California Air Resources Board

Greenhouse Gas Quantification Methodology

California Department of Food and Agriculture
State Water Efficiency and Enhancement Program

California Climate Investments

November 8, 2018

Table of Contents

Section A. Introduction

The goal of California Climate Investments is to reduce greenhouse gas (GHG) emissions and further the purposes of the Global Warming Solutions Act of 2006, known as Assembly Bill (AB) 32. The California Air Resources Board (CARB) is responsible for providing the quantification methodology to estimate the GHG emission reductions and other benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). CARB develops these methodologies based on the project types eligible for funding by each administering agency as reflected in the program Expenditure Records available at: https://www.arb.ca.gov/cc/capandtrade/auctionproceeds/expenditurerecords.htm. CARB staff periodically review each quantification methodology to evaluate its effectiveness and update methodologies to make them more robust, user-friendly, and appropriate to the projects being quantified.

For the California Department of Food and Agriculture (CDFA) State Water Efficiency and Enhancement Program (SWEEP) funded by Proposition 68, CARB staff developed this quantification methodology and SWEEP GHG Calculator Tool to provide methods for estimating GHG emission reductions of each proposed project (Section B), and provide instructions for documenting and supporting the estimate (Section C).

This methodology uses calculations to estimate the GHG emission reductions from on-farm pump and motor enhancement and/or replacement, irrigation system enhancement, and fuel conversion associated with implementation of SWEEP projects. These calculations are based on the current understanding of irrigation practices, irrigation system enhancements, fuel conversions, and GHG emission factors. Projects will report the total project GHG emission reductions estimated using this methodology.

CARB released the draft quantification methodology and SWEEP GHG Calculator Tool for public comment in November 2016. This quantification methodology and accompanying GHG emission reduction calculator have been updated to reflect CDFA Program updates and public comments received, and adopted for use in the Proposition 68-funded State Water Efficiency and Enhancement Program. No changes in the calculation of GHG benefits as described in the Fiscal Year 2016-17 State Water Efficiency and Enhancement Program Quantitative Methodology have been made.

SWEEP Project Types

CARB developed three project types that meet the objectives of the SWEEP and for which there are methods to quantify GHG emission reductions. Each project requesting funding must include at least one of the following project components for FY 2016-17:

- Pump and motor enhancement and/or replacement
- Irrigation system enhancement
- Fuel conversion

Per SWEEP Program Guidelines:[1]

Eligible projects must:

- Reduce GHG emissions; and
- Reduce water use.

Applicants must provide supporting documentation directly related to actual on-farm water consumption and GHG emissions.

Note: Projects that reduce water consumption but do not reduce GHG emissions are not considered an eligible project.

Section B of this quantification methodology details the methods to use based on the project component(s) proposed.

Methodology Development

CARB and CDFA developed this quantification methodology consistent with the implementation principles of California Climate Investments, including ensuring transparency, accountability, and outreach and access for disadvantaged communities as described in CARB's Funding Guidelines for Agencies that Administer California Climate Investments (Funding Guidelines).[2] CARB and CDFA developed this quantification methodology through a public process 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 reviewed peer-reviewed literature and tools, and consulted with experts, as needed, to determine methods appropriate for the SWEEP project types. CARB also consulted with CDFA 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.

Tools

This quantification methodology and the SWEEP GHG Calculator Tool rely on project-specific outputs from the following tools:

[1] https://www.cdfa.ca.gov/oefi/sweep/
[2] Funding Guidelines for Agencies Administering California Climate Investments. December 21, 2015. www.arb.ca.gov/cci-fundingguidelines.

A SWEEP Irrigation Water Savings Assessment Tool (SWEEP Water Savings Tool) is used to estimate the potential water savings of SWEEP projects. This calculator was modeled after an existing tool used by conservationists at the United States Department of Agriculture (USDA) National Resource Conservation Service (NRCS), but has been modified for use by SWEEP applicants. For projects that reduce water use and pump demand, applicants will use this tool to estimate water savings from proposed irrigation system enhancements. The water savings estimate determined by the SWEEP Water Savings Tool is used as an input in the SWEEP GHG calculator tool. The tool can be accessed at: https://www.cdfa.ca.gov/oefi/sweep/docs/IrrigationWaterSavingsAssessmentTool.xls.

