California Air Resources Board

**Greenhouse Gas Quantification Methodology for the
California Department of Food and Agriculture
State Water Efficiency and Enhancement Program
DWR (Prop 1) Joint Project**

**Greenhouse Gas Reduction Fund
FY 2016-17**

December 23, 2016

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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 (ARB) is responsible for providing the quantification methodology to estimate GHG emission reductions and other benefits from projects receiving monies from the Greenhouse Gas Reduction Fund (GGRF). ARB 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. ARB 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's (CDFA) State Water Efficiency and Enhancement Program (SWEEP), ARB staff developed this quantification methodology and the accompanying SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool for water supplier applicants to use to estimate the GHG emission reductions from the proposed Department of Water Resources (DWR) joint project. As a subset of the larger SWEEP Program, the joint project focuses on connecting agricultural operations that rely on groundwater pumped on-farm to centralized pressurized irrigation delivery systems. DWR, through Proposition 1 funds, will fund a project to pressurize an irrigation delivery system. CDFA, using SWEEP funds, will incentivize agricultural operations to connect to the pressurized system through grants for water and energy savings, provided the agricultural operations eliminate on-farm pumping.

This methodology uses calculations to estimate GHG emission reductions from reduced energy use as a result of the elimination of on-farm pumping in conjunction with centralized irrigation system enhancements. These calculations are based on the current understanding of irrigation practices, project specifications of irrigation system enhancements and fuel conversions, and GHG emission factors.

ARB released the draft quantification methodology and SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool for public comment in August 2016. This FY 2016-17 quantification methodology and accompanying GHG emission reduction calculator have been updated to reflect CDFA Program updates.

SWEEP DWR Joint Project

This methodology calculates the GHG emission reductions associated with the following activities:

1. Elimination of on-farm pumping; and
2. Irrigation delivery system enhancements (including pressurization).

Per SWEEP DWR joint program guidelines:

Eligible projects must:

- Reduce net GHG emissions; and
- Eliminate on-farm groundwater pumping; and
- Reduce on-farm 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 eliminate pumping are not considered an eligible project.

Methodology Development

ARB and CDFA developed this quantification methodology consistent with the guiding implementation principles of California Climate Investments, including ensuring transparency and accountability.[1] ARB 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.

ARB reviewed peer-reviewed literature and tools, and consulted with experts, as needed, to determine methods appropriate for the SWEEP DWR joint project. ARB 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

Water supplier applicants must use this quantification methodology, in conjunction with the accompanying SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool, to estimate the GHG emission reductions from their proposed SWEEP DWR joint project on behalf of the agricultural operations. The SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool can be downloaded from: www.arb.ca.gov/cci-quantification.

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[1] As described in Volume 1 of the California Air Resources Board's Funding Guidelines for Agencies Administering California Climate Investments. December 21, 2015. www.arb.ca.gov/cci-fundingguidelines.

