California Air Resources Board

Quantification Methodology

Climate Positive Landscaping

California Climate Investments

FINAL
May 7, 2021

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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 Climate Positive Landscaping (CPL) Program, CARB staff developed this CPL 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 carbon sequestration from tree planting, GHG emission reductions from avoided landfill methane emissions, avoided GHG emissions from lawn mowers and application of fertilizer, and GHG emissions associated with the implementation of CPL projects.

The CPL 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 CPL Benefits Calculator Tool as well as the total project GHG emission reductions per dollar of GGRF funds requested. The CPL 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 CPL Benefits Calculator Tool estimates the following co-benefits and key variables from CPL projects: select criteria and toxic air pollutants (in pounds (lbs))—including nitrogen oxide (NOx), reactive organic gases (ROG), and fine particulate matter less than 2.5 micrometers (PM2.5); material diverted from landfill (in tons); fossil fuel use reductions (in therms and kWh); energy and fuel cost savings (in dollars); compost production (in dry tons); compost application area (in acres); trees planted (in number of trees); and water savings (in gallons). Key variables are project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit (e.g., compost application, trees planted). Additional co-benefits for which CARB assessment methodologies were not incorporated into the CPL Benefits Calculator Tool may also be applicable to the project. Applicants should consult the CPL guidelines, solicitation materials, and agreements to ensure they are meeting CPL requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

Methodology Development

CARB and California Department of Resources Recycling and Recovery (CalRecycle) developed this Quantification Methodology[1] consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability.[2] CARB and CalRecycle developed this CPL 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 and proven tools and 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 CPL 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 CPL Quantification Methodology and Draft CPL Benefits Calculator Tool for public comment in March 2021. This Final CPL Quantification Methodology and accompanying CPL Benefits Calculator Tool have been updated to address public comments, where appropriate.

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] CARB worked with CalRecycle to develop this Quantification Methodology and Benefits Calculator Tool to promote new project types within the CCI portfolio of programs. Individual program eligibility and requirements will be set by the agency with available funding.
[2] California Air Resources Board. www.arb.ca.gov/cci-fundingguidelines

Tools

The CPL 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.

Transportation and Equipment Emissions
Transportation and equipment 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 factors were developed using CARB's Low Carbon Fuel Standard,[ii] CARB's Mobile Source Emission Factor Model (EMFAC 2014),[iii] California-modified Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (CA-GREET 2.0),[iv] U.S. Department of Transportation mileage assumptions,[v] and Small Off-Road Engines Emission Database.[vi] The WTW method accounts for the emissions associated with the production and distribution of different fuel types as well as any associated exhaust emissions.

Low Carbon Fuel Standard (LCFS) Regulation and Pathways
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)[vii] 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)[viii] 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.

United States Forest Service i-Tree Planting Software
The United States Forest Service (USFS) i-Tree Planting web-based tool provides quantitative data for an individual or population of trees planted as part of the project,

including the amount of carbon stored, the estimated effects of tree shade on building energy use, the dry weight of aboveground biomass, and rainfall interception based on project characteristics such as the climate zone, tree species, tree age, tree diameter at breast height (DBH), and tree location relative to a building. i-Tree Planting can be accessed at: https://planting.itreetools.org/. A description about the tool can be accessed at: https://planting.itreetools.org/help/.

The CPL Benefits Calculator Tool also includes water savings co-benefit calculations that require the use of the Department of Water Resources (DWR) Water Budget Calculator for New and Rehabilitated Residential/Non-Residential Landscapes[3] and the University of California Division of Agriculture and Natural Resources (UCANR) Water Use Classification of Landscape Species (WUCOLS) IV online database.[4] In order to estimate water savings resulting from the project activities, refer to CARB's Co-benefit Assessment Methodology for Water Savings, available at: https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/final_water_am.pdf, which includes an urban landscaping project example in Appendix C.

