LITERATURE REVIEW

for 2010-2012 Statewide Agricultural Energy Efficiency Potential & Market Characterization Study

FINAL

Prepared for:

Submitted by: Navigant Team
Date: October 4, 2011

Navigant Consulting, Inc.
1375 Walnut Street
Suite 200
Boulder, CO 80302

(303) 728-2500
www.navigantconsulting.com

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1 Executive Summary

This Literature Review is the first in a series of six reports pertaining to the *2010-2012 Statewide Agriculture Market Characterization and Energy Efficiency Potential Study* managed by Pacific Gas & Electric (PG&E) on behalf of PG&E, Southern California Edison (SCE), Southern California Gas (SCG), and San Diego Gas & Electric (SDG&E), and the California Public Utilities Commission (CPUC). This Study focuses on the following segments within California's agriculture industry: Dairies, Refrigerated Warehouses, Irrigated Agriculture, Greenhouses & Nurseries, Vineyards & Wineries, and Post Harvest Processing.

The purpose of this Literature Review is to inform all parties involved in the Study of foundational knowledge that will be used throughout the development of the Research Plan, Sampling Plan, Survey Instruments, primary research and analysis, and the remainder of the reports associated with this effort. The rest of this Executive Summary contains a summary of key findings extracted from resources related to each of the agriculture industry segments included in the Study.

1.1 Dairies

The dairy industry includes the production of milk on dairy farms and the processing of milk into products like cheese, milk powder, and butter. The focus of this Study is on the dairy farms that produce fluid milk.

Key Findings & Observations

- Energy use in dairies is well understood and well documented, however, available baseline saturations and technology adoption rates are out of date. Are there more up-to-date baseline surveys (conducted within the past 3-5 years)?
- Through various programs, PG&E and SCE have offered a number of energy efficiency measures to dairies in their territories. These programs have also offered audits and educational programs to dairy customers. No programs were found for SDG&E of SoCalGas dairy customers.
- A 2006-2007 report commissioned by the California Milk Advisory Board found that California's dairies should focus on process efficiency improvements.
- Anaerobic digesters are among the most promising technologies for livestock customers, offering an important waste management and cost reduction tool. However, widespread adoption of anaerobic digesters is limited by some of California's air management districts' pollution standards.
- Management of electricity consuming equipment to reduce or limit summer peak demand may be an additional area of focus for the sector and the IOUs.

1.2 Feedlots

Feedlots are used to fatten livestock, primarily cattle, before slaughter.

Key Findings & Observations

- Cattle feedlots are not heavy users of energy. Electrical and/or natural gas requirements are primarily to power feed mills, which blend food and nutrients for the animals, and pumps for water.

Some lighting may be required in some facilities. A baseline survey to understand potential energy efficiency opportunities may be appropriate, especially for feed mills. Other energy uses on the feedlots can be addressed with standard technology (lighting measures) and equipment that is already available for irrigation (pumps, drip irrigation).

- As for dairies, anaerobic digesters are among of the most promising technologies for livestock customers, offering an important waste management and cost reduction tool. However, widespread adoption of anaerobic digesters is limited by some of California's air management districts' pollution standards.

1.3 Refrigerated Warehouses

Companies offer refrigerated warehousing and cold storage services for raw or processed fruit and vegetable products, including processed meats, and frozen prepared dishes. These facilities are located in the Central Coast, Southern California, Bay Area, Sacramento Valley region and the San Joaquin Valley. The industry is segmented by private facilities operated by food processing companies housing goods before shipments of finished products, and public facilities operated by wholesalers and supermarkets.

PG&E currently offers education, audits and rebates to its refrigerated warehouse customers through two programs. No existing programs were identified for SCE, SoCalGas or SDG&E customers.

Key Findings & Observations

- The most important market driver for this industry is to reduce electricity costs.
- Existing programs have primarily focused on one-off measures aimed at single machines. Is adoption, and saturation of baseline and efficient technologies well understood by the IOUs?
- IOUs could partner with warehouse companies at the corporate level to support the adoption of ISO 500001, the Energy Management Standard.
- Site-specific management conditions determine the energy intensity of each warehouse. Additional energy efficiencies may be achieved with the adoption of the California Energy Commission's 2009 Nonresidential Compliance Manual for Refrigerated Warehouses. Further research is needed to identify best management practices to significantly reduce product loss. Many of these are likely tied to energy savings, although proof of concept would be required to verify that assumption, and would thus provide the IOUs with another way to help these customers reduce their energy use.

1.4 Irrigated Agriculture

The irrigated agriculture segment is a major user of electricity, primarily for pumping.
PG&E and SCE have offered various programs to customers in the irrigated agriculture segment, focusing primarily on pumps and pump tests. SoCalGas participated in the APEP II program with PG&E and SCE but otherwise has not offered specific programs or measures. SDG&E provides free pump tests but otherwise has not offered specific programs or measures in recent years.

Key Findings & Observations

- Utility programs, measures, and other offerings focus the pumping plant efficient (pumps, pump tests) and irrigation system components while savings could also be achieved immediately with improved groundwater well design and infrastructure. Also, some farms may still be using diesel and natural gas powered engines for water pumping.

- Providing energy and water conservation simultaneously is the key to a successful program.
- Embedded energy savings must be identified and recognized under CPUC energy efficiency programs to access deep savings within this sector. New program evaluation metrics would be needed to calculate overall energy savings if indirect savings were allowed by the CPUC. The reduced use resulting from emerging irrigation and planting methods could be accounted as an incentive to adopt more efficient water and energy conservation technologies. New programs may be designed to offer a holistic resource management approach where farms can receive incentives for both direct and indirect energy savings, water use efficiency improvements, greenhouse gas emission reductions, reduced run-off and other environmental benefits.
- There is insufficient empirical research data to determine the total technical potential of additional energy conservation and efficiency in California's irrigated agriculture
- There is a lack of information to assess adoption rates of cultural practices and irrigation systems that deliver both water and energy conservation.
- The impacts of "conversion acres", those that migrate from irrigation district delivered surface water to groundwater sources, are not currently quantified.

1.5 Greenhouses & Nurseries

The Greenhouses & Nurseries segment includes:

- o <u>Nurseries</u> which grow crops and ornamentals for transplanting
- o <u>Greenhouses</u> which grows plants for commercial landscaping (ornamentals) and commercial crop production (e.g., tomatoes and cucumbers)
- o <u>Mushroom Production</u>
- o <u>Floriculture</u>

PG&E, SoCalGas, and SDG&E currently offer rebates for energy efficiency measures targeting greenhouses and irrigation measures targeting water use in the sector.

Key Findings & Observations

- There is a lack of basic industry information about the Greenhouses & Nurseries segment.
- High-intensity energy and water requirements cannot be addressed without establishing baseline of information.
- A dedicated market characterization study of this segment may be needed to properly understand energy consumption patterns and opportunities to achieve savings and efficiency improvements.

1.6 Vineyards & Wineries

Wine Industry segment includes:

- o <u>Vineyards that cultivate winegrapes</u>
- o <u>Wineries that crush, process and bottle wine products</u>

PG&E currently runs a targeted program providing technical support and equipment rebates to wineries. Vineyards receive the products and services offered to the Irrigated Agriculture segment by all of the IOUs.

Key Findings & Observations

- Wineries are active participants in efficiency and renewable IOU programs.
- Vineyards and wineries have embraced resource conservation and sustainability principles.
- Wineries have new opportunities to advance energy management practices by adopting the 2011 ISO 50001 international energy management standard.

1.7 Post Harvest Processing

On or near frame post harvest processing activities primarily consist of cooling fresh market fruits and vegetables, drying of fruit and vegetable crops, and hulling and shelling of nut crops. Post harvest activities are energy intensive. California's IOUs have not offered any recent programs that directly targeted the post-harvest handling industry. A number of PG&E and SCE programs have offered audits and rebates for energy efficiency equipment, for which post-harvest processors could have been eligible. However, adoption and participation rates were not evaluated for this particular market segment. No programs were found for SDG&E or SoCalGas customers.

