California Air Resources Board

Quantification Methodology

California Department of Resources Recycling and Recovery Organics Grant Program

California Climate Investments

FINAL
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Section A. Introduction

California Climate Investments is a statewide initiative that puts billions of Cap-and-Trade dollars to work facilitating greenhouse gas (GHG) emission reductions; strengthening the economy; improving public health and the environment; and providing benefits to residents of disadvantaged communities, low-income communities, and low-income households, collectively referred to as "priority populations." Where applicable and to the extent feasible, California Climate Investments must maximize economic, environmental, and public health co-benefits to the State.

The California Air Resources Board (CARB) is responsible for providing guidance on estimating the GHG emission reductions and co-benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). This guidance includes quantification methodologies, co-benefit assessment methodologies, and benefits calculator tools. CARB develops these methodologies and tools based on the project types eligible for funding by each administering agency, as reflected in the program expenditure records available at: www.arb.ca.gov/cci-expenditurerecords.

For the California Department of Resources Recycling and Recovery (CalRecycle) Organics Grant Program (Organics), CARB staff developed this Organics Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits of each proposed project type. This methodology uses calculations to estimate GHG emission reductions from avoided landfill methane emissions and GHG emissions associated with the implementation of Organics Grant projects.

The Organics Benefits Calculator Tool automates methods described in this document, provides a link to a step-by-step user guide with project examples, and outlines documentation requirements. Projects will report the total project GHG emission reductions and co-benefits estimated using the Organics Benefits Calculator Tool as well as the total project GHG emission reductions per dollar of GGRF funds requested. The Organics Benefits Calculator Tool is available for download at: http://www.arb.ca.gov/cci-resources.

Using many of the same inputs required to estimate GHG emission reductions, the Organics Benefits Calculator Tool estimates the following co-benefits and key variables from Organics projects select criteria and toxic air pollutants (in pounds (lbs))—including nitrogen oxide (NO_x), reactive organic gases (ROG), diesel particulate matter (diesel PM), and fine particulate matter less than 2.5 micrometers ($PM_{2.5}$); edible food rescued and donated (in tons); material diverted from landfill (in tons); reduction of vehicle miles traveled (in miles); fossil fuel use reductions (in gallons and kWh); energy and fuel cost savings (in dollars); renewable fuel generation (in gallons and scf); renewable energy generation (in kWh); compost production (in dry tons); and compost application area (in acres). Key variables are project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit (e.g., renewable fuel generation, compost production, etc.). Additional co-benefits for which CARB assessment methodologies were not incorporated into the Organics Benefits Calculator Tool may also be applicable to the project. Applicants should consult the Organics Grant Program guidelines, solicitation materials, and agreements to ensure they are meeting Organics Grant Program requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

Methodology Development

CARB and CalRecycle developed this Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability.[1] CARB and CalRecycle developed this Organics Quantification Methodology to be used to estimate the outcomes of proposed projects, inform project selection, and track results of funded projects. The implementing principles ensure that the methodology would:

- Apply at the project-level;
- Provide uniform methods to be applied statewide, and be accessible by all applicants;
- Use existing methods;
- Use project-level data, where available and appropriate; and
- Result in GHG emission reduction estimates that are conservative and supported by empirical literature.

CARB assessed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the Organics Grant project types. CARB also consulted with CalRecycle to determine project-level inputs available. The methods were developed to provide estimates that are as accurate as possible with data readily available at the project level.

CARB released the Draft Organics Quantification Methodology and Draft Organics Benefits Calculator Tool for public comment in July 2019. This Final Organics Quantification Methodology and accompanying Organics Benefits Calculator Tool have been updated to address public comments, where appropriate, and for consistency with updates to the Organics Grant Program Guidelines.

In addition, the University of California, Berkeley, in collaboration with CARB, developed assessment methodologies for a variety of co-benefits such as providing cost savings, lessening the impacts and effects of climate change, and strengthening community engagement. Co-benefit assessment methodologies are posted at: www.arb.ca.gov/cci-cobenefits.

[1] California Air Resources Board. www.arb.ca.gov/cci-fundingguidelines

Tools

The Organics Benefits Calculator Tool relies on project-specific outputs from the following tools:

Compost Emission Reduction Factor (CERF)
The 2017 final draft *Method for Estimating Greenhouse Gas Emission Reductions from Diversion of Organic Waste from Landfills to Compost Facilities*[i] document (CERF) calculates the net avoided emissions from diverting organic waste from landfills to composting facilities. It includes California-specific emission factors for avoided landfill emissions attributable to the diversion of organic waste (i.e., food scraps, yard trimmings, branches, leaves, grass, and organic municipal waste). These emission reduction factors are used consistently across all organic waste diversion projects included in the Quantification Methodology and Benefits Calculator Tool. The methods used, assumptions, and results are detailed in the draft CERF.

Food Rescue Emission Reduction Factor
The GHG emission reduction factor for food rescue is calculated based on lifecycle GHG emissions from avoidable U.S. food waste as reported in *The Climate Change and Economic Impacts of Food Waste in the United States* (2012)[ii] and published in the International Journal on Food System Dynamics. These factors are also used by institutions such as the U.S. Department of Agriculture (USDA) and Organisation for Economic Co-operation and Development (OECD) to estimate emissions from food waste.

Refrigeration and Freezer Equipment Emissions
The emissions associated with refrigerant leakage from equipment used for food rescue was developed using the inventory from CARB's Refrigerant Management Program as described in *California's High Global Warming Potential Gases Emission Inventory (2015)* [iii]. The emissions associated with energy consumption of the refrigeration equipment is calculated based on the energy use requirements set by the California Energy Commission in *2015 Appliance Efficiency Regulations*[iv] and the Department of Energy in the *Code of Federal Regulations: 10 CFR 431.66 - Energy conservation standards and their effective dates.*[v]

Transportation Emissions
Transportation related emissions in this GHG quantification methodology are calculated based on a well-to-wheel (WTW) emission factor derived from carbon intensity data, fuel energy density values, and fuel efficiency values. The emission factor was developed using CARB's Low Carbon Fuel Standard,[vi] CARB's Mobile Source Emission Factor Model (EMFAC 2014),[vii] California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (CA-GREET 2.0),[viii] and U.S. Department of Transportation mileage assumptions.[ix] The WTW method accounts for the emissions associated with the production and distribution of different fuel types as well as any associated exhaust emissions.

