CALIFORNIA ENERGY COMMISSION

ENERGY RESEARCH AND DEVELOPMENT DIVISION

FINAL PROJECT REPORT

Reducing Greenhouse Gas Emissions Through Equipment Replacement and Modernization

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The author thanks the California Energy Commission for their support of Sunsweet Growers, Inc. in our continuous efforts to reduce our environmental footprint and greenhouse emissions.

PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy and advanced clean generation, energy-related environmental protection, energy transmission and distribution and transportation.

The Food Production Investment Program, established in 2018, encourages California food producers to reduce greenhouse gas (GHG) emissions. Funding comes from the California Climate Investments program, a statewide initiative that uses cap-and-trade dollars to help reduce GHG emissions, strengthen the economy, and improve public health and the environment.

The food processing industry is one of the largest energy users in California. It is also a large producer of GHG emissions.

The Food Production Investment Program will help producers replace high-energy-consuming equipment and systems with market-ready and advanced technologies and equipment. The program will also accelerate the adoption of state-of-the-art energy technologies that can substantially reduce energy use and costs and associated GHG emissions.

Reducing Greenhouse Gas Emissions Through Equipment Replacement and Modernization is the final report for the FPI-19-010 project conducted by Sunsweet Growers Inc. The information from this project contributes to the Energy Research and Development Division's FPIP Program.

For more information about the Energy Research and Development Division, please visit the CEC's research website (www.energy.ca.gov/research/) or contact the CEC at ERDD@energy.ca.gov.

ABSTRACT

Sunsweet Growers Inc. (Sunsweet) is the world's largest processor and marketer of dried fruit and a beverage manufacturer with a contract to manufacture beverages for PepsiCo. Sunsweet is a cooperative, owned by and representing 200 California prune producers and their respective farms. All of Sunsweet's California prune food processing and a significant portion of its beverage processing is done at its headquarters located in the city limits of Yuba City, California.

To produce these food and beverage products, Sunsweet relies on steam generation to power the equipment necessary for food and beverage processing including rehydrating prunes and heating water for equipment and facility sanitation. Sunsweet was awarded a grant to replace inefficient equipment at its headquarters to modernize the facility and reduce energy consumption and greenhouse gas emissions.

Sunsweet installed a new 200 horsepower variable frequency drive air compressor replacing two existing 100 horsepower fixed speed air compressors originally from 1999. Two 47-year-old boilers and 175 steam traps were replaced to improve efficiencies.

Natural gas and electricity consumption were measured for 3 months prior to installing the new equipment and 12 months post-installation. The new air compressors and new boilers reduced annual greenhouse gas emissions by more than 4,500 metric tons of carbon dioxide equivalent.

Keywords: Food processor, beverage processor, steam generation, greenhouse gas reduction, grant funds

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Introduction

California food production has traditionally been a high energy- and carbon-intensive industry. According to the California Air Resources Board, food processing in the state accounts for more than 3 million metric tons of carbon dioxide equivalent ($MTCO_2e$) of greenhouse gas (GHG) emissions. The food processing industry is one of California's largest energy users and a significant producer of GHG emissions. California food producers are encouraged to invest in new advanced technologies and equipment that provide significant benefits to the electrical grid, maximize the reduction of GHG emissions or reduce air pollution in under-resourced communities, or both.

Sunsweet Growers Inc. (Sunsweet), a California food processor more than 100 years old, with headquarters in Yuba City, California, is the world's largest processor and marketer of dried fruit. The company is perhaps best known as the household name brand behind prune products like Sunsweet Ones, Sunsweet Amazins, and Sunsweet Amazin Prune Juice. As a cooperative, Sunsweet is owned by and represents about 200 California prune producers and their respective farms. Sunsweet processes approximately 60,000 tons of prunes a year and processes other dried fruit including mangos, dates, and apricots. Sunsweet's Yuba City facility, which processes all prune products and a significant portion of the beverage contracts, produced about 25,599 $MTCO_2e$ annually.

Project Purpose

This project modernized Sunsweet's prune processing and beverage facility by installing new energy-efficient equipment to reduce GHG emissions, improve electrical and fuel use efficiency, reduce maintenance costs, and reduce potential downtime costs from outdated equipment. A compressor, two steam boilers, and related equipment were replaced with new energy-efficient equipment, as well as 175 steam traps.

This project was especially timely and significant. Sunsweet had been purchasing approximately 250 million pounds of steam annually from an adjacent cogeneration plant. As the cogeneration plant generated electricity for the grid, steam was created as a byproduct, which was supplied to Sunsweet's facility to offset the need to generate steam at its own facility. However, this long-term arrangement ended on December 31, 2019, at which time Sunsweet needed to produce 100 percent of the steam needed for food and beverage processing on site, solely using Sunsweet's own outdated and inefficient equipment.

Project Approach

Before installing the new equipment, Sunsweet implemented a measurement and verification plan to monitor, calculate, and report the GHG emissions savings, which included specifics on each of the sub-projects. For the boiler replacement, steam and natural gas flow readings were documented weekly to calculate baseline efficiency and emissions. For the air compressor replacement, power loggers recorded electricity consumption to establish a baseline. For the steam trap replacement, industry standard calculations were used to estimate steam loss, as direct measurement was impractical.

To prepare for installation, Sunsweet completed necessary site modifications, including structural adjustments for the new boilers, electrical upgrades for the air compressor, and verification of steam trap sizes. The company also obtained permits from the city of Yuba City. During execution, Sunsweet addressed unforeseen challenges such as the need for additional structural support for boiler room equipment, an unexpected air compressor motor failure, and deteriorated condensate return pipes in the steam system. Despite these challenges, the project was successfully implemented, ensuring improved efficiency and emissions reductions.

Project Results

Sunsweet originally estimated that the project would result in GHG emissions reduction of 4,465.26 $MTCO_2e$ annually. Summing up the cumulative GHG emissions reductions from all three sub-projects (new compressors, new boilers, and steam traps), the actual calculated savings is 4,966.36 $MTCO_2e$ per year. The calculated annual reduction of GHG emissions exceeds the original estimated $MTCO_2e$ savings of 17 percent to 19 percent annually.

Measurement and verification data were measured separately for each subproject. The boiler sub-project pre-installation measurement and verification period found the baseline GHG emissions generated by the original boilers totaled 19,601.72 $MTCO_2e$ annually. The post-installation measurement and verification results showed GHG emissions totaled 16,827.79 $MTCO_2e$ annually. Through the implementation of the new boilers and their respective auxiliary equipment, the boiler sub-project reduced 3,109.21 $MTCO_2e$ annually. The air compressor sub-project pre-installation measurement and verification data indicated baseline annual GHG emissions of 263.19 $MTCO_2e$. After installing a new air compressor, the measured GHG emissions totaled 116.26 $MTCO_2e$ annually, thus reducing GHG emissions by 146.93 $MTCO_2e$ annually. Finally, the GHG emissions reductions from implementing the steam trap sub-project were calculated using industry standard calculations. The replacement of 175 steam traps reduced GHG emissions by 1,700.2 $MTCO_2e$ annually.

From the results of the post-installation measurement and verification findings, it is clear that Sunsweet successfully allocated the grant funds and surpassed the project's GHG emission reduction goals. The benefits of this annual reduction of GHG emissions will benefit California and beyond for years to come.

Technology/Knowledge Transfer/Market Adoption (Advancing the Research to Market)

Sunsweet has close business relationships with the vendors contracted to participate in this project and has advised participating contractors that Sunsweet is open to meeting with other prospective businesses looking to take on similar projects. Through the contractors' experience and knowledge gained through working with Sunsweet on this project, the expertise gained through the collaboration will facilitate the successes of other businesses and their future endeavors to reduce GHG emissions.

The contractors who worked on the project also gained knowledge that will be carried forward from project to project, continuing to develop and grow. This is another important way that the grant funds used will continue to have an impact.

CHAPTER 1: Introduction

Facility Overview

Sunsweet Growers Inc. (Sunsweet), a food processor with more than 100 years of experience in the industry, prides itself on being the world's largest processor and marketer of dried fruit. With its main processing facility and headquarters in Yuba City, California, Sunsweet is known for its extensive agricultural roots. Sunsweet has expanded its business with two other locations strategically located to meet business needs. The headquarters facility focuses on key business areas, which include:

- Processing, pitting and packaging of prunes
- Processing and packaging of various other dried fruits including apricots, cranberries, and dates
- Processing and bottling of various Sunsweet beverages
- Processing and bottling of various Pepsi products
- All administrative efforts including marketing, accounting, and executive oversight

In an average year, Sunsweet processes approximately 60,000 tons of prunes in addition to the various other dried fruits that are processed in lesser quantities. On the beverage side of the operation, Sunsweet processes an average of 800,000 12-pack cases of Sunsweet juices and more than 12 million cases of various PepsiCo products.

As shown in Figure 1, Sunsweet's Yuba City Facility covers approximately 82 acres. Approximately 12 acres of the overall Sunsweet property are leased to a cogeneration facility while the remaining area is used for business purposes.

The current headquarters facility occupied by Sunsweet was built in 1974 and includes approximately 800,000 square feet of covered buildings. In 1997, Sunsweet expanded additional warehouses, bringing the total covered surface area to more than 1,000,000 square feet.

At the Yuba City facility, Sunsweet employs approximately 450 union employees. These employees are split across three shifts with two shifts of production and one shift of sanitation running about six days per week. In addition to the union employees, Sunsweet also employs approximately 100 administrative employees and is in the top five largest employers in Yuba City. Sunsweet employs approximately 800 employees in all their facilities.

Figure 1: Sunsweet Yuba City Facility

Source: Sunsweet

Project Overview

This project implemented new energy-efficient equipment to reduce GHG emissions, improve electrical and fuel use efficiency, reduce maintenance costs, and reduce potential downtime costs as a result of outdated equipment. Prior to the funding provided by the grant, Sunsweet relied on steam provided by a cogeneration facility located on Sunsweet's property. For about 30 years, the Greenleaf II facility operated under an existing contract directly with Pacific Gas and Electric Company (PG&E) to provide power to the grid. As a byproduct of the generation of power provided to the grid, Greenleaf II generated steam, which was sold to Sunsweet as part of its lease agreement. In December 2019, the existing contract with PG&E ended, resulting in Sunsweet having to generate all required steam on site to support production needs.