Applicants must use this quantification methodology, in conjunction with the accompanying SWEEP GHG Calculator Tool, to estimate the GHG emission reductions of the proposed project.

Major Updates

At CDFA's request, CARB updated this quantification methodology and the accompanying SWEEP GHG Calculator Tool from the previous versions[3] for CDFA to administer SWEEP with funding from Proposition 68. Changes include:

- General changes to document formatting and program language.
- Changes to reflect updates to the SWEEP Water Savings Tool.
- Updates to instructions and examples, where applicable.
- Formatting to reflect SWEEP funding from Proposition 68.

CARB also updated the accompanying SWEEP GHG Calculator Tool from the previous version.[4] The changes include:

- Formatting to reflect SWEEP funding from Proposition 68.

Program Assistance

CARB staff, CDFA staff, and SWEEP technical reviewers will review the quantification portions of the SWEEP project applications to ensure that the methods described in this document were properly applied to estimate the GHG emission reductions for the proposed project. Applicants should use the following resources for additional questions and comments:

- Questions on this quantification document should be sent to GGRFProgram@arb.ca.gov.
- Questions pertaining to the SWEEP should be sent to grants@cdfa.ca.gov.

[3] Greenhouse Gas Quantification Methodology for the California Department of Food and Agriculture State Water Efficiency and Enhancement Program FY 2015-16. Released March 15, 2016.
[4] Greenhouse Gas Emission Reduction Calculator (Version 2) for the California Department of Food and Agriculture State Water Efficiency and Enhancement Program FY 2015-16. Released July 22, 2016.

Section B. Greenhouse Gas Quantification Methodology

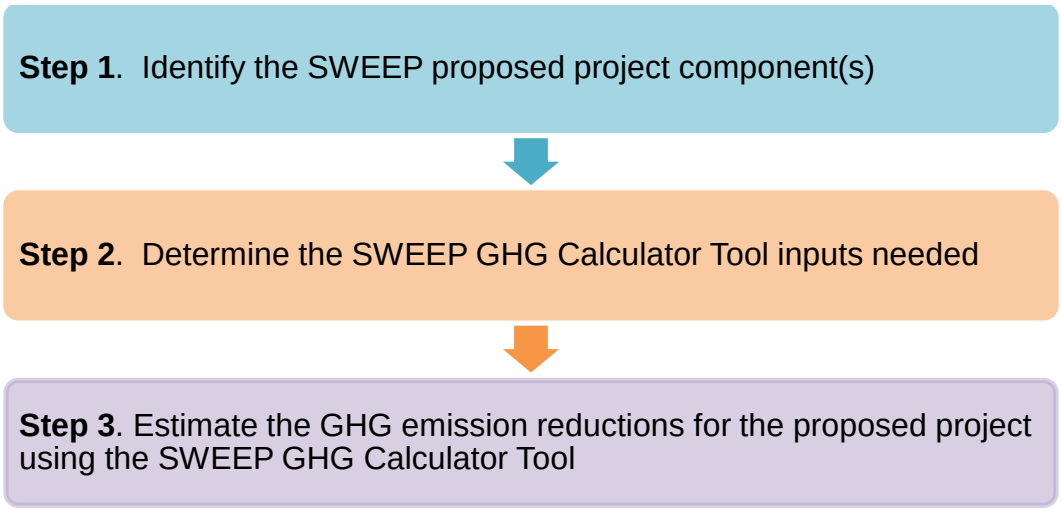
This quantification methodology accounts for GHG emission reductions of a proposed SWEEP project based on reduction in on-farm energy use as a result of pump and motor enhancements and/or replacement, reductions in pump demand from irrigation system enhancements, and fuel conversion (i.e., to a less carbon intensive fuel or installation of on-site renewable energy generation). In general, the GHG emission reductions are calculated using the following approaches:

Table 1. General Approach to GHG Quantification by Project Type

Pump and Motor Enhancements
$GHG\ Emission\ Reductions = GHG\ Emissions\ of\ Old\ Pump - GHG\ Emissions\ of\ New\ Pump\ (Including\ VFD)$
Irrigation System Enhancements (for systems utilizing pumps)
$GHG\ Emission\ Reductions = GHG\ Emissions\ Reductions\ of\ Pump\ Operation\ for\ Reduction\ in\ Water\ Use$
Fuel Conversions and Renewable Energy
$GHG\ Emission\ Reductions = GHG\ Emissions\ of\ Displaced\ Fuel\ or\ GHG\ Emission\ Reductions\ from\ Less\ Carbon\ Intensive\ Fuel$

Applicants will follow the steps outlined in Figure 1 to estimate the GHG emission reductions from the proposed project. Detailed instructions for each step are provided on subsequent pages.