Program Assistance

ARB and CDFA staff, in conjunction with subject matter experts, will review the quantification portions of SWEEP DWR joint project applications to ensure that the methods described in this document were properly applied to estimate the GHG emission reductions for the proposed joint 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.
- For more information on ARB's efforts to support implementation of GGRF investments, see: www.arb.ca.gov/auctionproceeds.
- Questions pertaining to the SWEEP should be sent to grants@cdfa.ca.gov.
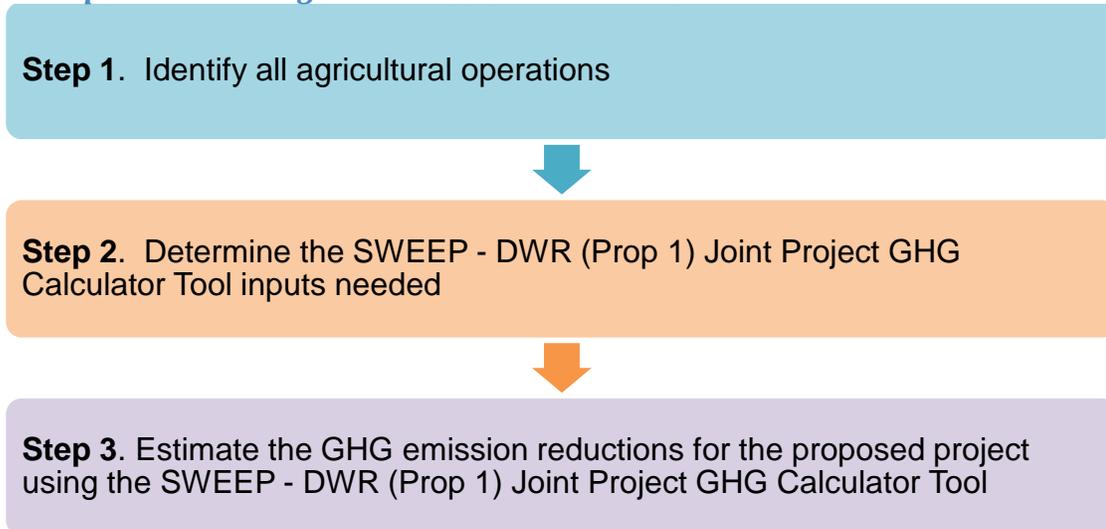
Section B. Quantification Methodology

This quantification methodology (1) accounts for GHG emission reductions of a proposed SWEEP DWR joint project based on reduction in on-farm energy use—as a result of eliminating groundwater pumping—and (2) accounts for the change in energy use from the enhancements made to the irrigation delivery system as part of the DWR Prop 1 funded project. DWR irrigation delivery system enhancements may include installation, replacement, or enhancement of new and existing system pumps, conversion to a less carbon intensive fuel, or installation of renewable energy generation. In general, the GHG emission reductions are calculated using the following approaches:

Table 1. General Approach to GHG Quantification

Agricultural Operations
GHG Emission Reductions = GHG Emissions of Existing Pumps
Water Supplier Delivery System
GHG Emissions From Irrigation Delivery System = *GHG Emissions of Proposed Water Delivery System* *− GHG Emissions of Existing Portion of Delivery System to be Enhanced*
Renewable Energy
GHG Emission Reductions = GHG Emissions of Displaced Fuel
Total Project
Total Project GHG Emission Reductions = *GHG Emissions Reductions from All Agriculutal Operators* *+GHG Emission Reductions from Renewable Energy* *− GHG Emissions from Irrigation Delivery System*

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. An example of a proposed SWEEP DWR joint project quantification is included in Appendix A.

Figure 1. Steps to Estimating GHG Emission Reductions

Step 1. Identify all agricultural operations

Step 2. Determine the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool inputs needed

Step 3. Estimate the GHG emission reductions for the proposed project using the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool

Step 1: Identify All Agricultural Operations

The water supplier must identify all agricultural operations that are a part of the proposed project. This must include any agricultural operations within the water supplier service area that jointly filed applications for SWEEP funding. Each agricultural operation is required to eliminate on-farm pumping as a water supply source. The agricultural operations associated with the proposed project will be identified in the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool under the **Inputs-Agricultural Operations** tab.

Step 2: Determine the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool Inputs Needed

Table 2 identifies the required data inputs needed to estimate the GHG emission reductions for proposed projects with the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool. Water suppliers must collect the necessary data from participating agricultural operations to complete the quantification.

Table 2. Required SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool Inputs

Agricultural Operations (Growers)
Existing Conditions (prior to any project modification)

• GGRF funds requested ($) as part of this solicitation
• Pump fuel amount or electricity use (gallons, therms, or kWh)
    o Must provide documentation from fuel receipts, electricity bills, etc.
• Fuel type
• For each pump:
    o Make, model, and serial number
    o Horsepower (hP)