<u>Low Carbon Fuel Standard (LCFS) Regulation and Pathways</u>
The LCFS pathways use a well-to-wheels (WTW) life-cycle approach to determine the emissions associated with 27 different transportation fuels taking into consideration the fuel production, transportation, distribution and use. This GHG quantification methodology uses the fuel production rates and GHG emissions from the *Low Carbon Fuel Standard (LCFS) Pathway for the Production of Biomethane from High Solids Anaerobic Digestion (HSAD) of Organic (Food and Green) Wastes* (2014)[x] and *Low Carbon Fuel Standard (LCFS) Pathway for the Production of Biomethane from the Mesophilic Anaerobic Digestion of Wastewater Sludge at Publicly-Owned Treatment Works (POTW)* (2014)[xi] to accurately and uniformly quantify GHG emission reductions attributable to the diversion of organic waste (i.e., food scraps, yard trimmings, branches, leaves, grass, and organic municipal waste) for the purpose of anaerobic digestion.

In addition to the tools above, the Organics Benefits Calculator Tool relies on CARB-developed emission factors. CARB has established a single repository for emission factors used in CARB benefits calculator tools, referred to as the California Climate Investments Quantification Methodology Emission Factor Database (Database), available at: http://www.arb.ca.gov/cci-resources. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

Applicants must use the Organics Benefits Calculator Tool to estimate the GHG emission reductions and co-benefits of the proposed project. The Organics Benefits Calculator Tool can be downloaded from: http://www.arb.ca.gov/cci-resources.

Updates

CARB staff periodically review each quantification methodology and benefits calculator tool to evaluate their effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified. CARB updated the Organics Quantification Methodology from the previous version[2] to enhance the analysis and provide additional clarity. The changes include:

- Simplification of user inputs for all project types;
- Addition of new biogas destruction devices;
- Addition of new vehicle fuel types and options for low NO_x vehicles;
- Addition of a link to a step-by-step User Guide with project examples; and
- Addition of new Co-benefits Summary tab in the Benefits Calculator Tool that summarizes co-benefits and key variables using many of the same inputs used to estimate the GHG emission reductions.

[2] Waste Diversion Grant and Loan Program Quantification Methodology released December 22, 2016

Section B. Methods

The following section provides details on the methods supporting emission reductions in the Organics Benefits Calculator Tool.

Project Type

CalRecycle developed four project types that meet the objectives of the Organics Grant Program and for which there are methods to quantify GHG emission reductions.[3] Other project features may be eligible for funding under the Organics Grant Program; however, each project requesting GGRF funding must include at least one of the following:

- Composting of organic material;
- Standalone anaerobic digestion (AD) of organics producing biofuels or bioenergy;
- Co-Digestion of organics at wastewater treatment plants producing biofuels or bioenergy; and
- Edible food rescue and food waste prevention.

General Approach

Methods used in the Organics Benefits Calculator Tool for estimating the GHG emission reductions and air pollutant emission co-benefits by activity type are provided in this section. The Database Documentation explains how emission factors used in CARB benefits calculator tools are developed and updated.

These methods account for methane emission reductions at landfills due to organics removed from the waste stream and used for compost, digestion, or rescued for consumption. Emission reductions can also be associated with the offset of fossil fuel in vehicle fuel, electricity production, or natural gas usage. Application of compost is outside of the boundary of the projects and is not included in the net GHG benefits for these project types. Emissions increases can occur from increased vehicles miles traveled for food delivery or pickup, fugitive emissions from waste processing, or refrigerant leakage and electricity consumption. In general, the GHG emission reductions are estimated in the Organics Benefits Calculator Tool using the approaches in Table 1. The Organics Benefits Calculator Tool also estimates air pollutant emissions and key variables using many of the same inputs used to estimate GHG emission reductions.

Using the same inputs for estimating GHG emission reductions, the Organics Benefits Calculator Tool also estimates criteria and toxic emission reductions. Because criteria and toxic emissions have a local impact compared to GHG emissions which have a global impact, criteria and toxic emissions are broken into two categories: local and

[3] https://www.calrecycle.ca.gov/Climate/GrantsLoans/

remote. Local emissions are those that take place at the project location. This can include emissions from process emissions, emissions from a generator or boiler, or onsite fossil fuel usage, etc. Remote emissions are those that take place outside of the project location boundary and can include electricity generation emissions from the electrical grid, reduction in diesel usage due to new RNG vehicles, etc. The Organics Benefits Calculator Tool calculates these emissions separately in the Co-benefit Summary Tab and also provides the net benefit.

Table 1. General Approach to Quantification by Project Types

Composting of Organic Material
GHG Emission Reductions = Avoided Landfill Methane Emissions – Fugitive Emissions from Composting Process
Standalone Anaerobic Digestion of Organics Producing Biofuels or Bioenergy
GHG Emission Reductions = Avoided Landfill Methane Emissions + Avoided Emissions from Use of Biomethane in Vehicle Fuel, Electricity Production or Pipeline Injection – Fugitive Emissions from AD Process
Co-Digestion of Organics at Wastewater Treatment Plants Producing Biofuels or Bioenergy
GHG Emission Reductions = Avoided Landfill Methane Emissions + Avoided Emissions from Use of Biomethane in Vehicle Fuel, Electricity Production, or Pipeline Injection – Fugitive Emissions from AD Process
Edible Food Rescue and Food Waste Prevention
GHG emission reductions = Avoided Food Production due to Food Waste Rescue or Prevention – Increased vehicle miles traveled (if applicable) – New Refrigeration Electricity Use and Refrigerant Leakage (if applicable)

A. Emission Reduction Estimates from Food Waste Rescue and Prevention

Both the GHG emission reductions and air pollutant emission estimates from food waste rescue and prevention are estimated as the difference between the baseline and project scenarios using Equations 1-6. Equations 1 and 2 estimate the annual emissions of new transportation vehicles associated with the pickup and delivery of rescued food.

Equation 1: GHG Emissions from Transportation Vehicles

$$GHG_{TR} = \sum_{i}\left[\left(\frac{VEF_{GHG} \times M}{1{,}000{,}000}\right) + \frac{(R_{Leak} \times R_{charge} \times R_{GWP})}{2{,}204.62}\right]$$

Where,			Units
GHG_{TR}	=	GHG emissions from transportation vehicle	$MTCO_2e$/ year
i	=	Number of identical vehicles	
VEF_{GHG}	=	Vehicle GHG Emission Factor	g/mile
M	=	Average Miles per Year for a Delivery Truck	miles/year
1,000,000	=	Conversion from g to MT	g/MT
R_{Leak}	=	The leak rate of the TRU, if necessary	%
R_{charge}	=	TRU refrigerant charge size, if necessary	lbs
R_{GWP}	=	GWP of the refrigerant. All TRUs are assumed to use R-134A	CO_2e
2,204.62	=	Conversion from lbs to MT	lbs/MT

Equation 1. The GHG emissions from food transportation vehicles are estimated as the vehicle GHG emission factor multiplied by average miles traveled per year divided by a conversion factor from g to MT (1,000,000) added to the leak rate of the TRU multiplied by the TRU refrigerant charge size multiplied by the GWP of the refrigerant divided by the conversion from pounds to MT (2,204.62) all multiplied by the number of new vehicles.

