California Air Resources Board

Quantification Methodology

California State Coastal Conservancy Climate Ready Program

California Climate Investments

FINAL
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Table of Contents

Section A. Introduction

California Climate Investments (CCI) 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 net GHG benefit 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 or conservation practices 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 State Coastal Conservancy (SCC) Climate Ready Program (CRP), CARB staff developed this CRP Quantification Methodology to provide guidance for estimating the net GHG benefit and selected co-benefits of each proposed project. This methodology uses calculations to estimate carbon sequestration in planted trees, GHG emission reductions from the effects of tree shade on building energy use, and GHG emissions associated with the implementation of CRP tree planting projects. This methodology also uses calculations to estimate carbon sequestration and GHG emission reductions from Natural Resources Conservation Service (NRCS) Conservation Practices and California Department of Food and Agriculture (CDFA) Compost Application Rates associated with the implementation of CRP carbon farming projects. These methods are adapted from the CCI Urban Greening and Healthy Soils Programs to fit CRP program needs.

The CRP Benefits Calculator Tool automates methods described in this document along with the i-Tree Planting and/or the online COMET-Planner CDFA HSP Calculator Tool. Projects will report the total project GHG benefit and co-benefits estimated using the CRP Benefits Calculator Tool as well as the total project GHG benefit per dollar of GGRF funds requested. The CRP Benefits Calculator Tool is available for download at: http://www.arb.ca.gov/cci-resources.

Using many of the same inputs required to estimate net GHG benefit, the CRP Benefits Calculator Tool estimates the following co-benefits and key variables: (for tree planting projects), trees planted (quantity of trees), energy use reductions (kWh and therms), energy and fuel cost savings (dollars), water savings (gallons and acre feet per year), and select criteria and toxic air pollutant emissions (pounds) – including reactive organic gases (ROG), nitrogen oxide (NOx), and fine particulate matter less than 2.5

micrometers ($PM_{2.5}$); (for carbon farming projects) particulate matter 2.5 micrometers and smaller ($PM_{2.5}$) (in lbs), nitrous oxides (NO_x) (in lbs), ammonia (NH_3) (in lbs), and land restored/treated (in acres). Key variables are project characteristics that contribute to a project's net GHG benefit and signal an additional benefit (e.g., energy use reductions, and number of trees planted).

Additional co-benefits for which CARB assessment methodologies were not incorporated into the CRP Benefits Calculator Tool may also be applicable to the project. Applicants, in coordination with the agency, should consult the CRP guidelines, solicitation materials, and agreements to ensure they are meeting CRP requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

Methodology Development

CARB and SCC developed this Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability.[1] CARB and SCC developed this CRP 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 net GHG benefit 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 CRP project types. CARB also consulted with SCC 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.

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 for Tree Planting

The CRP Benefits Calculator Tool relies on project-specific outputs from one of the two U.S. Department of Agriculture (USDA) Forest Service (USFS) urban tree carbon accounting tools:

The USFS i-Tree Planting web based tool provides quantitative data for an individual or population of trees to be planted as part of the project including the amount of carbon stored, the estimated effects of tree shade on building energy use, 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 i-Tree Planting tool is used statewide, subject to regular updates to incorporate new information, free of charge, and publicly available to anyone with internet access.

Tools for Carbon Farming

The CRP Benefits Calculator Tool also relies on project-specific outputs from the online COMET-Planner CDFA HSP Calculator Tool to estimate the net GHG benefit of the proposed project. The online COMET-Planner CDFA HSP Calculator Tool is available at: http://comet-planner-cdfahsp.com/. The tool relies on project-specific outputs from the following tools:

COMET-Planner is largely derived using a sample-based approach and model runs in COMET-Farm, which utilizes USDA entity-scale GHG inventory methods. Coefficients were generalized by multi-county regions defined by USDA Major Land Resource Areas. Emissions estimates represent field emissions only, including those associated with soils and woody biomass as appropriate, and do not include off-site emissions, such as those from transportation, manufacturing, processing, etc. COMET-Farm is a web-based, whole farm, GHG accounting systems that employs methods outlined in the USDA Methods for Entity-Scale Inventory guidance. Estimation methods used for most GHG sources in COMET-Planner rely on advanced methods (commonly referred to as "Tier 3" methodologies in IPCC quantification methods), such as process-based modeling in DayCent and regionally-specific empirical calculations. COMET-Planner is available at: http://www.comet-planner.com/.