Key Findings & Observations

- The accumulated effect of utilizing best practices and adopting continuous improvements deliver a highly productive agricultural industry.
- There is insufficient published information on energy use, potential for energy conservation or adoption rate of emerging technologies for this industry, especially post harvest drying and nut hulling and shelling. It may be appropriate to conduct surveys to assess the interest in energy management and technology adoption needs of this industry.
- There is a fundamental incompatibility between the drivers of this sector, especially post harvest drying, and the adoption of efficient technologies. Post harvest drying is extremely seasonal and investments in equipment are only made when necessary. Solar drying technologies are an ideal example as these appear to offer significant potential to reduce energy use in post harvest drying but they are expensive. At the same, the seasonal demand of the post harvest activities coincides with summer peak loads so the positive impact of solar technologies (and any energy efficiency technology) would be realized in energy use and demand reductions. The IOUs may consider focusing on developing attractive, collaborative subsidies (by partnering with agencies focusing on water and air pollution) that would incent customers to adopt efficient technologies.
- IOU efficiency programs have an opportunity to target post-harvest cooling. The Post-harvest cooling section offers valuable recommendations from the University of California, Cooperative Extensions Post-harvest Specialist to advance energy conservation and efficiency improvements in this energy intensive segment. The following are examples of research needed for this sector:
  - Determining the minimum water flow needed in hydro-coolers.
  - Optimizing airflow rates and reducing pressure drop in forced-air coolers.
  - For vacuum coolers:
    - Using a common refrigeration system for multiple vacuum tubes.
    - Minimizing the time water is sprayed in the water spray operation.

- Using high-speed vacuum pumps.
- Installing direct expansion or flooded evaporators.

2 Background

2.1 Purpose

Navigant Consulting, Inc. (Navigant) has been selected by California's Investor Owned Utilities (IOUs) to undertake a comprehensive assessment of the state's agricultural sector's energy efficiency needs and potentials. Pacific Gas & Electric is the contract manager for this effort, on behalf of the Program Advisory Committee (PAC), which includes representatives of the four IOUs (PG&E, SCE, SDG&E, SoCalGas) and the California Public Utilities Commission (CPUC).

The statement-of-work (SOW) for the *Statewide Agriculture Market Characterization and Energy Efficiency Potential Study* ("the Study") provides that the purpose of this Literature Review is to assemble a complete picture of existing research, knowledge, and data pertaining to the Agriculture Industry, in general and specifically in California.[1] The Literature Review ensures that foundational information is available to inform all parties involved in the Study throughout the development of the Research Plan, Sampling Plan, Survey Instruments, primary research and analysis, and reports. This report is one of six reports included in this Study.

2.2 Scope

Agriculture Industry segments included in this Literature Review are the seven listed in the project SOW: Dairies, Refrigerated Warehouses, Irrigated Agriculture, Greenhouses & Nurseries, Vineyards & Wineries, and Post Harvest Processing. Due to their low energy requirements relative to the other sectors, primarily for lighting and pumping, feedlots may be omitted from the Study in favor of the energy-intensive Greenhouses & Nurseries' subsegment Floriculture or Mushroom production. A cursory review of feedlots is provided in this report pending an official decision regarding the scope of the Study.

2.3 Methodology

Navigant performed a comprehensive review of relevant research reports, industry and market assessments, data, potentials studies, evaluations, and market assessments related to the agriculture industry generally, and with a specific focus on California. The secondary resources included the U.S. Department of Agriculture's Agricultural Census, statistics and publications, the California Department of Food and Agriculture's publications, statistics, and data, the County Agricultural Commissioner's Data for California, RD&D Roadmap documents published by the California Energy Commission, and reports for the IOUs, CPUC, and POUs. Navigant identified industry and trade associations where they existed as these may be able to provide information about their industries during the primary data collection phase.

This Literature Review contains summaries of relevant and available background information for each sector. Relevant information includes industry information (key players, statistics, and trends), baseline and foundational knowledge related to energy and water end-uses, and related technologies, IOU

[1] PG&E, Statement-of-Work

program offerings and measures related to each sector. Wherever possible, gaps in existing knowledge and opportunities for energy efficiency programs or research were noted. Available information varied by sector and some areas are much better understood than others.

2.4 Associated Documents

This report includes a separate appendix with the Annotated Bibliography, which includes summaries for important resources associated with this Literature Review and the project generally. The resources in the Annotated Bibliography are organized to include the full citation for the report, abstracts and/or direct quotes, and links to the resource (where available).

3 Introduction

California is the nation's top agricultural producer and exporter, and a major player in the global agricultural market (top 10). The sector generates over $36 billion in gross cash receipts annually through the production of over 81,500 farms and ranches. And yet resource constraints and economic considerations pose ongoing complications for the growth and sustainability of these sectors.

In particular, limited water resources across the state will continue to affect the sector indefinitely. Although irrigated agriculture is the most vulnerable to water constraints, every segment included in this Study relies on water for key operational activities.

Energy costs have been and remain another significant pressure on economically vulnerable farming and animal production businesses, as well as on industries related to those businesses, such as post harvest processing and refrigerated warehouses. Waste production presents an environmental challenge, especially for feedlots, dairies, and other concentrated animal production operations, although potential opportunities to reincorporate waste streams abound, such as when leveraged for waste-to-energy, composting, and secondary products.

Technologies available to mitigate energy use, water use, and waste issues have been largely limited to pumps for irrigation, dairy-related measures, and improved lighting, better motors, and other technologies, such as solar PV or solar water heating, that can be applied across many sectors. To access deeper savings, increased penetration of existing technologies will be needed along with development of increasingly improved options with better performance at lower costs. Waste mitigation and diversion in the form of new and better practices and technologies will be critical to reducing environmental impacts and maintaining profitability.

Organization of this Report

This Literature Review contains ten sections, including the Executive Summary and this section, and sections on Dairies, Refrigerated Warehouses, Irrigated Agriculture, Greenhouses & Nurseries, Vineyards & Wineries, Post Harvest Processing and an Appendix summarizing general agriculture sector programs currently offered by the IOUs as well as a list of evaluations found through secondary research.

4 Dairies

Dairies have long been an important part of California's agricultural economy. Since the early 1990s when California surpassed Wisconsin as the largest producer of fluid milk, the State has become responsible for about 22 percent of the national milk supply, approximately 40.6 billion pounds of milk in 2007.[2]

California's milk production is mostly concentrated in five counties—Tulare (27%), Merced (14%), Kings (10%), Stanislaus (10%) and Kern (9%)—which together represent 71 percent of state production.[3] The top counties in the state account for the vast majority of the cow population and dairy product production as well (see Table 1).

Table 1. Dairy Cows & Dairy Product Production in California (Top Counties)[4]

County	Farms with Dairy Cows	Cows	Commodity Value of Dairy Products (in $1,000)
California Total	**2,165**	**1,840,730**	**$6,569,172**
Top Counties Total	1,349	1,562,018	$5,609,219
Tulare	289	474,497	$1,685,257
Merced	280	273,242	$969,019
Stanislaus	268	191,729	$690,029
Kings	140	163,600	$551,827
Kern	52	124,756	$464,985
San Joaquin	132	109,336	$407,432
Fresno	93	114,768	$436,486
San Bernardino	95	110,090	$404,184
Top Counties as Percent Total	**62%**	**85%**	**85%**

4.1 Industry Overview

The majority of the milk produced in California is controlled by four major dairy cooperatives: California Dairies, Inc., Land O'Lakes, Dairy Farmers of America (DFA), and Humboldt Creamery, which was formerly independent, but is now owned by Foster Farms Dairy. In 2004, these producers represented over 80 percent of fluid milk production in California.[5] Of these cooperatives, only California Dairies, Inc. is based in-state, while the rest are national organizations.

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[2] USDA, National Agricultural Statistics Service (NASS), 2007 Census of Agriculture – California State and County Data, Volume 1, Part 5, 2009.

[3] California Agricultural Production Statistics, California Agricultural Statistical Review, 1. Available: http://www.cdfa.ca.gov/statistics/

[4] NASS 2007 Census, 2009.

[5] California Institute for Food and Agricultural Research. 2004. *Technology Roadmap: Energy Efficiency in California's Food Industry*. California Energy Commission, PIER Energy-Related Environmental Research. CEC-500-2006-073.

Trends

Across the country, the dairy industry as a whole is trending toward vertical integration[6], and California is no exception. Since 1987, the total number of California farms has declined steadily while the milk cow population has risen.[7] Dairy cooperatives have played a major role in the industry's consolidation, in part because their exemption from anti-trust laws[8] enables dairy cooperatives to serve as marketers of raw milk, as well as processors and manufacturers of dairy products.[9] As noted earlier, a small number of dairy cooperatives control the majority of milk production—as well as marketing—in California and across the United States, and there is even consolidation amongst these large cooperatives. Two former large California dairy cooperatives—the California Cooperative Creamery and Cal-West Dairymen, Inc.—became part of the DFA cooperative in the past decade.