Equation 2: Criteria and Toxics Emissions from Transportation Vehicles (Remote Benefit)

$$CT_{TR} = \sum_{i}\left(\frac{VEF_{CT} \times M}{454}\right)$$

Where,			Units
CT_{TR}	=	Criteria and Toxics emissions from transportation vehicle	lbs/year
i	=	Number of identical vehicles	
VEF_{CT}	=	Vehicle Criteria and Toxic Emission Factors	g/mile
M	=	Average Miles per Year for a Delivery Truck	miles/year
454	=	Conversion from g to lbs	g/MT

Equation 2. The criteria and toxic emissions from food transportation vehicles are estimated by vehicle emission factors multiplied by average miles traveled per year divided by a conversion factor from g to pounds (454) multiplied by the number of new vehicles.

Equations 3 and 4 estimate the annual emissions of new refrigeration equipment that is necessary to store the rescued food until it can be consumed or delivered to people. These equations take into account electricity consumption of the equipment and also refrigerant leakage which has a climate impact due to the high Global Warming Potential of many refrigerants.

Equation 3: GHG Emissions from Refrigeration Equipment

$$GHG_{RF} = \sum_{i} \left[((V \times EC + E_{Constant}) \times EF_{E,GHG}) + \frac{(R_{Leak} \times R_{charge} \times R_{GWP})}{2{,}204.62} \right]$$

Where,			Units
GHG_{RF}	=	GHG emissions from refrigeration equipment	$MTCO_2e$/ year
i	=	Number of identical units	
V	=	Volume of refrigeration compartment	ft^3
EC	=	Electricity consumption of refrigeration unit	kWh/year-ft^3
$E_{Constant}$	=	Electricity consumption of refrigeration unit constant factor	kWh/year
$EF_{E,GHG}$	=	Grid GHG electricity emission factor	$MTCO_2e$/ kWh
R_{Leak}	=	The leak rate of the refrigeration unit	%
R_{charge}	=	Refrigerant charge size	lbs
R_{GWP}	=	GWP of the refrigerant	CO_2e
2,204.62	=	Conversion from lbs to MT	lbs/MT

Equation 3. The GHG emissions from new refrigeration equipment is estimated as the volume of refrigeration compartment multiplied by electricity consumption of the refrigeration unit plus electricity consumption of refrigeration unit constant factor multiplied by the grid emission factor added to the leak rate of the refrigeration unit multiplied by the refrigerant charge size multiplied by the GWP of the refrigerant divided by the conversion from pounds to MT (2,204.62) all multiplied by the number of new identical refrigeration equipment pieces.

Equation 4: Criteria and Toxic Emissions from Refrigeration Equipment (Remote Benefit)

$$CT_{RF} = \sum_{i}((V \times EC + E_{Constant}) \times EF_{E,CT})$$

Where,			Units
CT_{RF}	=	Criteria and toxic emissions from refrigeration equipment	lbs/year
i	=	Number of identical units	
V	=	Volume of refrigeration compartment	ft^3
EC	=	Electricity consumption of refrigeration unit	$kwh/year\text{-}ft^3$
$E_{Constant}$	=	Electricity consumption of refrigeration unit constant factor	kWh/year
$EF_{E,CT}$	=	Grid criteria and toxic electricity emission factor	lbs/kWh

Equation 4. The criteria and toxic emissions from new refrigeration equipment is estimated as the volume of refrigeration compartment multiplied by electricity consumption of the refrigeration unit plus electricity consumption of refrigeration unit constant factor multiplied by the grid emission factor all multiplied by the number of new identical refrigeration equipment pieces. This is a remote benefit.

Equations 5 and 6 estimate the annual emissions reductions associated with the rescue of food waste for human consumption and food waste prevention. These equations are based on factors that take into account both upstream avoided food production emissions, avoided transportation emissions, and avoided emissions from disposal of food waste.

Equation 5: GHG Emission Reductions from Diversion of Food Waste or Source Reduction

$$GHG_{FW} = (FR + FW) \times EF_{FW}$$

Where,			Units
GHG_{FW}	=	GHG emissions reductions from diversion of food waste or source reduction	$MTCO_2e$
FR	=	Amount of food rescued	short tons
FW	=	Amount of food waste reduction	short tons
EF_{FW}	=	Food Waste Prevention and Rescue Emission Reduction Factor	$MTCO_2e$/ short ton of food waste

Equation 5. The GHG emission reductions from diversion of food waste or source reduction are estimated by the amount of food rescued plus the amount of source reduction multiplied by the food waste prevention and rescue emission reduction factor.

Equation 6: Criteria and Toxics Emission Reductions from Diversion of Food Waste or Source Reduction (Remote Benefit)

$$CT_{FW} = ((FR + FW) \times EF_{AFT}) + ((FR + FW) \times EF_{LF})$$

Where,			Units
CT_{FW}	=	Criteria and toxic emissions reductions from avoided transportation and avoided landfill flare emissions	lbs
FR	=	Amount of food rescued	lbs
FW	=	Amount of food waste reduction	lbs
EF_{AFT}	=	Avoided transportation for food waste emission reduction factor	lbs/short ton of food waste
EF_{LF}	=	Avoided landfill flare emission reduction factor	lbs/short ton of food waste

Equation 6. The criteria and toxic emission reductions from diversion of food waste or source reduction are estimated by the amount of food rescued plus the amount of source reduction multiplied by the avoided transportation for food waste emission reduction factor plus by the amount of food rescued plus the amount of source reduction multiplied by the avoided landfill flare emission factor. This is a remote benefit.

B. Emission Reduction Estimates from Composting Projects

Both the GHG emission reductions and air pollutant emission estimates from composting projects are estimated as the difference between the baseline of sending the organic materials to a landfill versus composting those materials using windrow or aerated static pile (ASP) composting processes. Equations 7 and 8 estimate the GHG reductions and Equations 9 and 10 estimate the criteria and toxics emissions.