Water Supplier
Existing Conditions (prior to any project modification)
• Annual water deliveries to the agricultural operations identified in Step 1 (gallons);
• Pump fuel amount and electricity use associated with water delivery to the agricultural operations identified in Step 1 (gallons, therms, or kWh)
o Must provide documentation from fuel receipts, electricity bills, etc.
o The energy demand from the portion of the water delivery system can be prorated per gallon based on total water deliveries and system-wide energy use.
• Fuel type for fuel used.
Proposed Project Details (both pre-project values and post-project estimates)
• Estimated annual water deliveries to the agricultural operations identified in Step 1 (gallons)
• Anticipated pump fuel amount and electricity use for enhanced pressurized system (gallons, therms, or kWh)
o This estimate must be substantiated with documentation from plant design.
• Capacity of renewable energy installations (kW)

Step 3: Estimate GHG Emission Reductions for the Proposed Project Using the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool

Applicants must use the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool to complete this step. The SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool can be downloaded from: www.arb.ca.gov/cci-quantification. The applicant will enter the project details into the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool to calculate the GHG emission reductions using the inputs identified in Step 2.

Read Me Tab
On the **Read Me** tab, enter the Project Name, Project ID from FAAST, 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 application documents. Please use the following file naming convention: "[FAAST ID]_[Project Name]" not to exceed 20 characters.

Project Name:	**Smith Brothers Irrigation District**
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

Inputs – Water Supplier Tab
Headers in red indicate a field that requires input by the project applicant. Water suppliers must complete all relevant data regarding the pressurized water delivery system enhancements. Definitions are provided in the **Definitions** tab. Inputs must be substantiated in the documentation provided in accordance with Section C. Documentation.

Inputs – Agricultural Operations Tab

Headers in red indicate a field that requires input by the project applicant. Water suppliers must complete all relevant data on behalf of each agricultural operation joint applicant that will be integrated with the enhanced delivery system that is receiving SWEEP incentive funds as part of this solicitation from the GGRF. Water suppliers must complete a single input row for each affected on-farm pump for all agricultural operation joint applicants. 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 total GHG emission reductions associated with SWEEP DWR joint project. In addition, the total GGRF funds requested and the total GHG emission reductions per total GGRF funds requested—the metric used for reporting—are summarized, as described below.

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

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

Section C. Documentation

Applicants must report the estimated GHG emission reductions from the proposed project and provide documentation of the calculations and inputs used. Total Project GHG Emission Reductions are estimated in the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool and is found in the **Summary** tab. In addition to SWEEP application requirements, applicants for GGRF 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 - DWR (Prop 1) Joint Project GHG Calculator Tool file(s) (in .xls, .xlsm, or .xlsx) with worksheets applicable to the project populated (ensure that the Total Project GHG Emission Reductions and Total Project GHG Emission Reductions/SWEEP GGRF 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 - DWR (Prop 1) Joint Project GHG Calculator Tool inputs (i.e., energy use, pump and motor specifications, and water savings estimates); • References to public documents that are the source of the project data; and • Any other information as necessary and appropriate to substantiate inputs	

Section D. Reporting after Funding Award

Accountability and transparency are essential elements for all GGRF California Climate Investment projects. As described in ARB's Funding Guidelines for Agencies that Administer California Climate Investments (Funding Guidelines),[2] each administering agency is required to track and report on the benefits of the California Climate Investments funded under their program(s). Each project funded by the GGRF is expected to provide real and quantifiable GHG emission reductions. The previous sections of this document provide the methods and tools to estimate the GHG emission reductions of a proposed project based on project characteristics and assumptions of expected conditions and activity levels. This section explains the minimum reporting requirements for administering agencies and funding recipients during project implementation, termed Phase 1, and after a project is completed, termed Phase 2. Table 3 below shows the project phases and when reporting is required.

Table 3. Quantification and Reporting By Project Phase

	Timeframe & Reporting Frequency	Quantification Methods
Project Selection	Period from solicitation to selection of projects and funding awards. Applicant submits application to SWEEP by due date in solicitation materials.	All applicants use methods in ARB's quantification methodology to estimate the GHG emission reductions of the project.
Phase 1	Covers the period from the beginning of the project until it becomes operational or the initial implementation is completed.	All awarded projects use methods in ARB's quantification methodology to update initial estimate of GHG emission reductions, as needed, based on project changes.
Phase 2	Starts after Phase 1 is complete and a project becomes operational.	GHG reduction achieved are quantified and reported for a subset of funded projects.

