the material degrades in a controlled aerobic process.
-	U.S. Landfill project protocol - Version 5.0	CAR	The installation of a system for capturing and destroying methane gas emitted from a landfill. The

			installation must exceed any regulatory requirement. Expansion of an existing project may be eligible as a new project as long as the gas cannot migrate between projects. The protocol accepts a wide range of technologies, including: (i) Methane destruction onsite (enclosed flare, open flare, electricity generation, thermal energy production), (ii) Methane transported offsite for destruction (direct-use or pipeline injection), (iii) Methane used as vehicle fuel (onsite or offsite).

CONTENTS

1 SOURCES

This methodology is based on the following methodologies:

- The Food Loss and Waste Accounting Standard (FLW Standard) (FLW Protocol, 2016)
- The GHG Protocol for Project Accounting (GHG Protocol, 2005)

The following have also informed the development of the methodology:

- Connecting Food Loss and Waste to Greenhouse Gas Emissions: Guidance for Companies (FLW Protocol, 2021)
- VM0042 Methodology for improved agricultural land management v1.0
- Methodology for the avoidance of GHG emissions through composting food waste using insects (pending approval)

This methodology uses the latest versions of the following tools from EPA and CDM:

- GHG emission factors hub (EPA, 2021)
- Emissions from solid waste disposal sites, CDM methodological tool v8.0

2 SUMMARY DESCRIPTION OF THE METHODOLOGY

The methodology applies to project activities which reduce the amount of food that would otherwise have been discarded, therefore leaving the human food chain. Project activities may prevent this loss or waste of food products at different stages of the food chain, e.g., at the farm level, food processing facility, retailer, foodservice/hospitality, or residential.

The methodology provides procedures to quantify the net greenhouse gas (GHG) emission reductions from keeping food (edible and/or inedible parts) in the human food chain. This current methodology version includes downstream emission reductions from diverting food away from a FLW destination (see section 3 Definitions). For other purposes (e.g., developing a corporate GHG inventory, general communication about the GHG emissions associated with food loss and waste), entities may reference *Connecting Food Loss and Waste to Greenhouse Gas Emissions: Guidance for Companies* (FLW Protocol, 2021).

The baseline scenario assumes the continuation of pre-project food diversion practices (i.e., sending food to an FLW destination). This methodology is applicable in situations where the baseline scenario for the FLW destination has no valorization such as use as soil amendments or energy recovery.

Additionality is demonstrated by the adoption, at the project start date, of one or more changes in pre-existing food diversion practices. A practice change constitutes adoption of a new practice (e.g., adoption of one or more of the practices that meets the applicability conditions, which may be among the illustrative "Types of Project Activities that Recover Food" listed in Appendix 2).

Table 1: Additionality and Crediting Baseline Methods

Additionality and Crediting Method	
Additionality	Project Method
Crediting Baseline	Project Method

3 DEFINITIONS

Biogenic CO_2
CO_2 emissions deriving from the respiration of organic matter by bacteria (biological processes) or its oxidation through physico-chemical processes (e.g., combustion or pyrolysis). Fast-cycling biogenic CO_2 emissions are considered climate neutral[1].

Food
This methodology uses the term "food" to refer broadly to all parts of plants, fungi, and animals —whether processed, semi-processed, or raw— that could be eventually eaten by humans[2].

Food Loss and Waste (FLW)
For this methodology specifically, "food loss and waste" and the acronym FLW refer to food (and any associated inedible parts) that goes to any FLW destination.[3]

FLW Destination
Refers to where food goes when removed from the human food supply chain (see Annex 1 for possible FLW destination options and details on each of them) (FLW Standard)

Inedible Parts

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[1] Biogenic CO_2 emissions originating from long-term carbon (C) stocks like soil C pools or forests add to the CO_2 concentration in the atmosphere and are considered as relevant to climate change

[2] For simplicity of expression, the definition of "food" for this methodology is broader than what is provided in the *FLW Standard*, which differentiates "food" (i.e., the edible parts intended for human consumption in a particular context) from its associated "inedible parts." For further details see definition of "Inedible parts" below.

[3] While there has been consensus emerging around a definition of FLW for the purpose of the UN SDG 12.3 target (i.e., excluding animal feed, and bio-based materials/biochemical processing destinations: see Champions 12.3's *Guidance on Interpreting SDG 12.3*), this is not universal. The abbreviation "FLW" is used in this methodology broadly as shorthand for "food loss and waste" but without the intention of invoking the definition ascribed to it in other programs.

Components associated with a food that, in a particular food supply chain, are not intended to be consumed by humans. Examples of inedible parts associated with food could include bones, rinds, and pits/stones[4] (FLW Standard).

Recovered Food
Food that has been kept in the human food chain because of the project activity; includes activities that focus on “prevention” (stopping food from being discarded in the first place) as well as “rescue” (redistributing to people food at risk of being discarded).

4 APPLICABILITY CONDITIONS

The methodology applies to project activities which reduce the amount of food that would otherwise have been discarded, therefore leaving the human food chain. Project activities may prevent this loss or waste of food products at different stages of the food chain, e.g., at the farm level, food processing facility, retailer, foodservice/hospitality, or residential.

The methodology is applicable under the following conditions:

1. The project activity must reduce the amount of food discarded compared to the baseline scenario. This may be demonstrated by evidence that, in the absence of the project, food would have been discarded and not consumed by humans.

2. A project activity that shifts food from one FLW destination to another destination (e.g., from landfill to composting) does not reduce the amount of food leaving the human food chain and thereby would not qualify to use this methodology. This focus on “food waste avoidance” is in line with the priority of other FLW reduction targets and programs such as the U.S. EPA’s Food Recovery Hierarchy and the United Nation’s SDG 12.3.

3. Project activities must introduce or implement one or more changes that reduce the amount of food discarded at any stage of the food’s life cycle, including farms and agricultural cooperatives; retailers and warehouses; restaurants, canteens, food vendors and other business-to-consumer and food stakeholders directly selling or serving food to end-users; and private households. Appendix 2 includes examples of the types of projects that reduce the amount of food discarded.

4. Project proponents can sufficiently quantify the emissions of the baseline scenario(s). This will require information on the following:
    - The characteristics of the treatment technology at the FLW destination where food would otherwise have gone in the baseline scenario can be quantified (e.g., landfill with flaring) to estimate baseline emissions from accepted default factors (e.g., available through regulatory data sources).
    - The transport distances within the baseline scenario (e.g., from the facility where food is discarded to the FLW destination) should be known or estimated.