In addition to the tools above, the CPL 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 CPL Benefits Calculator Tool to estimate the GHG emission reductions and co-benefits of the proposed project. The CPL Benefits Calculator Tool can be downloaded from: http://www.arb.ca.gov/cci-resources.

[3] Department of Water Resources (2017). *Water Budget Calculator for New and Rehabilitated Residential/Non-Residential Landscapes*. https://cadwr.app.box.com/s/5k39tv10u42rp5bn2uebd7fodkxzgve7
[4] University of California Division of Agriculture and Natural Resources. (2019). *Water Use Classification of Landscape Species (WUCOLS) IV online database*. http://ucanr.edu/sites/WUCOLS/Plant_Search/

Section B. Methods

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

Project Type

CARB and CalRecycle developed multiple project types that meet the objectives of the CPL and for which there are methods to quantify GHG emission reductions. Other project features may be eligible for funding under the CPL; however, this CPL methodology only estimates benefits from the following project types:

- Composting of organic material;
- Lawn management; and
- Tree planting.

General Approach

Methods used in the CPL 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.

For projects with a composting component, these methods account for methane emission reductions at landfills due to organics removed from the waste stream and used for compost. Application of compost is outside of the boundary of the projects and is not included in the net GHG benefits for these project types. Emission increases can occur from fugitive emissions from waste processing.

For projects with a tree planting component, these methods account for carbon storage in planted trees, energy savings from the benefits of tree shade, and the GHG emissions associated with the implementation of the tree planting projects.

For projects that are replacing lawns with more sustainable practices, these methods account for avoided emissions from lawn mowing equipment and avoided emissions from application and manufacture of fertilizer.

In general, the GHG emission reductions are estimated in the CPL Benefits Calculator Tool using the approaches in Table 1. The CPL 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 CPL 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 remote. Local emissions are those that take place at the project location. This can include emissions from process emissions 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 CPL 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 Type

Composting of Organic Material
GHG Emission Reductions = Avoided Landfill Methane Emissions – Fugitive Emissions from Composting Process
Lawn Management
GHG Emission Reductions = Avoided Fertilizer Usage Emissions + Avoided Lawn Maintenance Equipment Usage
Tree Planting
Net GHG benefit = carbon storage in planted trees – carbon in planted trees not assumed to survive[5] *+ GHG reductions from energy savings from shade*[6] *– GHG emissions from tree planting and maintenance*

[5] This methodology applies a 3% annual tree mortality rate to the years after the period of establishment care (including replacement) provided by the project through year 10, at which time tree mortality is substantially reduced. This assumption is based on USFS publications and personal communication with John Melvin, State Urban Forester, CAL FIRE (April 19, 2016).

[6] Some tree planting sites may not provide shade to buildings and will therefore not result in building energy savings. If there are no trees that provide tree shade to conditioned buildings in the proposed project, this variable may be set to 0. If only a subset of trees will provide shade, see the step-by-step user guide for additional details about how to apply the third party tool, i-Tree Planting.

A. GHG Benefit from Carbon Stored in Trees

The GHG benefit from carbon stored in trees planted by the project is calculated as the sum of carbon stored in individual trees 40 years after project start. A 3% annual tree mortality rate[7] is included for the years after the period of establishment care (including replacement) provided by the project through year 10.[8] Equation 1 determines the GHG benefit from carbon stored in live project trees at the end of the project based on i-Tree Planting outputs.