Goals and Objectives

With this new and urgent need to produce its own steam, Sunsweet relied on the Food Production Investment Program (FPIP) grant to offset costs associated with the implementation of new and energy/fuel efficient equipment to meet the project's goals. These goals included:

- Reduce GHG emissions by approximately 17 percent, equivalent to 4,457 metric tons of carbon dioxide equivalent ($MTCO_2e$)/year through installing advanced energy-efficient equipment.
- Support Sunsweet's efforts to continuously reduce its environmental impact.

CHAPTER 2: Project Approach

Project Description

This project consisted of three sub-projects: replacing the two existing boilers with two new economizer-equipped boilers, replacing two 100 HP air compressors with load/unload control with a single 200 HP variable speed oil-free air compressor, and replacing 175 steam traps with new GEM steam traps. The outdated equipment was replaced with commercially available drop-in replacements that provide greater energy efficiency and lower GHG emissions than the previously installed equipment.

Project Team

Sunsweet's internal project team included:

- Jacob Pittman, Vice President of Manufacturing Operations
- Mike Miguel, Director of Project Management and Innovation
- Darius Bracy, Maintenance Manager

In addition to the internal Sunsweet team, R.F. MacDonald Co. played a key role in the engineering, design, procurement, and installation of the boiler and auxiliary equipment. With more than 65 years of experience, the R.F. MacDonald team also undertook the mechanical installation of the 175 steam traps throughout the facility.

Jerry Ramsey of RMQ Design and Consulting also played a vital role in Sunsweet's measurement and verification (M&V) plan by assisting the team with performing data collection and verification throughout the project's duration. He also helped develop initial projections of reductions for the project proposal.

David Colleta of Thermal Energy International was responsible for performing an audit of the steam traps around the facility. The audit he performed resulted in the M&V data for this portion of the project.

Projected Benefits

Sunsweet estimated that this project would provide a reduction in annual GHG emissions of approximately 17 percent. Quantitative estimates of the projected annual reductions for electricity and natural gas are shown in Table 1.

Table 1: Estimated Annual Reductions

Benefit	Baseline	Post-Installation	Annual Reduction
Electricity Usage	1,391,200 kWh	1,168,515 kWh	222,685 kWh
Natural Gas Usage	5,110,917 therms	4,238,886 therms	872,031 therms

kWh = kilowatt-hour
Source: Sunsweet

The reduction in GHG emissions was estimated by Sunsweet to be 4,457 $MTCO_2e$ annually, from an estimated starting point of 25,599 $MTCO_2e$ annually. Other estimates of potential benefits included energy cost reductions and other air pollution reductions, shown in Table 2.

Table 2: Other Estimated Reductions

Benefit	First Year Reduction	Total Reduction Over 20 Year Project Life
Energy and Fuel Cost Savings ($)	$701,710	$14,034,196
Fossil Fuel Based Energy Use Reductions (kWh)	494,136	9,882,727
Fossil Fuel Based Energy Use Reductions (therms)	872,031	17,440,620
NOx emission reductions (lbs)	35,335	706,709
ROG emission reductions (lbs)	711	14,222
PM2.5 emission reductions (lbs)	666	13,312
PM10 emission reductions (lbs)	17	349

lbs=pounds
Source: Sunsweet

Measurement and Verification Plan

Sunsweet hired a third-party contractor to implement and gather data for the M&V plan. RMQ Design and Consulting (RMQ), a contractor on the project, measured and confirmed pre-installation measurements/calculations of electricity consumption, natural gas use, and GHG emissions. RMQ was also responsible for performing post-installation measurements for at least 12 months, calibrating equipment as necessary to ensure efficiency, and analyzing data to determine the overall reduction and savings of electricity, natural gas, and GHG emissions that directly resulted from this project. RMQ also prepared and provided reports at each stage summarizing all findings to Sunsweet. This information was ultimately compiled into various required reports and submitted to the California Energy Commission (CEC).

Baseline Measurements

Sub-project 1: Boilers

Sunsweet planned to replace two existing Cleaver-Brook Model DL-68 Water Tube Boilers manufactured in 1975 with two new Cleaver-Brooks D-Type Industrial Water-Tube Boilers. Figures 2 and 3 are photos of the two existing boilers that were part of Sunsweet's Yuba City facility for nearly 45 years.

Figure 2: Old Boiler #1

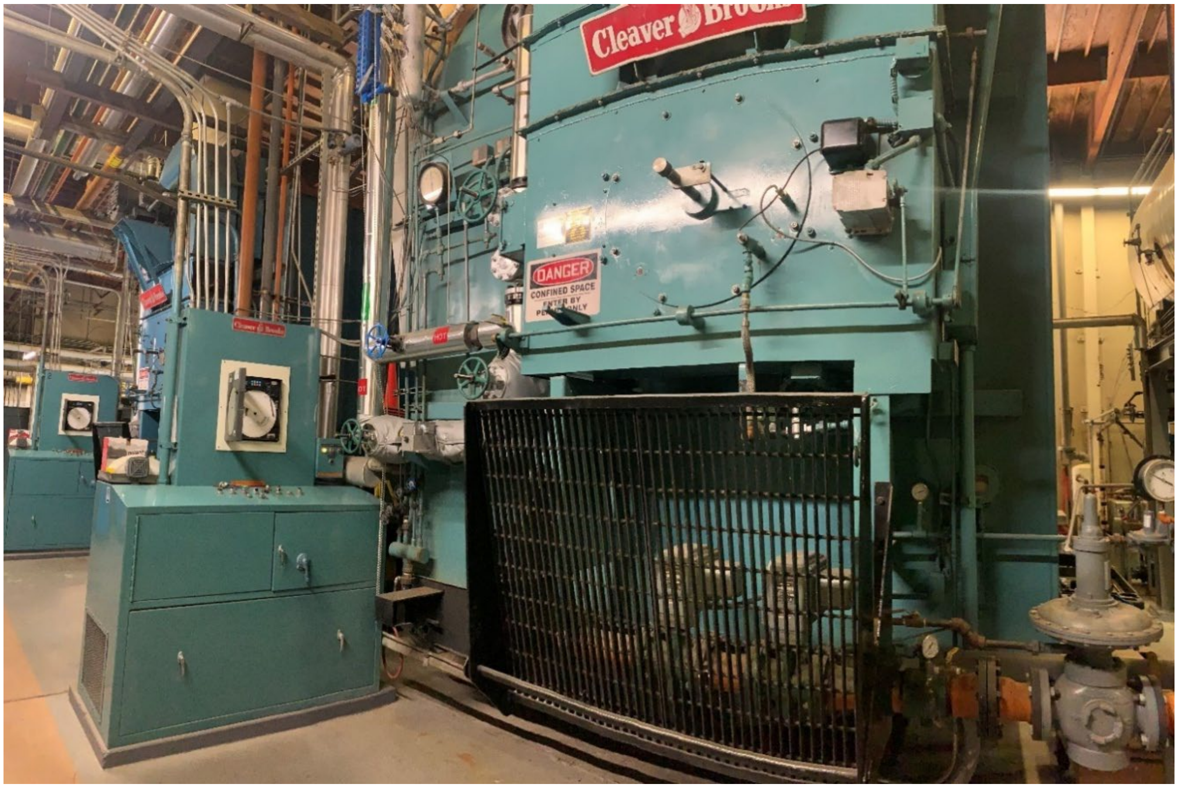


Photo is Boiler #1, one of two Cleaver-Brook Model DL-68 Water Tube Boilers manufactured in 1975 that was replaced.

Source: Sunsweet

Figure 3: Old Boiler #2

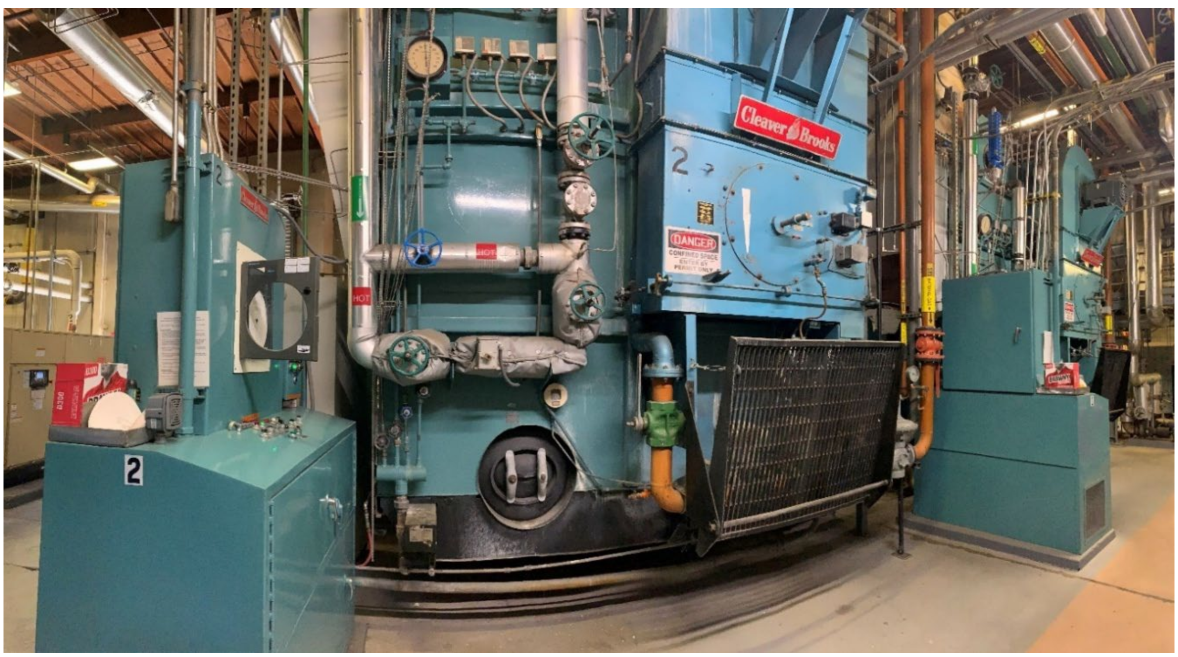


Photo of Boiler #2, the second of the two boilers to be replaced.