[4] What is considered inedible varies among users (e.g., chicken feet are consumed in some food value chains but not others), changes over time, and is influenced by a range of variables including culture, socio-economic factors, availability, price, technological advances, international trade, and geography. In some sectors, inedible parts may also be referred to as by-products, or co-products.

- The project activity must be able to provide sufficient data on the mass of the food that would have been sent to an FLW destination in the baseline scenario, as well as its characteristics. The following data considerations should be taken into account:
  - At a minimum, the food should be classified at a product category level (e.g., meat). Where possible, classifying food at an ingredient level (e.g., beef) will enable the use of more accurate emission factors. This data needs to be specific to the project boundary and related to the activities covered.
  - Due to the variability in what is considered “inedible”, project proponents are *not* required to distinguish between edible or inedible parts of food.
  - The data may be based on any quantification method but should strive to minimize the degree of uncertainty (see guidance in Chapter 9 of the *FLW Standard*). The data may be from direct measurements, inferred from surveys, or indirectly calculated from existing food records (e.g., food purchased minus food served) (see the *FLW Standard* for additional guidance on possible quantification methods and the tradeoffs). In most situations, a representative sampling with direct measurements will result in a quantification of FLW that is more accurate than an estimate based on an indirect calculation; and both are typically - although not always - more accurate than FLW estimated from surveys.
  - Credible evidence such as contractual agreements, or waste management records can be provided to show that the food recovered by the project activity was previously sent to the FLW destinations used for the baseline scenario.
  - Credible evidence such as contractual agreements, receipts of sale of food, and waste management records can be provided to show that the food was retained for sale (or use) and not sent to any FLW destination.

5. Project proponents must provide data to estimate the proportion of food that has been effectively consumed due to the project activity and/or eventually discarded by the implemented project activities (i.e., to quantify the leakage). If no data are available, conservative default factors must be applied to adjust for the risk of leakage.

There may be minimal GHG savings possible in baseline scenarios where the FLW is valorized by the facility that receives it (e.g., is converted into a soil amendment, produces biomethane). In order to address the possible impact on an FLW destination facility from reducing the amount of food available as a feedstock, conservative leakage factors must be used.

5 PROJECT BOUNDARY

The spatial extent of the project boundary encompasses the region(s) or state(s) where food ends up (the FLW destination) under the baseline scenario, as well as the region(s) or state(s) where the recovered food is used or consumed as a result of the project activities (if different from that of the baseline scenario).

a. <u>Baseline emission sources</u>

The main baseline emissions accounted for under this methodology are associated with the treatment of food in the FLW destination. Optionally, emissions from transport activities can be accounted for if required evidence and data exist.

b. Project emission sources

GHG emissions from food transport and processing (e.g., additional food processing to convert the food recovered into new food products, or further transportation activities, like home delivery), must be included when applicable.[5] An illustrative diagram is presented in Figure 1.

Activities excluded from the project boundary are those that would continue to occur as part of typical food storage, handling, cooking and consumption, such as refrigeration or freezing, cooking, digestion of food and treatment of human excreta, and discarding food (which is already covered by the leakage factor).

Note: A significant amount of GHG emissions is embodied in the production of food. Using and consuming a higher proportion of available food would therefore, in aggregate, generate reductions in production-related GHG emissions. However, since GHG emissions associated with food supply chain emissions are difficult to prove as having taken place, this current methodology version only covers downstream emissions.

[5] This is in line with the *GHG Protocol for Project Accounting* guidance for secondary effects. GHG Protocol for Project Accounting Section 2.6: "A project activity's total GHG reductions are quantified as the sum of its associated primary effect(s) and any significant secondary effects (which may involve decreases or countervailing increases in GHG emissions)."

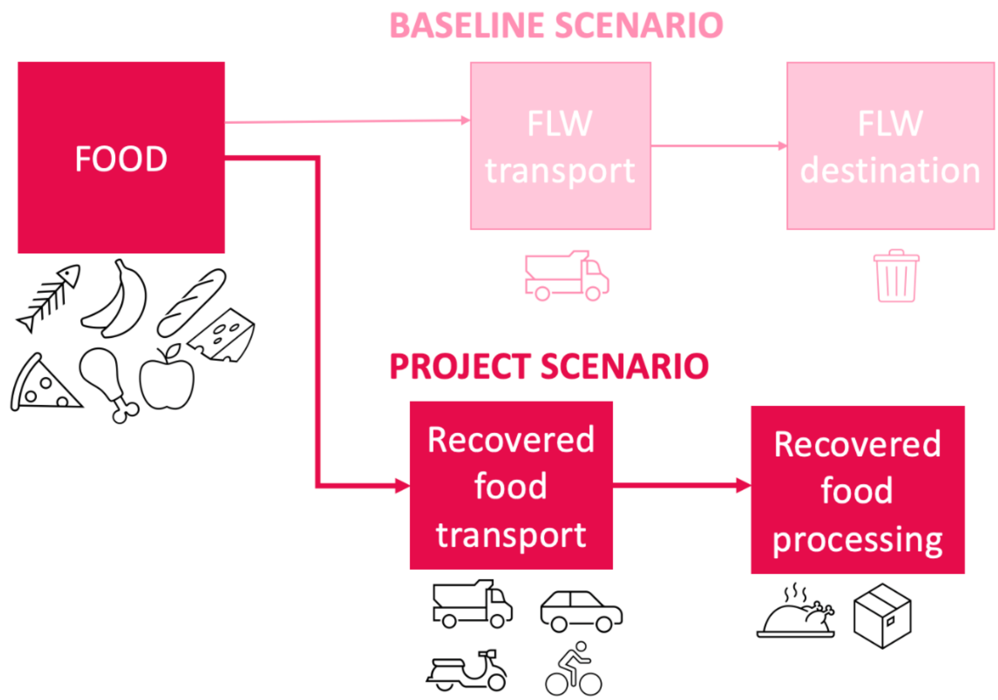

Figure 1. Schematic block diagram of the stages included inside the Project Boundary. Icons are provided for easy visualization and are not restrictive.

The greenhouse gases included in or excluded from the project boundary are shown in Table 2 below.

Table 2: GHG Sources Included or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	FLW transport	CO_2	Optional	Not a major emission source and excluding it from the baseline is conservative.
		CH_4	Optional	Not a major emission source and excluding it from the baseline is conservative.
		N_2O	Optional	Not a major emission source and excluding it from the baseline is conservative.
	Food decomposition	CO_2	No	Biogenic CO_2 emissions from food decay are assumed to be climate-neutral and are therefore excluded.
		CH_4	Yes	Biogenic CH_4 emissions are a major source of emissions in the baseline scenario.