Equation 1: GHG Benefit of Carbon Stored in Live Project Trees

$$GHG_{CSC} = \frac{\sum_i C_{ITP,i} \times (1-0.03)^{10-YC}}{2{,}204.62}$$

Where,			Units
GHG_{CSC}	=	GHG benefit of carbon stored in live project trees estimated using i-Tree Planting	MT CO_2e
$C_{ITP,i}$	=	Carbon stored in each group of project trees (i), over the 40 year quantification period (from i-Tree Planting)	lb CO_2e
0.03	=	Mortality rate (3% annual)	
10	=	Years after planting with greatest risk for mortality	years
YC	=	Years of establishment and replacement care provided by project (the maximum value for the purposes of this equation is 9 years; enter 9 if the project provides establishment and replacement care for a longer period of time)	years
i	=	Project tree species planted	
2,204.62	=	Conversion factor from lb to MT	lb/MT

[7] Roman, Lara. (2014). How many trees are enough? Tree death and the urban canopy. *Scenario Journal*. http://www.fs.fed.us/nrs/pubs/jrnl/2014/nrs_2014_roman_001.pdf
United States Department of Agriculture Forest Service. *i-Tree ECO Guide to Using the Forecast Model*. http://www.itreetools.org/resources/manuals/Ecov6_ManualsGuides/Ecov6Guide_UsingForecast.pdf
United States Department of Energy Information Administration. (1998). *Method for Calculating Carbon Sequestration by Trees in Urban and Suburban Settings*. http://www3.epa.gov/climatechange/Downloads/method-calculating-carbon-sequestration-trees-urban-and-suburban-settings.pdf

[8] Establishment and replacement care reduces the risk of mortality of trees planted by the project. Because this methodology applies an increased mortality rate in the first ten years after planting when trees are most at risk, the maximum value for years of establishment care in Equations 1-4 is 9 years to limit the tree mortality rate to 3%.

B. GHG Benefit from Energy Savings as a Result of Strategically Planting Trees to Shade Buildings

The GHG benefit from energy savings is calculated as the total annual energy savings from individual trees planted strategically to shade buildings (i.e., planted within 60 feet) during the 40 year quantification period, accounting for tree mortality. Equation 2 determines the GHG emission reductions from energy savings throughout the quantification period of the project based on i-Tree Planting outputs.

Equation 2: GHG Benefit from Energy Savings

$$GHG_{ESC} = \left(\frac{\sum_i ER_{ITP,i}}{1{,}000} \times EF_{ELEC} + \sum_i NG_{ITP,i} \times 10 \times EF_{NG}\right) \times (1 - 0.03)^{10-YC}$$

Where,			Units
GHG_{ESC}	=	GHG benefit from energy savings estimated using i-Tree Planting	MT CO_2e
$ER_{ITP,i}$	=	Total electricity reductions from each group of project trees over the 40 year quantification period (from i-Tree Planting)	kWh
EF_{ELEC}	=	GHG emission factor for electricity	MT CO_2e/ MWh
1,000	=	Conversion factor from kWh to MWh	kWh/MWh
$NG_{ITP,i}$	=	Total annual natural gas reductions from each group of project trees over the 40 year quantification period (from i-Tree Planting)	MMBtu
10	=	Conversion factor from MMBtu to therms	therm/ MMBtu
EF_{NG}	=	GHG emission factor for natural gas	MT CO_2e/ therm
0.03	=	Mortality rate (3% annual)	
10	=	Years after planting with greatest risk for mortality	years
YC	=	Years of establishment and replacement care provided by project (the maximum value for the purposes of this equation is 9 years; enter 9 if the project provides establishment and replacement care for a longer period of time)	years
i	=	Group of project trees planted	

C. GHG Emissions from Project Implementation

Tree planting projects must account for GHG emissions from tree planting, maintenance, and other tree-related activities. The GHG emissions from implementation of tree planting projects are calculated by deducting 5%[9] of the annual reductions obtained through carbon storage and avoided emissions from energy savings. Equation 3 is used to determine the GHG emissions from implementation of tree planting projects.