The Denitrification-Decomposition (DNDC) model is a process-based computer simulation model of carbon (C) and nitrogen (N) biogeochemistry and was developed for quantifying carbon sequestration and emissions of greenhouse gases in agroecosystems. The core of DNDC modeling consists of microbe-mediated biochemical processes commonly occurring in terrestrial soils. The processes simulated include decomposition, nitrification, denitrification, fermentation, and methanogenesis. A full description of the DNDC scientific basis and processes, including all equations involved, is available at http://www.dndc.sr.unh.edu/.

COMET-Planner and DNDC are used statewide, subject to regular updates to incorporate new information, free of charge, and publicly available to anyone with internet access.

State Coastal Conservancy staff will use the CRP Benefits Calculator Tool to estimate the co-benefits of the proposed project. The CRP-Benefits Calculator Tool is available at: http://www.arb.ca.gov/cci-resources. The tool relies on project-specific outputs from the DNDC model.

In addition to the tools above, the CRP Quantitative Methodology relies on CARB-developed emission factors. CARB has established a single repository for emission factors, 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. More information on quantification methods is available in the COMET-Planner Report.[2]

The agency, in coordination with applicants, must use the CRP Benefits Calculator Tool to estimate the net GHG benefits and co-benefits of the proposed project. The CRP Benefits Calculator Tool can be downloaded from: http://www.arb.ca.gov/cci-resources.

[2] http://bfuels.nrel.colostate.edu/health/COMET-Planner_Report_Final.pdf

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 Climate Ready Quantification Methodology from the previous version to enhance the analysis and provide additional clarity. The changes include:

- Correction of water savings estimate as irrigation savings only (previous version incorrectly summed rainfall interception, stormwater runoff, and irrigation savings as total water savings);
- A new weblink to the new URL for the water budget workbook per CCI water co-benefit assessment methodology.
- Removal of iTree streets from the Calculator Tool and Quantification Methodology for consistency across projects, streamline reporting, and reduce error in data collection.
    - Equation 2 and 4 have been removed from this document as they pertained to iTree Streets. The remaining equations were not renumbered.
    - Some iTree Streets references remain for transparency purposes and for context in this revision.

Section B. Methods

The following section provides details on the methods supporting emission reductions in the CRP Benefits Calculator Tool. Two project types are available in the CRP Benefits Calculator Tool for tree planting utilizing the i-Tree tool. Another project type is available in the CRP Benefits Calculator Tool for carbon farming utilizing the online COMET-Planner CDFA HSP Calculator tool.

Tree Planting Project Types

SCC incentivizes tree planting project activities for which there are methods to quantify a net GHG benefit.[3] Other project features may be eligible for funding under the Climate Ready Program; however, each project requesting GGRF funding must include at least one of the following:

- Sequester and store carbon by planting trees; or
- Reduce building energy use from strategically planting trees to shade buildings

Carbon Farming Project Type

SCC also incentivizes carbon farming project activities (initially developed for CDFA's Healthy Soils Program) for which there are methods to quantify a net GHG benefit. Other project features may be eligible for funding under the SCC CRP carbon farming project type; however, each project quantified by the online COMET-Planner CDFA HSP Calculator Tool must include at least one of the following Practice Implementations, as defined by NRCS Conservation Practice Standards[4] (CPS; each practice is uniquely numbered) or CDFA Compost Application Rates for California Croplands and Rangelands[5]:

[3] California State Coastal Conservancy (2018). Climate Ready Grant Announcement, Nature-Based Solutions for Climate Adaptation. http://scc.ca.gov/files/2018/04/Climate-Ready-Announcement.pdf.
[4] Details about specific NRCS California Conservation Practices can be found at https://efotg.sc.egov.usda.gov/; California; Section IV; Old Section IV; Conservation Practices – CA Approved.
[5] Details about CDFA Compost Application Practices can be found at https://www.cdfa.ca.gov/oefi/healthysoils/docs/CompostApplicationRate_WhitePaper.pdf.