Economic Challenges

Despite the dominance of California's milk production on the national market, the statewide dairy industry is under economic pressure brought on by several years of declining milk prices and reduced demand for fluid milk. This trend is further compounded by high energy costs and environmental concerns related to air and water quality.[10]

Although the crisis of low prices started in the early part of the last decade, the severity of the problem dramatically increased between spring 2008 and 2009, when national milk prices dropped to even with, and at times below, production costs.[11] Over 100 California dairies closed in 2009 as a result of the price drops.[12] Simultaneously, milk production costs rose sharply in a short time, Between 2006 and 2009, milk production costs increased by 28 percent, in contrast to a 24 percent increase in the previous 15 years combined (from 1990 to 2005).[13] Skyrocketing feed prices were largely to blame.[14]

In California, high prices for electricity and natural gas create additional pressure, as do environmental regulations related to air and water quality, and higher business operating costs (taxes, etc.).[15] Issues related to taxes will not be explored in depth here but should be noted as an important element of the overall stressors on the industry as a whole.

Strategic Direction – McKinsey Report

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[6] Lowe and Gereffi, 2009, pg. 5.

[7] USDA, 2009.

[8] Miller, James J. and Don P. Blayney, *Dairy Backgrounder, LDP-M-145-01*, United States Department of Agriculture Economic Research Service, July 2006, pg. 6. http://www.ers.usda.gov/publications/ldp/2006/07Jul/ldpm14501/ldpm14501.pdf

The exemption is through the Capper-Volstead Act, passed in 1922, which provides specific exemptions from anti-trust laws to associations of agricultural producers. US Code Title 7, Section 291 & 292. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=browse_usc&docid=Cite:+7USC291

[9] Miller and Blayney, 6.

[10] California Agricultural Production Statistics, California Agricultural Statistical Review, 1. Available: http://www.cdfa.ca.gov/statistics/

[11] Ellerby, Justin, *Challenges and Opportunities for California's Dairy Economy*, California Center for Cooperative Development, 2010, 5.

[12] Ellerby, 5.

[13] Ellerby, 5.

[14] Ellerby, 5.

[15] Ellerby, 99-105.

In 2005, the California Milk Advisory Board commissioned McKinsey & Company to conduct a study of the challenges and opportunities facing California's dairy industry. McKinsey & Co. provided its findings in a two-part report: "Foundations for a Consumer-Driven Dairy Growth Strategy", released in 2006, and "Options for a Consumer-Driven Dairy Growth Strategy", released in 2007 (collectively, the "McKinsey Report"). The report identified environmental regulations as one of three key challenges for California's dairy industry and cited the issue with anaerobic digesters as an example.

Because the McKinsey Report is not available to the public, a summary of the findings related to anaerobic digesters is excerpted here from the report *Challenges and Opportunities for California's Dairy Economy*[16]:

> The main thrust of the [McKinsey] report's recommendation in this regard is that improved research is necessary to improve the scientific basis for regulations, which the industry has often contended are misaligned with biochemical and operational realities. The conflict over NOx emissions from anaerobic digesters is only one of the most recent and prominent examples… Much of the work of UC Davis researcher … Dr. Frank Mitloehner has changed many assumptions informing dairy regulations. His studies have revised the estimated environmental impact of manure lagoons downward and instead shift emphasis to impacts from cows' crude protein intake, cow belching, silage off-gassing, and aerobic manure decomposition. [17]

Finally, the McKinsey Report found that "further investment in production efficiency is also necessary if the state is to build back a strong advantage in total cost of milk production, particularly against other competitive Western states. Pre-harvest and processing research and development may have been relatively neglected in this regard in favor of marketing and promotion."[18] Energy use is a key parameter related to the conversation around production efficiency and could offer an important opportunity for the IOUs to work with industry on harvesting deeper savings with existing equipment through process efficiency improvements.

In general, the McKinsey report is extremely well regarded within the dairy industry and its findings could be used strategically by IOU program managers seeking to better understand the needs of their dairy customers.

4.2 Energy

Dairy farms have been studied extensively and the California IOUs appear to have a thorough understanding of how energy is used on-farm, and of the technologies available for conservation purposes. Utility programs have been deployed to the industry over the past few years to help dairy farm customers reduce their energy consumption. Energy is also consumed through the water required for dairy farm operation, both process related (e.g., hot water for cleaning, water for washing waste into waste lagoons) and irrigation related. Finally, livestock waste presents a unique opportunity for waste-to-energy conversion technologies to reduce on-farm electricity and natural gas requirements.

[16] Ellerby, 99-105.
[17] Ellerby, 102.
[18] Ellerby, 102.

4.2.1 Direct Energy Use

Major energy end-uses include harvest, cooling and storing milk, water pumping and heating, ventilation, and lighting.[19] Electricity is the main energy source for most processes on a dairy farm. SCE's *Dairy Farm Energy Management Guide* provides a breakdown of electrical energy use on a representative California dairy farm, which is reproduced in Figure 1.

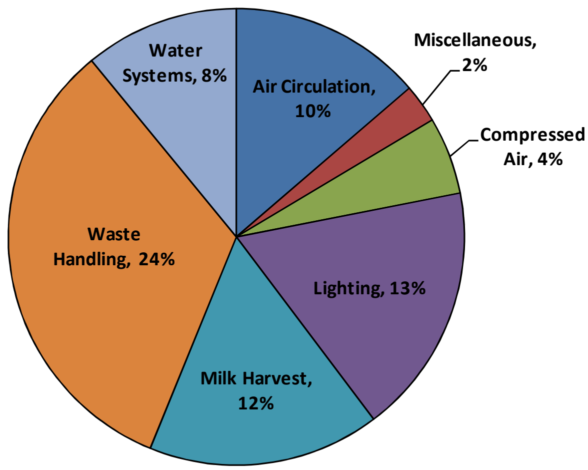

Figure 1. Electrical Energy Use on a Representative California Dairy Farm[20]

SCE's *Dairy Farm Energy Management Guide*[21], published in 2004, provides detailed descriptions of electrical end-uses, summarized as follows:

- The milking system ("milk harvest") extracts milk from dairy cows and transports the milk to on-farm storage systems. The vacuum pump is the key energy use within the milk harvest process.
- Milk cooling is the single largest electrical energy end-use on dairy farms. Milk must be cooled from about 99°F to at least 50°F. Compressors, condensers, evaporators, thermostatic expansion valves, and heat exchangers are equipment related to the milk refrigeration process.
- Lighting is a large electrical users on dairy farms, especially large farms that operate on or near 24-hour per day cycles. Different types of lighting are required for specific needs: visually intensive task lighting, lighting for livestock handling, and general lighting.
- Because dairy cows are susceptible to heat stress, proper ventilation is critical for ensuring dairy production levels and animal well-being.
- Heated water is used for cleaning milking systems and must meet specific temperatures to prevent contamination.

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[19] Collar, C. et al, *Dairy and Livestock*, California Dairy Energy Project, 2000. http://www.energy.ca.gov/process/agriculture/ag_pubs/calif_dairy_energy.pdf

[20] Southern California Edison, *Dairy Farm Energy Efficiency Guide*, http://www.sce.com/b-sb/design-services/dairy-farm-energy-efficiency-guide.htm

[21] Southern California Edison, *Dairy Farm Energy Efficiency Guide*, http://www.sce.com/b-sb/design-services/dairy-farm-energy-efficiency-guide.htm

- Water pumping is needed to supply fresh water to dairy cows, and for washing and other on-farm uses.
- Compressed air is increasingly used to help move animals throughout the dairy.

A survey of 93 dairies in the San Joaquin Valley, conducted in 1994-1995, established baseline data on vacuum pumps, pre-coolers, and water heaters (Table 2).[22] Additionally, the SCE *Dairy Farm Energy Management Guide*, published in 2004, contains energy consumption ranges for specific equipment. However, this data may be out of date, and also does not provide insight on penetrations of various technologies. More recent, publicly-available baseline data on key equipment types, including efficiency levels and penetration, was not identified in the course of this research effort. This may represent an area of research for the IOUs to undertake as a precursor to designing programs to improve dairy energy efficiency.

Table 2. Results of 1994-1995 Baseline Equipment Survey of Dairies in San Joaquin Valley

Equipment	Penetration by Technology Type
Vacuum Pumps	Water ring: 95% Lobe Blower: 3% Turbine: 2% Average horsepower per milking unit: 1.02 ± 0.28 hp
Precoolers	Heat exchangers (typically plate type coolers): 58% Heat exchanges (with well water & chilled water): 36% No precooling: 5%
Water Heaters (fuel)	Propane: 68% Natural gas: 26% Electricity: 5% Vacuum pump heat exchanger: 1 dairy

The UC Cooperative Extension study also calculated the average dairy electricity used to be 42 kWh per cow per month or the equivalent to over 504 kW hours per year.[23] The SCE 2004 guide offers a wide range from 300 to 1,500 kWh per cow per year, while PG&E audit data offers a range from 700 to 900 kWh per cow per year.[24] These data points reveal an increase in electricity consumption per cow per year at dairy farms from the mid-1990s to the mid-2000s. This increase may be attributed in part to the increase in milk production per cow from 16,405 pounds per cow in 1995 to 18,204 pounds per cow in the year 2000.[25]

Figure 2 provides electricity consumption and peak demand load from audits conducted at dairy farms. Cow milk production declines during cold months, lowering total milk production, electricity demand

[22] Collar, C. et al, 2000.
[23] Collar, C. et al, 2000.
[24] FX Rongere, PG&E, Tulare, November 9th., 2006 presentation
[25] USDA, 2002 Statistical Bulletin Number 978, http://www.ers.usda.gov/publications/sb978/sb978.pdf

and consumption.