Figure 1. Steps to Estimating GHG Emission Reductions



Step 1: Identify the Project Components and Appropriate Methods for the Proposed Project

For GHG quantification purposes, eligible SWEEP projects consist of several potential project components. Applicants may incorporate more than one project component and can use multiple methods identified in this quantification methodology, as appropriate, to quantify the GHG emission reductions. Applicants must identify the project components that apply to the project as identified in the 2016 SWEEP "Request for Grant Applications" (i.e., guidelines) or from Table 2 of this document. All projects must achieve energy use reductions and result in water use reductions. To achieve both objectives, projects may require multiple components. The project components identified will determine which subsections of this quantification methodology and sections of the accompanying GHG Calculator Tool must be used in order to estimate the GHG emission reductions.

Each calculation is for a single irrigated plot with a dedicated pump. For projects with additional pumps being upgraded or multiple plots, applicants must perform calculations on the additional Inputs tabs for each pump or individual plot. Project acreage and funding requested needs only to be included once for a project (i.e., in the first Input tab). Total GHG Emission Reductions are displayed as a cumulative total of each Input tab in the Summary Tab.

Table 2. Project Components and Appropriate Quantification Methods

Pump and Motor Enhancements
Install a variable frequency drive (VFD) (booster pump or well pump)
Motor replacement or efficiency improvement
Pump replacement or efficiency improvement
Irrigation System Enhancements (for systems utilizing pumps)
Install or modify irrigation system that results in a reduction in system pressure
Install automated irrigation system, scheduling, soil moisture sensors, or other techniques to reduce water use that reduce pump demand
Fuel Conversions and Renewable Energy
Change fuel types to less carbon intensive fuel (in conjunction with water savings measures)
Install renewable energy on-site to offset fuel use

Step 2: Determine the SWEEP GHG Calculator Tool Inputs Needed

Table 3 identifies the required data inputs needed to estimate the GHG emission reductions for proposed projects with the SWEEP GHG Calculator Tool by project component. Links for the SWEEP GHG Calculator Tool and SWEEP Water Savings Tool calculator are available in Section A. Introduction, Tools. Instructions for using the SWEEP Water Savings Tool are included within the tool on the **Instructions** tab.

Table 3. Required SWEEP GHG Calculator Tool Inputs for Eligible Project Components

All Projects
General Information (Read Me worksheet) • Project name; • Project ID; • Contact Name; • Contact Phone Number; • Contact Email; and • Date Completed. **Existing Conditions** (prior to any project modification) • Total Irrigated Project Area (acres); • Total Funds requested ($); • Pump fuel amount or electricity use (gallons, therms, or kWh); and • Fuel type.
Pump and Motor Enhancements
Greenhouse Gas Quantification Inputs (both pre-project values and post-project estimates) (Inputs worksheet) • Motor Rated Horsepower (hP); • Operational hours in a growing season; this parameter is only needed for pre-project scenario for determining baseline energy demand if energy use data is unavailable; • Overall Pumping Efficiency (%); and • System Pressure, in units of feet, determined from the following user inputs: o Pumping depth (ft) – this is depth from which groundwater is pumped o Discharge pressure from pump (ft) o Friction losses (ft); if unknown, use a default of 10 ft for well pumps and 5 ft for booster pumps *Note: If pressures are known in units of pounds per square inch (psi), the calculator tool provides a mechanism for conversion to units of feet.* • If a VFD will be installed, specify appropriate VFD scenario (booster or well)
Irrigation System Enhancements (for systems utilizing pumps)
Greenhouse Gas Quantification Inputs (Inputs worksheet) • Water savings, as estimated in cell F6 on the **Summary** tab of the SWEEP Water Savings Tool (%). If the project includes system repairs preventing leakage, these values should be captured in the SWEEP Water Savings Tool.

Fuel Conversions and Renewable Energy
Greenhouse Gas Quantification Inputs (Inputs worksheet) • New fuel type if converting to a different fuel; and • Capacity of renewable energy installations (kW). *Note: The renewable energy capacity is not the expected output.* • If converting fuels, enter the change from the drop down menu in the CARB GHG calculator tool.