		N_2O	Yes	N_2O emissions may arise from landfill, combustion, and digestate application.
Project	Recovered food transport	CO_2	Yes	CO_2 emitted from the combustion of fossil fuels to transport recovered food must be included.
		CH_4	No	De minimis, therefore excluded.
		N_2O	No	De minimis, therefore excluded.
	Recovered food processing (electricity consumption)	CO_2	Yes	CO_2 may be emitted from electricity generation during processing of recovered food.
		CH_4	No	De minimis, therefore excluded.
		N_2O	No	De minimis, therefore excluded.
	Recovered food processing (fossil fuel consumption)	CO_2	Yes	CO_2 may be emitted from combustion of fossil fuels during processing of recovered food.
		CH_4	No	De minimis, therefore excluded.
		N_2O	No	De minimis, therefore excluded.

6 BASELINE SCENARIO

The baseline scenario is the situation where the food is not ultimately consumed by people and is sent to any FLW destination. Baseline emissions are the GHG emissions related to the diversion of food in pre-project conditions, and which have been avoided by the project activity. An illustrative diagram is presented in Figure 2.

The time period considered when calculating the food diverted from a FLW destination and the related GHG emissions is one calendar year (365 days). In the absence of sufficient data for a year period, or in case of an anomalous year (e.g., because of serious disruptions due to a natural disaster or a pandemic like COVID), a 3-year average may be considered.

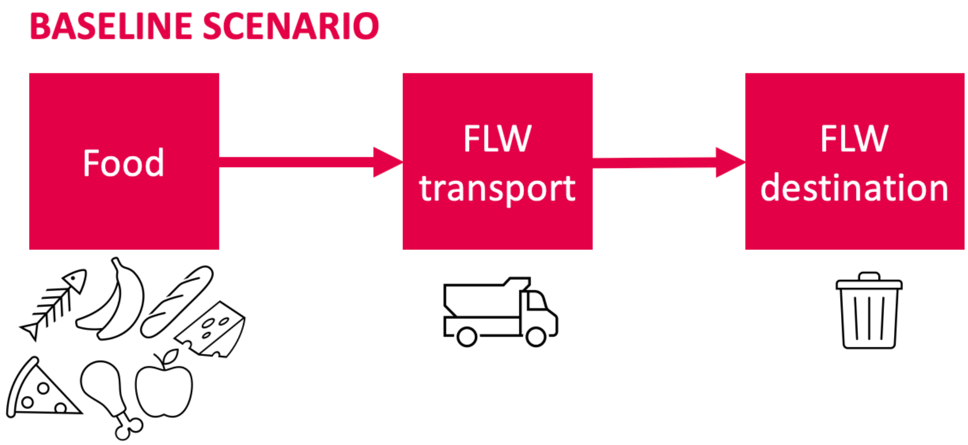

Figure 2. Schematic block diagram of the stages included in Baseline scenario.

7 ADDITIONALITY

This methodology uses a project method for the demonstration of additionality. The project proponent shall apply the following steps:

Step 1: Demonstrate regulatory surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Methodology Requirements*.

Step 2: Identify barriers that would prevent the implementation of a practice that keeps food from leaving the human supply chain

The project proponent must determine whether there are barriers (e.g., investment, institutional, and cultural and social barriers) to the proposed activity's adoption. The identified barriers are only sufficient grounds for demonstrating additionality if they prevent potential project proponent(s) from carrying out the proposed project activity if it was not expected to be registered as a VCS project.

The project proponent must document and describe the barriers to implementation of a practice that keeps food in the human supply chain. Such barriers may include, the following, among others:

Investment barriers:

- Similar activities have only been implemented with grants or other non-commercial finance terms in the region;
- Lower cost to discard food compared to the cost of keeping in the human supply chain.

Institutional barriers:

- Lack of skilled and/or properly trained labor familiar with FLW tracking and monitoring;
- Disjointed markets, transport and storage;
- Overly strict quality standards for perishable items;
- Inaccurate ordering and forecast demand;
- Expiry dates on food items that do not accurately reflect edibility;
- Lack of communication and cooperation amongst actors in the supply chain.

Cultural and/or social barriers:

- Lack of motivating incentives to change practices;
- Lack of visibility of the issue;
- High aesthetic standards for produce and a consumer tendency to not purchase suboptimal foods;
- Activity is the "first of its kind": No activity of this type is currently operational in the host country or region.

The project proponent must provide documented evidence that demonstrates the existence of the identified barriers. Anecdotal evidence may be included but alone is not sufficient proof of barriers. The types of evidence may include:

- Peer-reviewed and/or published studies;
- Relevant studies or surveys undertaken by universities, research institutions, NGOs, companies, bilateral/multilateral institutions; and/or
- Relevant statistical data from national or international statistics.

Step 3: Demonstrate that the adoption of the proposed project activity (or activities) is not common practice

The above test shall be complemented with an analysis of the extent to which the proposed activity has already been adopted in the relevant sector and region. The project proponent must determine whether the proposed project activity or scope of activities[6] are common practice in each region included within the project spatial boundary. Common practice is defined as greater than 20% adoption rate[7] in the applicable geographic area.

Evidence must be provided in the form of publicly available information contained in:

- Peer-reviewed scientific literature;
- Independent research data; and/or
- Reports or assessments compiled by industry associations.

[6] This refers to all activities implemented across an aggregated project.

[7] Based on the latest version of the CDM *Methodological tool: Common practice.*

The highest-quality available evidence source appropriate to the project must be used. Evidence at the 2nd order jurisdictional level (i.e., state or province) where the project is being developed is preferred. If supporting evidence is not available at this level, aggregated data at a country or regional level may be used, with justification.

A project proponent may include project instances where more than one activity to keep food from leaving the human supply chain will be implemented at the same location[8]. When evidence on adoption rates for the combined activities does not exist, the project proponent may multiply the adoption rates of the individual activities to estimate the combined, or “stacked”, activity adoption rate.

For example, Activity A to reduce FLW has an adoption rate of 20% and Activity B to reduce FLW has an adoption rate of 15%; by combining, or stacking, these two activities, the adoption rate would be 3% (i.e., 20% x 15%).

If the above steps are satisfied, then the proposed project activity is additional.

For future revisions, developing a standardized method will be considered to ensure additionality of project activities.