Equation 7: GHG Emission Reductions from Windrow Composting

$$GHG_{COM,WIN} = \left((FS_{WIN} \times COM_{FOOD}) - RES_{WIN,FOOD}\right) \times ERF_{WIN,FOOD} + \left((FS_{WIN} \times COM_{GREEN}) - RES_{WIN,GREEN}\right) \times ERF_{WIN,GREEN}$$

Where,

			Units
$GHG_{COM,WIN}$	=	GHG emission reductions from windrow composting	MT CO_2e
FS_{WIN}	=	Amount of feedstock diverted to windrow composting	short tons
COM_{FOOD}	=	Percentage of feedstock that is food waste	%
$RES_{WIN,FOOD}$	=	Amount of food waste residual material that is screened out before composting	short tons
$ERF_{WIN,FOOD}$	=	Emission reduction factor for windrow composting of food waste	MT CO_2e/ short ton
FS_{WIN}	=	Amount of feedstock diverted to windrow composting	short tons
COM_{GREEN}	=	Percentage of feedstock that is green waste	%
$RES_{WIN,GREEN}$	=	Amount of green waste residual material that is screened out before composting	short tons
$ERF_{WIN,GREEN}$	=	Emission reduction factor for windrow composting of green waste	MTCO2e/ short ton

Equation 7. The GHG emission reductions from windrow composting are estimated by the amount of food waste feedstock subtracted by the residual food waste feedstock multiplied by the emission reduction factor for windrow composting of food waste plus the amount of green waste feedstock subtracted by the residual green waste feedstock multiplied by the emission reduction factor for windrow composting of green waste.

Equation 8: GHG Emission Reductions from ASP Composting

$$GHG_{COM,ASP} = \left((FS_{ASP} \times COM_{FOOD}) - RES_{ASP,FOOD}\right) \times ERF_{ASP,FOOD} + \left((FS_{ASP} \times COM_{GREEN}) - RES_{ASP,GREEN}\right) \times ERF_{ASP,GREEN}$$

Where,			Units
$GHG_{COM,ASP}$	=	GHG emission reductions from ASP composting	MT CO_2e
FS_{ASP}	=	Amount of feedstock diverted to ASP composting	short tons
COM_{FOOD}	=	Percentage of feedstock that is food waste	%
$RES_{ASP,FOOD}$	=	Amount of food waste residual material that is screened out before composting	short tons
$ERF_{ASP,FOOD}$	=	Emission reduction factor for ASP composting of food waste	MT CO_2e/ short ton
FS_{ASP}	=	Amount of feedstock diverted to ASP composting	short tons
COM_{GREEN}	=	Percentage of feedstock that is green waste	%
$RES_{ASP,GREEN}$	=	Amount of green waste residual material that is screened out before composting	short tons
$ERF_{ASP,GREEN}$	=	Emission reduction factor for ASP composting of green waste	MTCO2e/ short ton

Equation 8. The GHG emission reductions from ASP composting are estimated by the amount of food waste feedstock subtracted by the residual food waste feedstock multiplied by the emission reduction factor for ASP composting of food waste plus the amount of green waste feedstock subtracted by the residual green waste feedstock multiplied by the emission reduction factor for ASP composting of green waste.

Equation 9: Criteria and Toxics Emission Reductions from Windrow Composting (Remote Benefit)

$$CT_{COM,WIN} = \left((FS_{WIN} \times COM_{FOOD}) - RES_{WIN,FOOD}\right) \times ERF_{WIN,FOOD,CT} + \left((FS_{WIN} \times COM_{GREEN}) - RES_{WIN,GREEN}\right) \times ERF_{WIN,GREEN}$$

Where,			Units
$CT_{COM,WIN}$	=	Criteria and toxics emissions reductions from windrow composting	lb pollutant
FS_{WIN}	=	Amount of feedstock diverted to windrow composting	short tons
COM_{FOOD}	=	Percentage of feedstock that is food waste	%
$RES_{WIN,FOOD}$	=	Amount of food waste residual material that is screened out before composting	short tons
$ERF_{WIN,FOOD,CT}$	=	Avoided landfill emission factor for windrow composting of food waste	lb pollutant/ short ton
FS_{WIN}	=	Amount of feedstock diverted to windrow composting	short tons
COM_{GREEN}	=	Percentage of feedstock that is green waste	%
$RES_{WIN,GREEN}$	=	Amount of green waste residual material that is screened out before composting	short tons
$ERF_{WIN,GREEN,CT}$	=	Avoided landfill emission factor for windrow composting of green waste	lb pollutant /short ton

Equation 9. The criteria and toxic emission reductions from windrow composting are estimated by the amount of food waste feedstock subtracted by the residual food waste feedstock multiplied by the emission reduction factor for avoided landfill methane from food waste plus the amount of green waste feedstock subtracted by the residual green waste feedstock multiplied by the emission reduction factor for avoided landfill methane from green waste. This is a remote benefit.

Equation 10: Criteria and Toxics Emission Reductions from ASP Composting (Remote Benefit)

$$CT_{COM,ASP} = \left((FS_{ASP} \times COM_{FOOD}) - RES_{ASP,FOOD}\right) \times ERF_{ASP,FOOD,CT} + \left((FS_{ASP} \times COM_{GREEN}) - RES_{ASP,GREEN}\right) \times ERF_{ASP,GREEN,CT}$$

Where,

			Units
$CT_{COM,ASP}$	=	Criteria and toxics emissions reductions from ASP composting	lb pollutant
FS_{ASP}	=	Amount of feedstock diverted to ASP composting	short tons
COM_{FOOD}	=	Percentage of feedstock that is food waste	%
$RES_{ASP,FOOD}$	=	Amount of food waste residual material that is screened out before composting	short tons
$ERF_{ASP,FOOD,CT}$	=	Avoided landfill emission factor for ASP composting of food waste	lb pollutant/ short ton
FS_{ASP}	=	Amount of feedstock diverted to ASP composting	short tons
COM_{GREEN}	=	Percentage of feedstock that is green waste	%
$RES_{AS\{,GREEN}$	=	Amount of green waste residual material that is screened out before composting	short tons
$ERF_{ASP,GREEN,CT}$	=	Avoided landfill emission factor for ASP composting of green waste	lb pollutant/ short ton

Equation 10. The criteria and toxic emission reductions from ASP composting are estimated by the amount of food waste feedstock subtracted by the residual food waste feedstock multiplied by the emission reduction factor for avoided landfill methane from food waste plus the amount of green waste feedstock subtracted by the residual green waste feedstock multiplied by the emission reduction factor for avoided landfill methane from green waste. This is a remote benefit.

C. Emission Reduction Estimates from Standalone Anaerobic Digestion Projects

Both the GHG emission reductions and air pollutant emission estimates from Standalone AD projects are estimated as the difference between the baseline sending the organic materials to a landfill verses digesting those materials using a dedicated digester. Equation 11 estimates the GHG reductions and Equations 12 through 16 estimate the criteria and toxics emissions.