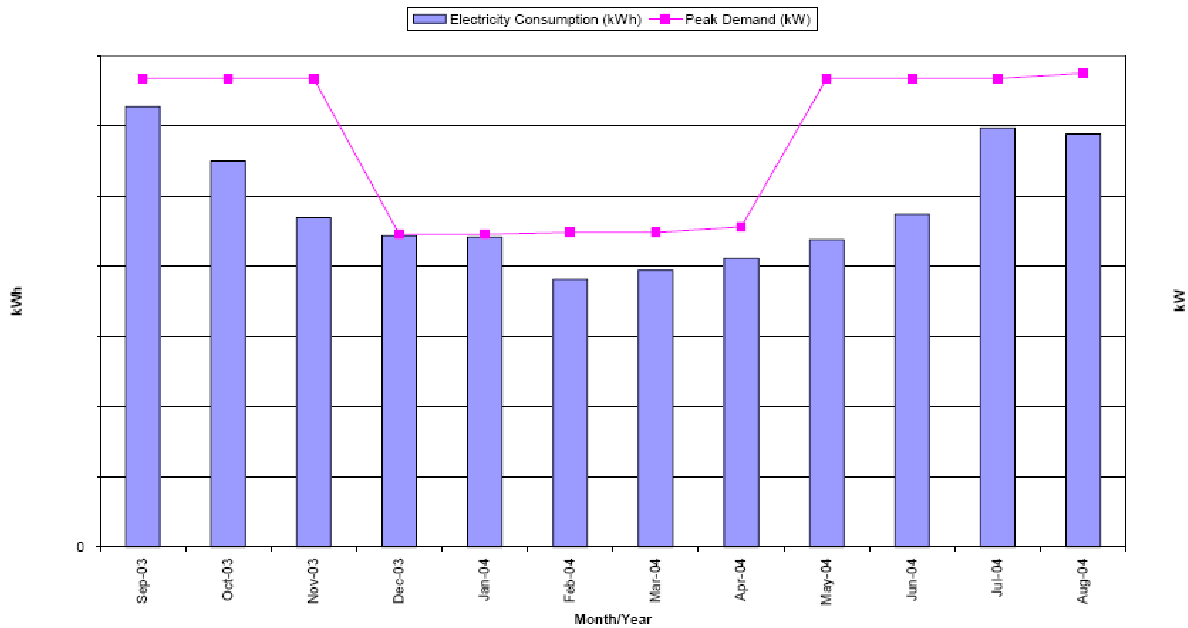

Figure 2. Electricity Load in Dairies[26]

4.2.2 Energy Use Through Water

Most dairy farms supplement purchased animal feed with on-farm irrigated feed crops. Irrigated agricultural practices are similar to those used by other field crop farmers growing alfalfa and corn. Water is also used to flush manure and bedding from cow barns with the effluent flowing to storage lagoons. The IOUs should seek to understand how much energy, direct and indirect, is related to dairy farm irrigation and practices.

Dairy farms also require hot water. Hot water is used for cleaning milking units, pipelines, receivers, and bulk milk storage tanks, which are all part of the milking system.[27] SCE's Dairy Farm Energy Management Guide[28] observes that the minimum hot water requirement is four gallons of 170°F (77°C) water per milking unit for each rinse/wash/rinse cycle and provides the following water temperatures for the milk equipment washing cycles:

- Pre-rinse cycle: 95°F - 110°F
- Wash cycle: 155°F - 170°F
- Acid rinse cycle: 95°F - 110°F
- Sanitize cycle: 75°F (minimum depending on sanitizer directions)

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[26] No units were available in this presentation document, FX Rongere, 2006.

[27] SCE, Dairy Farm Energy Management Guide, 85.

[28] SCE, Dairy Farm Energy Management Guide, 85.

4.3 Technologies

There are numerous efficient technologies and equipment available to mitigate energy use on dairy farms. Table 3 provides examples of some of these technologies. Additionally, anaerobic digestion technology is highlighted below.

Table 3. Examples of Energy Efficiency Technologies for Dairy Farms[29]

End-Use	Purpose	Existing Equipment	Efficient/Emerging Equipment	Benefits/Barriers
Refrigeration	Milk cooling	•	• Refrigeration heat-recovery systems	• Recover waste heat from milk-cooling condensers which can be used to preheat water for washing milk equipment • Improve efficiency of heat-exchangers
			• Water-cooled precoolers	• See above
Pumping for vacuum pumps and milking pumps	Milk harvest	• Constant-speed pumps	• Variable-speed drives	• May not be cost-effective for smaller farms (fewer than 8 hours of milking per day)
Ventilation	Temperature control for herd	• Fans	• High-efficiency fans	• Improves direct cooling of cows
Anaerobic digesters	Waste-management			• Waste management system • Energy-conversion system • Do not currently meet existing NOx restrictions in California

Dairy Waste as Energy

Waste management is a major concern for dairy farms. Many dairy farms in the San Joaquin Valley region manage between 1,000 to 10,000 cows, which generate significant amounts of solid waste. Manure from dairy cows contains water-contaminating nutrients, salts, bacteria, and organic matter, while air pollutants such as ammonia, volatile organic compounds, methane and nitrous oxide are given off by feed, manure as it decomposes, and the cows themselves.

Storage lagoons are a primary source of the air pollutants associated with dairy operations, and leakage from these holding areas can result in contamination of soil and water resources. Typically, some of the manure is spread as fertilizer on cropland at the dairy farm but this does not address all of the waste product. The Regional Water Quality Control Boards and the local Air Pollution Districts regulate the practices required by dairy farms to comply with environmental laws.

Anaerobic digesters using covered lagoons are a proven technology to extract methane gas from dairy waste to power on-farm electric generation using reciprocating engines. However, the adoption of maximum nitrous oxides limits at 9 parts per million of NOx, or 0.15 grams per brake horsepower-hour, established by the San Joaquin Air Pollution District and Sacramento Municipal Air Quality Management District, have significantly impacted the widespread adoption of these technologies by

[29] Madison Gas & Electric, http://www.mge.com/business/saving/BEA/_escrc_0013000000DP22YAAT-2_BEA1_CEA_CEA-10.html,

dairy farmers.[30] A more comprehensive analysis of the current and future state of affairs regarding this subject should be undertaken by the IOUs to assess barriers and opportunities. If dairies were allowed to use this technology, the biogas produced by the anaerobic digesters could be used to replace conventional fuels for generators and to replace conventional transportation fuels. The bioeffluent from the anaerobic digestion process could be used to fertilize fields on-farm or at composting facilities.

P&GE and SoCalGas have invested resources to explore and develop pipeline quality biomethane. Although there are no current biomethane injection projects operating in California, SoCalGas Rule 30 Biogas Guidance Document and PG&E Rule 21 established gas quality specifications for future pipeline injection standards.[31] SoCalGas calculated the economic range for biogas to approximate 1,000 standard cubic feet per minute or greater, or raw gas, and concluded that small and medium scale biogas production facilities for pipeline injection were not economical.[32] SoCalGas has granted energy efficiency incentives to Onion Gills and National Beef companies to develop distributed bioenergy resources.[33]

4.4 Utility Programs

The *California Dairy Energy Efficiency Program (DEEP)*, managed by EnSave, offers rebates to PG&E's dairy customers for efficient lighting, ventilation, motor, and milk processing equipment (see Table 4). SCE, SoCalGas, and SDG&E do not currently offer specific programs for dairy customers, although these customers may access rebates for general measures targeting lighting, motors, and other equipment. Pump tests offered by the IOUs may be applicable to some dairy farms. In the past, PG&E and SCE offered several programs to dairy customers (see
Table 5).