Phase 1 reporting is required for all SWEEP funded projects. CDFA will collect and submit data to ARB to satisfy Phase 1 reporting requirements. Funding recipients must report any changes that impact GHG emission reduction estimates (i.e. assumptions or quantitates) to CDFA prior to project completion.

Phase 2 reporting is required for only a subset of SWEEP projects and is intended to document actual project benefits achieved after the project becomes operational. Phase 2 data collection and reporting will not be required for every project. CDFA will be responsible for identifying the subset of individual projects that must complete Phase 2 reporting, identifying who will be responsible for collecting Phase 2 data, and for reporting the required information to ARB. ARB will work with CDFA to address Phase 2 procedures, including but not limited to:

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[2] California Air Resources Board. Funding Guidelines for Agencies Administering California Climate Investments. (December 21, 2015). www.arb.ca.gov/cci-fundingguidelines

- The timelines for Phase 2 reporting, i.e., when does Phase 2 reporting begin, how long will Phase 2 reporting be needed.
- As applicable, approaches for determining the subset of projects that need Phase 2 reporting (i.e., how many X projects out of Y total projects are required to have Phase 2 reporting).
- Methods for monitoring or measuring the necessary data to quantify and document achieved GHG reductions and other select project benefits.
- Data to be collected, including data fields needed to support quantification of GHG emission benefits.
- Reporting requirements for transmitting the data to ARB or CDFA for program transparency and use in reports.

Once the Phase 2 quantification method and data needs are determined, ARB will develop and post the final ARB approved Phase 2 methodology for use in Phase 2 reporting.

Appendix A. Example Project

The following is a hypothetical project[3] to demonstrate how the FY 2016-17 SWEEP DWR Joint Project 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

An irrigation district near Fresno is partnering with 10 local agricultural operations to build infrastructure for a pressurized delivery system. Each agricultural operation will be eliminating on-farm pumping and implementing on-farm measures to reduce water use as part of SWEEP. Each of the 10 agricultural operations currently pumps groundwater with diesel fuel.

The irrigation district sources irrigation water primarily from a surface reservoir. The current delivery system employs several older, inefficient vertical turbine pumps used in conjunction with a diesel motor. Through DWR's Prop 1 funding, the irrigation district proposes to convert the existing open-channel delivery system to a pressurized delivery system by replacing the inefficient diesel motor/pump system with a new and more efficient electric pumping system equipped with variable frequency drive (VFD) controllers. The proposed system was designed to meet the delivery needs of the 10 agricultural operations. The system design plans for the irrigation district estimate that the facility will use 200 MWh of electricity to meet the water demand.

In addition, the irrigation district proposes to install 50 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 - DWR (Prop 1) Joint Project GHG Calculator Tool.

Methods to apply

Step 1. Identify all agricultural operations that are included in the proposed project

The first step is for the water supplier to identify all agricultural operations that are included in the proposed project. The water supplier will consolidate applications from each of the 10 agricultural operations that are associated with the project. Once the water supplier has connected with each of the applicants, the water supplier can compile the relevant data needed to estimate net project GHG emission reductions.

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[3] The hypothetical project has not undergone verification of any 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 the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool

The applicant determines all of the required inputs from Table 2 for the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool to estimate GHG emission reductions. The water supplier must include information about the water delivery system as well as aggregate data from agricultural operations. The next step for the water supplier applicant is to review the **Read Me** tab of the SWEEP - DWR (Prop 1) Joint Project 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 Irrigation District
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

Next, the water supplier applicant enters proposed irrigation system enhancement information for both pre-project and post-project scenarios into the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool located in the **Inputs – Water Supplier** 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 - DWR (Prop 1) Joint Project GHG Calculator Tool from the example proposed project.