Equation 11: GHG Emission Reductions from Standalone Anaerobic Digestion

$$GHG_{SAD} = (FS_{SAD} - RES_{SAD}) \times ERF_{SAD}$$

Where,			Units
GHG_{SAD}	=	Net GHG benefit from standalone AD	MT CO_2e
FS_{SAD}	=	Amount of feedstock diverted to standalone AD	short tons
RES_{SAD}	=	Amount of standalone AD residual material that is screened out before digestion	short tons
ERF_{SAD}	=	Emission reduction factor for standalone AD projects based on final use of biomethane (vehicle fuel, onsite electricity, or injection into natural gas pipeline).	MT CO_2e/ short ton

Equation 11. The GHG emission reductions from standalone anaerobic digestion are estimated by the amount of feedstock subtracted by the residual feedstock multiplied by the emission reduction factor for standalone AD.

Equation 12: Criteria and Toxics Emission Reductions from Standalone Anaerobic Digestion Avoided Diesel Usage (Remote Benefit)

$$CT_{ADR,SAD} = DP_{SAD} \times (FS_{SAD} - RES_{SAD}) \times CE \times (TEF_{Diesel} - TEF_{AF}) \times FE \times \frac{1}{454}$$

Where,			Units
$CT_{ADR,SAD}$	=	Criteria and toxic emission reductions from replacement of diesel with renewable fuel (renewable natural gas (RNG), dimethyl ether (DME), or hydrogen)	lb pollutants
DP_{SAD}	=	Amount of biomethane available to offset diesel fuel usage (if applicable)	gallons of diesel eq./ short ton
FS_{SAD}	=	Amount of feedstock diverted to standalone AD	short tons
RES_{SAD}	=	Amount of standalone AD residual material that is screened out before digestion	short tons
CE	=	Conversion efficiency from RNG to DME or hydrogen	%
TEF_{Diesel}	=	Transportation emission factor of diesel	g/mile
TEF_{AF}	=	Transportation emission factor of alternative fueled vehicle	g/mile
FE	=	Fuel efficiency	miles/gallon
$1/454$	=	Conversion factor from g to lb	lb/g

Equation 12. The criteria and toxic emission reductions from avoided diesel usage are estimated by available biomethane to offset diesel fuel usage multiplied by the amount of feedstock for standalone AD subtracted by the residual feedstock multiplied by the conversion efficiency from renewable natural gas (RNG) to dimethyl ether (DME) or hydrogen multiplied by the difference of transportation emission factors between diesel and the alternative fuel multiplied by the fuel efficiency of the vehicle divided by the conversion factor to convert from g to lb. This is a remote benefit.

Equation 13: Criteria and Toxics Emission Reductions from Standalone Anaerobic Digestion Usage of Grid Power (Remote Benefit)

$$CT_{Grid\,,SAD} = \left(EP_{SAD} \times (FS_{SAD} - RES_{SAD}) \times ERF_{grid}\right) - \left(EU_{grid} \times (FS_{SAD} - RES_{SAD}) \times ERF_{grid}\right)$$

Where,			Units
$CT_{grid,SAD}$	=	Criteria and toxic emission reductions from avoided grid electricity and electrical demand from processing waste	lb pollutants
EP_{SAD}	=	Facility electricity production that is sent to the grid for electricity generation projects (if applicable)	kWh/short ton
FS_{SAD}	=	Amount of feedstock diverted to standalone AD	short tons
RES_{SAD}	=	Amount of standalone AD residual material that is screened out before digestion	short tons
ERF_{grid}	=	Grid criteria and toxic emission reduction factors	lb/kWh
EU_{grid}	=	Electricity consumption to process waste material	kWh/ short ton

Equation 13. The criteria and toxic emission reductions from usage of grid power is estimated by facility electricity production that is sent to the grid for electricity generation projects multiplied by the amount of feedstock for standalone AD subtracted by the residual feedstock multiplied by the emission factor of the grid subtracted by the electricity consumption to process waste at the facility multiplied by the amount of feedstock for standalone AD subtracted by the residual feedstock multiplied by the emission factor of the grid. This is a remote benefit.

Equation 14: Avoided Flare Criteria and Toxics Emissions from Standalone Anaerobic Digestion (Remote Benefit)

$$CT_{flare\,,SAD} = (FS_{SAD} - RES_{SAD}) \times ERF_{flare}$$

Where,			Units
$CT_{flare,SAD}$	=	Criteria and toxic emission reductions from avoided grid electricity and electrical demand from processing waste	lb pollutants
FS_{SAD}	=	Amount of feedstock diverted to standalone AD	short tons
RES_{SAD}	=	Amount of standalone AD residual material that is screened out before digestion	short tons
ERF_{flare}	=	Flare criteria and toxic emission reduction factors	lb/short ton

Equation 14. The criteria and toxic emission reductions from avoided landfill flare emissions is estimated by the amount of feedstock for standalone AD subtracted by the residual feedstock multiplied by the emission factor of the flare. This is a remote benefit.

Equation 15: Criteria and Toxics Emissions from Processing of Diverted Material for Standalone Anaerobic Digestion (Local Benefit)

$$CT_{proc,SAD} = \left((FS_{SAD} - RES_{SAD}) \times DU_{proc} \times EF_{equip}\right) + \left((FS_{SAD} - RES_{SAD}) \times RNGU_{proc} \times EF_{boiler}\right)$$

Where,			Units
$CT_{proc,SAD}$	=	Criteria and toxic emissions from processing waste	lb pollutants
FS_{SAD}	=	Amount of feedstock diverted to standalone AD	short tons
RES_{SAD}	=	Amount of standalone AD residual material that is screened out before digestion	short tons
DU_{proc}	=	Diesel usage to manage waste at the digester	gallon/short ton
EF_{equip}	=	Off-road diesel equipment criteria and toxic emission factors	lb/gallon
$RNGU_{proc}$	=	RNG usage to generate heat in a boiler to manage waste at the digester	scf/short ton
EF_{boiler}	=	Boiler criteria and toxic emission factors	lb/scf

Equation 15. The criteria and toxic emissions from processing are estimated by the amount of feedstock for standalone AD subtracted by the residual feedstock multiplied by the diesel usage to manage waste multiplied by the emission factor of off-road diesel equipment plus the amount of feedstock for standalone AD subtracted by the residual feedstock multiplied by the RNG usage to generate heat in a boiler to manage waste multiplied by the emission factor of a boiler. This is a local benefit.