Equation 3: GHG Emissions from Tree Planting Project Implementation

$$GHG_{PI} = (GHG_{CSC} + GHG_{ESC}) \times EF_{IMP}$$

Where,			Units
GHG_{PI}	=	GHG emissions from tree planting	MT CO_2e
GHG_{CSC}	=	GHG benefit from carbon stored in live project trees estimated using i-Tree Planting	MT CO_2e
GHG_{ESC}	=	GHG benefit from energy savings estimated using i-Tree Planting	MT CO_2e
EF_{IMP}	=	Emission factor for project emissions	

The process and transportation emissions associated with tree removal in an urban wood and biomass utilization project are excluded from this quantification methodology because the trees to be utilized are trees that would be removed and transported to a landfill without the project. Process emissions at a mill or biomass facility are factored into the emission reduction factor for these activities.

Air Pollutant Co-Benefit from Trees Planted by the Project

The air pollutant emissions co-benefit from trees planted by the project is calculated as the sum of air pollutant emissions removed from the atmosphere by individual trees during the 40 year quantification period, accounting for a 3% annual tree mortality rate for the years after the period of establishment care (including replacement) provided by the project through year 10. Equations 4 and 5 are used to determine the air pollutant emission co-benefits from live project trees at the end of the project based on i-Tree Planting outputs.

[9] U.S. Department of Agriculture Forest Service, Tree Guides (multiple publications). https://www.fs.fed.us/psw/topics/urban_forestry/products/tree_guides.shtml

Equation 4: $PM_{2.5}$ Emissions Co-benefit from Tree Absorption (Local Benefit)

$$PM_{2.5,TA} = \left((ER_{PM,ITP} \times 0.28\right) \times (1 - 0.03)^{10-YC}$$

Where,			Units
$PM_{2.5,TA}$	=	$PM_{2.5}$ benefit of tree planting in live project trees estimated using i-Tree Planting	lb
$ER_{PM,ITP}$	=	Total $PM_{2.5}$ savings over the 40 year quantification period calculated from i-Tree Planting	lb
0.28	=	Conversion from PM_{10} to $PM_{2.5}$	$PM_{2.5}/PM_{10}$
0.03	=	Mortality rate (3% annual)	
10	=	Years after planting with greatest risk for mortality	years
YC	=	Years of establishment and replacement care provided by project	years

Equation 5: NO_x Emissions Co-benefit from Tree Absorption (Local Benefit)

$$NO_{x,TA} = \left(ER_{NOx,ITP}\right) \times (1 - 0.03)^{10-YC}$$

Where,			Units
$NO_{x,TA}$	=	NO_x benefit of tree planting in live project trees estimated using i-Tree Planting	lb
$ER_{NOx,ITP}$	=	Total NO_x savings over the 40 year quantification period calculated from i-Tree Planting	lb
0.03	=	Mortality rate (3% annual)	
10	=	Years after planting with greatest risk for mortality	years
YC	=	Years of establishment and replacement care provided by project	years

D. Air Pollutant Co-benefit from Energy Savings as a Result of Strategically Planting Trees to Shade Buildings

Equations 6 through 8 are used to determine the air pollutant emission co-benefits from energy savings throughout the quantification period of the project based on i-Tree Planting outputs.

Equation 6: $PM_{2.5}$ Emissions Co-benefit from Energy Savings (Remote Benefit)

$$PM_{2.5,ES} = \left((ER_{ITP}) \times PM_{ELEC} + (NG_{ITP}) \times PM_{NG}\right) \times (1 - 0.03)^{10-YC}$$

Where,

			Units
$PM_{2.5,ES}$	=	$PM_{2.5}$ benefit from energy savings estimated using i-Tree Planting	lb
ER_{ITP}	=	Total energy savings over the 40 year quantification period calculated from i-Tree Planting	kWh
PM_{ELEC}	=	$PM_{2.5}$ emission factor for electricity	lb/kWh
NG_{ITP}	=	Total natural gas savings over the 40 year quantification period calculated from i-Tree Planting	MMBtu
PM_{NG}	=	$PM_{2.5}$ emission factor for natural gas	lb/MMBtu
0.03	=	Mortality rate (3% annual)	
10	=	Years after planting with greatest risk for mortality	years
YC	=	Years of establishment and replacement care provided by project	years