8 QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

The steps for calculation of the baseline emissions are as follows:

1. Determine the mass of the food that without adoption of the project activity would have been going to an FLW destination.
    - The data may be based on any quantification method but should strive to minimize the degree of uncertainty (see guidance in Chapter 9 of the *FLW Standard*). The data may be from direct measurements, inferred from surveys, or indirectly calculated from existing food records (e.g., food purchased minus food served) (see the *FLW Standard* for additional guidance on possible quantification methods and the tradeoffs).
    - In most situations, a representative sampling with direct measurements will result in a quantification of FLW that is more accurate than an estimate based on an indirect calculation; and both are typically - although not always - more accurate than FLW estimated from surveys.

[8] For example, a project may include both enhanced demand planning and improved package design in a retail location.

2. Characterize the food diverted out of the FLW destination by type (as adjustments should be made for products based on their dry matter content).
3. Apply GHG emission factors to characterize the Baseline Emissions for the relevant destination(s).
   - Option 1 is to use default emission factors if more detailed information is *not* available.
   - Option 2 is to use more detailed information specific to the particular food type and/or FLW destination from which the food is being diverted.
4. Follow guidance to derive and apply a relevant leakage factor.
5. Calculate baseline emissions.

An emission factor is an aggregated GHG emission value per FLW quantity with the metric of kilograms of carbon dioxide equivalent (kg CO_2e) per kilogram of food (kg food).

Option 1

This option uses default emission factors for the calculation of projects world-wide. A set of default emission factors for four FLW destinations are presented in **Table 3**, and have been adapted from the *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM): Organic Materials Chapters (November 2020)* (U.S. Environmental Protection Agency (EPA), 2020)[9]. These emission factors include the collection and transportation of food to the destination facility (e.g., transport to landfill), equipment use as relevant, and the facility activities (e.g., landfill gas) and exclude any avoided emissions from co-product offsets (e.g., most notably, energy production). Despite being from a U.S. source, these emission factors are globally representative for these four FLW destinations since they are technology-based —rather than geography-dependent. Project proponents should use country-specific emission factors where and if available.

As seen in **Table 3**, the dry matter (DM) content (or alternatively, the water content) across the types of food can vary greatly (e.g., 100% DM on oils to 5% DM on some vegetables). Around 50% of the mass of the DM in food is carbon, which when digested, burned, or in some way respired or transformed, is released to the atmosphere in the form of (biogenic) carbon dioxide or methane. In anaerobic conditions, most of the carbon in the organic matter becomes CH_4, hence the emission factors from landfill for “dry” food products are six times higher than “wet” food products in **Table 3**. The DM content of the food discarded is thus a critical parameter that determines the amount of GHG (methane in particular) emissions from landfills. This parameter also influences the biogas production in anaerobic digestors, but in those facilities the biogas is typically collected for further use. It is assumed that the fugitive CH_4 emissions are a constant parameter for such reactors (see **Table 3**). This parameter does not affect the GHG emissions from combustion and composting either (see **Table 3**), because in these cases (aerobic treatment processes) the carbon content in the food is not converted into CH_4 but respired or oxidized into biogenic CO_2. As stated in **Table 2**, biogenic CO_2 emissions from food are

9 https://www.epa.gov/sites/default/files/2020-12/documents/warm_organic_materials_v15_10-29-2020.pdf

considered climate neutral in this methodology, therefore the emission factors depicted in **Table 3** are the same for all the food category groups for these types of treatment technologies.

Table 3 is divided into three main groups of food categories according to their DM content: *wet, semi-wet* and *dry*. Only the landfill emission factors have been adjusted (from the EPA's average default factors of 0.63 and 1.62 MT CO_2e/wet short ton, for landfills with and without flaring, respectively – see Exhibit 1-47 EPA 2020[9]) to reflect the average DM content for these three groups and the related methane production potential, i.e., the known carbon available for the methanogenesis in anaerobic conditions (see Appendix 3 for calculation details of the emission factors presented in **Table 3**). If the food recovered is composed of mixed ingredients from multiple food categories, and project proponents cannot calculate or estimate the composition mix, they should assume then the emission factors from the "wet" food group (although food waste has a 27% DM content on average in the US – see Exhibit 1-48, EPA 2020[9] – a conservative factor is suggested here to be aligned with the VCS accounting principles, see *VCS Standard, v4.0*). If the food recovered is composed of mixed ingredients from multiple food categories, and project proponents can calculate or estimate the DM content of the composition mix, they can derive the specific emission factor from the recovered food-mix following the calculation details presented in Appendix 3 and illustrated in **Table 6**.

Table 3: GHG emission factors (kg CO_2e/kg food) for Option 1 calculation of baseline emissions. Wet food-mixes include fruits, vegetables, tubers or liquid dairy (yoghurt, milk); semi-wet food-mixes include cheese, fish, eggs and meat; dry food-mixes include cereals, pulses, oils and fats.

	Landfill[α] (no flaring /with flaring)	Combustion[b]	Composting[c]	Anaerobic digestion[d] (wet /dry)
Wet food-mix (DM < 25%)	0.93 / 0.36	0.044	0.132	0.121 / 0.154
Semi-wet food-mix (25% < DM < 50%)	2.64 / 1.03	0.044	0.132	0.121 / 0.154
Dry food-mix (DM > 50%)	6.16 / 2.39	0.044	0.132	0.121 / 0.154
Collection & Transport	0.022 / 0.022	0.011	0.033	0.099 / 0.099

[a] Includes CH_4 emissions from the anaerobic degradation of food in a conventional landfill (without landfill gas flaring nor recovery). Adapted emission factor from Exhibit 1-47 EPA 2020[9]. Carbon storage is excluded.
[b] Includes non-biogenic CO_2 and N_2O emissions from the combustion process. Adapted emission factors from Exhibit 1-47 EPA 2020[9]). Excludes avoided emissions from co-product offsets.
[c] Includes fugitive CH_4 and N_2O emissions from composting. Adapted emission factors from Exhibit 1-47 EPA 2020[9]). Excludes avoided emissions from co-product offsets.
[d] Includes fugitive CH_4 and N_2O emissions from the digester and from the digestate application on

land. Collection & Transport emissions include GHG emissions from the collection and transport of waste to the facility, a secondary transport of digestate to land and the emissions from its spreading on land (adapted emission factor from Exhibit 1-47 EPA 2020[9]). Excludes avoided emissions from co-product offsets.