Equation 16: Criteria and Toxics Emissions from Electricity Generation at a Standalone Anaerobic Digestion Facility (Local Benefit)

$$CT_{elec,SAD} = (FS_{SAD} - RES_{SAD}) \times AF_{SAD} \times 0.00102 \times EF_{gen}$$

Where,			Units
$CT_{elec,SAD}$	=	Criteria and toxic emissions from onsite production of electricity	lb pollutants
FS_{SAD}	=	Amount of feedstock diverted to standalone AD	short tons
RES_{SAD}	=	Amount of standalone AD residual material that is screened out before digestion	short tons
AF_{SAD}	=	Amount of fuel production per ton of waste	scf/short ton
0.00102	=	Conversion of scf to MMBtu	MMBTU/scf
EF_{gen}	=	Electricity generation device criteria and toxic emission factor	lb/MMBtu

Equation 16. The criteria and toxic emissions from onsite production of electricity is estimated by the amount of feedstock for standalone AD subtracted by the residual feedstock multiplied by amount of fuel production per short ton of waste multiplied by the conversion from scf to MMBtu multiplied by the emission factor for the electricity generation device. This is a local benefit.

D. Emission Reduction Estimates from Co-Digestion Anaerobic Digestion Projects

Both the GHG emission reductions and air pollutant emission estimates from Co-Digestion AD projects are estimated as the difference between the baseline sending the organic materials to a landfill versus digesting those materials using a co-digestion process. Equation 17 estimates the GHG reductions and Equations 18 through 22 estimate the criteria and toxics emissions.

Equation 17: GHG Emission Reductions from Co-Digestion Anaerobic Digestion

$$GHG_{COD} = (FS_{COD} - RES_{COD}) \times ERF_{COD}$$

Where,			Units
GHG_{COD}	=	Net GHG benefit from co-digestion AD	MT CO_2e
FS_{COD}	=	Amount of feedstock diverted to co-digestion AD	short tons
RES_{COD}	=	Amount of co-digestion AD residual material that is screened out before digestion	short tons
ERF_{COD}	=	Emission reduction factor for co-digestion AD projects based on final use of biomethane (vehicle fuel, onsite electricity, or injection into natural gas pipeline).	MT CO_2e/ short ton

Equation 17. The GHG emission reductions from co-digestion AD are estimated by the amount of feedstock subtracted by the residual feedstock multiplied by the emission reduction factor for co-digestion AD.

Equation 18: Criteria and Toxics Emission Reductions from Co-Digestion Anaerobic Digestion Avoided Diesel Usage (Remote Benefit)

$$CT_{ADR,COD} = DP_{SAD} \times (FS_{COD} - RES_{COD}) \times CE \times (TEF_{Diesel} - TEF_{AF}) \times FE \times \frac{1}{454}$$

Where,			Units
$CT_{ADR,COD}$	=	Criteria and toxic emission reductions from replacement of diesel with renewable fuel (RNG, DME, or hydrogen)	lb pollutants
DP_{COD}	=	Amount of biomethane available to offset diesel fuel usage (if applicable)	gallons of diesel eq./ short ton
FS_{COD}	=	Amount of feedstock diverted to co-digestion AD	short tons
RES_{COD}	=	Amount of co-digestion AD residual material that is screened out before digestion	short tons
CE	=	Conversion efficiency from RNG to DME or hydrogen	%
TEF_{Diesel}	=	Transportation emission factor of diesel	g/mile
TEF_{AF}	=	Transportation emission factor of alternative fueled vehicle	g/mile
FE	=	Fuel efficiency	miles/gallon
$1/454$	=	Conversion factor from g to lb	lb/g

Equation 18. The criteria and toxic emission reductions from avoided diesel usage are estimated by available biomethane to offset diesel fuel usage multiplied by the amount of feedstock for co-digestion AD subtracted by the residual feedstock multiplied by the conversion efficiency from RNG to DME or hydrogen multiplied by the difference of transportation emission factors between diesel and the alternative fuel multiplied by the fuel efficiency of the vehicle divided by the conversion factor to convert from g to lb. This is a remote benefit.

Equation 19: Criteria and Toxics Emission Reductions from Co-Digestion Anaerobic Digestion Usage of Grid Power (Remote Benefit)

$$CT_{grid,COD} = \left(EP_{COD} \times (FS_{COD} - RES_{COD}) \times ERF_{grid}\right) - \left(EU_{grid} \times (FS_{COD} - RES_{COD}) \times ERF_{grid}\right)$$

Where,			Units
$CT_{grid,COD}$	=	Criteria and toxic emission reductions from avoided grid electricity and electrical demand from processing waste	lb pollutants
EP_{COD}	=	Facility electricity production that is sent to the grid for electricity generation projects (if applicable)	kWh/short ton
FS_{COD}	=	Amount of feedstock diverted to co-digestion AD	short tons
RES_{COD}	=	Amount of co-digestion AD residual material that is screened out before digestion	short tons
ERF_{grid}	=	Grid criteria and toxic emission reduction factors	lb/kWh
EU_{grid}	=	Electricity consumption to process waste material	kWh/ short ton

Equation 19. The criteria and toxic emission reductions from usage of grid power is estimated by facility electricity production that is sent to the grid for electricity generation projects multiplied by the amount of feedstock for co-digestion AD subtracted by the residual feedstock multiplied by the emission factor of the grid subtracted by the electricity consumption to process waste at the facility multiplied by the amount of feedstock for co-digestion AD subtracted by the residual feedstock multiplied by the emission factor of the grid. This is a remote benefit.

Equation 20: Avoided Flare Criteria and Toxics Emissions from Co-Digestion Anaerobic Digestion (Remote Benefit)

$$CT_{flare,COD} = (FS_{COD} - RES_{COD}) \times ERF_{flare}$$

Where,			Units
$CT_{flare,COD}$	=	Criteria and toxic emission reductions from avoided grid electricity and electrical demand from processing waste	lb pollutants
FS_{COD}	=	Amount of feedstock diverted to co-digestion AD	short tons
RES_{COD}	=	Amount of co-digestion AD residual material that is screened out before digestion	short tons
ERF_{flare}	=	Flare criteria and toxic emission reduction factors	lb/short ton

Equation 20. The criteria and toxic emission reductions from avoided landfill flare emissions is estimated by the amount of feedstock for co-digestion AD subtracted by the residual feedstock multiplied by the emission factor of the flare. This is a remote benefit.