Soil Management Practices

Cropland Management Practice Implementations

- Cover Crop (CPS 340)
    - Add Legume Seasonal Cover Crop to Irrigated Cropland
    - Add Non-Legume Seasonal Cover Crop to Irrigated Cropland

- Nutrient Management (CPS 590)
    - Improved N Fertilizer Management on Irrigated Croplands – Reduce Fertilizer Application Rate by 15%
- Residue and Tillage Management – No Till (CPS 329)
    - Intensive Till to No Till or Strip Till on Irrigated Cropland
    - Intensive Till to No Till or Strip Till on Non-Irrigated Cropland
- Residue and Tillage Management – Reduced Till (CPS 345)
    - Intensive Till to Reduced Till on Irrigated Cropland
    - Intensive Till to Reduced Till on Non-Irrigated Cropland

Compost Application Practice Implementations[6]

These Implementations are both for Compost Purchased from a Certified Facility and On-Farm Compost

- Annual Crops (CDFA Compost Application)
    - Compost (C/N > 11) Application to Annual Crops
    - Compost (C/N < or = 11) Application to Annual Crops
- Grasslands (CDFA Compost Application)
    - Compost (C/N > 11) Application to Grazed Grassland
    - Compost (C/N > 11) Application to Grazed Irrigated Pasture
- Perennials Orchards and Vineyards (CDFA Compost Application)
    - Compost (C/N > 11) Application to Perennials, Orchards and Vineyards
    - Compost (C/N < or = 11) Application to Perennials, Orchards and Vineyards

[6] These practice implementations are in Compost Purchased from a Certified Facility and On-Farm Compost. Some project sites may be ineligible for Compost Application as the quantifications of the implementations are no applicable due to high soil organic matter. Refer to the SCC Carbon Farming Project types and the Compost Ineligibility Map at www.arb.ca.gov/cci-quantification.

General Approach to Tree Planting

Methods used in the CRP Benefits Calculator Tool for estimating the net GHG benefit 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 carbon storage in planted trees, energy savings from the benefits of tree shade, and the GHG emissions associated with the implementation of tree planting projects. In general, the net GHG benefit is estimated in the CRP Benefits Calculator Tool using the approaches in Table 1. The CRP Benefits Calculator Tool also estimates air pollutant emission co-benefits and key variables using many of the same inputs used to estimate the net GHG benefit.

Table 1. General Approach to Quantification by Project Activity

Tree Planting and Energy Savings from Tree Shade
Net GHG benefit = carbon storage in planted trees – carbon in planted trees not assumed to survive[7] + GHG reductions from energy savings from shade[8] – GHG emissions from tree planting and maintenance.

User Tip:
Due to the difference in the outputs from the two urban tree accounting tools available for use, some equations are tool-specific, as indicated below.

General Approach to Carbon Farming

Methods used in the online COMET-Planner CDFA HSP Calculator Tool and the CRP Benefits Calculator Tool for estimating the net GHG benefit and air pollutant emission co-benefits by activity type are provided in this section. More Information about the CDFA and CARB Compost Application practices is available in the CDFA and CARB White Paper.[7] The CCI Quantification Methodology Emission Factor Database Documentation[8] explains how emission factors used in CARB Benefits Calculator Tools are developed and updated.

The CRP Quantification Methodology also estimates air pollutant emission co-benefits (NO_x and $PM_{2.5}$) and key variables (NH_3 and land restored/treated) using the same inputs used to estimate the net GHG benefit.

[7] https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/dndc_calculations.pdf
[8] https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials

A. GHG Benefit from Carbon Stored in Trees Planted by the Climate Ready Project

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, accounting for a 3% annual tree mortality rate[9] for the years after the period of establishment care (including replacement) provided by the project through year 10.[10] Equation 1 is used to determine the GHG benefit from carbon stored in live project trees at the end of the project if the agency in coordination with the applicant used i-Tree Planting. Equation 2 is removed from the quantification methodology and tool to streamline the accounting process and apply a consistency across projects.