Baseline emissions can be calculated with Equation 1:

$$BE_y = M_{FLW,y} * EF_{i,y} \quad (1)$$

Where:

BE_y	=Baseline emissions in year y (tCO_2e)
$M_{FLW,y}$	=Mass of recovered food by the project activities in year y (e.g., tonnes)
$EF_{i,y}$	=Emission factor of FLW destination treatment technology i, plus the related collection/transportation emission factor, for year y (both found in **Table 3**)

Option 2

This option can be used if more detailed information is available for the FLW destination in the baseline scenario. This may include calculating the FLW destination-specific emissions using site-specific data from the identified facility. Similarly, this may include calculating transport emissions for the FLW collection by applying the relevant emission factors (e.g., according to transport mode and vehicle). Equation 2 can be followed:

$$BE_y = BE_{CH4\_y} + BE_{Trans\_y} \quad (2)$$

Where;

BE_{CH4_y}	=Baseline CH_4 emissions from food decomposition in year y (see Equation 3)
BE_{Trans_y}	=Baseline GHG emissions from collection and transport of FLW to destination facility in year y (see Equation 4)

Equation 3 is based on the simplified approach for monitoring reduced organic waste emissions as shown in the CDM tool *Emissions from solid waste disposal sites,* version 8.0 (Equation 15 in Appendix)[10].

$$BE_{CH4\_y} = \Phi_y * (1 - f_y) * GWP_{CH4} * \sum_{y=1}^{20} Default_{org,y} * M_{FLW,y} \quad (3)$$

Where:

Φ_y =Default value for model correction factor to account for uncertainties → 0.75

f_y =Fraction of CH_4 captured at the destination (waste treatment) facility, flared, combusted or recovered in year y (nil value for conventional landfills)

GWP_{CH4} =Global warming potential of methane (100 years)

[10] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-04-v8.0.pdf

$Default\_{org,y}$ =Correction factor based on climatic zone for year y (Table 2 in Appendix[10])
$M_{FLW,y}$ =Mass of recovered food by the project activities in year y (e.g., tonnes)

More precise transportation emissions if distances to destination are known (based on EF for a waste collection truck) can be calculated with Equation 4:

$$BE_{Trans\_y} = D_{,y} * M_{FLW,y} * EF_{trans.mode,\,i,\,y} \quad (4)$$

Where:

$D_{,y}$ =Distance travelled for the collection of recovered food (km) during year y
$M_{FLW,y}$ =Mass of the recovered food during year y (e.g., tonnes)
$EF_{trans.mode,\,i,\,y}$ =Emission factor of the transportation mode *i* in year y, e.g., in kg CO_2e/t-km

The emission factors per transport mode and vehicle type can be taken from the GHG emission factors hub (EPA, 2021), DEFRA[11] or CDM Tool 12[12]. To correctly calculate the transportation related emissions, the transport mode, vehicle type, and distances traveled need to be known.

8.2 Project Emissions

Project activity emissions are those related to the new project activities taking place to recover food (avoid FLW), i.e., keeping food within the human supply chain and calculated using the following Equation 5:

$$PE_y = PE_{Trans\_y} + PE_{Proc\_y} \quad (5)$$

Where:

PE_y =Project emissions in year y (tCO_2e)
PE_{Trans_y} =Project emissions from transportation to collect and deliver the recovered food in year y (tCO_2e). This factor must consider all trips for the different transportation stages (e.g., collection, distribution, delivery) required for the completion of the project activities covered in the Project Boundary (see Equation 6)
PE_{Proc_y} =Project emissions from electricity consumption or other energy and/or material use for additional processing in year y (tCO_2e), if considered additional (see Equation 7)

The emission factors per transport mode and vehicle type, as well as per fuel type (energy usage for additional processing activities) and electricity consumption (country or regional grid-mix average factors), can be taken from the GHG emission factors hub (EPA, 2021), DEFRA[13] or CDM

[11] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020

[12] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-12-v1.1.0.pdf

[13] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2020

Tool 12[14]. To correctly calculate the transportation related emissions, the transport mode, vehicle type and distances traveled need to be known.

Generally, emissions are estimated by multiplying an activity with a relevant emission factor for that activity. It follows that, the calculation of the transport emissions can be calculated using the following Equation 6:

$$PE_{Trans\_y} = D_{,y} * M_{\_FLW,y} * EF_{\_trans.mode,\ i,\ y} \qquad (6)$$

Where:

$D_{,y}$	=Distance travelled for the collection of recovered food (km) during year y
$M_{FLW,y}$	=Mass of the recovered food during year y (e.g., in tonnes)
$EF_{trans.mode,\ i,\ y}$	=Emission factor of transportation mode *i* in year y, e.g., in kg CO_2e/tonne-km

The processing emissions can be calculated using the following equation

$$PE_{Process\_y} = Elec\_cons_{,y} \times EF\_electricity + FC_{i,y} \times EF\_fuel + OE_{,y} \qquad (7)$$

Where:

$Elec\_cons_{,y}$	=Electricity consumption (e.g. in kWh) in year y
EF_elec	=Emission factor of the region- or state-specific grid-mix (e.g., in kg CO_2e/kWh)
$FC_{,i,y}$	=Consumption of fuel *i* in year y, e.g. in gallons
$EF\_fuel_{\ ,y}$	=Emission factor for fuel *i* in year y, e.g. in kg CO_2e/gallon
$OE_{,y}$	=Other emissions from the consumption of additional materials needed for the processing and delivering the new food product, e.g. packaging

Project proponents need to ensure unit consistency during calculations, making sure values are mathematically and physically correct (e.g., the units are adjusted if needed to be converted), as these are a frequent source of errors in GHG quantifications.

8.3 Leakage

A project that avoids FLW at a certain point in the supply chain may still result in FLW later in the supply chain; this is referred to as "eventual discard" for the purpose of this methodology. The risk of leakage from eventual discard will depend on the type of FLW that the project activities address, where in the food chain the project activities intervene, the type of activities themselves, and the consumer behavior related to the project. For example, the risk of leakage in a project that addresses food recovery by consumers (e.g., an app where consumers make a conscious choice to recover food) likely has lower risk of leakage than a project that keeps food in the human chain at the farm or retailer level, but still depends on someone to eat, or immediately process, or deep freeze (and not discard), the recovered food. As another example, a project that recovers food and processes it to produce a new product (e.g., fruit that does not meet retail quality standards is collected and processed as jam), may also extend considerably the shelf life of that food, thereby reducing the risk of leakage.

Project proponents need to present evidence that the food recovered in the project is unlikely to be eventually disposed of downstream. Such evidence may be through peer-reviewed literature, expert testimony, measurements, surveys, or monitoring of key parameters. The applied **leakage factor should reflect the probability** that the recovered food is discarded and can be expressed in

[14] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-12-v1.1.0.pdf

percentage, i.e., as a leakage factor (LF) of food that would eventually end up in an FLW destination.