Table 4. Incentives Offered to Dairy Farmers through California DEEP[34]

End-Use/Technology	Equipment	Incentive Amount
Milk Processing	Milk-precooler	calculated
	Vacuum pump VSD	calculated
	Milk transfer pump VSD	calculated
	Compressor heat recovery unit (electric or gas-fired water heaters)	calculated
	Scroll compressor for bulk tank	calculated
Ventilation	Ventilation Fan or Box Fan 24"–26"; 36"; 48"; 50"-52" (retrofit)	calculated
	High Volume Low Speed (HVLS) Fan 16-Foot Diameter; 18-Foot Diameter; 20--Foot Diameter; 24'-Foot Diameter	calculated
Exterior Lighting	Greater than/ equal to 750 watt lamp (L1028)	$75
	Greater than/ equal to 250 watt lamp (L1027)	$45
	Greater than/ equal to 175 watt lamp (L1012)	$25
	Greater than/ equal to 100 watt lamp (L1011)	$20
Interior Lighting	Greater than/ equal to 750 watt lamp (L1009)	$90

[30] Warner, Dave, "Permitting Issues for Anaerobic Digesters in the San Joaquin Valley", California Energy Commission Workshop on Biopower in California, delivered April 21, 2009. http://www.energy.ca.gov/2009_energypolicy/documents/2009-04-21_workshop/presentations/06-San_Joaquin_Air_District_Presentation.pdf

[31] Lucas Jim, Investor Owned Utility Efforts to Develop the BioEnergy Market, a power point presentation to the California Biomass Collaborative, 8th. Forum, April 6, 2010. http://biomass.ucdavis.edu/events/2011-cec-forum/

[32] Lucas, 2010.

[33] SOCALGAS, efficiency. http://www.socalgas.com/innovation/energy-resource-center/energy-efficiency.shtml

[34] Managed by EnSave, details available: http://www.ensave.com/energy-efficiency.html

	Greater than/ equal to 250 watt lamp (L1030)	$75
	Greater than/ equal to 175 watt lamp (L1029)	$40
	Greater than/ equal to 125 watt lamp (L1008)	$35
Controls	Time Clock	$36
Motors	Premium Efficiency Motor (10 HP)	$125
	Premium Efficiency Motor (15 HP)	$155
	Premium Efficiency Motor (20 HP)	$210
	Premium Efficiency Motor (25 HP)	$360
Irrigation	Sprinkler to Micro irrigation—Field/Vegs	$44 per acre
	Low Pressure Sprinkler Nozzle—Portable	$1.15 per nozzle
	Low Pressure Sprinkler Nozzle—Solid set	$1.15 per nozzle

Table 5. Current & Historical IOU Dairy Programs

Program Name	IOU	Measures Offered	Program Cycle	Program Statistics
Dairy Energy Efficiency Program[35]	PG&E	Rebates on EE milking equipment, lighting, ventilation, controls and motors. See Table 4 for more information on measures currently offered.	2006-2008; 2009-2011	Continuation of the 04-05 Multi-measure Farm Program.
California Multi-Measure Farm Program[36]	PG&E SCE	Installations of: • Variable speed drives for milking vacuum pumps • Plate & frame heat exchangers for pre-cooling milk • VSDs for milk transfer pumps • Compressor heat recovery units for waste heat from refrigeration compressors • Scroll compressors for cooling milk	2004-2005	The program was offered to 2,120 dairy producers throughout PG&E's and SCE's service territories. A total of 118 farmers participated in the program (four of the five measures evaluated), the majority of the participants and savings were attained in PG&E's territory. Plate cooler usage factor: 81.9% Milk Transfer Pump VSD usage factor: 88.6% Compressor Efficiency usage factor: 64.1%
2004-2005 IDEEA Constituent Program[37]	SCE	*Ag Ventilation Efficiency* activity, provided education and cash incentives for installations of high-volume, low-speed fans. This technology is targeted to dairies.	2004-2005	The *Agricultural Ventilation Efficiency* activity did not meet its kWh and kW goals. The technology has a slow penetration rate, although post-installation satisfaction was high.

4.5 Summary of Observations

- Anaerobic digesters will provide a significant benefit to dairy farms in the form of waste management and biogas production, provided that cost effective generation technologies are developed to comply with nitrous oxide emissions standards. Restrictions on nitrous oxide emissions are the key barrier to implementing on-site electricity generation from anaerobic digester's

[35] https://www.pge.com/regulation/EnergyEfficiency2009-2011-Portfolio/Testimony/PGE/2009/EnergyEfficiency2009-2011-Portfolio_Test_PGE_20090302-01Atch22.pdf
[36] http://www.calmac.org/publications/PG%26E_AG_and_FP_Report_20090727.pdf
[37] http://www.calmac.org/publications/CA_MM_EMV_Revised_Report_01-08-_CALMAC.pdf

biogas production on animal farms.   Biogas can be generated and utilized as biomethane for pipeline injection of compressed as a transportation fuel.

- Investments in process efficiency are a priority for the industry. The McKinsey report recommended that the dairy industry focus on investments to improve process efficiency. Assuming the industry is now primed to recognize this as a strategic area of focus that would help limit its risk, the IOUs might consider offering incentives for, and otherwise facilitating the adoption of, process efficiency improvements. The California IOUs should consider working directly with organizations such as the California Milk Advisory Board and dairy cooperatives to identify efficiency improvements and productivity gains from participating in utility programs.
- Baseline saturations and technology adoption rates may offer valuable insights into where to focus future utility programs. Saturation studies conducted years ago on the dairy industry are out of date. It is not clear how well the IOUs understand the baseline technology saturations across the industry, and this is a key element of designing an effective program. The IOUs should mine their database of existing programs and projects to glean relevant data on baseline and efficiency measures.
- Research management of electricity consuming equipment and opportunities to reduce or limit summer peak demand.

5 Feedlots

In 2007, California had about 662,000 beef cows on 11,827 farms.[38] Of these, the largest 1,482 farms made up 75 percent of the total beef cattle population: 37% had 500 or more cows, 24% had 200 to 499 cows, and 13 percent had 100 to 199 cows.[39] In contrast, over 47 percent of the farms had fewer than 10 beef cows.[40] These data imply that California's beef cattle industry is dominated by large, industrial-type farms[41], also known as confined animal feeding operations (CAFOs) or simply, feedlots.

In industrial animal production, feedlots are used to fatten livestock before slaughter. Although the term most commonly refers to this stage in the production of beef cattle, a feedlot can also be used in the production of other livestock, such as swine. Beef cattle typically spend most of their lives grazing on pastureland prior to being transferred to a feedlot for the 3-4 months prior to slaughter.

The beef cattle industry in California has been on the decline for several years. In 2002, a team of researchers undertook a survey of 280 ranchers in 40 counties across the state.[42] The survey found that most California cows are shipped off-farm for fattening on pastureland or in feedlots, or for processing into meat. As a result, many of the remaining cattle operations are cow-calf ranching type rather than feedlots.[43] Recent data bear out these observations: in 2007, beef cattle ranching and farming operations[44] collectively had around three million head of cattle on 13,149 farms, compared with the 662,000 beef cows on 11,827 farms.[45]

Cattle feedlots are primarily open-air holding areas densely packed with cows. The main electricity end-uses on a feedlot are the feed mills used for blending food and the pumps for water (drinking, washing, and irrigating any on-farm crops), and some may have lighting requirements. Like dairies, cattle feedlots produce large volumes of waste that threaten the quality of water and soil resources and contribute to air pollution; anaerobic digester technologies are a potential boon for feedlots, provided that they can be developed to comply with California's air quality restrictions on nitrous oxide emissions.

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[38] NASS, 2009.
[39] NASS, 2009.
[40] NASS, 2009.
[41] NASS, 2009.
[42] Anderson, Matt, et. al. (California Agriculture), *California's Cattle and Beef Industry at the Crossroads*, California Agriculture 56(5):152-156. DOI: 10.3733/ca.v056n05p152. September-October 2002.
[43] Anderson, et. al., 2002.
[44] Includes dairy herd replacements but does not include dairy cows themselves, which are counted as "milk cows" or farms that are 100 percent pastureland.
[45] NASS, 2009.

6 Refrigerated Warehouses

The profitability of California's agricultural industry is consolidated through the supply chain services provided by public and private refrigerated warehouse (warehouses) businesses. These large, strategically located cold and frozen storage facilities extend the shelf life, safety and quality of locally grown and imported perishable food commodities. The productivity gains in the production and post harvest processing are extended further with the delivery of energy efficiency refrigeration systems. The warehouses business is highly competitive and operated by multinational corporations with highly-skilled personnel that adopt continuous resource management practices to optimize systems performance. There are several opportunities to further optimize performance in refrigerated warehouses.

6.1 Industry Overview

California's warehouse companies offer refrigerated warehousing and cold storage services for raw or processed fruit and vegetable products, including processed meats, and frozen prepared dishes. These facilities are located along urban regions in the Central Coast, Southern California, Sacramento Valley region and the San Joaquin Valley. The industry is segmented by private facilities operated by food processing companies housing goods before shipment of finished product, and public facilities operated by wholesalers and supermarkets.