Source: Sunsweet

Sunsweet implemented the first phase of the M&V plan in March of 2020. To capture the data, total steam flow readings from a Honeywell 4500 chart recorder installed on each of the two boilers were documented at the same time on a weekly basis. Simultaneously, total natural gas consumption based on gas flow readings from a PG&E natural gas service meter supplying natural gas exclusively to the boilers was read and documented at the same time weekly. The respective data, captured over a three-month time frame, were entered into an Excel spreadsheet and converted to British thermal units (BTUs) to calculate the efficiencies of the boilers in terms of BTUs out as steam produced compared to BTUs in as natural gas therms. The baseline efficiencies of the existing boilers were accurately established through this method. Baseline GHG emissions calculations were based on equation 14 of the Quantification Methodology for the CEC FPIP (refer to Appendix B — Quantification Methodology for the CEC FPIP). In this case, the baseline GHG emissions in pounds per year is equal to the annualized baseline natural gas consumption in therms multiplied by the air pollution emission factor for natural gas. Tables 3 and 4 show the pre-installation measurement results and the corresponding annualized projections, respectively.

Table 3: Sub-project 1 Boiler Replacement Pre-install Measurements

	Boiler 1	Boiler 2	Totals
Steam Produced (lbs)	29,600,000	39,632,000	69,232,000
Natural Gas Used (therms)	416,381	556,293	972,674
GHG Emissions ($MTCO_2e$)	2,210.98	2,953.92	5,164.90
Boiler Efficiency (percent)	71.09%	71.24%	71.18%

Source: Sunsweet

Table 4: Sub-project 1 Boiler Replacement Annualized Projections

Forecast Steam Produced (lbs) with Existing Boilers	Forecast Natural Gas Used with Existing Boilers (Therms)	Forecast GHG Emissions with Existing Boilers ($MTCO_2e$)	Forecast Boiler Efficiency of Existing Boilers
114,590,124	1,609,853	8,548.32	71.09%
152,663,378	2,144,762	11,388.69	71.24%
267,253,502	3,754,615	19,937.01	71.18%

Source: Sunsweet

Sub-project 2: Air Compressors

Sunsweet planned to replace two 100 HP Atlas Copco CA75 single-stage rotary screw air compressors with a single 200 HP variable speed oil-free air compressor. Figure 4 is a photograph of the two 100 HP air compressors that were replaced.

Figure 4: Old Air Compressors

The two 100 HP Atlas Copco CA75 single-stage rotary screw air compressors that were replaced.

Source: Sunsweet

To generate a baseline for the air compressor replacement sub-project, Sunsweet implemented a Fluke 1736 power logger and a PCE-PA-8000 power logger to both existing units. The data were exported from the power loggers on a weekly basis and entered into an Excel spreadsheet as kilowatt-hours (kWh) of power consumption. The baseline emissions in pounds per year were equal to the annualized electrical power consumption in kilowatt-hours multiplied by the air pollution emission factor for grid electricity. Figure 5 is a progress photo showing one of the air compressors with its respective power logger attached to it.

Figure 5: Pre-install Measurement of Old Air Compressor

One of the old air compressors with its associated power logger. Also shown in the photo is the laptop used by the M&V subcontractor to download data from the power logger.

Source: Sunsweet

Power consumption of each air compressor was measured for a minimum of three months beginning in May 2020. The Fluke power logger took samples at a rate of 10.24 kilohertz (kHz) and averaged the data for one minute. The one-minute averages were recorded in a text file that was then imported into an Excel spreadsheet. The PCE power logger sampled data once per second and averaged the data for 10 seconds. The 10-second data averages were recorded in an Excel-compatible file. The resulting data were then entered into an Excel spreadsheet as kilowatt-hours of power consumption. Baseline GHG emissions calculations were based on equation 16 of the Quantification Methodology for the CEC FPIP (refer to Appendix B). In this case, the baseline emissions in pounds per year were equal to the annualized baseline electrical power consumption in kilowatt hours multiplied by the air pollution emission factor for grid electricity. Tables 5 and 6 show the pre-installation measurement results and the corresponding annualized projections, respectively.

Table 5: Air Compressor Pre-installation Measurements

	Air Compressor 1	Air Compressor 2	Totals
kWh Used	171,146.57	182,987.97	354,134.54
GHG emissions ($MTCO_2e$)	39.00	41.70	80.71

Source: Sunsweet

Table 6: Pre-installation Air Compressor Annual Projections

	Air Compressor 1	Air Compressor 2	Totals
kWh Used	558,122.76	596,738.51	1,154,861.27
GHG emissions ($MTCO_2e$)	127.20	136.00	263.19

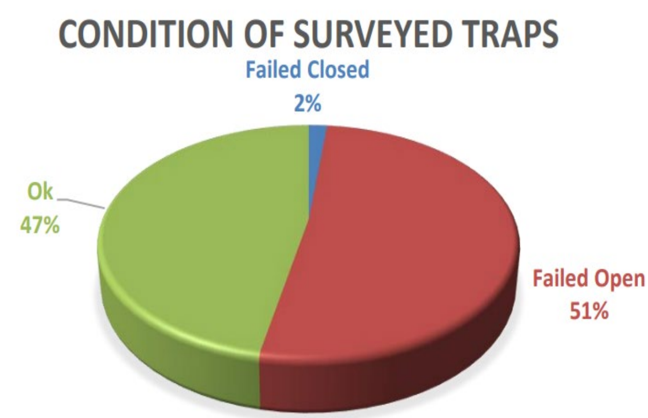
Source: Sunsweet

Sub-Project 3: Steam Traps

For the steam trap replacement sub-project, data were provided by David Coletta of Thermal Energy International as part of its third-party audit for Sunsweet and was used in lieu of measuring the steam flow of all 175 steam traps for practical reasons. In this case, industry standard calculations were adequate to establish baseline steam flow using equivalent pipe size.

A survey of all 175 steam traps included in their detailed evaluation also revealed that an overwhelming percentage of the existing steam traps were no longer in functioning condition. Figure 6 is a pie chart illustrating the number of steam traps still in good condition vs failed. Figure 7 shows an example of a failing steam trap.

Figure 6: Condition of Old Steam Traps



Source: Sunsweet

Figure 7: Steam Trap with Leak (#59)

Trap 59 of 175 showing the leak in the trap allowing steam to escape.

Source: Sunsweet

Calculations for baseline GHG emissions were based on equation 14 of the Quantification Methodology for the CEC FPIP (refer to Appendix B — Quantification Methodology for the CEC FPIP). Baseline emissions in $MTCO_2e$ were equal to the annualized baseline natural gas consumption due to steam loss in therms multiplied by the air pollution emission factor for natural gas. Table 7 shows the pre-install audit results in terms of annualized projections of additional natural gas used and the corresponding GHG emissions.

Table 7: Pre-install Steam Trap Audit Results

Natural Gas Therms Used	Emission Factor for Natural Gas	GHG Emissions ($MTCO_2e$)
354,890	0.00531 $MTCO_2e$/therm	1,884.47

Calculated annual baseline of additional natural gas used and GHG emissions due to inefficient steam traps.

Source: Sunsweet

Project Implementation

Preparations, Procurement, and Installation

Sub-Project 1: Boilers

Following the completion of the boiler sub-project pre-installation stage, Sunsweet took steps to prepare the facility and procure the new equipment.

Sunsweet executed a 3D scan of the boiler room to assist with the development of engineered drawings for the boiler replacement sub-project. With the completed 3D scans, Sunsweet worked with RF MacDonald's structural engineering firm to evaluate the existing conditions of the boiler room.

In compliance with the requirements of the city of Yuba City, Sunsweet obtained all relevant permits for the replacement of the two boilers.

To keep production running throughout the process of removal and replacement of the old boilers, Sunsweet rented a mobile boiler for the duration of construction and installation of the new boilers. This rental was instrumental in allowing regular operations to continue during the transition period.

Old Boilers Specs:

- Two D-Type Industrial Water-Tube Boilers
- Cleaver Brooks Model WT 400X-CN5
- Rated at 60,000 lbs of steam per hour (each)
- Purchased in 1974
- Used for supply and control of steam used in plant processes

New Boilers Specs:

- Two D-Type Industrial Water-Tube Boilers
- Cleaver Brooks Model CW-NB-200D-50
- Rated at 60,000 lbs of steam per hour (each)
- Purchased in 2020
- Used for supply and control of steam used in plant processes

Figure 8 shows the rental boiler that was temporarily installed to maintain Sunsweet's normal production level. Figure 9 shows the old boiler being removed from the building and loaded onto a heavy haul truck.

Figure 8: Rental Boiler in Operating Position

The rental boiler in its operating position, connected to Sunsweet utilities and supplying steam.

Source: Sunsweet

Figure 9: Crane Hauling Away Old Boiler #1

Boiler #1 being loaded onto a truck with a crane to be hauled away.

Source: Sunsweet

The new boilers did not fit the existing foundations, so the foundations were completely replaced. In addition, Sunsweet made piping modifications to accommodate the new boiler layout, which included feed water, condensate return, and natural gas supply. As the previous units had lower electrical requirements, Sunsweet also undertook the necessary electrical modifications to upsize the feeder cables and breaks. Figures 10 and 11 show the foundation preparation for the new boilers. Figure 12 shows the two new boilers.

Figure 10: Foundation Prep for New Boiler #1

The foundation for the original boiler #1 that was demoed and prepared for new foundation.

Source: Sunsweet

Figure 11: Foundation Prep for New Boiler #2

The foundation from the original boiler #2 that was demoed and prepared for the new foundation.

Source: Sunsweet

Figure 12: New Boilers

In the center of the photo is the first new boiler that was installed and to the right side of the photo is the second new boiler.