The leakage emissions (LE) can be calculated using methods analogous to those described in the Project Emissions scenario (i.e., an activity multiplied with the relevant emission factor for that activity). In many cases collecting data to calculate the leakage with a great degree of accuracy might not be feasible, or be cost prohibitive, and thereby **default leakage factors can be applied.**

In **Table 4**, default leakage factors for the U.S. are provided according to food types and the point in the supply chain the project activity is implemented. These are based on the average food loss statistics reported by USDA[15] (values for year 2019), and while useful, as proxies also contain several assumptions. Similarly, in **Table 5** default leakage factors for Europe are provided based on the results reported on a recent study that covered the former 28 countries of the EU (Caldeira et al., 2019), i.e. including the United Kingdom. The leakage factors for the EU have higher granularity (thus precision) than those presented for the U.S., as in Table 5 the food waste was estimated and reported for every stage of the food supply chain. Reported leakage factors may be redundant for some food types, as they may be presented as single food ingredients (e.g. beverage milk), inside a broader food group (e.g. dairy products) and inside one of the three high-level food categories of this methodology (e.g. wet). Project proponents should first use the most specific leakage factors that better represent the recovered food items, making a weighted-average of the food-mix if more than one food type is being recovered. Leakage factors of broader categories shall be used when no specific data on the composition of the recovered food-mix is available. To apply leakage factors for other geographies, project proponents are recommended to use country-specific data from national statistics or reports on FLW. Project proponents are suggested to use FAO's[16] FLW database if national data are missing. When country-specific data is not available for a certain food group and food supply chain stage in FAO's database, project proponents are suggested to use region-wise statistics from same source, e.g. if primary production loss for fruits and vegetables is not available for Afghanistan, then use the FWL average of the same food group and supply chain stage for West and Central Asia instead.

Table 4. Default leakage factors for recovered food per food type to apply in US projects, shown at different levels of aggregation (USDA). Wet food-mix includes fruits, vegetables, tubers, liquid dairy (yoghurt, milk); semi-wet food-mix includes cheese and meat; dry food-mix includes cereals, pulses and oils.

Food group categories	Primary production	Retail[a]	Final consumer[b]
Wet food-mix	16%	11%	22%
Semi-wet food-mix	14%	5%	23%
Dry food-mix	0%	15%	18%
Meat, fish, eggs	27%	5%	22%
Meat	-	4%	23%

[15] https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system/food-availability-per-capita-data-system/#Loss-Adjusted%20Food%20Availability

[16] https://www.fao.org/platform-food-loss-waste/flw-data/en/

Fish and seafood	-	8%	31%
Eggs	-	7%	21%
Dairy products	0%	11%	20%
Beverage milks	0%	12%	23%
Cheese	0%	6%	24%
Fruits	18%	12%	21%
Grains	0%	12%	20%
Nuts	0%	6%	19%
Vegetables	31%	9%	23%
Fats	0%	21%	22%
Oils	0%	21%	10%
Legumes	0%	6%	10%

[a] Losses here include retail, distribution, manufacturing, and processing.
[b] Food services are here considered as a final consumer together with residential households.

Table 5. Default leakage factors for recovered food per food type to apply in EU projects, shown at different levels of aggregation (adapted from Caldeira et al., 2019). Wet food-mix includes fruits, vegetables, tubers and dairy; semi-wet food-mix includes meat, fish and eggs; dry food-mix includes cereals, sugar beets and oil crops.

Food group categories	Primary production	Processing & manufacturing	Retail & distribution	Food services	Households
Wet food-mix	**10.5%**	**6.2%**	**1.5%**	**17.4%**	**2.8%**
Semi-wet food-mix	**1.9%**	**14.7%**	**2.3%**	**11.9%**	**3.8%**
Dry food-mix	**2.2%**	**10.5%**	**0.9%**	**5.1%**	**1.3%**
Meat	0.8%	4.7%	2.8%	11.8%	2.8%
Fish	0.0%	37.8%	2.4%	6.1%	3.7%
Dairy	3.3%	7.2%	2.6%	27.6%	3.9%
eggs	4.8%	1.6%	1.6%	17.7%	4.8%
cereals	1.5%	3.2%	2.2%	10.2%	2.8%
fruit	16.3%	9.0%	1.2%	12.7%	2.2%
vegetables	19.6%	3.8%	1.3%	17.8%	3.2%
potatoes	2.8%	4.9%	0.7%	11.4%	1.9%
sugar beets	2.6%	0.0%	0.3%	1.1%	0.3%
oil crops	2.5%	28.2%	0.3%	4.0%	0.8%

When assessing leakage, it is also important to take into account that the operating conditions of some treatment facilities may change because of the implementation of a FLW reduction project. For example, a reduction in the amount of food previously going to an anaerobic digester may result in its biomethane output being reduced, or it may require additional organic matter be imported from elsewhere to compensate for the imbalance created by reducing the amount of food available as feedstock for the digestor. A leakage factor therefore needs to be included for those facilities where a co-product or valorization of FLW already occurs. Such facilities might include:

- Landfill with biogas recovery, with heat, power or combined heat and power generation or upgrading of biogas to biomethane for further use in other applications;
- Combustion or incineration with heat, power or combined heat and power generation;
- Anaerobic digestion, with heat, power or combined heat and power generation or upgrading of biogas to biomethane for further use in other applications; and/or
- Composting, that is ultimately being used in gardening activities or applied on agricultural soils.

Project proponents must include the GHG implications of removing food from the FLW destinations and account for these as an additional leakage factor. As an example, the identified FLW destination targeted by a project may be a landfill with biogas recovery with power generation. The amount of food diverted from the landfill would reduce the amount of biogas produced in the baseline scenario and thus the produced electricity. By way of example, an average mix of FLW could have produced 2.66 kg CO_2e/kg food (see **Table 3**), or 0.11 kg CH_4/kg food. Applying a conservative landfill gas recovery efficiency of 22.3% and an electricity generation efficiency of 40% for a modern cogeneration plant (Ciuła et al., 2020), this would imply a power loss of 0.145 kWh/kg food[17]. Taking the average U.S. grid emission factor from EPA's GHG Emission Factors hub, this would result in a leakage factor for the reduced electricity production of 0.06 kg CO_2e/kg food diverted.

If a leakage factor is used (i.e., a percentage of the baseline scenario given eventual discard), the leakage emissions are calculated as follows

$$LEy = BE_y * \%LF_y \quad (8)$$

Where:

LE_y = Leakage in year y (tCO_2e)

BE_Y = Baseline emissions in year y (tCO_2e)

$\%LF_y$ = Leakage factor as a % of the baseline scenario that may eventually occur.