Existing Portion of Delivery System to be Enhanced
The "Existing Portion of Delivery System to be Enhanced" section is required for every applicant. Each project descriptor must have the associated project input.

Existing Portion of Delivery System to be Enhanced	
Input Data	**Pre-Project**
Water deliveries in previous year (gallons)	3,000,000
Total existing system pump fuel use (gallons, scf)	1,000
Fuel type from existing system fuel use	Diesel
Fuel Emissions Factor	0.013717
Total existing system pump electricity use (kWh)	
Pre-project system emissions	13.72

Proposed Enhanced System
The "Proposed Enhanced System" section is required for every applicant. Each project descriptor must have the associated project input. If proposed project includes a renewable energy component, please include the capacity of installation and the nearest reference city. The reference city will populate the appropriate capacity factor. Total electrical energy demand entered for the proposed system must include the power sourced from renewable installations.

Proposed Enhanced System	
Input Data	Post-Project
Estimated post project annual water delivery (gallons)	3,000,000
Total proposed system pump fuel use (gallons, scf)	
Fuel type from proposed system fuel use	
Fuel Emissions Factor	#N/A
Total proposed system pump electricity use (kWh)	200,000
Post-project system emissions	75.80
Renewable Energy	
Input Data	Post-Project
Renewable energy capacity (kW)	50
Nearest Reference City	Fresno
Renewable energy emission reductions	2,907.02
GHG Emission Increase	(2,844.94)

Agricultural Operations

This section is required to be completed on behalf of all agricultural operations associated with the project receiving SWEEP funds from GGRF as part of this solicitation. Below are sample inputs for the example proposed SWEEP DWR joint project. Each engine or motor that is utilized to pump groundwater on-farm must be reported. For some agricultural operations, this will be multiple engines or motors. When entering multiple engines or motors, do not duplicate the GGRF funds requested column.

Agricultural Operation Information (Name, Location)	GGRF Funds Requested ($)	Engine / Motor Make	Engine / Motor Model	Engine / Motor Serial Number	Rated Horsepower	Annual Pump fuel or electricity use (gallons, scf, kWh)	Fuel type	Fuel Emissions Factor	Annual Emissions (MTCO2e)
GF Farms #1, Farmertown	25,000	AZ Company	X Model	125FGz62	100	200	Diesel	0.013717	2.7
GF Farms #1, Farmertown	-	Pumper Co	Model P	888AAA8	50	100	Diesel	0.013717	1.4
GF Farms #1, Farmertown	-	PumpCity	Pumper	912aa	300	750	Diesel	0.013717	10.3
GF Farms #2, Farmertown	50,000	AZ Company	Z Model	1563a	200	350	Diesel	0.013717	4.8
GF Farms #2, Farmertown	-	AZ Company	Z Model	885	500	1,000	Diesel	0.013717	13.7
GF Farms #3, Farmertown	75,000	AZ Company	Z Model	986	40	50	Diesel	0.013717	0.7
GF Farms #4, Farmertown	50,000	AZ Company	Z Model	8887dra3	40	200	Diesel	0.013717	2.7
GF Farms #5, Farmertown	150,000	AZ Company	Z Model	546f	100	100	Diesel	0.013717	1.4
GF Farms #6, Farmertown	100,000	AZ Company	Z Model	647f	50	50	Diesel	0.013717	0.7
GF Farms #7, Farmertown	50,000	AZ Company	Z Model	648f	50	150	Diesel	0.013717	2.1
GF Farms #8, Farmertown	25,000	AZ Company	Z Model	649f	100	75	Diesel	0.013717	1.0
GF Farms #9, Farmertown	25,000	AZ Company	Z Model	650f	100	100	Diesel	0.013717	1.4
GF Farms #10, Farmertown	25,000	AZ Company	Z Model	651f	50	50	Diesel	0.013717	0.7
GF Farms #10, Farmertown	-	AZ Company	Z Model	652f	100	100	Diesel	0.013717	1.4
								#N/A	-
								#N/A	-
								#N/A	-
								#N/A	-
								#N/A	-
								#N/A	-
								#N/A	-
								#N/A	-
								#N/A	-
								#N/A	-
On-Farm GHG Emission Reductions									44.92

The applicant can select the **Summary** 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 SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool (in .xls, .xlsm, or .xlsx) and all of the required documentation as noted in Section C. Documentation. The summary documentation that provides the GHG emission reductions from the project can be found in the **Summary** tab of the SWEEP - DWR (Prop 1) Joint Project GHG Calculator Tool.