Source: Sunsweet

After reviewing the 3D scans taken during the procurement phase, the structural engineer indicated that the concrete tilt up wall would not be able to support the weight of the auxiliary equipment as previously anticipated due to the placement of the louvers, which bring air into the boiler room. Thus, a second structure was developed and constructed to support the horizontal mounting beam on the roof (Figure 13). This exterior steel structure lands three vertical beams on top of independent foundations to support the horizontal mounting beam, which in turn supports the auxiliary boiler equipment mounted on the roof.

Figure 13: Exterior Steel Frame for Auxiliary Boiler Equipment

The exterior steel structure that was built to support roof mounted boiler equipment. Also shown is the rear of the newly installed boilers.

Source: Sunsweet

Sub-project 2: Air Compressors

For the air compressor sub-project, the plan was to install one Ingersoll Rand Oil-Free 200 HP air compressor equipped with variable frequency drive. Sunsweet handled all the necessary electrical modifications since the new air compressor is an upsize from two 100 HP to one 200 HP. Additionally, because of a change in footprint and layout, Sunsweet executed necessary piping modifications for infeed and discharge of cooling water as well as air discharge. The original concrete pedestals on which the existing 100 HP air compressors sat were modified to accommodate the footprint of the new 200 HP air compressor. Figures 14 and 15 show the concrete modification and the new air compressor, respectively.

Pre-install Air Compressors:

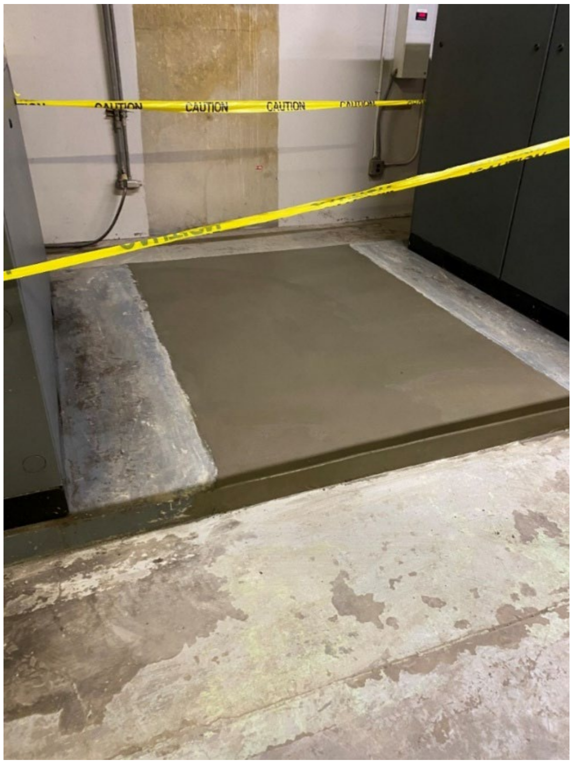
- Rotary Screw Air Compressors (2 each)
- Atlas-Copco Model GA75 Rotary Screw Load/Unload Air Compressors
- 100 HP each

- Purchased in 1998
- Used for supply and control of plant compressed air; operated in a "trim" mode to control plant compressed air pressure

Post-install Air Compressor:

- Rotary Screw Air Compressor (1 each)
- Ingersoll Rand Model IRN 200H-OF Rotary Screw Variable Speed Air Compressor
- 200 HP
- Purchased in 2021
- Used for supply and control of plant compressed air; operated in a "trim" mode to control plant compressed air pressure

Figure 14: Concrete Modification to Air Compressor Pedestal



The concrete modification to the pedestal the new air compressor sits on.

Source: Sunsweet

Figure 15: New 200 HP Air Compressor

The operator side of the new 200 HP air compressor.

Source: Sunsweet

Sub-project 3: Steam Traps

For the steam trap sub-project, Sunsweet had expected to execute small piping modifications to account for the shorter length of the new steam traps compared to the existing steam traps. In the execution phase, Sunsweet realized the condition of the condensate return pipes had deteriorated in several areas, which resulted in more extensive piping modifications than originally expected. Despite requiring more piping material than planned, this sub-project was successfully executed and the installation of the new steam traps was completed two months earlier than predicted. Figure 16 shows one of the new steam traps.

Figure 16: Newly Installed GEM Steam Trap

An installed steam trap with the manufacturer-supplied insulated jacket.

Source: Sunsweet

Project Changes and Challenges

In the pre-installation M&V phase of the boiler sub-project, progress was delayed due to problems with intermittent leaks that interfered with the accuracy of the data.

Originally, the pre-installation data collection on the boilers was slated to begin in April 2020. However, there were issues with the boiler efficiencies calculated during that time. In that time period, the data gathered indicated efficiencies above 90 percent for both boilers, which was not possible for boilers of this type and age. The steam flow instrumentation was re-calibrated for both boilers, but this did not correct the problem. PG&E performed a calibration on their natural gas meter in May of 2020, but the problem persisted. After much time and effort, the problem was still not resolved. PG&E insisted that their meter was functioning properly, and the instrument technicians demonstrated that the steam flow instruments were functioning properly. In November 2020, Sunsweet decided to install new natural gas meters for each boiler. The new natural gas meters were installed in late December, but the problem became worse, with efficiency calculations of more than 100 percent. The physical installations of all the components were checked and it was discovered that the downstream impulse tubes between the orifice plate and the differential pressure transmitter for each boiler had intermittent leaks. These leaks resulted in a larger pressure differential and unusually high steam flow readings. The tubes were repaired, and the problem was corrected, allowing collection of baseline data to begin on January 8, 2021. Although these unforeseen difficulties caused delays, progress was able to resume as soon as the issue was addressed.

During the first half of 2021, Sunsweet underwent a change in personnel and leadership. The role of vice president of operations was taken over by Jacob Pittman.

In the last quarter of 2022, the start of post-installation M&V data gathering for the boilers was delayed due to staffing constraints of the contractors responsible for tuning the boilers. This late start somewhat delayed the progress of the boiler sub-project, which in turn affected the completion date of the post-installation data collection phase.

The COVID-19 pandemic posed some challenges in the form of shipping delays, but these were minor issues that did not significantly affect the project timeline or budget.

CHAPTER 3: Project Results

Pre-installation Findings

The findings from the three-month measurement period can be summarized in three sections – Boilers, Air Compressors, and Steam Traps.

The first sub-project's findings from the previously existing boilers found that they consumed 972,674 therms of natural gas and in result produced a total of 5,164.90 $MTCO_2e$ over three months. These data were then calculated to project the annual GHG emissions produced, totaling 19,601.72 $MTCO_2e$.

Findings from the air compressor sub-project yielded data showing that the old 100 HP air compressors consumed 354,134.54 kWh of electricity over the three-month measurement period, producing 80.71 $MTCO_2e$ of GHG emissions. Annualized projections calculated a total of 263.19 $MTCO_2e$ produced per year by the existing air compressors.

For the steam trap sub-project, Sunsweet used the information provided by Thermal Energy International. The audit conducted by Thermal Energy International yielded data calculating that the additional natural gas consumed to supplement the steam lost by inefficient or failed steam traps totaled 354,890 therms per year, which equated to an additional 1,884.47 $MTCO_2e$ of GHG emitted annually.

Post-installation Measurement and Verification Results

Sub-project 1: Boilers

The data collected accurately represent the natural gas consumption and steam production of these boilers for normal plant operations and for plant maintenance support during non-production hours during the period of November 11, 2021, through November 10, 2022 (Table 8).

One outlier was encountered during data collection. The data collected on February 28, 2022, for Boiler 2 were very inconsistent with the data collected during the rest of the verification period, showing an efficiency of only 37 percent while the efficiency during the rest of the verification period was from 81 percent to 89 percent. No instrumentation problems or leaks in instrument tubing were found. It is possible that the boiler was left in a "standby" mode for a period of time which would have maintained the pressure and temperature of the boiler, consuming natural gas, but producing little to no steam. Since no equipment errors were identified, those data are still included in the results and related calculations (Table 9).

Annual air pollutant emissions reduction calculations were based on equation 14 of the Quantification Methodology for the CEC FPIP (refer to Appendix B — Quantification Methodology for the CEC FPIP).

Table 8: Sub-project 1 - Post-installation Boiler Measurement Results

	Boiler 1	Boiler 2	Totals
Steam Produced (lbs)	136,878,553	130,374,949	267,253,502
Natural Gas Used (therms)	1,623,098	1,545,978	3,169,076
GHG Emissions ($MTCO_2e$)	8,618.65	8,209.14	16,827.79
Boiler Efficiency (percent)	83.65%	85.06%	84.33%

Source: Sunsweet

Table 9: Annual Projected Natural Gas and GHG Reduction

Projected Therm Use Reduction	Projected GHG Reduction ($MTCO_2e$)
-585,539	-3,109.21

Source: Sunsweet

Results show that post-installation GHG emissions were calculated to equal 16,827.79 $MTCO_2e$ annually. When subtracted from projected pre-install emissions of 19,937.01 $MTCO_2e$ annually, they represent a projected reduction of 3,109.21 $MTCO_2e$ annually in emissions.

Sub-project 2: Air Compressors

Power consumption of the new Ingersoll Rand Oil-Free 200 HP air compressor was measured over 12 months. A Fluke 1736 3-phase power logger was used to record power consumption for the new air compressor. The data collected accurately represent the power consumption of this air compressor for normal plant operations and for plant maintenance support during non-operational periods. Holidays and down time due to equipment failure were excluded.

During the post-installation M&V phase of this sub-project, Sunsweet experienced a challenge that extended the duration of the 12-month M&V period caused by a motor failure of the new replacement unit. The problem was eventually diagnosed to have been caused by manufacturing defects. The failed motor was addressed under the manufacturer's warranty, and there have been no other incidents since with the new air compressor.