Equation 1: GHG Benefit of Carbon Stored in Live Project Trees *(i-Tree Planting)*

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

Where,			Units
GHG_{CSC}	=	GHG benefit of carbon stored in live project trees estimated using i-Tree Planting	MT CO_2e
C_{ITP}	=	Carbon stored in each group of project trees i over the 40 year quantification period (from i-Tree Planting)	lb CO_2e
i	=	Each group of project trees planted	
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. SCC requires a minimum of 10 years for establishment and replacement care at the project location, so the calculator is set to a default of 9 years to represent the maximum value.)	years
2,204.62	=	Conversion factor from lb to MT	lb/MT

[9] Roman, Lara. (Spring 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. (April 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

[10] 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, taking tree mortality into account. Equation 3 is used to determine the GHG emission reductions from energy savings throughout the quantification period of the project if the agency in coordination with the applicant used i-Tree Planting.

Equation 4 is removed from the quantification methodology and tool to streamline the accounting process and apply a consistency across projects.

Equation 3: GHG Benefit from Energy Savings *(i-Tree Planting)*

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

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/ kWh
NG_{ITP}	=	Total fuel reductions from each group of project trees over the 40 year quantification period (from i-Tree Planting)	MMBtu
i	=	Group of project trees planted	
10	=	Conversion factor from MMBtu to therms	therms/ 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. SCC requires a minimum of 9 years for establishment and replacement care at the project location, so the calculator is set to a default of 9 years to represent the maximum value.)	years

C. GHG Emissions from Tree Planting Implementation

Tree planting projects must account for GHG emissions from tree planting, maintenance, and other related activities. The GHG emissions from implementation of tree planting projects are calculated by deducting 5%[11] of the annual reductions obtained through carbon storage and avoided emissions from energy savings. Equation 5 is used to determine the GHG emissions from implementation of tree planting projects.

Equation 5: GHG Emissions from Tree Planting Project Implementation

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

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 (from Equation 1)	MT CO_2e
GHG_{CSI}	=	GHG benefit from carbon stored in live project trees estimated using i-Tree Streets (from Equation 2)	MT CO_2e
GHG_{ESC}	=	GHG benefit from energy savings estimated using i-Tree Planting (from Equation 3)	MT CO_2e
GHG_{ESI}	=	GHG benefit from energy savings estimated using i-Tree Streets (from Equation 4)	MT CO_2e
EF_{IMP}	=	Emission factor for project implementation emissions	

[11] U.S. Department of Agriculture Forest Service, Tree Guides (multiple publications). http://www.fs.fed.us/psw/programs/uesd/uep/tree_guides.shtml.

D. Net GHG Benefit from Tree Planting

The net GHG benefit from any project is the sum of the carbon stored in planted trees and emission reductions from energy savings, less the GHG emissions associated with the implementation of the project. Equation 6 is used to determine the net GHG benefit from Climate Ready projects.

Equation 6: Net GHG Benefit

$$GHG = (GHG_{CSC} + GHG_{CSI} + GHG_{ESC} + GHG_{ESI}) - GHG_{PI}$$

Where,			Units
GHG	=	Net GHG benefit from the project	MT CO_2e
GHG_{CSC}	=	GHG benefit of carbon stored in live project trees estimated using i-Tree Planting (from Equation 1)	MT CO_2e
GHG_{CSI}	=	GHG benefit of carbon stored in live project trees estimated using i-Tree Streets (from Equation 2)	MT CO_2e
GHG_{ESC}	=	GHG benefit from energy savings estimated using i-Tree Planting (from Equation 3)	MT CO_2e
GHG_{ESI}	=	GHG benefit from energy savings estimated using i-Tree Streets (from Equation 4)	MT CO_2e
GHG_{PI}	=	GHG emissions from project implementation (from Equation 5)	MT CO_2e

E. Air Pollutant Co-Benefit from Trees Planted by the Project

The air pollutant emission 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 7 and 8 are used to determine the air pollutant emission co-benefits from live project trees at the end of the project if the agency in coordination with the applicant used i-Tree Planting.