Step 3: Estimate GHG Emission Reductions for the Proposed Project Using the SWEEP GHG Calculator Tool

Applicants must use the SWEEP GHG Calculator Tool to complete this step. The Calculator Tool can be downloaded from www.arb.ca.gov/cci-quantification. The applicant will enter the project details into the SWEEP GHG Calculator Tool to calculate the GHG emission reductions over the useful life[5] using the inputs identified in Step 2.

Read Me Tab

On the **Read Me** tab, enter the Project Name, Project ID, and the contact information for person who can answer project specific questions from staff reviewers on the quantification calculations. This file must be submitted with other required documents.

Inputs Tab

Headers in red indicate a field that requires input by the project applicant. For each project component section, please complete all relevant data. For example, if the project is not making changes to the pump or motor, the existing pump information will still be utilized in determining energy reductions from irrigation system enhancements. If applicants are implementing more than one project or their project impacts more than one pump or well site, the applicant should run the calculator tool for each pump or well site impacted. Project acreage and funding requested needs only to be included once for a project, in the first Input tab. Definitions are provided in the **Definitions** tab. Inputs must be substantiated in the documentation provided in accordance with Section C. Documentation.

Summary Tab

The **Summary** tab identifies the annual and useful life GHG emission reductions associated with SWEEP project enhancements. In addition, the total funds awarded, Total GHG emission reductions per acre, and the reporting metric of the project are summarized.

- **Net GHG Benefits over Useful Life** is equal to the sum total of each of the GHG emission reductions calculated in Section B and are automatically summed over the useful life in the SWEEP GHG Calculator Tool.

[5] For purposes of SWEEP projects, the life of a proposed project (i.e., useful life) is defined as the number of years recipients are expected to use and maintain their system. The default useful life for these projects is 10 years.

- **Total GHG Emission Reductions per Total Funds Requested** is calculated as:

$$\frac{Total\ Project\ GHG\ Emission\ Reductions\ in\ Metric\ Tons\ of\ CO_2e}{SWEEP\ Funds\ Requested\ (\$)}$$

Section C. Documentation

In addition to SWEEP application requirements, applicants for funding are required to document results from the use of this quantification methodology, including supporting materials to verify the accuracy of project-specific inputs.

Applicants are required to provide electronic documentation that is complete and sufficient to allow the calculations to be reviewed and replicated. Paper copies of supporting materials must be available upon request by agency staff.

The following checklist is provided as a guide to applicants; additional data and/or information may be necessary to support project-specific input assumptions.

	Documentation Description	Completed
1.	Project Application	
2.	Project description, including excerpts or specific references to the location in the main SWEEP application of the project information necessary to complete the applicable portions of the quantification methodology	
3.	Populated SWEEP GHG Calculator Tool file (in.xls) with worksheets applicable to the project populated (ensure that the Total Project GHG Emission Reductions and Total Project GHG Emission Reductions/SWEEP Funds Requested fields in the summary worksheet contain calculated values)	
4.	Project data support, including: • Calculator inputs determined in Step 2; • Documentation of the project data used to support SWEEP GHG Calculator Tool inputs (i.e., energy use, pump and motor specifications, and water savings estimates (SWEEP Water Savings Tool)); • References to public documents that are the source of the project data; and • Any other information as necessary and appropriate to substantiate inputs	

Appendix A. Example Project

The following is a hypothetical project[6] to demonstrate how the SWEEP Program Quantification Methodology would be applied. This example does not provide examples of the supporting documentation that is required of actual project applicants.

Overview of the proposed project

A 100 acre farm in the Central Valley utilizes a high pressure solid set sprinkler system to irrigate vegetable crops. The farmer sources irrigation water primarily from an on-site groundwater well that employs an older, inefficient vertical turbine pump rated at 100 horsepower (hP) used in conjunction with a diesel motor. A pump test reported an overall pumping efficiency of 70%. Through CDFA's SWEEP grant program, the farmer proposes to convert the existing high pressure irrigation system to a low pressure micro-drip irrigation system. The farmer also proposes to replace the inefficient diesel motor/pump system with a new and more efficient electric motor/pump system rated at 80 hP with a VFD controller. In addition, the farmer proposes to install 20 kilowatt (kW) solar panels to provide renewable electricity to supplement a portion of the power to the electric pump system. Below are the steps that the applicant would perform to estimate the proposed project GHG emission reductions utilizing the SWEEP GHG Calculator Tool.