Equation 7: NO_x Emissions Co-benefit from Energy Savings (Remote Benefit)

$$NO_{x,ES} = \left((ER_{ITP}) \times NOX_{ELEC} + (NG_{ITP}) \times NOX_{NG}\right) \times (1 - 0.03)^{10-YC}$$

Where,

			Units
$NO_{x,ES}$	=	NO_x benefit from energy savings estimated using i-Tree Planting	lb
ER_{ITP}	=	Total energy savings over the 40 year quantification period calculated from i-Tree Planting	kWh
NOX_{ELEC}	=	NO_x emission factor for electricity	lb/kWh
NG_{ITP}	=	Total natural gas savings over the 40 year quantification period calculated from i-Tree Planting	MMBtu
NOX_{NG}	=	NO_x emission factor for natural gas	lb/MMBtu
0.03	=	Mortality rate (3% annual)	
10	=	Years after planting with greatest risk for mortality	years
YC	=	Years of establishment and replacement care provided by project	years

Equation 8: ROG Emissions Co-benefit from Energy Savings

$$ROG_{ES} = \left((ER_{ITP}) \times ROG_{ELEC} + (NG_{ITP}) \times ROG_{NG}\right) \times (1 - 0.03)^{10-YC}$$

Where,

			Units
ROG_{ES}	=	ROG benefit from energy savings estimated using i-Tree Planting	lb
ER_{ITP}	=	Total energy savings over the 40 year quantification period calculated from i-Tree Planting	kWh
ROG_{ELEC}	=	ROG emission factor for electricity	lb/kWh
NG_{ITP}	=	Total natural gas savings over the 40 year quantification period calculated from i-Tree Planting	MMBtu
ROG_{NG}	=	ROG emission factor for natural gas	lb/MMBtu
0.03	=	Mortality rate (3% annual)	
10	=	Years after planting with greatest risk for mortality	years
YC	=	Years of establishment and replacement care provided by project (the maximum value for the purposes of this equation is 9 years; enter 9 if the project provides establishment and replacement care for a longer period of time)	years

E. Emission Reduction Estimates from Community Composting Projects

Both the GHG emission reductions and air pollutant emission estimates from community composting projects are estimated as the difference between the baseline of sending the organic materials to a landfill versus composting those materials using windrow composting processes. Equation 9 estimates the GHG reductions and Equation 10 estimates the criteria and toxics emissions.

Equation 9: Emission Reductions Estimates from Avoided Methane Emissions from Community Composting Projects

$$GHG_{CC} = (CP \div 1.4 \div 0.58) \times \left(COM_{FW} \times ERF_{FW,GHG} + COM_{GW} \times ERF_{GW,GHG}\right)$$

Where,			Units
GHG_{CC}	=	GHG emission reduction estimates from community composting projects	$MTCO_2e$
CP	=	Annual compost production	Cubic yards
1.4	=	Conversion factor from cubic yards to short tons	Short ton/cubic yard
0.58	=	Conversion factor from short tons of compost to short tons of feedstock	short ton of feedstock/ short ton of compost
COM_{FW}	=	Composition of food waste in feedstock	%
$ERF_{FW,GHG}$	=	Avoided methane emissions from food waste feedstock	MTCO2e/ short ton
COM_{GW}	=	Composition of green waste in feedstock	%
$ERF_{GW,GHG}$	=	Avoided methane emissions from green waste feedstock	MTCO2e/ short ton

Equation 10: Emission Reductions Estimates from Avoided Flare Emissions from Community Composting Projects (Remote Benefit)

$$CT_{CC} = (CP \div 1.4 \div 0.58) \times \left(COM_{FW} \times ERF_{FW,CT} + COM_{GW} \times ERF_{GW,CT}\right)$$