Equation 7: $PM_{2.5}$ Emissions Co-benefit from Tree Absorption

$$PM_{2.5,TA} = (ER_{PM,ITP} + (ER_{PM,ITS} \times 20 \times 0.28)) \times (1 - 0.03)^{10-YC}$$

Where,			Units
$PM_{2.5,TA}$	=	$PM_{2.5}$ benefit of tree planting in live project trees estimated using i-Tree Planting and i-Tree Streets	lb
$ER_{PM,ITP}$	=	Total $PM_{2.5}$ savings over the 40 year quantification period calculated from i-Tree Planting	lb
$ER_{PM,ITS}$	=	Annual PM_{10} savings 40 years after project start calculated from i-Tree Streets	lb
20	=	Years adjusted for annual savings output at year 40	years
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 (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

Equation 8: NO_x Emissions Co-benefit from Tree Absorption

$$NO_{x,TA} = (ER_{NOx,ITP} + (ER_{NOx,ITS} \times 20)) \times (1 - 0.03)^{10-YC}$$

Where,			Units
$NO_{x,TA}$	=	NO_x benefit of tree planting in live project trees estimated using i-Tree Planting and i-Tree Streets	lb
$ER_{NOx,ITP}$	=	Total NO_x savings over the 40 year quantification period calculated from i-Tree Planting	lb
$ER_{NOx,ITS}$	=	Annual NO_x savings 40 years after project start calculated from i-Tree Streets	lb
20	=	Years adjusted for annual savings output at year 40	years
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

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

Equations 9 through 11 are used to determine the air pollutant emission co-benefits from energy savings throughout the quantification period of the project if the agency in coordination with the applicant used i-Tree Planting.

Equation 9: $PM_{2.5}$ Emissions Co-benefit from Energy Savings

$$PM_{2.5,ES} = \Big(\big(ER_{ITP} + (ER_{ITS} \times Shade\ \% \times 20 \times 1{,}000)\big) \times PM_{ELEC} + (NG_{ITP} + (NG_{ITS} \times 0.1 \times 20)) \times PM_{NG}\Big) \times (1 - 0.03)^{10-YC}$$

Where,			Units
$PM_{2.5,ES}$	=	$PM_{2.5}$ benefit from energy savings estimated using i-Tree Planting and i-Tree Streets	lb
ER_{ITP}	=	Total energy savings over the 40 year quantification period calculated from i-Tree Planting	kWh
ER_{ITS}	=	Annual energy savings 40 years after project start calculated from i-Tree Streets	MWh
Shade %		The percent of the trees that will be planted to shade buildings (i.e. within 60 ft); for users of i-Tree Streets	%
20	=	Years adjusted for annual energy savings output at year 40	years
1,000	=	Conversion factor from MWh to kWh	kWh/MWh
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
NG_{ITS}	=	Annual natural gas savings 40 years after project start calculated from i-Tree Streets	therms
0.1	=	Conversion from therms to MMBtu	MMBtu/therms
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 (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

Equation 10: NO_x Emissions Co-benefit from Energy Savings

$$NO_{X,ES} = \Big(\big(ER_{ITP} + (ER_{ITS} \times Shade\,\% \times 20 \times 1{,}000)\big) \times NO_{X,ELEC} + (NG_{ITP} + (NG_{ITS} \times 0.1 \times 20)) \times NO_{X,NG}\Big) \times (1 - 0.03)^{10-YC}$$

Where,

			Units
$NO_{x,ES}$	=	NO_x benefit from energy savings estimated using i-Tree Planting and i-Tree Streets	lb
ER_{ITP}	=	Total energy savings over the 40 year quantification period calculated from i-Tree Planting	kWh
ER_{ITS}	=	Annual energy savings 40 years after project start calculated from i-Tree Streets	MWh
Shade %		The percent of the trees that will be planted to shade buildings (i.e. within 60 ft); for users of i-Tree Streets	%
20	=	Years adjusted for annual energy savings output at year 40	years
1,000	=	Conversion factor from MWh to kWh	kWh/MWh
$NO_{X,ELEC}$	=	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
NG_{ITS}	=	Annual natural gas savings 40 years after project start calculated from i-Tree Streets	therms
0.1	=	Conversion from therms to MMBtu	MMBtu/therm
$NO_{X,NG}$	=	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 (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

Equation 11: ROG Emissions Co-benefit from Energy Savings

$$ROG_{ES} = \left(\left(ER_{ITP} + (ER_{ITS} \times Shade\ \% \times 20 \times 1{,}000) \right) \times ROG_{ELEC} + (NG_{ITP} + (NG_{ITS} \times 0.1 \times 20)) \times ROG_{NG} \right) \times (1 - 0.03)^{10-YC}$$