Issues Encountered During Data Collection:

1) Power to the power analyzer was inadvertently disconnected from October 11, 2022, at 3:03 PM until October 19, 2022, at 1:37 PM.
2) Data collected when the new air compressor was shut down due to compressor failure were not included because they would have impacted the calculations for average hourly power consumption and GHG emissions. This occurred a total of seven times during the measurement period, all due to equipment malfunctions. These failures are listed:
   1: Air compressor mechanical failure, June 10, 2021, 6:44 p.m. to June 13, 2021, 1:08 p.m.
   2: Air compressor mechanical failure, June 21, 2021, 9:07 p.m. to June 24, 2021, 11:07 a.m.

3: Air compressor electrical failure, July 17, 2021, 10:38 a.m. to August 12, 2021, 9:30 a.m.

4: Air compressor electrical/mechanical failure, September 22, 2021, 7:54 p.m. to December 14, 2021, 12:39 p.m.

5: Air compressor mechanical failure, March 1, 2022, 10:22 p.m. to March 4, 2022, 7:02 a.m.

6: Air compressor mechanical failure, July 21, 2022, 3:15 p.m. to July 25, 2022, 5:35 a.m.

7: Air compressor mechanical failure, November 3, 2022, 5:01 p.m. to November 7, 2022, 1:22 p.m.

The first four air compressor failures were caused by material defects in the main compressor shaft and a defective shaft wear sensor. These resulted in two main motor failures and two main compressor shaft failures. When the problem was diagnosed in September 2021, it took more than two months to get replacement components due to supply-chain issues caused by the COVID-19 pandemic. Both the vendor and the compressor manufacturer fully supported Sunsweet in resolution of the issues.

Annual air pollutant emissions reduction calculations were based on equation 16 of the Quantification Methodology for the CEC FPIP (Table 10).

Table 10: Sub-project 2 - Post-install Measurement Results for New Air Compressor (9,970 hours)

kWh Used	GHG Emissions ($MTCO_2e$)
672,734.45	152.32

Source: Sunsweet

Results show that post-installation GHG emissions were measured at 116.26 $MTCO_2e$ per year (Table 11). When subtracted from projected pre-installation emissions of 263.19 $MTCO_2e$ annually, the data show a reduction of 146.93 $MTCO_2e$ per year in GHG emissions (Table 12).

Table 11: Sub-project 2 - Post-install Annual Projection (7,560 hours)

kWh Used	GHG Emissions ($MTCO_2e$)
510,117.60	116.26

Source: Sunsweet

Table 12: Sub-project 2 - Post-install Projected Annual GHG Reduction

Pre-Install Annual GHG ($MTCO_2e$)	Post-Install Annual GHG ($MTCO_2e$)	Post-Install Annual GHG Reduction ($MTCO_2e$)
263.19	116.26	-146.93

Source: Sunsweet

Sub-project 3: Steam Traps

As previously mentioned in the pre-installation section, Sunsweet determined it would be impractical to measure the efficiencies of all 175 steam traps individually over a 12-month period. Thus, the post-installation M&V stage of this sub-project was based on data provided by David Coletta of Thermal Energy International as part of its third-party audit for Sunsweet. Annual air pollutant emissions reduction calculations were based on equation 14 of Quantification Methodology for the CEC FPIP (refer to Appendix B - Quantification Methodology for the CEC FPIP). In this case, the reduced emissions $MTCO_2e$ annually will be equal to the annualized baseline natural gas consumption due to steam loss in therms minus the annual reduction in natural gas use in therms, multiplied by the air pollution emission factor for natural gas. As indicated by the report, the annual projected reduction in GHG emissions is 1,710.21 $MTCO_2e$ annually (Table 13).

Table 13: Sub-project 3 - Post-install Steam Trap Audit Results

Calculated Post-Install Annual Projection of Additional Natural Gas Used and GHG Emissions by New Steam Traps

Natural Gas Savings (Therms)	GHG Reduction ($MTCO_2e$)
322,074	1,710.21

Source: Sunsweet

Sunsweet estimated the three sub-projects would reduce 4,457 $MTCO_2e$ annually, which is a 17 percent reduction in GHG emissions (Table 14). After the three sub-projects were installed and one year of monitoring completed, the GHG emissions were reduced by 4,966.36 $MTCO_2e$. This is a 19 percent reduction, surpassing the original project estimate by 2 percent.

Conclusions

Table 14: Actual vs. Planned GHG Reduction

Actual GHG Reduction ($MTCO_2e$)	Estimated GHG Reduction ($MTCO_2e$)	Difference ($MTCO_2e$)
4,966.36	4,457	+509.36

Source: Sunsweet

The verified data for actual GHG reductions exceed the original estimate of project GHG reduction by 509.36 $MTCO_2e$. Overall, the combined reduction in GHG emissions slightly exceeded the original project goals. From the results of the post-installation M&V process, it is clear that Sunsweet has successfully allocated the grant funds to achieve the project GHG emission reduction goals. This project has been a success and the resulting annual reduction of GHG emissions will improve air quality for the residents of Yuba City and the state of California, reducing air pollution and its effects on climate change.

CHAPTER 4: Technology/Knowledge/Market Transfer Activities

Sunsweet's final project report will be available as public information readily available to all, in large part thanks to the audience of the CEC. By making this report accessible, it is Sunsweet's hope to share the many benefits of modernizing business facilities and replacing aging equipment with newer, more energy-efficient versions.

Sunsweet partnered with a variety of local and California-based contractors to implement this project. Given the close business relationships Sunsweet has nurtured over the years with the vendors and contractors involved in the project, these partners have been advised that Sunsweet is open to meeting with other prospective businesses looking to take on similar projects. Through the experience and knowledge gained from collaborating with Sunsweet on this project, the expertise of vendors and contractors who participated in the project will go on to facilitate the future successes of other businesses and their endeavors to reduce GHG emissions.

Sunsweet will also provide knowledge gained, project results, lessons learned, and other relevant information to key industry stakeholders such as those that have provided letters of support for this project. Knowledge gained through this project will be shared extensively with the food production industry. Sunsweet plans to share project highlights, achievements, and lessons of this project through its unparalleled relationships with the food processing industry, and the dried fruit processing industry specifically. This knowledge sharing will be through printed materials, emails, and presentations at relevant industry events.

As evidenced by the letters of support received for this project, Sunsweet is well positioned to share knowledge through these methods based on partnerships with the California Prune Board (representing 800 prune growers and 28 prune, juice, and ingredient handlers/ processors); the California League of Food Processors (the only statewide food producing organization in California focused specifically on protecting the interests of food processors before all branches of state government); and the Agricultural Council of California (representing more than 15,000 farmers across California). These organizations have committed in their letters to "assisting in promoting and sharing the knowledge gained from this project in partnership with Sunsweet Growers" to support this project's knowledge sharing. In addition, Sunsweet will share results in its annual reports, which are distributed to all 200 growers in print and online.

CHAPTER 5: Conclusions/Recommendations

Sunsweet's total reduction of annual GHG emissions has exceeded expectations. The results of the project show how much potential there is in adopting energy-efficient technologies to reduce GHG emissions. In overachieving the project's GHG reduction goals, this project has proven beyond a doubt that smart investments into energy-efficient technology will yield significant energy savings and reductions of harmful GHG emissions.

Sunsweet recommends that companies and businesses across California take on similar projects to reduce their emissions, as the benefits of doing so far outweigh the costs. Not only will updating ageing equipment modernize facilities, it also will save on energy costs in the long run and reduce negative impacts to the environment.

As the technologies installed through this project are commercially available and drop-in ready, there is a broad range of industrial sectors/facilities in California that could use these technologies with great market potential in the immediate future. An underlying assumption is that boilers, steam traps, air compressors, and related technologies are commonly used in the food processing industry, as well as in the hotel and laundromat industries, among others. Deployment rates of energy efficiency technologies are increasing, yet still slowed due to the level of financial investment required. The assumption is that the main barrier to implementing technologies has to this point been the financial investment required and prolonged return on investment, considering the extensive costs of technologies. However, programs such as the FPIP have helped accelerate the adoption of technologies and have generated increased interest in energy-efficient technologies. If industries/businesses can be reached with information about the benefits and impacts of these new technologies, there is strong potential that more California facilities will implement these GHG emissions reducing technologies.

CHAPTER 6: Benefits to California

The success of this project has benefited the food processing industry by reducing harmful GHG emissions that pollute the air. Cleaner air improves the quality of the food produced. The success of this project bodes well for the success of similar future projects of other businesses and companies, which will bolster confidence in investing money into upgrading facilities. More companies taking on significant projects to reduce GHG emissions will collectively improve the health of California's air quality.

The Yuba City Sunsweet facility has benefited greatly from being able to produce its own steam and updating aging equipment. Overall use of natural gas and electricity at the facility has become more energy efficient and reduces expenses related to utilities in the long run.

Additionally, all vendors and businesses contracted in all phases of the project are local and California based. The vendors are R.F. MacDonald Co., with multiple locations in California; Motion Industries, based in Chico, California; and Ingersoll Rand, with a location in Sacramento, California. All funds used in this project were directly injected back into the local economy.

Furthermore, as a grower-owned cooperative, all revenue earnings/savings are passed on to Sunsweet's 200 prune grower-owners, many of whom live in the disadvantaged communities targeted by Senate Bill 535 (De León, Chapter 830, Statutes of 2012) and the low-income communities targeted by Assembly Bill 1550 (Gomez, Chapter 369, Statutes of 2016). Therefore, the renewable energy and direct energy cost savings from this project directly benefit residents of disadvantaged or low-income communities.