Methods to apply

Step 1. Identify the SWEEP Proposed Project Type(s)

The first step is to identify applicable project components that will reduce both GHG emissions and water usage. CDFA has identified applicable project components in the SWEEP guidelines. In addition, Table 1 of this document provides a list of the most common eligible project components expected to be funded under SWEEP. The applicant must identify at least one project component from the list of applicable project components that defines the proposed project. All projects must both achieve energy use reductions to achieve GHG emission reductions and water use reductions. To achieve both objectives, many projects will include multiple components. The project components identified will inform the sections of the SWEEP GHG Calculator Tool required to determine GHG emission reductions. Each calculation is for a single irrigated plot with a dedicated pump. For projects with multiple plots, applicants must perform calculations for each individual plot and submit each run as well as a cumulative value for net GHG emission reductions.

In the above example, the project applicant identified irrigation system conversion that reduced system pressure and reduce water usage, motor/pump system replacement to improve system efficiency, VFD controller installation, and solar PV installation to provide renewable energy.

[6] The hypothetical project has not undergone verification of any SWEEP Program requirements; all assumptions about location type and features are for quantification methodology demonstration purposes only.

Steps 2 & 3. Determine the Inputs Needed and Estimate GHG Emission Reductions (using SWEEP GHG Calculator Tool)

The applicant determines all of the required inputs from Table 2 for the SWEEP GHG Calculator Tool to estimate GHG emission reductions. The next step for the applicant is to review the **Read Me** tab of the SWEEP GHG Calculator Tool and to enter the project identifier information. Below is an example of the required project identifier information that is entered by an applicant.

Project Name:	Smith Brothers Farm
Project ID - FAAST:	12-3456789
Contact Name:	John Smith
Contact Phone Number:	916-555-1234
Contact Email:	john@smithbros.com
Date Completed:	12/1/2016
Total Irrigated Project Area (acres):	100
Total funds requested ($):	$ 100,000

Next, the applicant enters in the identified proposed project information for both pre-project and post-project cases into the SWEEP GHG Calculator Tool in the **Inputs** tab. The red headers under the "Input Data" column are project descriptors and indicate the fields (highlighted in yellow) that the applicant enters into the applicable pre-project and post-project columns. Below are sample inputs for the SWEEP GHG Calculator Tool from the example proposed project.

General Project Information

The "General Project Information" section is required for every applicant. Each project descriptor must have the associated project input.

General Project Information	
Input Data	Pre-Project
Field or Ranch Name	West Field
Pump fuel or electricity use (gallons, scf, kWh)	5,000
Fuel type	Diesel
Fuel Emissions Factor	0.013717

Pump and Motor Enhancement and Replacement

This section is required for proposed projects that incorporate improvements to the irrigation pump system. If pressures are not known in units of feet, please utilize the green "Pressure Conversion" tab to convert pressure into units of feet.

Pump and Motor Enhancement and Replacement - This Section required for all applicants		
Input Data	Pre-Project	Post-Project
Motor Rated Horsepower (hP)	100	80
Operational Hours (hr) (if Known) - If unknown, leave cell blank		
Overall Pumping Efficiency (%)	75%	75%
System Pressure (ft)	User may override system pressure if known.	User may override system pressure if known.
Pumping depth (ft)	350	350
Discharge pressure (ft)	100	50
Friction losses (ft)	10	10
Are you installing a VFD?	N/A	VFD Well Pump

Irrigation System Enhancement (for systems utilizing pumps)
This section is required for irrigation system modifications and improvements that result in water savings. Water savings results are determined from the SWEEP Water Savings Tool (as described in the CDFA SWEEP Guidelines), accessible at: https://www.cdfa.ca.gov/oefi/sweep/. The SWEEP Irrigation Water Savings estimate in percentage (%) is the value used for this calculator. Estimated water savings from leakage repair is calculated as part of the SWEEP Water Savings Tool.

Irrigation System Enhancement (for systems utilizing pumps)		
Input Data	Pre-Project	Post-Project
Water Savings (SWEEP Water Savings Tool) (%)	N/A	20%

Fuel Conversions and Renewable Energy
This section is required for pump system fuel conversions and renewable energy installations. Below are sample inputs (post-project) for the example SWEEP proposed project.