Equation 21: Criteria and Toxics Emissions from Processing of Diverted Material for Co-Digestion Anaerobic Digestion (Local Benefit)

$$CT_{proc,COD} = \left((FS_{COD} - RES_{COD}) \times DU_{proc} \times EF_{equip}\right) + \left((FS_{COD} - RES_{COD}) \times RNGU_{proc} \times EF_{boiler}\right)$$

Where,			Units
$CT_{proc,COD}$	=	Criteria and toxic emissions from processing waste	lb pollutants
FS_{COD}	=	Amount of feedstock diverted to co-digestion AD	short tons
RES_{COD}	=	Amount of co-digestion AD residual material that is screened out before digestion	short tons
DU_{proc}	=	Diesel usage to manage waste at the digester	gallon/short ton
EF_{equip}	=	Off-road diesel equipment criteria and toxic emission factors	lb/gallon
$RNGU_{proc}$	=	RNG usage to generate heat in a boiler to manage waste at the digester	scf/short ton
EF_{boiler}	=	Boiler criteria and toxic emission factors	lb/scf

Equation 21. The criteria and toxic emission from processing emissions is estimated by the amount of feedstock for co-digestion AD subtracted by the residual feedstock multiplied by the diesel usage to manage waste multiplied by the emission factor of off-road diesel equipment plus the amount of feedstock for co-digestion AD subtracted by the residual feedstock multiplied by the RNG usage to generate heat in a boiler to manage waste multiplied by the emission factor of a boiler. This is a local benefit.

Equation 22: Criteria and Toxics Emissions from Electricity Generation at a Co-Digestion Anaerobic Digestion Facility (Local Benefit)

$$CT_{elec,COD} = (FS_{COD} - RES_{COD}) \times AF_{COD} \times 0.00102 \times EF_{gen}$$

Where,

			Units
$CT_{elec,COD}$	=	Criteria and toxic emissions from onsite production of electricity	lb pollutants
FS_{COD}	=	Amount of feedstock diverted to co-digestion AD	short tons
RES_{COD}	=	Amount of co-digestion AD residual material that is screened out before digestion	short tons
AF_{COD}	=	Amount of fuel production per ton of waste	scf/short ton
0.00102	=	Conversion of scf to MMBtu	MMBTU/scf
EF_{gen}	=	Electricity generation device criteria and toxic emission factor	lb/MMBtu

Equation 22. The criteria and toxic emission from onsite production of electricity is estimated by the amount of feedstock for co-digestion AD subtracted by the residual feedstock multiplied by amount of fuel production per short ton of waste multiplied by the conversion from scf to MMBtu multiplied by the emission factor for the electricity generation device. This is a local benefit.

E. Total Emission Reduction Estimates from Organics Grant Projects

Equations 23 through 26 estimate the net benefits for GHG and co-pollutants associated with all organics grant project types.

Equation 23: Net GHG Benefit

$$GHG = GHG_{FW} - (GHG_{TR} + GHG_{RF}) + GHG_{COM,WIN} + GHG_{COM,ASP} + GHG_{SAD} + GHG_{COD}$$

Where,

			Units
GHG	=	Net GHG benefit from the project	MT CO_2e
GHG_{FW}	=	GHG benefit of food waste diversion and source reduction (from Equation 5)	MT CO_2e
GHG_{TR}	=	GHG emissions from delivery vehicles (from Equation 1)	MT CO_2e
GHG_{RF}	=	GHG emissions from refrigeration unit (from Equation 3)	MT CO_2e
$GHG_{COM,WIN}$	=	GHG emission reductions from windrow composting (from Equation 9)	MT CO_2e
$GHG_{COM,ASP}$	=	GHG emission reductions from ASP composting (from Equation 10)	MT CO_2e
GHG_{SAD}	=	Net GHG benefit from standalone AD (from Equation 12)	MT CO_2e
GHG_{COD}	=	Net GHG benefit from co-digestion AD (from Equation 13)	MT CO_2e

Equation 23. The net GHG benefit from all organics projects is estimated to be the GHG benefit of food waste diversion and source reduction (from equation 5) subtracted by the GHG emissions from delivery vehicles (from equation 1) subtracted by the GHG emissions from refrigeration units (from equation 3) plus the GHG emission reductions from windrow composting (from equation 9) plus the GHG emission reductions from ASP composting (from equation 10) plus the GHG emission reductions from standalone AD (from equation 12) plus the GHG benefit from co-digestion AD (from equation 13).

Equation 24: Net Criteria and Toxics Benefit (Local Benefit)

$$CT_{Local} = -CT_{proc,SAD} - CT_{elec,SAD} - CT_{proc,COD} - CT_{elec,COD}$$

Where,

			Units
CT_{Local}	=	Net criteria and toxics local benefit from the project	lb pollutant
$CT_{proc,SAD}$	=	Criteria and toxic emissions from processing waste in standalone AD projects (from Equation 15)	lb pollutant
$CT_{elec,SAD}$	=	Criteria and toxic emissions from onsite production of electricity waste in standalone AD projects (from Equation 16)	lb pollutant
$CT_{proc,COD}$	=	Criteria and toxic emissions from processing waste in co-digestion AD projects (from Equation 21)	lb pollutant
$CT_{elec,COD}$	=	Criteria and toxic emissions from onsite production of electricity in co-digestion AD projects (from Equation 22)	lb pollutant

Equation 24. The net local criteria and toxic emission reductions from all organics projects is estimated to be the emissions from processing waste in standalone AD projects (from equation 15) subtracted by the emissions from onsite production of electricity in standalone AD projects (from equation 16) subtracted by emissions from processing waste in co-digestion AD projects (from equation 21) subtracted by the emissions from onsite production of electricity in co-digestion AD projects (from equation 22)

Equation 25: Net Criteria and Toxics Benefit (Remote Benefit)

$$CT_{Remote} = CT_{FW} - (CT_{TR} + CT_{RF}) + CT_{COM,WIN} + CT_{COM,ASP} + CT_{ADR,SAD} + CT_{grid,SAD} + CT_{flare,SAD} + CT_{ADR,COD} + CT_{grid,COD} + CT_{flare,COD}$$