Where,

			Units
CT_{CC}	=	Criteria and toxic emission reduction estimates from community composting projects	lbs
CP	=	Annual compost production	Cubic yards
1.4	=	Conversion factor from cubic yards to short tons	Short ton/cubic yard
0.58	=	Conversion factor from short tons of compost to short tons of feedstock	short ton of feedstock/ short ton of compost
COM_{FW}	=	Composition of food waste in feedstock	%
ERF_{FW}	=	Avoided flare emissions from food waste feedstock	lbs/ short ton
COM_{GW}	=	Composition of green waste in feedstock	%
ERF_{GW}	=	Avoided flare emissions from green waste feedstock	lbs/ short ton

F. Emission Reduction Estimates from Lawn Management Projects

Both the GHG emission reductions and air pollutant emission estimates from lawn management projects are estimated to be the avoided emissions from lawn mowing and fertilizer application. The project life is estimated to be 10 years. Equation 11 and 14 estimate the GHG reductions and Equations 12, 13, and 15 estimate the criteria and toxics emissions.

Equation 11: GHG Emission Reductions from Avoided Equipment Usage

$$GHG_{TR} = EF_{EQ,GHG} \times AL \times \frac{1}{454} \times \frac{1}{2{,}204} \times PF \times PL$$

Where,

			Units
GHG_{TR}	=	GHG emission reductions from avoided lawn equipment usage	MT CO_2e
$EF_{EQ,GHG}$	=	GHG emission factor from lawn mower equipment	gCO2/hr
AL	=	Lawn mowing equipment run time	hr
454	=	Conversion factor from g to lbs	lb/g
2,204	=	Conversion factor from lbs to metric tons	MT/lb
PF	=	Average load factor	%
PL	=	Project life	years

Equation 12: $PM_{2.5}$ and NO_x Emission Reductions from Avoided Equipment Usage

$$CT_{TR} = EF_{EQ,NOx,PM} \times AL \times \frac{1}{454} \times PF \times PL$$

Where,

			Units
CT_{TR}	=	Criteria and toxic emission reductions from avoided lawn equipment usage	lbs
$EF_{EQ,NOx,PM}$	=	NO_x and $PM_{2.5}$ emission factor from lawn mower equipment	g/hr
AL	=	Lawn mowing equipment run time	hr
454	=	Conversion factor from g to lbs	lb/g
PF	=	Average load factor	%
PL	=	Project life	years

Equation 13: ROG Emission Reductions from Avoided Equipment Usage

$$CT_{TR,ROG} = \left(EF_{EQ,ROG,EX} \times AL + EF_{EQ,ROG,ST} \times S + \left(EF_{EQ,ROG,D} + EF_{EQ,ROG,Rest} \times 365\right) + EF_{EQ,ROG,Run} \times AL\right) \times \frac{1}{454} \times PF \times PL$$

Where,			Units
$CT_{TR,ROG}$	=	ROG emission reductions from avoided lawn equipment usage	lbs
$EF_{EQ,ROG,EX}$	=	ROG exhaust emission factor from lawn mower equipment	g/hr
AL	=	Lawn mowing equipment run time	hr
$EF_{EQ,ROG,ST}$	=	ROG start emission factor from lawn mower equipment	g/start
S	=	Starts per year	starts/yr
$EF_{EQ,ROG,D}$	=	ROG diurnal emission factor from lawn mower equipment	g/day
$EF_{EQ,ROG,REST}$	=	ROG resting loss emission factor from lawn mower equipment	g/day
365	=	days per year	day/year
$EF_{EQ,ROG,RUN}$	=	ROG running loss emission factor from lawn mower equipment	g/hr
454	=	Conversion factor from g to lbs	lb/g
PF	=	Average load factor	%
PL	=	Project life	years