8.4 Net GHG Emission Reductions and Removals

The net GHG emission between the project and the baseline, including any leakage are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \quad (9)$$

[17] An energy density of methane of 55 MJ/kg is assumed.

Where:

ER_Y = Net GHG emissions reductions and removals[18] in year y (tCO_2e)

BE_Y = Baseline emissions in year y (tCO_2e)

PE_y = Project emissions in year y (tCO_2e)

LE_y = Leakage in year y (tCO_2e)

9 MONITORING

9.1 Data and Parameters Available at Validation

Where discretion exists in the selection of a value for a parameter, the principle of conservativeness must be applied (as described in Section 2.2.1 of the *VCS Standard*, v4.0).

Data / Parameter	GWP_{CH4}
Data unit	$t\ CO_2e/t\ CH_4$
Description	Global warming potential of methane
Equations	*Equation 3*
Source of data	IPCC defaults to be taken from the most recent IPCC reports
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	Unless otherwise directed by the VCS Program, VCS Standard v4.0 requires that CH_4 must be converted using the 100-year global warming potential derived from the latest IPCC Assessment Report.
Purpose of Data	Calculation of baseline and project emissions
Comments	-

9.2 Data and Parameters Monitored

[18] GHG removal (i.e.., carbon uptake and subsequent sequestration in a permanent C pool, e.g., the soil) is unlikely to be relevant in projects under this methodology as removals represent permanent removal of CO2 from the atmosphere.

Data / Parameter:	M_{FLW}
Data unit:	Tonnes (wet matter)
Description:	Mass of the recovered food
Equations	*Equations 1, 3, 4, 6*
Source of data:	Direct measurements, inferred from surveys, or indirectly calculated from existing food records
Description of measurement methods and procedures to be applied:	Since the dry matter content of the recovered food is a critical parameter for the calculation of avoided GHG emissions, project proponents should/shall strive for full characterization of the recovered food-mix in terms of composition. If the composition of the recovered food cannot be inferred from existing records, this should be derived through sampling. Once the composition of the recovered food-mix is known, standard water or dry matter content % (as those shown in Table 6) can be applied.
Frequency of monitoring/recording:	Annual records must be used as a minimum; however, food waste might strongly depend on season or period of the year, therefore a monthly or weekly registry could help identify the most important periods during the year to focus efforts on food recovery activities
QA/QC procedures to be applied:	In those project activities where the recovered food has a heterogeneous composition, i.e with diverse food ingredients from different origins and/or seasonality, food-mix compositions inferred from records need to be cross-checked with source sampling
Purpose of data:	Calculation of baseline and project emissions
Comments:	-

Data / Parameter:	f_y
Data unit:	-
Description:	fraction of CH_4 captured at the destination (waste treatment) facility, flared, combusted or recovered in year y (zero for conventional facilities)
Equations	Equation 3
Source of data:	Select the maximum value from the following: (a) contract or regulation requirements specifying the amount of methane that must be destroyed/used (if available) and (b) historic data on the amount captured
Description of measurement methods	-

and procedures to be applied:	
Frequency of monitoring/recording:	For application A: Once for the crediting period (fy = f) For application B: Annually
QA/QC procedures to be applied:	-
Purpose of data:	Calculation of project emissions
Calculation method:	-
Comments:	-

Data / Parameter:	D_y
Data unit:	Km or miles
Description:	The distance travelled for the collection of recovered food during year y
Equations	Equations 4, 6
Source of data:	Logistic logbook, trip records or indirectly calculated from location data, e.g. recovered food point and project warehouse or processing facility address
Description of measurement methods and procedures to be applied:	-
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	-
Purpose of data:	Calculation of project emissions
Calculation method:	-
Comments:	-

Data / Parameter:	$Elec\_cons_y$

Data unit:	kWh
Description:	electricity consumption in year y for processing the recovered food (if applicable)
Equations	Equation 7
Source of data:	Electricity purchase bills
Description of measurement methods and procedures to be applied:	-
Frequency of monitoring/recording:	Annual
QA/QC procedures to be applied:	-
Purpose of data:	Calculation of project emissions
Calculation method:	-
Comments:	-

Data / Parameter:	$FC_{,i,y}$
Data unit:	Liters or gallons
Description:	The consumption of fuel i in year y for processing the recovered food (if applicable)
Equations	Equation 7
Source of data:	Fuel purchase bills
Description of measurement methods and procedures to be applied:	-
Frequency of monitoring/recording:	Annual

QA/QC procedures to be applied:	-
Purpose of data:	Calculation of project emissions
Calculation method:	-
Comments:	-

9.3 Description of the Monitoring Plan

Monitored parameters are collected and recorded at the sample unit scale, and emission reductions are estimated independently for every sample unit. The main objective of monitoring is to quantify recovered food flows, distribution distances and transport modes during the project crediting period, prior to each verification, and energy and material consumption related to food processing when applicable.

Project proponents must detail the procedures for collecting and reporting all data and parameters listed in Section 9.2. The monitoring plan must contain at least the following information:

- A description of each monitoring task to be undertaken, and the technical requirements therein;
- Definition of the accounting boundary, spatially delineating any differences in the accounting boundaries and/or quantification approaches;
- Parameters to be measured, including any parameters required for the selected model (additional to those specified in this methodology);
- Data to be collected and data collection techniques and sample designs for directly- sampled parameters;
- Modeling plan, if applicable; Anticipated frequency of monitoring, including anticipated definition of "year";
- 10-year baseline re-evaluation plan, detailing source of regional (sub-national) agricultural production data and procedures to revise the baseline schedule of management activities where necessary;
- Quality assurance and quality control (QA/QC) procedures to ensure accurate data collection and screen for, and where necessary, correct anomalous values, ensure completeness, perform independent checks on analysis results, and other safeguards as appropriate;
- Data archiving procedures, including procedures for any anticipated updates to electronic file formats. All data collected as a part of monitoring process, including QA/QC data, must be archived electronically and be kept at least for two years after the end of the last project crediting period; and
- Roles, responsibilities and capacity of monitoring team and management.

10 REFERENCES

Caldeira, C., De Laurentiis, V., Corrado, S., van Holsteijn, F., & Sala, S. (2019). Quantification of food waste per product group along the food supply chain in the European Union: a mass flow analysis. *Resources, Conservation and Recycling*, *149*(June), 479–488. https://doi.org/10.1016/j.resconrec.2019.06.011

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U.S. Environmental Protection Agency (EPA). (2020). *Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model (WARM) Organic Materials Chapters* (Issue November).