The most important market driver for this industry is electricity expenses. Industry experts approximate that 27 percent of product is lost due to improper temperature control by warehouse management.

6.2 Energy

There are over 150 warehouses operating 365 days a year to preserve perishable products, utilizing 448 million cubic feet of storage volume, consuming annually over 1 billion kWh of electricity, mostly by lighting and cooling systems.[46] Singh estimates that warehouses on average used 1.6 kWh/ft^3-yr, representing 20 percent of the total electric energy consumption of the food industry. Singh estimated the total annual cost of energy in California's cold storage sector at 39.5 million dollars year.[47]

Prakash and Singh's report estimates that 15 percent of the electricity load is used by pumps, motors, fans, conveyers and lighting systems, 5 percent is utilized by sanitation and cleaning and the remaining 80 percent is used to meet cooling, freezing and refrigeration loads.[48] Other characteristics of warehouse management include: no outside air ventilation, large refrigeration systems use ammonia rather than more conventional refrigerants, evaporator fan coils are suspended or otherwise mounted in the cooler or freezer, coupled to multiple compressors and condensers.[49]

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[46] Singh, R. Paul, 2008. Benchmarking Study of the Refrigerated Warehousing Industry Sector in California. Davis, Calif.: *California Energy Commission*. PIER Report. http://ucce.ucdavis.edu/files/datastore/234-1193.pdf

[47] Singh, 2008.

[48] Prakash, B., and R. Paul Singh (University of California, Davis). 2008. *Energy Benchmarking of Warehouses for Frozen Foods*. Sacramento, Calif.: California Energy Commission, PIER Program. http://ucce.ucdavis.edu/files/datastore/234-1194.pdf.

[49] Shirakh, Maziar, Pennington, G. William, Hall, Valerie T. and Jones, Melissa (California Energy Commission) 2009. 2008 Building Energy Efficiency Standards: Nonresidential Compliance Manual. *California Energy Commission*. Report number CEC-400-2008-017-CMF-Rev 1. http://www.energy.ca.gov/title24/2008standards/nonresidential_manual.html

An internet-based warehouse energy management tool designed to support managers with comparative information to estimate energy usage to an industry benchmark was released in 2008 by R. Paul Singh of UC Davis.[50] The tool also can be used by managers to identify efficiency measures to improve warehouse productivity.

The Singh tool is available at: http://bae.engineering.ucdavis.edu/WarehouseEnergy.swf

The adoption of the 2009 California Energy Commission's Nonresidential Compliance Manual for Refrigerated Warehouses affects the refrigerated space insulation levels, under slab heating in freezers, evaporator fan controls, compressor part-load efficiency in specific applications, condenser sizing, condenser fan power, and condenser fan controls. Other sections of the manual address interior lighting power.[51] These new standards are all mandatory and no prescriptive requirements or performance compliance paths are offered for refrigerated warehouses. These new standards regulate storage space, not quick chilling space or process equipment. As with other preceding building standards, it is assumed that energy conservation and efficiency improvements will be gained from the new refrigerated warehouse standards.

Other opportunities exist to encourage warehouse managers to adopt energy management practices. The 2011, release of the American National Standards Institute (ANSI) ISO 50001, Energy Management Systems is a new opportunity for energy efficiency programs to promote the benefits of energy management system. Utility representatives and supportive warehouse managers can use ISO 50001 to raise corporate awareness that successful energy management requires dedicated staff and project funding to adopt energy efficiency standards.[52]

Future IOU efficiency programs could be designed to advance energy management practices before prescribing hardware specific measures. Warehouses could be supported to conduct benchmarking studies to identify technical potential for improvements. Additional support could be provided to assess the benefits of ISO 50001 and how best to adopt a systems approach to energy management. The key to success is to reduce produce loss. IOUs could partner with warehouse companies at the corporate level to support the development of energy management commitments, by providing innovate programs with flexible principles that meet customer needs.

The following list of improvement opportunities to increase energy efficiency in refrigerated warehouses is offered by Thompson, 2008.

- **Lighting.** Installing efficient lighting, like high bay fluorescent lamps or LED fixtures when their cost drops, will produce dependable, cost-effective electricity savings and requires no management. Because it has little market penetration it should be a high priority for incentives.
- **Optimization.** Optimizing the use of refrigerated space often requires just consolidating product in fewer rooms and turning off refrigerated space in unneeded cold rooms. Capital costs are minimal and electricity savings are great. The industry needs to consolidate product and shutdown unneeded cold rooms.

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[50] Singh, R. Paul (University of California, Davis) 2008. Benchmarking Study of the Refrigerated Warehousing Industry Sector in California. Davis, Calif.: *California Energy Commission*. PIER Report. http://ucce.ucdavis.edu/files/datastore/234-1193.pdf

[51] Shirakh, Maziar, Pennington, G. William, Hall, Valerie T. and Jones, Melissa (California Energy Commission) 2009. 2008 Building Energy Efficiency Standards: Nonresidential Compliance Manual. *California Energy Commission*. Report number CEC-400-2008-017-CMF-Rev 1. http://www.energy.ca.gov/title24/2008standards/nonresidential_manual.html

[52] International Organization for Standardization 2011. Energy Management Systems – Requirements with Guidance for Use. *ISO 50001*. http://webstore.ansi.org/RecordDetail.aspx?sku=ISO+50001%3a2011

- **Refrigeration Improvements.**
  - Increasing refrigerant suction pressure can be done with computer-based control systems that are common in produce cooling facilities. The pressure can be increased when refrigeration demand drops because of reduced input of warm product or lower outside temperatures. Improved control can often be achieved by reprogramming an existing computer. No specific energy saving testing has been done for this technology.
  - Screw compressors are now available and older units can be retrofitted with variable speed motor controls. This allows the units to operate efficiently over a wider range of refrigerant flows. Adding capacity modulation to one or at most two screw compressors will allow a well-programmed control system to efficiently operate compressors.
  - There are several approaches to reducing electricity use for fan operation in forced-air coolers. Research is needed on the cost and electricity savings for installing low airflow resistance evaporator coils, slowing evaporator fan speed when there is less refrigeration demand, proper design of airflow channels, and increasing package vent area.
  - Storage areas may also benefit from speed control on evaporator fans or cycling single speed evaporator fans.
- **Building Shell Improvements.** Applying 'Cool Roof' coatings and painting exterior walls with high reflectivity paint will reduce heat input from solar radiation. Electricity savings are small but this method requires no ongoing management or operating expenses.
- **New Construction or Product Replacement.** A number of conservation methods appear to be economically feasible only when used in a new installation or when failed equipment is replaced. These include the use of high efficiency motors, adding roof or wall insulation, increasing refrigeration pipe sizing, and insulating refrigeration pipes.

6.3 Technologies

A survey conducted in 2008 revealed the range of energy efficiency technologies used by warehouses in 2008.[53] The majority of respondents had installed upgraded insulation capacity, a few had retrofitted buildings with cool roofs, and half are using high efficiency lighting systems, and the majority use aggressive evaporative condensers. Other technologies being used include thermo-siphon oil cooling, computer controls, VFD controls for compressors, condensers and evaporators. Floating head pressure and sensor controlled doors also are identified.[54]

The replacement of heat producing lighting systems is identified as an important easy to undertake and cost-effective area to achieve energy savings in warehouse facilities. These lighting conversions will require the replacement of high-pressure sodium, metal halide or high intensity fluorescent lamps currently installed in warehouse facilities with cool energy efficient LED lighting systems.

[53] Singh, 2008
[54] Singh, 2008

6.4 Utility Programs

The IOUs have targeted the refrigerated warehouses sector with a handful of sector-specific programs, summarized in Table 6. Additionally, many of the general commercial measures offered could be applied to refrigerated warehouses. It is not known how many facilities have taken advantage of the measures offered.