The residents of the local community surrounding the Yuba City facility suffer from a pollution burden percentile of 66 percent and will benefit from this project's reduction of air contaminant emissions. As a direct result of lowering GHG emissions, the local community will enjoy better air quality, and the state of California will benefit from the decrease in air pollution. Over the next few years, the cumulative reduction in GHG emissions will be able to positively impact air pollution on a global scale.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
A	amps
BTU	British thermal unit
CARB	California Air Resources Board
CEC	California Energy Commission
Diesel PM	diesel particulate matter
Eleccomp	electrical consumption
FPIP	Food Production Investment Program
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
GWP	global warming potential
hp	horsepower
kHz	kilohertz
kWh	kilowatt-hours
lbs	pounds
M&V	measurement and verification
MEASUR	Manufacturing Energy Assessment Software for Utility Reduction
$MTCO_2e$	metric tons of carbon dioxide equivalent
NOx	nitrous oxide
PG&E	Pacific Gas and Electric Company
PM2.5	particulate matter with a diameter less than 2.5 micrometers
RMS	root mean square
RMQ	RMQ Design and Consulting
ROG	reactive organic gas
Sunsweet	Sunsweet Growers Inc.
U.S. DOE	United States Department of Energy
V	volts
VFD	variable frequency drive

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CALIFORNIA ENERGY COMMISSION

ENERGY RESEARCH AND DEVELOPMENT DIVISION

APPENDIX A: Measurement and Verification Plan

May 2025 | CEC-500-2025-020

APPENDIX A: Measurement and Verification Plan

Overview

This project consists of three sub-projects. The sub-projects include the replacement of the existing two boilers with two new economizer-equipped boilers, replacement of two 100 HP air compressors with load/unload control with a single 200 HP variable speed oil-free air compressor, and replacement of 175 non-operational steam traps.

Sunsweet relies on steam for the equipment necessary for overall food and beverage processing, and facility sanitation. The affected equipment that is integral to this process and the focus of this project includes two boilers and 175 steam traps. Sunsweet also relies on electricity for the generation of compressed air which is incorporated into the processes. All outdated and inefficient equipment will be replaced with commercially available drop-in replacements that will provide greater GHG emission reductions than current equipment.

Sunsweet will use third party contractors to implement and gather data for the M&V plan. RMQ Design and Consulting will measure and confirm pre-installation measurements/ calculations of electricity consumption, natural gas usage, and GHG emissions against estimates. RMQ is also responsible for performing post-installation measurements for at least one year; calibrating any equipment as needed to ensure efficiency; and analyzing data to determine overall reduction and savings of electricity, natural gas, and GHG emissions that directly result from this project. RMQ will also prepare and provide a Pre-Installation M&V Findings Report and a Post-installation Measurement and Verification Findings Report to Sunsweet for review and submission to the CEC.

Sunsweet's production remains consistent throughout the year. The team believes that the M&V plan implementation can take place at any time throughout the year, and similar results can be taken from the study. Since the transition away from Green Leaf II Cogeneration Plant took place at the end of 2019, Sunsweet has produced the vast majority of the steam used for production with the two existing boilers. In the event that Yuba City cogeneration plant, to the south of Sunsweet's facility, does produce power to supplement power for PG&E, the steam byproduct will be incorporated into the process by turning down one of the boilers. The Yuba City cogeneration plant operates on a peak usage basis, primarily during the summertime. Sunsweet does not believe this will be an issue and affect the M&V plan because this occurrence is few and far between. Also, Sunsweet believes that the cogeneration plant will not be an issue in the M&V plan since they have chosen to expand the recording window from three months to five months so as to have a larger sample time.

Baseline Measurements

Boilers 1 and 2 steam production: The existing boilers are two Cleaver-Brook Model DL-68 Water Tube Boilers manufactured in 1975; each is equipped with a natural gas fired Model WT400X-CN5 burner. These boilers were originally capable of producing 60,000 pounds per hour each; however, the current output is about 50,000 pounds per hour for each unit. Each boiler has a Honeywell 4500 chart recorder with steam flow totalization capability that were installed within the last seven years and are comparable to those used for the proposed replacement boilers. Unfortunately, the precision of the steam flow measuring devices is not available due to their age but Sunsweet expects similar accuracy to that of the proposed boilers which is better than 1.25 percent of full-scale flow. On June 6, 2020, the steam flow measurement device was calibrated by subcontractor R.F. MacDonald. R.F. MacDonald reported that the device was properly calibrated. Total steam flow will be read and documented weekly for each boiler beginning March 8, 2020, and continue for a minimum of three months or for a period determined by the CEC Commission Agreement Manager.

There is a Sage Prime SIP natural gas meter for measuring the natural gas flow to each boiler. No other equipment is connected to these meters. The total natural gas consumption for each boiler will be read and documented at the same time as the total steam flow for the boilers.

The data will be entered into an Excel spreadsheet and converted to British thermal units (BTUs) to calculate the efficiency of the boilers as BTUs out as steam compared to BTUs in as natural gas therms. The baseline efficiency of the boilers will be accurately established through this procedure.

Baseline GHG emissions calculations will be based on equation 14 of the Quantification Methodology for the CEC FPIP. In this case, the baseline emissions in pounds per year will be equal to the annualized baseline natural gas consumption in therms multiplied by the air pollution emission factor for natural gas.

100 hp Air Compressors (2): Sunsweet currently operates two Atlas Copco GA75 single-stage rotary screw compressors, rated at 100 HP. Power consumption of each compressor will be measured. A Fluke 1736 power logger and a PCE-PA-8000 power logger will be used to collect the measurement data. The data will be collected weekly beginning May 14 and will continue for a minimum of three months or for a period determined by the Commission Agreement Manager. The Fluke power logger takes samples at a rate of 10.24 kHz and averages the data for one minute. The one-minute averages are recorded in a text file that will be imported to an Excel spreadsheet. The PCE power logger samples data once per second and averages the data for 10 seconds. The ten-second data averages are recorded in an Excel-compatible file. The data will be entered into an Excel spreadsheet as kilowatt-hours of power consumption.

Baseline GHG emissions calculations will be based on equation 16 of the Quantification Methodology for the CEC FPIP. In this case, the baseline emissions in pounds per year will be equal to the annualized baseline electrical power consumption in kilowatt hours multiplied by the air pollution emission factor for grid electricity.

Steam Traps: Data provided by David Coletta of Thermal Energy International as part of a third-party audit for Sunsweet will be used, since it would not be practical to measure current steam flow through 175 steam traps. Industry standard calculations should be adequate to establish the baseline steam flow through equivalent pipe sizes. This documentation is attached.

Baseline GHG emissions calculations will be based on equation 14 of the Quantification Methodology for the CEC FPIP. In this case, the baseline emissions in pounds per year will be equal to the annualized baseline natural gas consumption due to steam loss in therms multiplied by the air pollution emission factor for natural gas.

Post-Installation Verification

New Boilers 1 and 2: The project plan is to install two Cleaver-Brooks D-Type Industrial Watertube Boilers, model NB-200D-50-250 rated at 60,000 pounds per hour of steam generation. Each boiler will have new instrumentation with steam flow totalization capability. The instrumentation installed will have a level of precision that is expected to be better than 1.25 percent of full-scale flow or better. Total steam flow will be read and documented weekly for each boiler after installation and commissioning and continue for one year or for a period determined by the Commission Agreement Manager.

The same Sage Prime SIP natural gas meter used for baseline measurements will be read and documented at the same time as the total steam flow for the new boilers.

The data will be entered into an Excel spreadsheet and converted to British thermal units (BTUs) to calculate the efficiency of the new boilers as BTUs out as steam compared to BTUs in as natural gas therms. The post-commissioning efficiency of the new boilers will be accurately established for comparison with the baseline boiler efficiency through this procedure.

Annual air pollutant emissions reduction calculations will be based on equation 14 of the Quantification Methodology for the CEC FPIP. In this case, the reduced emissions in pounds per year will be equal to the annualized baseline natural gas consumption in therms minus the annual reduction in natural gas use in therms, multiplied by the air pollution emission factor for natural gas.

New 200 hp Variable Speed Drive Air Compressor: The project plan is to install one Ingersoll Rand Oil-Free 200 HP air compressor equipped with variable frequency drive. Power consumption of the new air compressor will be measured. A Fluke 1736 power logger or a PCE-PA-8000 power logger will be used to collect the measurement data and the same scan rate will be used in the post installation M&V plan as in the pre installation M&V plan. The data will be collected weekly after installation and commissioning of the new air compressor and will continue for one year or for a period determined by the Commission Agreement Manager. The data will be entered into the same Excel spreadsheet used for baseline data as kilowatt-hours of power consumption. The spreadsheet will provide a comparison of baseline power consumption and new air compressor power consumption.

Annual air pollutant emissions reduction calculations will be based on equation 16 of the Quantification Methodology for the CEC FPIP. In this case, the reduced emissions in pounds per year will be equal to the annualized baseline electrical power consumption in kilowatt hours minus the annual reduction in electrical power consumption in kilowatt hours, multiplied by the air pollution emission factor for grid electricity.

Steam Traps: Data provided by David Coletta of Thermal Energy International as part of a third-party audit for Sunsweet will be used. That documentation is attached.

Annual air pollutant emissions reduction calculations will be based on equation 14 of the Quantification Methodology for the CEC FPIP. In this case, the reduced emissions in pounds per year will be equal to the annualized baseline natural gas consumption due to steam loss in therms minus the annual reduction in natural gas use in therms, multiplied by the air pollution emission factor for natural gas.

ENERGY RESEARCH AND DEVELOPMENT DIVISION

APPENDIX B: Quantification Methodology for the CEC FPIP

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APPENDIX B:
Quantification Methodology for the CEC FPIP

California Air Resources Board

California Energy Commission
Food Production Investment Program

California Climate Investments

October 1, 2019

List of Acronyms and Abbreviations

Acronym	Term
A	amps
CARB	California Air Resources Board
CEC	California Energy Commission
Diesel PM	diesel particulate matter
FPIP	Food Production Investment Program
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
hp	horsepower
kWh	kilowatt hours
lbs	pounds
MEASUR	Manufacturing Energy Assessment Software for Utility Reduction
MTCO2e	metric tons of carbon dioxide equivalent
NOx	nitrous oxide
PM2.5	particulate matter with a diameter less than 2.5 micrometers
ROG	reactive organic gas
RMS	root mean square
U.S. DOE	United States Department of Energy
V	volts

List of Definitions

Term	Definition
Co-benefit	A social, economic, and/or environmental benefit as a result of the proposed project in addition to the GHG emission reduction benefit.
Energy and fuel cost savings	Changes in energy and fuel costs to the operator because of changing the quantity of energy or fuel used conversion to an alternative energy or fuel source, and renewable energy or fuel generation.
Key variable	Project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit (e.g., renewable energy generated).
Quantification period	Number of years that the project element will provide GHG emission reductions. Sometimes also referred to as "Project Life."