Fuel Conversions and Renewable Energy		
Input Data		Post-Project
Renewable energy capacity (kW)		20
New fuel type		Electricity
Fuel Emissions Factor		0.000379
Fuel conversion		Diesel to Electricity
Conversion Factor		0.303205568

The applicant can select the “GHG Calculations” Tab to view the estimated project GHG emission reductions.

Submit Documentation

To complete the quantification process, the applicant must submit an electronic copy of the calculator (in .xls, .xlsm, or .xlsx) and all of the required documentation as noted in Section C. The summary documentation that provides the GHG emission reductions from the project can be found in the **Summary** tab of the SWEEP GHG Calculator Tool.

For this example, the Annual GHG Emission Reductions ($MTCO_2e$) is equal to the difference between GHG emissions pre-project and the GHG emissions post-project, accounting for the installation of on-site renewable energy. Total GHG Emission Reductions ($MTCO_2e$) is the annual reductions multiplied by the expected useful life of the installed equipment using a default value, as defined by CDFA, of 10 years. The applicant in this example would report the Net GHG Benefits over the Useful Life as 733.37 $MTCO_2e$.

The SWEEP Funds Requested ($) is equal to the total funds requested. In this example, the amount is $100,000. The total GHG emission reductions ($MTCO_2e$) per funds represent the benefits over Useful Life per dollar requested. For this example this value would be 0.0073 $MTCO_2e$ per $.

Results	GHG Emissions (MTCO2e)	Description
GHG Benefits per Growing Season	71.11	Annual GHG Emission Reductions (MTCO2e/yr)
Net GHG Benefits over Useful Life	711.07	Total GHG Emission Reductions (MTCO2e)
GHG Benefits per Acre-Year	0.71107	Total GHG Emission Reductions (MTCO2e) per Acre per Year
Total GGRF Funds Requested ($)	$ 100,000	Total SWEEP funds requested
Total GHG Emission Reductions per Total GGRF Funds Requested ($)	0.0071	Total Reductions per SWEEP funds requested

Appendix B. Equations Supporting the SWEEP GHG Calculator Tool

Methods used in the SWEEP GHG Calculator Tool for estimating the GHG emission reductions by activity type are provided in this appendix. The GHG emission reductions from the project are quantified within the SWEEP GHG Calculator Tool using the equations below.

A. Irrigation System Pressure Changes

Equation 1.a: Pre-Project Head (for use in Eq. 3.c and Eq. 4.a)

$$TDH_{pre\ project} = H_{pumping\ elevation\ pre\ project} + H_{discharge\ pressure\ pre\ project} + H_{friction\ loss\ pre\ project}$$

Equation 1.b: Post-Project Head (for use in Eq. 4.a)

$$TDH_{post\ project} = H_{pumping\ elevation\ post\ project} + H_{discharge\ pressure\ post\ project} + H_{friction\ loss\ post\ project}$$

Where,			Units
$TDH_{project}$	=	Total dynamic head or system pressure requirement, pre and post project	Feet
$H_{pumping\ elevatior}$	=	Elevation head, the vertical distance which the water must be pumped, pre and post project	Feet
$H_{discharge\ pressur}$	=	Pressure head, is the maximum operating pressure of the water system converted from psi to feet of head, pre and post project	Feet
$H_{friction\ loss}$	=	Friction head loss, is the loss of pressure due to the flow of water through pipe and fittings, pre and post project. Default friction losses are estimated at 10 ft.	Feet

B. GHG Emissions from Motor and Pump Efficiency Improvements

(Eq. 2.a) GHG Emissions from Existing Pump for Non-Electric Pumps

$$GHG_{pre\ project} = Fuel\ Use\ x\ EF_{fuel\ pre\ project}$$

(Eq. 2.b) GHG Emissions from Existing Pump for Electric Pumps with actual use data

$$GHG_{pre\ project} = Electricity\ Use\ x\ EF_{electricity}$$

(Eq. 2.c) GHG Emissions from Existing Pump for Electric Pumps (if actual use data is unavailable)

$$GHG_{pre\ project} = HP_{pre\ project}\ x\ \eta_{pre\ project}\ x\ Operational\ Hours_{\ pre\ project}\ x\ 0.746\ x\ EF_{electricity}$$