Table 6. Current & Historical IOU Programs for Refrigerated Warehouses

Program Name	IOU	Year	Measures Offered	Stats or Anticipated Results
2009-2011 Energy Efficiency Portfolio Program (Statewide Agriculture Program PGE2103)[55]	PG&E	2009-2011	Financial incentives for EE pumping, refrigeration, process loads, process heating, lighting. Specifically: • Lighting (0.05 cents/kWh + $100/pk kW) • AC & refrigeration: (0.15 cents/kWh + $100/pk kW) • Motors & other: (0.09 cents/kWh + $100/pk kW) • Gas measures: ($1 per therm)	Not yet evaluated: Target audits: 100 in 2009, 430 in 2010, 370 in 2011 Incentives delivered: $8,657,512 in 2009, $12,120,518 in 2010, $13,852,020 in 2011
2004-2005 IDEEA Constituent Program[56]	SCE	2004-2005	*Refrigerated Warehouses* activity, providing information and financial incentives for EE freezer/cooler doors, refrigeration controls, lighting retrofits and non-condensable purgers	Five measures were offered, the program met its energy savings goals and expended all available incentives to fund the projects (only 4 participants) - the kWh realization rate was 104% and kW realization rate was 100%

6.5 Summary of Observations

- Site-specific management conditions determine the energy intensity of the warehouse business. The use of the Refrigerated Warehouse Energy Tool may encourage warehouse managers to adopt energy efficiency and management control technologies with the objective of improving their performance compared to the industry benchmark. Further research is needed to identify best management practices to significantly reduce product loss.
- IOUs could partner with warehouse companies at the corporate level to support the adoption of ISO 50001, the Energy Management Standard.

[55] Rock, Kerstin and Wong, Crispin (The Cadmus Group). 2009. *Process Evaluation of PG&E's Agriculture and Food Processing Program*. Portland, Oregon: Pacific Gas and Electric Company. CALMAC Study ID PGE0276.0. http://www.calmac.org/publications/PG%26E_AG_and_FP_Report_20090727.pdf

[56] Bronfman, Ben and West, Anne (Quantec) 2008. Southern California Edison 2004-2005 IDEEA Constituent Program Evaluations. Portland, Oregon: *Southern California Edison*. Report number SCE0234.01. http://www.calmac.org/publications/IDEEA_Constituent_Program_Evaluations_-_Vol_1_FINAL_072808.pdf; http://www.calmac.org/publications/IDEEA_Constituent_Program_Evaluations_-_Vol_2_FINAL_AppendicesES.pdf

7 Irrigated Agriculture

California farms irrigate over 8 million acres of arable land[57] to produce over 400 commodities. Electricity used to power water pumps typically accounts for more than 95 percent of all on-farm electric use.[58] The balance of the electrical use depends on the crop grown, the hydrological conditions, climate and the extent to which the business engages on post-harvest activities. Some natural gas may be used for gas-fired water pumps but electricity is the dominant energy source in this segment.

During the drought of the late 1980s and early 1990s, significant efforts were undertaken by scientists, consultants and farmers to research, develop and adopt water efficiency hardware, software and best management practices. Lessons learned from that period include:

- High efficiency water use is a desired outcome for irrigated agriculture.
- Farms cannot always achieve water conservation outcomes, which depend on whether the farm had previously under-irrigated or over-irrigated its crops.
- At times of water scarcity, permanent vine and tree farms may only apply water for maintenance levels to ensure survival with low yields.
- Farmers will attempt to purchase very expensive water that may be available, or abandon annual crops.
- Farmers calculate the amount and cost of water available to determine the type of field crops to plant and how much water to apply to vineyards and orchards.
- Farmers tend to avoid the negative impact of water scarcity by learning how best to irrigate and use water conservation technologies and management practices.

7.1 Industry Overview

The 2007 Agricultural Census found 53,400 irrigated farms in California.[59] About 45,700 of these farms contribute to crop production while some are used partly or exclusively for pastureland and others are not currently harvested.[60] Over 16.2 million acres of land is irrigated in California, of which about 7.4 million is harvested cropland. Many irrigated farms are larger than 1,000 acres: thirty-eight percent of the acreage is irrigated at farms with 1,000 to 5,000 acres, while almost 19 percent of the irrigated acreage is cultivated by farms with more than 5,000 acres.[61] The size of irrigated cropland versus other types of irrigated land is not known.

The largest crops by acreage include nuts (almonds, pistachios, and walnuts), grapes, tomatoes, broccoli and lettuce. In 2009, there were 810,000 acres of irrigated land planted with almond trees, an additional 126,000 acres of pistachios, and 250,000 acres with walnuts.[62] Although there is no academic report on the subject, visual inspection by trade allies reveal that most of the nut crops are using pressurized drip and micro irrigation systems.

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[57] National Agricultural Statistics Service (NASS) 2009. *2007 Census of Agriculture: United States*. US Department of Agriculture. Report No. AC-07-A-5. http://www.agcensus.usda.gov/Publications/2007/Full_Report/usv1.pdf

[58] Cervinka, V. et. al. 1974. Energy Requirements for Agriculture in California. Davis, Calif.: *California Department of Food and Agriculture*.

[59] California Department of Food and Agriculture (CDFA) 2011. California Agricultural Production Statistics 2009-2010. Sacramento, Calif.: *California Department of Food and Agriculture*. http://www.cdfa.ca.gov/Statistics/

[60] NASS,2009.

[61] NASS, 2009.

[62] CDFA, 2011.

Grape growing, including table, wine, and raisins, occupies over 789,000 acres of cultivated land.[63] Excluding winegrapes, grape vineyards represent 280,000 acres (raisin) and 89,000 (table) for a combined total of 369,000 acres. Many vineyard growers also have adopted drip systems and soil and weather monitoring technologies to optimize the use of available water. The rate of technology adoption depends on the wine growing region of the state. The Napa Valley and the Central Coast wine growing regions are almost all using drip irrigation.[64] It is not known what adoption of this technologies has occurred among growers of grapes for raisins and table grapes.

In 2009, there were 312,000 acres planted with processing tomatoes, 116,000 acres with broccoli, and over 215 million acres with different lettuce varieties.[65] These high-value crops are being grown using advanced agronomic practices to maximize yield and quality. Pressurized sprinkler irrigation systems are typically used during early plant growth with these crops. Drip irrigation systems have become widely adopted for post-establishment, but there is no source of academic information yet available to confirm the extent of the adoption rate.

7.2 Energy

Energy use in irrigated agriculture is inextricably linked with water. California's on-farm electricity demand from groundwater pumping is calculated at 4.5 million megawatt-hours (MWh) per year with an additional 2.9 million MWh per year from the use of on-farm booster pumps.[66] Embedded energy associated with groundwater resources varies by source and location (See Table 7. Embedded Energy in Water (Sample for Central Valley)

Source	Embedded Energy
Sample Groundwater	210 – 430 kWh/AF
State Water Project Imports	600 – 700 KWh/AF
Central Valley Project Imports	200 – 650 kWh/AF
AF = Acre-foot = 325,851 Gallons	

). Not all farms irrigate exclusively from groundwater sources, most receive surface water allocations from irrigation districts. Additional electricity is used to pump and transport surface water resources through conveyance and delivery systems.

Table 7. Embedded Energy in Water (Sample for Central Valley)

Source	Embedded Energy
Sample Groundwater[67]	210 – 430 kWh/AF
State Water Project Imports[68]	600 – 700 KWh/AF
Central Valley Project Imports[69]	200 – 650 kWh/AF
AF = Acre-foot = 325,851 Gallons	

[63] CDFA, 2011.
[64] Burt, C. M. and D. J. Howes. 2011. Low Pressure Drip/Micro System Design – Analysis of Potential Rebate. San Luis Obispo, Calif.: Irrigation Training and Research Center, California Polytechnic State University. http://www.itrc.org/reports/design.htm.; C. Burt, 2011 personal conversation
[65] CDFA, 2011
[66] Burt, Charles, Howes, Dan and Wilson, Gary (Irrigation Training and Research Center) 2003. *California Agricultural Water Electrical Energy Requirements.* Sacramento, Calif.: Public Interest Energy Research Program. ITRC Report No. R 03-006. http://www.itrc.org/reports/energyreq/energyreq.pdf
[67] GEI Consultants and Navigant Consulting, Inc. 2010. *Embedded Energy in Water Studies—Study 1: Statewide and Regional Water-Energy Relationship.* San Francisco, Calif.: California Public Utilities Commission. CALMAC Study ID CPU0052. Appendix G, page G2. http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/Embedded+Energy+in+Water+Studies1_and_2.htm
[68] "CPUC Study 1: Wholesale Water Energy Model": http://arcgis01.geiconsultants.com:8080/waterEnergy/
[69] "CPUC Study 1: Wholesale Water Energy Model": http://arcgis01.geiconsultants.com:8080/waterEnergy/

The following categories represent the most important energy using activities in irrigated agriculture:

- Well pumping, canal and river pumping;
- Booster pressure pumping;
- Drainage system recirculation pumping;
- Frost control.