For this example, the Total Project GHG Emission Reductions (MTCO$_2$e) is the annual reductions multiplied by project life. For purposes of SWEEP DWR joint projects, the proposed project life is defined as the number of years recipients must verify the elimination of on-farm groundwater pumping. The reporting requirements, and therefore project life, for these projects is 3 years from project completion.

The SWEEP Funds Requested ($) is equal to the total GGRF funds requested from agricultural operations. In this example, the amount is $575,000. The Total GHG Emission Reductions (MTCO$_2$e) per Total GGRF Funds represent the total benefits for the proposed project per dollar requested. For this example this value would be 0.00006 MTCO$_2$e per GGRF $.

Results	GHG Emissions (MTCO2e)	Description
GHG Benefits per Growing Season	2,889.86	Annual GHG Emission Reductions (MTCO2e/yr)
Total Project GHG Emission Reductions	8,669.59	Total GHG Emission Reductions (MTCO2e)
Total GGRF Funds Requested ($)	575,000.00	Total SWEEP funds requested
Total GHG Emission Reductions per Total GGRF Funds Requested ($)	0.01508	Total Reductions per SWEEP funds requested

Appendix B.   Equations Supporting the SWEEP - DWR (Prop 1) Joint Project Calculator Tool

A.   Pre-Project Water Delivery System Emissions

Equation 1.a: GHG Emissions from Existing Portion of System with Non-Electric Pumps

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

Equation 1.b: GHG Emissions from Existing Portion of System with Electric Pumps

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

Equation 1.c: GHG Emissions from Existing Portion of System

$$GHG_{pre-project} = GHG_{pre-project\ fuel} + GHG_{pre-project\ electricity}$$

Where,

			Units
GHG$_{pre-project\ fuel}$	=	GHG emissions from fuel use in existing water delivery system that provides water to the agricultural operations identified in Step 1	MTCO$_2$e
Fuel Use	=	Pre-project documented fuel use (i.e., fuel receipts)	gallons or scf
EF$_{fuel\ pre-project}$	=	Emission factor of pre-project fuel	MTCO$_2$e/ gallon or scf
GHG$_{pre-project\ electricity}$	=	GHG emissions from electricity use in existing water delivery system that provides water to the agricultural operations identified in Step 1	MTCO$_2$e
Electricity Use	=	Pre-project documented electricity use (i.e., utility bills)	kWh
EF$_{electricity}$	=	Emission factor of electricity	MTCO$_2$e/kWh
GHG$_{pre-project}$	=	GHG emissions from existing water delivery system	MTCO$_2$e

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B.   Post-Project Water Delivery System Emissions

Equation 2.a: GHG Emissions from Enhanced System with Non-Electric Pumps

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

Equation 2.b: GHG Emissions from Enhanced System with Electric Pumps

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

Equation 2.c: GHG Emissions from Enhanced System

$$GHG_{post-project} = GHG_{post-project\ fuel} + GHG_{post-project\ electricity}$$

Where,

			Units
GHG$_{post-project\ fuel}$	=	GHG emissions from fuel use in proposed enhanced water delivery system	MTCO$_2$e
Fuel Use	=	Estimated post-project fuel use with supportable documentation from project design plans	gallons or scf