Equation 14: GHG Emission Reductions from Avoided Fertilizer Usage and Application

$$GHG_{FA} = \left[A \times FUP \times AR \times EF_{FA} \times 43.56 \times 298 \times \frac{1}{2{,}204} + A \times FUP \times AR \times EF_{FP} \times 43.56 \times \frac{1}{2{,}204}\right] \times PL$$

Where,			Units
GHG_{FA}	=	GHG emission reductions from avoided fertilizer usage	MT
A	=	Acres of lawn removed	Acres
FUP	=	Fertilizer user percentage (Contractor = 1 and In-house = 0.75)	%
AR	=	Application rate of fertilizer	lb N/ 1000 sq ft
EF_{FA}	=	GHG emission factor of N_2O from the application of fertilizer	lb N_2O/ lb N
43.56	=	Conversion factor from 1,000 sq feet to acres	1000 sq ft/acre
298	=	Global warming potential of N_2O	
2,204	=	Pounds to metric tons conversion	lb/MT
EF_{FP}	=	GHG emission factor from the production of fertilizer	lb CO_2e /lb N
PL	=	Project life	years

Equation 15: NOx Emission Reductions from Avoided Fertilizer Usage and Application

$$CT_{FA} = [A \times FUP \times AR \times EF_{FA} \times 43.56 + A \times FUP \times AR \times EF_{FP} \times 43.56] \times PL$$

Where,			Units
CT_{FA}	=	Criteria and toxic emission reductions from avoided fertilizer usage	lbs
A	=	Acres of lawn removal	Acres
FUP	=	Fertilizer user percentage (Contractor = 1 and In-house = 0.75)	%
AR	=	Application rate of fertilizer	lb N/ 1000 sq ft
EF_{FA}	=	NO_x emission factor from the application of fertilizer	lb NO_x/ lb N
43.56	=	Conversion factor from 1,000 sq feet to acres	1000 sq ft/acre
EF_{FP}	=	NO_x emission factor from the production of fertilizer	lb CO_2e /lb N
PL	=	Project life	years

G. Net GHG, Criteria, and Toxic Emission Impacts

Equations 16 and 17 estimates the net benefits for GHGs, criteria, and toxic emissions associated with a CPL project.

Equation 16: Net GHG Impacts

$$GHG_{Net} = GHG_{CSC} + GHG_{ESC} - GHG_{PI} + GHG_{CC} + GHG_{TR} + GHG_{FA}$$

Where,

			Units
GHG_{Net}	=	Net GHG benefit from the project	MT CO_2e
GHG_{CSC}	=	GHG Benefit of Carbon Stored in Live Project Trees	MT CO_2e
GHG_{ESC}	=	GHG Benefit from Energy Savings as a Result of Strategically Planting Trees to Shade Buildings	MT CO_2e
GHG_{PI}	=	GHG Emissions from Project Implementation	MT CO_2e
GHG_{CC}	=	GHG Emission Reductions from Community Composting Projects	MT CO_2e
GHG_{TR}	=	GHG Emission Reductions from Avoided Equipment Usage	MT CO_2e
GHG_{FA}	=	GHG Emission Reductions from Avoided Fertilizer Usage and Application	MT CO_2e

Equation 17: Net Criteria and Toxic Emissions Impacts

$$CT_{Net} = CT_{ESC} + CT_{CC} + CT_{TR} + CT_{FA}$$

Where,

			Units
CT_{Net}	=	Net criteria and toxic emissions benefit from the project	lbs
CT_{ESC}	=	Criteria and toxic emissions benefit from Energy Savings as a Result of Strategically Planting Trees to Shade Buildings	lbs
CT_{CC}	=	Criteria and toxic emissions benefit from Community Composting Projects	lbs
CT_{TR}	=	Criteria and toxic emissions benefit from Avoided Equipment Usage	lbs
CT_{FA}	=	Criteria and toxic emissions benefit from Avoided Fertilizer Usage and Application	lbs

Section C. References

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