Where,

			Units
CT_{Remote}	=	Net criteria and toxics remote benefit from the project	lb pollutant
CT_{FW}	=	Criteria and toxics benefit of food waste diversion and source reduction (from Equation 6)	lb pollutant
CT_{TR}	=	Criteria and toxics emissions from delivery vehicles (from Equation 2)	lb pollutant
CT_{RF}	=	Criteria and toxics emissions from refrigeration unit (from Equation 4)	lb pollutant
$CT_{COM,WIN}$	=	Criteria and toxics emissions reductions from windrow composting (from Equation 9)	lb pollutant
$CT_{COM,ASP}$	=	Criteria and toxics emissions reductions from ASP composting (from Equation 10)	lb pollutant
$CT_{ADR,SAD}$	=	Criteria and toxic emission reductions from replacement of diesel with renewable fuel (RNG, DME, or hydrogen) (from Equation 12)	lb pollutant
$CT_{grid,SAD}$	=	Criteria and toxic emission reductions from avoided grid electricity and electrical demand from processing waste (from Equation 13)	lb pollutant
$CT_{flare,SAD}$	=	Criteria and toxic emission reductions from avoided landfill flare (from Equation 14)	lb pollutant
$CT_{ADR,COD}$	=	Criteria and toxic emission reductions from replacement of diesel with renewable fuel (RNG, DME, or hydrogen) in co-digestion AD projects (from Equation 18)	lb pollutant
$CT_{grid,COD}$	=	Criteria and toxic emission reductions from avoided grid electricity and electrical demand from processing waste in co-digestion AD projects (from Equation 19)	lb pollutant
$CT_{flare,COD}$	=	Criteria and toxic emission reductions from avoided landfill flare (from Equation 20)	lb pollutant

Equation 25. The net remote criteria and toxic emission reductions from all organics projects is estimated to be the emission reductions from food waste and source reduction (from equation 6) subtracted by the emissions from delivery vehicles (from equation 2) subtracted by the emissions from refrigeration units (from equation 4) subtracted by the emission reductions from windrow composting (from equation 9) plus the emission reductions from ASP composting (from equation 10) plus the avoided diesel emissions from standalone AD (from equation 12) plus the avoided grid emissions for standalone AD (from equation 13) plus the avoided flare emissions from standalone AD (from equation 14) plus the avoided diesel emissions from co-digestion AD (from equation 18) plus the avoided grid emissions for co-digestion AD (from equation 19) plus the avoided flare emissions from co-digestion AD (from equation 20).

Equation 26: Net Criteria and Toxics Benefit

$$CT = CT_{Local} + CT_{Remote}$$

Where,			Units
CT_{Local}	=	Net criteria and toxics local benefit from the project	lb pollutant
CT_{Local}	=	Net criteria and toxics local benefit from the project (from Equation 24)	lb pollutant
CT_{Remote}	=	Net criteria and toxics remote benefit from the project (from Equation 25)	lb pollutant

Equation 26. The net criteria and toxic emission reductions from all organics projects is estimated to be the sum of the emissions from local impacts (from equation 24) and the emissions from remote impacts (from equation 25).

Section C. References

The following references were used in the development of this Quantification Methodology and the Organics Benefits Calculator Tool.

10 CFR 431.66 - Energy conservation standards and their effective dates
http://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8

California Air Resources Board. (2015). CA-GREET 2.0.
https://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

CARB's California's High Global Warming Potential Gases Emission Inventory Emission Inventory Methodology and Technical Support Document (2016)
http://www.arb.ca.gov/cc/inventory/slcp/doc/hfc_inventory_tsd_20160411.pdf

CARB Method for Estimating Greenhouse Gas Emission Reductions from Composting of Commercial Organic Waste (2017)
https://www.arb.ca.gov/cc/waste/cerffinal.pdf

CARB Low Carbon Fuel Standard (LCFS) Pathway for the Production of Biomethane from High Solids Anaerobic Digestion (HSAD) of Organic (Food and Green) Wastes (2014)
http://www.arb.ca.gov/fuels/lcfs/121514hsad.pdf

CARB Low Carbon Fuel Standard (LCFS) Pathway for the Production of Biomethane from the Mesophilic Anaerobic Digestion of Wastewater Sludge at Publicly-Owned Treatment Works (POTW) (2014)
http://www.arb.ca.gov/fuels/lcfs/121514wastewater.pdf

California Air Resources Board. (2017). OFFROAD2017 – ORION Web Database.
https://www.arb.ca.gov/orion/

CARB Refrigerant Management Program
http://www.arb.ca.gov/cc/rmp/rmprefrigerants.htm

CARB Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Proposed Re-Adoption of the Low Carbon Fuel Standard (2014)
http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15isor.pdf

Climate Action Reserve Organic Waste Digestion Project Protocol Version 2.1 (2014)
http://www.climateactionreserve.org/wp-content/uploads/2009/10/Organic_Waste_Digestion_Project_Protocol_Version2.1.pdf

The Climate Change and Economic Impacts of Food Waste in the United States (2012)
http://www.cleanmetrics.com/pages/ClimateChangeImpactofUSFoodWaste.pdf

CARB EMFAC 2014 Web Database
http://www.arb.ca.gov/emfac/2014/

San Joaquin Valley Air Pollution Control District, Greenwaste Compost Site Emissions Reductions from Solar-powered Aeration and Biofilter Layer (2013)
http://www.valleyair.org/Grant_Programs/TAP/documents/C-15636-ACP/C-15636_ACP_FinalReport.pdf

U.S. EPA Emission Factors for Greenhouse Gas Inventories (2015)
https://www.epa.gov/sites/production/files/2015-12/documents/emission-factors_nov_2015.pdf

US Department of Transportation: Table VM-1 Annual Vehicle Distance Traveled in Miles and Related Data - 2014 by Highway Category and Vehicle Type
http://www.fhwa.dot.gov/policyinformation/statistics/2014/vm1.cfm

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[i] http://www.arb.ca.gov/cc/waste/cerffinal.pdf

[ii] http://www.cleanmetrics.com/pages/ClimateChangeImpactofUSFoodWaste.pdf

[iii] http://www.arb.ca.gov/cc/inventory/slcp/doc/hfc_inventory_tsd_20160411.pdf

[iv] http://www.energy.ca.gov/2015publications/CEC-400-2015-021/CEC-400-2015-021.pdf

[v] http://www.ecfr.gov/cgi-bin/text-idx?SID=ea9937006535237ca30dfd3e03ebaff2&mc=true&node=se10.3.431_166&rgn=div8

[vi] Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Proposed Re-Adoption of the Low Carbon Fuel Standard, December 2014 available at: http://www.arb.ca.gov/regact/2015/lcfs2015/lcfs15isor.pdf

[vii] http://www.arb.ca.gov/emfac/2014/

[viii] Direct values (without energy efficiency ratio adjustments). Source: California Air Resources Board, CA-GREET 1.8b versus 2.0 CI Comparison Table, April 1, 2015 available at: http://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/040115_pathway_ci_comparison.pdf

[ix] http://www.fhwa.dot.gov/policyinformation/statistics/2014/vm1.cfm

[x] http://www.arb.ca.gov/fuels/lcfs/121514hsad.pdf

[xi] http://www.arb.ca.gov/fuels/lcfs/121514wastewater.pdf