Where,			Units
$\eta_{project}$	=	Overall pumping plant efficiency, pre and post project	%

$\eta_{project}$	=	Overall pumping efficiency, pre and post project. This value incorporates pump efficiency and motor efficiency, among other factors.	%
$GHG_{pre\ project}$	=	GHG emissions from existing pump	$MTCO_2e$
Fuel use	=	Pre project fuel use	Gallons or scf
$EF_{fuel\ pre\ project}$	=	Emission factor of pre project fuel	$MTCO_2e$ per gallon or scf
Electricity use	=	Pre project electricity use	kWh
$EF_{electricity}$	=	Emission factor from electricity (0.000306 $MTCO_2e$/kWh)[7]	$MTCO_2e$/ kWh
$HP_{pre\ project}$	=	Pre project rated motor horsepower	hP
Operational Hours $_{baseline}$	=	Baseline irrigation hours based on plant requirements, area, and flow rate	Hours
0.746	=	Conversion from hP to kilowatts	kWh/hP

C. GHG Emissions from Post Project Pump Demand and Fuel Conversions

(Eq. 3.a) GHG Emissions from Post Project Pump Demand

$$GHG_{pump} = (1 - Water\ Savings_{NRCS})) \ x \ \frac{TDH_{post\ project}}{TDH_{pre\ project}} \ x \ \frac{\eta_{pre\ project}}{\eta_{post\ project}} x \ GHG_{pre\ project}$$

(Eq. 3.b) GHG Emissions Adjustment for fuel conversions

$$GHG_{pump,adj} = GHG_{pump} \ x \ \frac{EER\ Adjusted\ Carbon\ Intensity_{New\ fuel}}{EER\ Adjusted\ Carbon\ Intensity_{Old\ fuel}}$$

Where,			Units
GHG_{pump}	=	GHG emissions from pump changes	$MTCO_2e$
Water Savings	=	Water savings from SWEEP Irrigation Water Savings Assessment Tool, as found in cell F6 in the **Summary** tab.	%
$GHG_{pump,adj}$	=	GHG emissions from pump changes accounting for fuel conversions	$MTCO_2e$
EER Adjusted Carbon Intensity	=	Energy Economy Ratio lifecycle emission factor for fuel with an adjustment to reflect for the relative efficiency of a specific fuel used in a motor[8]	g/MJ

[7] For the purposes of quantification methodologies, CARB developed a California grid electricity emission factor based on total in-state and imported electricity emissions ($MTCO_2e$) divided by total consumption in MWh. Emissions from CARB GHG inventory (2013), available online at: http://www.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_by_sector_00-12_sum_2014-03-24.pdf. Consumption data from CEC Energy Almanac (2013), available online at: http://energyalmanac.ca.gov/electricity/electricity_generation.html

[8] EER adjusted CI values. Source: California Air Resources Board, CAGREET 1.8b versus 2.0 CI Comparison Table, April 1, 2015

D. GHG Emission Reductions from VFD Installation and System Pressure Reductions

(Eq. 4.a) GHG Emission Reductions from VFD Installation (for Electric Pumps) with no changes in pressure demand from irrigation system changes

$$GHG_{VFD} = Energy\ Savings_{VFD}\ x\ HP_{post\ project}\ x\ EF_{electricity}$$

(Eq. 4.b) GHG Emission Reductions from VFD Installation (for Electric Pumps) accounting for reduced pressure demand from irrigation system changes

$$GHG_{VFD} = Energy\ Savings_{VFD}\ x\ HP_{post\ project}\ x\ (1 - Water\ Savings_{NRCS})\ x\ \left(1 - \frac{TDH_{pre\ project} - TDH_{post\ project}}{TDH_{pre\ project}}\right) x\ EF_{electricity}$$

Where,			Units
GHG_{VFD}	=	GHG emissions reductions from VFD installation	MT CO_2e
Energy $Savings_{VFD}$	=	Energy savings for VFD installations (from DEER). The energy savings here incorporate an assumed VFD efficiency of 97%[9]	kWh/hP
$HP_{post\ project}$	=	Post project rated motor horsepower	hP