Where,			Units
ROG_{ES}	=	ROG benefit from energy savings estimated using i-Tree Planting and i-Tree Streets	lb
ER_{ITP}	=	Total energy savings over the 40 year quantification period calculated from i-Tree Planting	kWh
ER_{ITS}	=	Annual energy savings calculated from i-Tree Streets	MWh
Shade %		The percent of the trees that will be planted to shade buildings (i.e. within 60 ft); for users of i-Tree Streets	%
20	=	Years adjusted for annual energy savings output at year 40	years
1,000	=	Conversion factor from MWh to kWh	kWh/MWh
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
NG_{ITS}	=	Annual natural gas savings 40 years after project start calculated from i-Tree Streets	therms
0.1	=	Conversion from therms to MMBtu	MMBtu/therm
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

G. Net Air Pollutant Co-Benefit from Tree Planting

The net air pollutant emission co-benefits from any project is the sum of the individual air pollutant emissions adsorbed by planted trees, and emission reductions from energy savings. Equations 12 through 14 are used to determine the net air pollutant emission co-benefits from CRP projects.

Equation 12: $PM_{2.5}$ Net Emissions Benefit

$$PM_{2.5} = PM_{2.5,TA} + PM_{2.5,ES}$$

Where,

			Units
$PM_{2.5}$	=	Net $PM_{2.5}$ benefit from the project	lb
$PM_{2.5,TA}$	=	$PM_{2.5}$ benefit of tree absorption in live project trees estimated using i-Tree Planting or i-Tree Streets (from Equation 6)	lb
$PM_{2.5,ES}$	=	$PM_{2.5}$ benefit from energy savings estimated using i-Tree Planting or i-Tree Streets (from Equation 8)	lb

Equation 13: NO_x Net Emissions Benefit

$$NO_X = NO_{X,TA} + NO_{x,ES}$$

Where,

			Units
NO_x	=	Net NO_x benefit from the project	lb
$NO_{x,TA}$	=	NO_x benefit of tree absorption in live project trees estimated using i-Tree Planting or i-Tree Streets (from Equation 7)	lb
$NO_{x,ES}$	=	NO_x benefit from energy savings estimated using i-Tree Planting or i-Tree Streets (from Equation 9)	lb

Equation 14: ROG Net Emissions Benefit

$$ROG = ROG_{ES}$$

Where,

			Units
ROG	=	Net ROG benefit from the project	lb
ROG_{ES}	=	ROG benefit from energy savings estimated using i-Tree Planting or i-Tree Streets (from Equation 10)	lb

H. Emissions Reductions from Carbon Farming Projects

Both the net GHG benefit and air pollutant emission reductions from project implementation are estimated using Equations 15-17.

Equation 15: Emission Reductions from Project Practice Implementation

$$ER_{CFP} = QA_{PIM} \times Yr \times ERC_{POL,PIM,C}$$

Where,

			Units
ER_{CFP}	=	GHG and air pollutant emissions reductions from carbon farming project implementation.	$MTCO_2e$/yr or lbs/yr
QA_{PIM}	=	Quantified area of project site for a practice implementation	acres
Yr	=	Number of years project practice will be implemented	year
$ERC_{POL,PIM,C}$	=	Emission Reduction Coefficient for a given pollutant for a practice implementation implemented in a county.	$MTCO_2e$/acre-yr or lbs/acre-yr

Equation 16: Quantified Area of Project Practice Implementation

$$QA = PA_{PIM} - CA_{PIM}$$

Where,

			Units
QA	=	Quantified area: The area project site where the practice implementation is estimated for Benefits	acres
PA_{PIM}	=	Project area: The area where the practice is implemented in the project.	acres
CA_{PIM}	=	Continuing area: The area in the project where any practice implementation was implemented in the previous year. CA has a value of zero for new practices to the Project area.	acres

Equation 17: Area Calculation for Linear Practice Implementations

$$A_{PIM} = \frac{1}{43{,}560} \times L_{PIM} \times W_{PIM}$$

Where,

			Units
A_{PIM}	=	Area of a practice implementation.	acres
L_{PIM}	=	The center-line length of a linear practice implementation.	feet
W_{PIM}	=	The width of a practice implementation, determined by the agency in coordination with the applicant, Conservation Practice Standard, Conservation Practice Specification, or Conservation Management Plan. Refer to Climate Ready Program Guidelines.	feet

Section C. References

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

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