Section A. Introduction

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

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

For the California Energy Commission (CEC) Food Production Investment Program (FPIP), CARB staff developed this FPIP Quantification Methodology to provide guidance for estimating the GHG emission reductions and selected co-benefits of each proposed project type, as defined in the FPIP guidelines (CEC, 2019). This methodology uses calculations to estimate GHG emission reductions from replacing equipment with more energy-efficient alternatives, installing various efficiency measures, producing renewable energy/fuel, replacing refrigerants with lower global warming potential (GWP) alternatives, and reducing refrigerant leakage rates; and GHG emissions associated with the implementation of FPIP projects.

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

Using many of the same inputs required to estimate GHG emission reductions, the FPIP Benefits Calculator Tool estimates the following co-benefits and key variables from FPIP projects: energy and fuel cost savings ($), fossil fuel-based energy use reductions (kWh and therms), water use reductions (gallons), and renewable energy generation (kWh). Key variables are project characteristics that contribute to a project's GHG emission reductions and signal an additional benefit (e.g., renewable energy generated). Additional co-benefits for which CARB assessment methodologies were not incorporated into the FPIP Benefits Calculator Tool may also be applicable to the project. Applicants should consult the FPIP guidelines, solicitation materials, and agreements to ensure they are meeting FPIP requirements. All CARB co-benefit assessment methodologies are available at: www.arb.ca.gov/cci-cobenefits.

Methodology Development

CARB and CEC developed this Quantification Methodology consistent with the guiding principles of California Climate Investments, including ensuring transparency and accountability (CARB, 2025a). CARB and CEC developed this FPIP Quantification Methodology to be used to estimate the outcomes of proposed projects, inform project selection, and track results of funded projects. The implementing principles ensure that the methodology would:

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

CARB assessed peer-reviewed literature and tools and consulted with experts, as needed, to determine methods appropriate for the FPIP project types. CARB also consulted with CEC 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.

Tools

The FPIP Benefits Calculator Tool may use project-specific outputs from the following tools:

> The Manufacturing Energy Assessment Software for Utility Reduction (MEASUR) software tool was developed by the United States Department of Energy (U.S. DOE) to help manufacturers increase industrial energy efficiency by calculating the efficiency of specific systems and pieces of equipment within a plant. The tool may be used to estimate baseline existing energy consumption and model future project-based energy consumption from pumps, process heating equipment, fans, and steam systems. These outputs can then be inputted into the FPIP Benefits Calculator Tool. The MEASUR tool can be accessed at: https://www.energy.gov/eere/amo/measur.
>
> The AIRMaster+ software tool was developed by the U.S. DOE to help users analyze energy use and savings opportunities in industrial compressed air systems. The tool may be used to estimate baseline existing and model future project-based energy consumption from air compression systems. These outputs can then be inputted into the FPIP Benefits Calculator Tool. The AIRMaster+ tool can be accessed at: https://www.energy.gov/eere/amo/articles/airmaster.

MEASUR and AIRMaster+ are used nationally, subject to regular updates to incorporate new information, free of charge, and publicly available to anyone with internet access.

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

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

Section B. Methods

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

Project Type and Components

CEC identified several technologies for projects that meet the objectives of FPIP and for which there are methods to quantify GHG emission reductions (CEC, 2019). Other project components may be eligible for funding under the FPIP; however, each project requesting GGRF funding must include at least one of the following:

- Installation, replacement, retrofit, or operational optimization to increase energy efficiency of:
  - Compressor controls and system optimization;
  - Machine drive controls and upgrades;
  - Mechanical dewatering;
  - Advanced motors and controls, including variable frequency drives (VFDs);
  - Refrigeration optimization or replacement (including low GWP refrigerants);
  - Drying equipment;
  - Process equipment insulation;
  - Boilers, economizers;
  - Steam traps, condensate return, heat recovery;
  - Evaporators;
  - Internal metering, software, and controls (to manage/control energy usage, with project that reduces energy usage);
  - Other types of controls, such as compressed air, automatic blow down for boilers;
  - Waste heat to power (including pressure reduction turbines);
  - Industrial cooking equipment;
- Renewable electricity generation; and
- Renewable natural gas production.

General Approach

Methods used in the FPIP Benefits Calculator Tool for estimating the GHG emission reductions and air pollutant emission co-benefits by project 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 onsite reductions in grid electricity and natural gas usage, additional renewable electricity generation and renewable natural gas production (i.e., beyond that associated with grid electricity reductions), and refrigerant replacement and leakage reduction. In general, the GHG emission reductions are estimated in the FPIP Benefits Calculator Tool using the approaches in Table B-1. The FPIP Benefits Calculator Tool also estimates air pollutant emission co-benefits and key variables using many of the same inputs used to estimate GHG emission reductions.

Table B-1: General Approach to Quantification

Food Production Facility Improvement
GHG Emission Reductions = (Baseline energy consumption emissions – Project energy consumption emissions) + (Baseline refrigerant emissions – Project refrigerant emissions) + (Additional GHG benefit of renewable electricity generation) + (Additional GHG benefit of renewable natural gas production)

Source: California Air Resources Board

GHG Emission Reductions from Food Production Facility Improvement Projects

Equation 1: GHG Emission Reductions from Food Production Facility Improvement Projects

$$ER_{GHG} = \left(AER_{GHG,Equip} + AER_{GHG,Refrig} + AER_{GHG,Gen}\right) \times Q$$

Where,			Units
ER_{GHG}	=	Total GHG emission reductions from the project.	$MTCO_2e$
$AER_{GHG,\,Equip}$	=	Annual GHG emission reductions from equipment installation, replacement, retrofit, or optimization (sum of all components, from Equation 2).	$MTCO_2e$/yr
$AER_{GHG,\,Refrig}$	=	Annual GHG emission reductions from refrigerant replacement and leakage reduction (sum of all refrigerants, from Equation 10).	$MTCO_2e$/yr
$AER_{GHG,\,Gen}$	=	Annual GHG emission reductions from the production of renewable energy/fuel (from Equation 11).	$MTCO_2e$/yr
Q	=	Quantification period	Years

Equation 1. The GHG emission reductions from food production facility improvement projects are estimated as the sum of GHG emission reductions from equipment installation, replacement, retrofit, or optimization; refrigerant replacement and leakage reduction; and additional renewable energy/fuel production; multiplied by the quantification period.

Equation 2: Annual GHG Emission Reductions from Equipment Installation, Replacement, Retrofit, or Optimization

$$AER_{GHG,Equip} = \left[\sum(NG_{baseline} - NG_{project}) \times EF_{GHG,NG}\right] + \left[\sum(Elec_{baseline} - Elec_{project}) \times EF_{GHG,Elec}\right]$$

Where,

			Units
$AER_{GHG, Equip}$	=	Annual GHG emission reductions from equipment installation, replacement, retrofit, or optimization (sum of all components).	$MTCO_2e$/yr
$NG_{baseline}$	=	Baseline annual natural gas consumption for a particular set of components, prior to project implementation (from Equation 3).	therm/yr
$NG_{project}$	=	Future annual natural gas consumption for a particular set of components, after project implementation (from Equation 3).	therm/yr
$EF_{GHG, NG}$	=	GHG emission factor for natural gas.	$MTCO_2e$/therm
$Elec_{baseline}$	=	Baseline annual electricity consumption for a particular set of components, prior to project implementation.	kWh/yr
$Elec_{project}$	=	Future annual electricity consumption for a particular set of components, after project implementation.	kWh/yr
$EF_{GHG, Elec}$	=	GHG emission factor for grid electricity.	$MTCO_2e$/kWh

Equation 2. Annual GHG emission reductions from equipment installation, replacement, retrofit, and optimization are estimated as the sum of the difference between the baseline and project scenario annual natural gas consumption for all project components, multiplied by the GHG emission factor for natural gas, plus and the sum of the difference between the baseline and project scenario annual electricity consumption for all project components, multiplied by the GHG emission factor for grid electricity.

Equation 3: Annual Natural Gas Consumption

$$NG_x = NG_{comp} \times N$$

Where,

			Units
NG_x	=	Annual natural gas consumption for a particular set of components (x = baseline or project).	therm/yr
NG_{comp}	=	Annual natural gas consumption, per unit or component.	therm/yr/unit
N	=	Number of identical units.	units

Equation 3. Annual natural gas consumption is estimated by multiplying the annual natural gas consumption of each unit or component by the number of identical units.

Equation 4: Annual Electricity Consumption

$$Elec_x = Elec_{comp} \times N$$

Where,			Units
$Elec_x$	=	Annual electricity consumption for a particular set of components (x = baseline or project).	therm/yr
$Elec_{comp}$	=	Annual electricity consumption, per unit or component.	therm/yr/unit
N	=	Number of identical units.	units

Equation 4. Annual electricity consumption is estimated by multiplying the annual natural gas consumption of each unit or component by the number of identical units.

For the majority of project components, electricity consumption (Eleccomp) is calculated using a third-party tool or derived from equipment specifications. However, Eleccomp for motors and variable speed/frequency drives are calculated within the FPIP Benefits Calculator Tool using Equation 5 and Equation 6, respectively.

Equation 5: Annual Electricity Consumption from Motors

$$Elec_{motor} = AOH_{motor} \times HP_{motor} \times L_{motor} \times 0.746 \times \frac{1}{E_{motor}}$$

Where,			Units
$Elec_{motor}$	=	Annual electricity consumption from a motor.	kWh/yr
AOH_{motor}	=	Annual operating hours for the motor.	hrs/yr
HP_{motor}	=	Motor nameplate horsepower rating.	hp
L_{motor}	=	Motor load.	%
0.746	=	Conversion from hp to kW.	kW/hp
E_{motor}	=	Motor efficiency under actual load conditions.	%

Equation 5. Annual electricity consumption from motors is estimated by multiplying the annual operating hours, nameplate horsepower rating, motor load, and conversion factor (0.746), then dividing by the motor efficiency under actual load conditions.