APPENDIX 1: FLW DESTINATIONS

The following definitions are from the *FLW Standard* (FLW Protocol, 2016).

Animal feed: Diverting material from the food supply chain* (directly or after processing) to animals (*Excludes crops intentionally grown for bioenergy, animal feed, seed, or industrial use)

Bio-based Materials / Biochemical Processing: Converting material into industrial products. Examples include creating fibers for packaging material, creating bioplastics (e.g., polylactic acid), making "traditional" materials such as leather or feathers (e.g., for pillows), and rendering fat, oil, or grease into a raw material to make products such as soaps or cosmetics. "Biochemical processing" does not refer to anaerobic digestion or production of bioethanol through fermentation

Codigestion/anaerobic digestion: Breaking down material via bacteria in the absence of oxygen. This process generates biogas and nutrient-rich matter. Codigestion refers to the simultaneous anaerobic digestion of food loss and waste and other organic material in one digester. This destination includes fermentation (converting carbohydrates—such as glucose, fructose, and sucrose—via microbes into alcohols in the absence of oxygen to create new products)

Composting/aerobic processes: Breaking down material via bacteria in oxygen-rich environments. Composting refers to the production of organic material (via aerobic processes) that can be used as a soil amendment

Controlled combustion: Sending material to a facility that is specifically designed for combustion in a controlled manner, which may include some form of energy recovery (this may also be referred to as incineration)

Land Application: Spreading, spraying, injecting, or incorporating organic material onto or below the surface of the land to enhance soil quality

Landfill: Sending material to an area of land or an excavated site that is specifically designed and built to receive wastes

Not harvested/plowed-in: Leaving crops that were ready for harvest in the field or tilling them into the soil

Refuse/discards/litter: Abandoning material on land or disposing of it in the sea. This includes open dumps (i.e., uncovered, unlined), open burn (i.e., not in a controlled facility), the portion of harvested crops eaten by pests, and fish discards (the portion of total catch that is thrown away or slipped)

Sewer/wastewater treatment: Sending material down the sewer (with or without prior treatment), including that which may go to a facility designed to treat wastewater

Other: Sending material to a destination that is different from the 10 listed above, such as biodiesel or other biofuels. This destination should be described

APPENDIX 2: TYPES OF PROJECT ACTIVITIES THAT RECOVER FOOD (NOT EXHAUSTIVE)

Derived from *ReFED solutions combined finance and impact* Excel file

Farm level

Gleaning

Value-added processing

Donation coordination & matching, education

Imperfect & surplus produce channels

Processing & Warehouse level

Reduced warehouse handling

Intelligent routing

Intelligent packaging & improved package design

Standardized data labels

Enhanced demand planning

Manufacturing line optimization

Retailer level

Dynamic pricing

Value-added processing

First expired first out

FLW apps

Food bank donations

Residential & B2C level

Education campaigns

Lunch improvements

Smaller, flexible portions

Buffet signage

Smart fridges

APPENDIX 3: CALCULATION DETAILS OF LANDFILL EMISSION FACTORS

The proposed grouping of recovered food items in "wet", "semi-wet" and "dry" has been based on several key ingredients considered representative of all traded food. These ingredients are presented in **Table 6,** together with their relative water weight fraction, the corresponding dry matter (DM) content and the related emission factors (EF) from landfill (with and without landfill gas recovery and flaring).

The default EF presented in **Table 3** are calculated as a simple average of the ingredients composing each category; the "wet" group (DM < 25%) includes milk and yogurt, all the listed fruits and vegetables and potatoes; the "semi-wet" group (25% < DM < 50%) includes cheese and meat; the "dry" group (DM > 50%) includes all the cereals, pulses, sugars and oils/fats.

The calculated group average EF (presented in **Table 3**) are a linear extrapolation from the two US-average emission factors from landfill (1.62 and 0.63 MTCO_2e/wet short ton, for landfills without recovery and with recovery and flaring, respectively) reported in Exhibit 1-47 EPA 2020[9], taking into account that the average DM content of all the food waste is 27% (Exhibit 1-48 in same source). The resulting EF were thus adjusted to the DM content of each food ingredient and finally converted to metric tons with a 1.102 wet short ton/metric ton factor. Converted EF are then in MT CO_2e/MT food, which is an equivalent unit to the reported kg CO_2e/kg food. To illustrate the calculation with maize, its EF of 5.93 for landfill without gas recovery (see **Table 6**) is derived by multiplying 1.62 by 0.9/0.27 and further multiplied by 1.102. The factor for cereals in turn is based on an average across the 3 food ingredients in that category.

Table 6. GHG emission factors (EF) from landfilling (with and without landfill gas recovery) of a representative list of main food ingredients, based on their water and DM content. EF (in kg CO_2e/kg food) are extrapolated from the values reported in EPA 2020[9].

Food ingredients	Water weight fraction (%)*	DM content (%)*	EF for landfill without gas recovery	EF for landfill with gas recovery and flaring
CEREALS	**11%**	**89%**	**5.89**	**2.29**
maize	10%	90%	5.93	2.31
rice	12%	88%	5.85	2.27
wheat	11%	89%	5.89	2.29
DAIRY	**75%**	**25%**	**1.66**	**0.64**
cheese	50%	50%	3.31	1.29
milk	90%	10%	0.67	0.26
yogurt	85%	15%	0.99	0.38
FRUITS & VEGETABLES	**86%**	**14%**	**0.90**	**0.35**
apple	86%	14%	0.96	0.37

banana	75%	25%	1.66	0.65
carrot	88%	12%	0.77	0.30
grape	81%	19%	1.29	0.50
lettuce	95%	5%	0.33	0.13
tomato	95%	5%	0.36	0.14
MEAT	**63%**	**37%**	**2.42**	**0.94**
beef	*54%*	46%	*3.02*	*1.18*
pork	*61%*	39%	*2.58*	*1.00*
poultry	*75%*	25%	*1.66*	*0.64*
PULSES & OILSEEDS	**9%**	**91%**	**6.05**	**2.35**
soy bean	*9%*	91%	*6.05*	*2.35*
ROOTS & TUBERS	**79%**	**21%**	**1.37**	**0.53**
potato	*79%*	21%	*1.37*	*0.53*
OTHER	**0%**	**100%**	**6.61**	**2.57**
palm oil	*0%*	100%	*6.61*	*2.57*
sugar cane	*0%*	100%	*6.61*	*2.57*

*Water weight fractions and DM content are from publicly available USDA data.