E. GHG Emissions Reductions from Installation of Renewable Energy

(Eq. 5) GHG Emission Reductions from pump (use $GHG_{pump,adj}$ if applicable)

$$GHG_{Renew} = Capacity\ x\ Capacity\ Factor_{solar}\ x\ 8{,}766\ x\ EF_{electricity}$$

Where,			Units
Capacity	=	Capacity of renewable energy installation	kW
Capacity Factor	=	Statewide average of renewable performance, 18%[10]	%
8,766	=	Hours per year of renewable energy generation potential	Hours
GHG_{Renew}	=	GHG emissions reductions from on-site renewable energy	$MTCO_2e$

[9] United States Department of Agriculture, Natural Resources Conservation Service (January 2010). Engineering Technical Note No. MT-14, "Variable Speed Drive (VSD) for Irrigation Pumping." Available online at: http://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs144p2_054026.pdf

[10] CEC (2013). Cost-Effectiveness of Rooftop Photovoltaic Systems for Consideration in California's Building Energy Efficiency Standards. Available online at: http://www.energy.ca.gov/2013publications/CEC-400-2013-005/CEC-400-2013-005-D.pdf

F. GHG Emissions Reductions from SWEEP Project Implementation

(Eq. 6) GHG Emission Reductions from pump (use $GHG_{pump,adj}$ if applicable)

$$GHG_{post\ project} = GHG_{pre\ project} - GHG_{pump} + GHG_{VFD} + GHG_{Renew}$$

Where,			Units
$GHG_{post\ project}$	=	GHG emissions reductions from the SWEEP project improvements compared to the previous irrigation system	$MTCO_2e$

Appendix C. Emission Factors

Fuel	CO_{2e} Emission Factor	Unit
Diesel	0.013717	MTCO2e/gal
Natural Gas[11]	0.0000793	MTCO2e/scf
Electricity	0.000379	MTCO2e/kWh
Biodiesel/Renewable Diesel[12]	0.006050	MTCO2e/gal
Motor Gasoline[13]	0.01141	MTCO2e/gal
Solar Power	0	
Wind Power	0	
Renewable Other	0	

The emission factors for different fuel types are from CARB's Low Carbon Fuel Standard (LCFS) Program.[14] LCFS fuel assessments include the direct emissions associated with producing, transporting, and using the fuels, as well as significant indirect effects on GHG emissions, such as changes in land use for some biofuels. LCFS provides carbon intensity (CI) values for each fuel type, expressed in grams of carbon dioxide equivalent per megajoule (gCO_2e/MJ). CI values are converted to appropriate units (as shown in the table above) using the applicable fuel energy densities and standard conversion rates (as shown below). Fuel conversions utilize the Energy Economy Ratio (EER) adjusted CI values to reflect the relative efficiency of a specific fuel used in a motor. Fuel conversions to renewable energy do not have a conversion value and are reflected in the renewable energy capacity installed.

[11] The natural gas carbon intensity (CI) value used is a petroleum-based compressed natural gas (CNG) delivered via pipeline and compressed at the station. The emissions associated with compression are subtracted from the total CNG CI value. The compression CI value used is available at: https://www.arb.ca.gov/fuels/lcfs/022709lcfs_cng.pdf.

[12] The biodiesel/renewable diesel CI value used is an average of the biodiesel and renewable diesel CI values of feedstock derived from both animal fats and plant oils.

[13] The motor gasoline CI value used is the CI requirements of California reformulated gasoline (CaRFG) for years 2016-2020.

[14] California Air Resources Board (CARB) Low Carbon Fuel Standard (LCFS) Program (final regulation effective January 1, 2016). Available online at: https://www.arb.ca.gov/regact/2015/lcfs2015/lcfsfinalregorder.pdf.

Fuel Emission Factor

$$EF_{Fuel} = CI_{EER} \times ED_{Fuel} \times 10^{-6}$$

Energy Economy Ratio (EER)

$$CI_{EER} = \frac{CI_{fuel}}{EER}$$

Where,			Units
EF_{fuel}	=	Emission factor of fuel	$MTCO_2e$/gal, scf, or kWh
CI_{EER}	=	EER adjusted CI value of fuel	gCO_2e/MJ
ED_{fuel}	=	Energy density of fuel	MJ/gal, scf, or kWh
CI_{fuel}	=	Carbon intensity of fuel	gCO_2e/MJ
EER	=	Reflects relative efficiency of fuel used in motor	dimensionless