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EF$_{\text{fuel post-project}}$	=	Emission factor of post-project fuel	MTCO$_2$e/ gallon or scf
GHG$_{\text{post-project electricity}}$	=	GHG emission from electricity use in proposed enhanced water delivery system	MTCO$_2$e
Electricity Use	=	Estimated post-project electricity use with supportable documentation from project design plans	kWh
EF$_{\text{electricity}}$	=	Emission factor of electricity	MTCO$_2$e/kWh
GHG$_{\text{post-project}}$	=	GHG emissions from proposed enhanced water delivery system	MTCO$_2$e

C. GHG Emission Reductions from Installation of Renewable Energy

Equation 3: GHG Emission Reductions from Renewable Energy

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

Where,   <u>Units</u>

Capacity	=	Capacity of renewable energy installation	kW
Capacity Factor	=	Regional average of renewable performance[4]	
8,766	=	Hours per year of renewable energy generation potential	hours
GHG$_{\text{Renew}}$	=	GHG emissions reductions from on-farm renewable energy	MTCO$_2$e

D. GHG Emission Reductions from Agricultural Operations

Equation 4.a: GHG Emission Reductions from Agricultural Operations with Fuel Use

$$GHG_{on-farm \ fuel} = Fuel \ Use \ x \ EF_{fuel \ on-farm}$$

Equation 4.b: GHG Emission Reductions from Agricultural Operations with Electricity Use

$$GHG_{on-farm \ electricity} = Electricity \ Use \ x \ EF_{electricity}$$

Equation 4.c: GHG Emission Reductions from Agricultural Operations

$$GHG_{on-farm} = GHG_{on-farm \ fuel} + GHG_{on-farm \ electricity}$$

Where,   <u>Units</u>

GHG$_{\text{on-farm fuel}}$	=	GHG emission from fuel use in existing on-farm pump	MTCO$_2$e
Fuel Use	=	On-farm documented fuel use (i.e., fuel receipts)	gallons or scf
EF$_{\text{fuel on-farm}}$	=	Emission factor of fuel currently used on-farm	MTCO$_2$e/ gallon or scf
GHG$_{\text{on-farm electric}}$	=	GHG emission from electricity use in existing on-farm pump	MTCO$_2$e
Electricity Use	=	On-farm documented electricity use from pumping (i.e., utility bills)	kWh
EF$_{\text{electricity}}$	=	Emission factor of electricity	MTCO$_2$e/kWh

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[4] 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

| GHG$_{on-farm}$ | = | GHG emission reductions from elimination of on-farm pumping | MTCO$_2$e |

E.   GHG Emission Reductions from SWEEP DWR Joint Project Implementation

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Equation 5: GHG Emission Reductions from SWEEP DWR Joint Project

$$GHG_{total} = GHG_{on-farm} + GHG_{renew} - (GHG_{post-project} - GHG_{pre-project})$$

Where,   Units

GHG$_{total}$ =   GHG emissions reductions from the SWEEP DWR joint project   MTCO$_2$e
implementation

Appendix C.   Emission Factors

Fuel	CO2e Emission Factor	Unit
Diesel	0.013717	MTCO2e/gal
Natural Gas[5]	0.0000793	MTCO2e/scf
Biodiesel/Renewable Diesel[6]	0.006050	MTCO2e/gal
Motor Gasoline[7]	0.01141	MTCO2e/gal
Electricity	0.000379	MTCO2e/kWh
Solar Power	0	
Wind Power	0	
Renewable Other	0	

The emission factors for different fuel types are from ARB's Low Carbon Fuel Standard (LCFS) Program.[8] 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.

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$_2$e/gal, scf, or
                                                                                                      kWh

CI $_{EER}$ =   EER adjusted CI value of fuel   gCO$_2$e/MJ
ED $_{fuel}$ =   Energy density of fuel   MJ/gal, scf, or kWh
CI $_{fuel}$ =   Carbon intensity of fuel   gCO$_2$e/MJ
EER   =   Reflects relative efficiency of fuel used in motor   dimensionless

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[5] 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.
[6] 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.
[7] The motor gasoline CI value used is the CI requirements of California reformulated gasoline (CaRFG) for years 2016-2020.
[8] California Air Resources Board (ARB) 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.