Equation 6: Annual Electricity Consumption from Variable Frequency Drives

$$Elec_{VFD} = HP_{VFD} \times 0.746 \times \sum_i (S_i^3 \times AOH_i)$$

Where,			Units
$Elec_{VFD}$	=	Annual electricity consumption from a variable frequency drive.	kWh/yr
HP_{VFD}	=	Nameplate horsepower rating for the variable frequency drive.	hp
0.746	=	Conversion from hp to kW.	kW/hp
S	=	Operating speed, as a percentage of maximum speed, for each operating condition i.	%
AOH	=	Annual operating hours at a particular speed, for each operating condition i.	hrs/yr

Equation 6. Annual electricity consumption from variable frequency drives is estimated by multiplying the nameplate horsepower rating, conversion factor (0.746), and the summation of operating speed conditions multiplied by the annual operation hours for each respective operating speed.

The FPIP Benefits Calculator Tool also contains calculators that can be used to estimate motors parameters, such as motor load, using Equation 7 – Equation 9.

Equation 7: Motor Load

$$L_{motor} = P/P_R$$

Where,			Units
L_{motor}	=	Motor load.	%
P	=	Measured three-phase power.	kW
P_R	=	Input power at full rated load.	kW

Equation 7. Motor load is estimated by dividing the measured three-phase power (Equation 9) by the input power at full rate load (Equation 10).

Equation 8: Motor Input Power at Full Rated Load

$$P_R = \frac{HP_{motor} \times 0.746}{E_R}$$

Where,			Units
P_R	=	Input power at full rated load.	kW
HP_{motor}	=	Motor nameplate horsepower rating.	hp
0.746	=	Conversion from hp to kW.	kW/hp
E_R	=	Motor efficiency at full rated load.	%

Equation 8. Input power at full rated load is estimated by multiplying the horsepower rating by a conversion factor (0.746), then dividing by the motor efficiency at full rated load.

Equation 9: Three-Phase Power

$$P = \frac{V \times I \times PF \times \sqrt{3}}{1{,}000}$$

Where,			Units
P	=	Measured three-phase power.	kW
V	=	RMS voltage, mean line-to-line of three phases.	V
I	=	RMS current, mean of three phases.	A
PF	=	Power factor.	%
$\sqrt{3}$	=	Constant for three phase power.	Unitless
1,000	=	Conversion from kW to W.	W/kW

Equation 9. Measured three-phase power is estimated by multiplying RMS voltage, RMS current, power factor, and a constant for three phase power (√3), then dividing by a conversion factor (1,000).

Equation 10: Annual GHG Emission Reductions from Refrigerant Replacement and Leakage Reduction

$$AER_{GHG,Refrig} = \sum_{i=1}^{n}(RC_{baseline} \times GWP_{baseline} \times LR_{baseline} \times N_i/2{,}205) - \sum_{j=1}^{m}\left(RC_{project} \times GWP_{project} \times LR_{project} \times N_j/2{,}205\right)$$

Where,

			Units
$AER_{GHG,\ Refrig}$	=	Annual GHG emission reductions from refrigerant replacement and leakage reduction (sum of all refrigerants).	$MTCO_2e$/yr
$RC_{baseline}$	=	Refrigerant charge of the baseline refrigeration system.	lb
$GWP_{baseline}$	=	Global Warming Potential of the baseline refrigerant	$MTCO_2e$/MT
$LR_{baseline}$	=	Refrigerant leakage rate of the baseline refrigeration system.	%/yr
$RC_{project}$	=	Refrigerant charge of the refrigeration system proposed by the project.	lb
$GWP_{project}$	=	Global Warming Potential of the refrigerant proposed by the project.	$MTCO_2e$/MT
$LR_{project}$	=	Refrigerant leakage rate of the refrigeration system proposed by the project.	%/yr
N	=	Number of identical units.	units
2,205	=	Conversion factor from pounds to metric tons	lb/MT

Equation 10. Annual GHG emission reductions from refrigerant replacement and leakage reduction are estimated as the difference between the baseline and project scenarios. The baseline and project scenarios are estimated as the multiplication of the refrigerant charge, global warming potential, refrigerant leakage rate, and number of identical units, divided by a conversion factor (2,205).

Equation 11: Annual GHG Emission Reductions from Additional Renewable Energy/Fuel Production

$$AER_{GHG,Gen} = \left(RenElec \times EF_{GHG,Elec}\right) + \left(RNG \times EF_{GHG,NG}\right)$$

Where,

			Units
$AER_{GHG,\ Gen}$	=	Annual GHG emission reductions from the production of renewable energy/fuel.	$MTCO_2e$/yr
$RenElec$	=	Annual renewable electricity generation as a result of the project.	kWh/yr
$EF_{GHG,\ Elec}$	=	GHG emission factor for grid electricity.	$MTCO_2e$/kWh
RNG	=	Annual renewable natural gas production as a result of the project.	kWh/therm
$EF_{GHG,\ NG}$	=	GHG emission factor for natural gas.	$MTCO_2e$/therm

Equation 11. Annual GHG emission reductions from additional renewable energy/fuel production are estimated as the sum of annual renewable electricity generation multiplied by

the GHG emission factor for grid electricity, plus annual renewable natural gas production multiplied by the GHG emission factor for natural gas.

Air Pollutant Reductions from Food Production Facility Improvement Projects

Equation 12: Air Pollutant Emission Reductions from Food Production Facility Improvement Projects

$$ER_{AP} = ER_{AP,Local} + ER_{AP,Remote}$$

Where,

			Units
ER_{AP}	=	Total air pollutant emission reductions from the project.	lb
$ER_{AP,\ Local}$	=	Total onsite air pollutant emission reductions from food production facility improvement projects.	lb
$ER_{AP,\ Remote}$	=	Total offsite air pollutant emission reductions from food production facility improvement projects.	lb

Equation 12. The criteria and toxic air pollutant emission reductions (PM2.5, NOx, and ROG) from food production facility improvement projects are estimated as the sum of local (Equation 13 and Equation 14) and remote (Equation 15, Equation 16, and Equation 17) air pollutant emission reductions.

Equation 13: Local Air Pollutant Emission Reductions from Food Production Facility Improvement Projects

$$ER_{AP,Local} = AER_{AP,NG} \times Q$$

Where,

			Units
$ER_{AP,\ Local}$	=	Total onsite air pollutant emission reductions from food production facility improvement projects.	lb
$AER_{AP,\ NG}$	=	Annual avoided air pollutant emissions from the reduced onsite use of natural gas.	lb/yr
Q	=	Quantification period	Years

Equation 13. Local air pollutant emission reductions are estimated by multiplying the annual avoided air pollutant emissions from reduced onsite use of natural gas by the quantification period.

Equation 14: Annual Air Pollutant Emission Reductions from the Reduced Onsite Use of Natural Gas

$$AER_{AP,NG} = \sum (NG_{baseline} - NG_{project}) \times EF_{AP,NG}$$

Where,			Units
$AER_{AP,NG}$	=	Annual avoided air pollutant emissions from the reduced onsite use of natural gas.	lb/yr
$NG_{baseline}$	=	Baseline annual natural gas consumption for a particular set of components, prior to project implementation.	therm/yr
$NG_{project}$	=	Future annual natural gas consumption for a particular set of components, after project implementation.	therm/yr
$EF_{AP,NG}$	=	Air pollutant emission factor for natural gas.	lb/therm

Equation 14. The annual air pollutant emission reductions from the reduced onsite use of natural gas is estimated as the sum of the difference between the baseline and project scenario annual natural gas consumption for all project components, multiplied by the air pollutant emission factor for natural gas.

Equation 15: Remote Air Pollutant Emission Reductions from Food Production Facility Improvement Projects

$$ER_{AP,Remote} = (AER_{AP,Elec} + AER_{AP,RenElec}) \times Q$$

Where,			Units
$ER_{AP,Remote}$	=	Total offsite air pollutant emission reductions from food production facility improvement projects.	lb
$AER_{AP,Elec}$	=	Annual avoided air pollutant emissions from the reduced onsite use of grid electricity.	lb/yr
$AER_{AP,RenElec}$	=	Annual avoided emissions from the generation of renewable electricity.	lb/yr
Q	=	Quantification period	Years

Equation 15. Remote air pollutant emission reductions are estimated by the sum of annual avoided air pollutant emissions from reduced onsite use of grid electricity and from production of renewable electricity, multiplied by the quantification period.

Equation 16: Annual Air Pollutant Emission Reductions from the Reduced Onsite Use of Grid Electricity

$$AER_{AP,Elec} = \sum (Elec_{baseline} - Elec_{project}) \times EF_{AP,Elec}$$

Where,			Units
$AER_{AP,Elec}$	=	Annual avoided air pollutant emissions from the reduced onsite use of grid electricity.	lb/yr
$Elec_{baseline}$	=	Baseline annual electricity consumption for a particular set of components, prior to project implementation.	kWh/yr
$Elec_{project}$	=	Future annual electricity consumption for a particular set of components, after project implementation.	kWh/yr
$EF_{AP,Elec}$	=	Air pollutant emission factor for grid electricity.	lb/kWh

Equation 16. The annual air pollutant emission reductions from the reduced onsite use of grid electricity is estimated as the sum of the difference between the baseline and project scenario annual electricity consumption for all project components, multiplied by the air pollutant emission factor for grid electricity.

Equation 17: Annual Air Pollutant Emission Reductions from the Generation of Additional Renewable Electricity

$$AER_{AP,RenElec} = RenElec \times EF_{AP,Elec}$$

Where,			Units
$AER_{AP,\ RenElec}$	=	Annual avoided emissions from the generation of renewable electricity.	lb/yr
$RenElec$	=	Annual renewable electricity generation as a result of the project.	kWh/yr
$EF_{AP,\ Elec}$	=	Air pollutant emission factor for grid electricity.	lb/kWh

Equation 17. The annual air pollutant emission reductions from the generation of renewable electricity is estimated as the annual renewable electricity generation multiplied by the air pollutant emission factor for grid electricity.