The Sacramento and San Joaquin Valley regions consume the majority of electricity for water pumping, while the Central Coast regions demand higher energy intensity per unit of water pumped. Central Valley farms receive an important proportion (50 percent or more in good water years) of total water used from surface water deliveries. Central Coast farms rely almost exclusively on ground sources for irrigation water. The highest irrigated agriculture pumping energy users are located in western Fresno, Merced and Kern counties in the San Joaquin Valley region.[70]

Almost 20 years after the early 1990s drought, California irrigated agriculture has achieved significant improvements in the management of water resources. Although there are few scientific studies documenting the scope of the improvement achieved, industry trade allies believe that the use of advanced technologies and management practices has greatly optimized the amount of water available for plant growth. Achieving higher water use efficiency while better managing deep percolation and runoff have achieved "phenomenal across-the-board improvements in yield per acre, and per unit of crop evapotranspiration in crops such as almonds, processing tomatoes, and peppers.[71] There are no academic studies, however, to corroborate these observations.

An input output analysis of all energy values was conducted in the cultivation of peppers using buried drip irrigation systems. Results from participating farms in the Central Coast region showed reductions in water use (acre-feet/acre), increased energy use (MBtu/acre), higher yields (tons/acre), higher water use efficiencies (tons/acre-feet) and overall improvement in energy use efficiency (tons/MBtu).[72] Although there is no academic study to confirm a trend, it is believed by industry trade allies that most, if not all peppers grown in California are now utilizing buried drip irrigation systems.[73]

Barriers

Farmers utilize best practices to comply with regulated irrigated agriculture application and drainage management practices. The driver to any decision related to watering crops is driven by the source, amount, and cost of available water for irrigated agriculture. Although energy costs are secondary, but required to make planting decisions, adoption of water quality standards and water conservation goals can require additional energy use for irrigated agriculture. Regulations that limit the amount of excess irrigation water (drainage tail water) and spillage require additional energy to power recirculation pumps.[74]

Water conservation policies can lead to the use of more energy intensive on-farm drip and micro irrigation systems. Farmers are generally willing to spend more on energy and incurr higher costs to acquire and deliver scarce water resources or to improve crops yields or quality. The design-dependent

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[70] Burt, 2011; Burt, 2003

[71] C. Burt, 2011 personal conversation

[72] Irrigation Training and Research Center. 1996. Row Crop Drip Irrigation on Peppers Study – High Rise Farms. San Luis Obispo, Calif.: Irrigation Training and Research Center, California Polytechnic State University. http://www.itrc.org/reports/highrise.htm.

[73] C. Burt, 2011 personal conversation

[74] Burt, 2003

factors that influence the total pressure requirement of an irrigation system are determined by the irrigation dealer, and the farmer will typically accept the design that is provided, without questioning options for reducing pressure.[75] Farmer's behavior driven by water source priorities relegates energy conservation to a second level of concern, a distinct barrier to adopting energy efficiency measures.

Issues

Significant efforts have been undertaken by the IOUs and other public and private institutions to advance the water and energy efficiency of irrigated agriculture. The industry has achieved improvements and is continuously aware of the need to achieve further gains to optimize water and energy use. The efforts to promote electricity efficiency in irrigated agriculture using funds from the Public Goods Charge emphasize hardware design and installation in new construction or retrofit projects. Farmers are encouraged to look at opportunities for greater savings with premium efficiency motors or the use of variable frequency drives for water pumping, and software to optimize irrigation system design.

There are other opportunities to achieve overall energy savings or efficiency improvements, particularly if the IOU programs could offer a flexible approach to optimize pumping plant efficiency, the method to irrigate crops and the indirect energy benefits accrued from these practices. For example, improving the design, construction and maintenance of the ground water well can directly impact the performance of the pumping system. The delivery of irrigated water using drip irrigation technologies can improve the use of fertilizers, lowering the embedded energy intensity of crop fertilization. Drip systems also are known for creating reduced weed pressures, lowering the cost and embedded energy expenditure from herbicide applications. Similar results can occur with the use of pesticides, depending on crop and growing conditions. New program evaluation metrics would be needed to calculate overall energy savings that account for both direct and indirect energy, as well as electricity and diesel fuel consumption.

Achieving higher participation rates in irrigated agriculture programs offered by the IOUs may require the development of policies that provide incentives for achieved embedded energy savings that result from the adoption of water conservation technologies. Depending on the original irrigation technology and water supply source, water conserving technologies may increase total energy use.[76] Although there are no academic studies estimating the rate of adoption, it is assumed that more irrigated acreage will continue to be supplied with pressurized drip/micro irrigation systems.

The conversion from surface irrigation delivery to pressurized delivery systems has energy implications, often increasing on-farm electricity use. Pressurized irrigation systems offer many more opportunities for precise irrigation timing and control than conventional surface irrigation,.bBut a flexible water supply is necessary to take advantage of many of those opportunities.

Irrigation districts will need to modernize their infrastructure to deliver clean, pressurized and flexible delivery of irrigation water to farms adopting drip and micro irrigation technologies. Otherwise, farms will be required to access ground water sources. These sources are obviously more energy intensive than surface water supplied by irrigation districts. The Irrigation Training and Research Center (ITRC) at Cal Poly San Luis Obispo University has documented through a survey of twenty-one irrigation districts in the Central Valley, the conversion of 73,000 acres to drip and micro irrigation systems. "Conversion

[75] C. Burt, 2011 personal conversation
[76] Burt, 2003

acres are those on which farmers used only groundwater for drip/micro irrigation although surface irrigation water was available.[77]"

The study reveals that farmers need to convert to more expensive ground water sources because of the lack of flexible water delivery by their respective irrigation districts. The extra energy required for groundwater pumping is estimated at 76,000MWh per year.[78] These results have important implications for future electricity demand from irrigated agriculture as acreage migrates from surface to pressurized irrigation systems. A sustained rate of "conversion acres" in the San Joaquin Valley region can have significant hydrologic water balance implications with a concomitant impact on energy demand. IOUs would benefit from research studies to predict outcomes and assess unintended consequences, possibly providing guidance to design future programs addressing these issues.

Opportunities

The California Public Utilities Commission's *Embedded Energy in Water Study* 1 estimates that 7.7 percent of the state's electricity use is embedded in the pumping, transportation, treatment and distribution of water resources.[79] Agricultural end-uses represent some portion of this embedded energy, and reductions in overall water use on farms would contribute to energy savings across the water distribution system.

The concept of indirect energy in irrigated agriculture processes can be extended to agricultural fertilizers and petro-chemical products. For example, the use of vegetable transplants and sub-surface drip tape may reduce total water applied, improve fertilizer application practices and decrease the use of petrochemicals for weed and pest control management. The amount of energy embedded in these chemical products, especially ammonia-based fertilizers, is significant. The reduced use resulting from emerging irrigation and planting methods could be accounted as an incentive to adopt more efficient water and energy conservation technologies.

There may be future opportunities to design programs that utilize a holistic approach to credit benefits from achieving both direct and indirect energy conservation and efficiency gains. Farm managers may embrace innovative programs providing rewards for achieving their most important objectives. New programs may be designed to offer a holistic resource management approach where farms can receive incentives for both direct and indirect energy savings, water use efficiency improvements, greenhouse gas emission reductions, reduced run-off and other environmental benefits.

7.3 Technologies

Great technological advancements have contributed to improvements in the use of water resources. A menu of technologies and best practices has become industry standard including the following:

- Energy Management:
  - Pumping plant efficiency test data to generate repairs and upgrades.
  - Premium efficiency motors, variable frequency drives and automated controls.
  - Time of Use pump operation scheduling.
- Water Management:

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[77] Burt, 2011

[78] Burt, 2011

[79] GEI Consultants and Navigant Consulting, Inc. 2010. *Embedded Energy in Water Studies—Study 1: Statewide and Regional Water-Energy Relationship*. San Francisco, Calif.: California Public Utilities Commission. CALMAC Study ID CPU0052. http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/EM+and+V/Embedded+Energy+in+Water+Studies1_and_2.htm.

  - Irrigation scheduling practices.
  - Data acquisition, evaluation, decision making tools.
- On-Farm Irrigation Technologies:
  - Low pressure precision application irrigation systems.
  - Design, operation and maintenance.
- Improved Water Delivery by Irrigation Districts
  - Improved flexibility of deliveries given to farmers.
  - Reduced canal seepage and spill.

Additional technical improvements are needed to achieve energy savings from the use of drip and micro irrigation technologies. The Irrigation Training and Research Center (ITRC) documented the potential to reduce pump discharge pressures through improved irrigation system design. ITRC estimates a technical potential to reduce pump discharge pressures by 13 to 17 pounds per square inch of pressure (psi). The report offers recommendations for a potential utility rebate to "encourage energy efficiency by lowering system pressure demands."[80] Examples of current and emerging technologies related to water extraction, pressurization and delivery are provided in Table 8.

Table 8. Examples of Energy Efficiency Technologies for Irrigated Agriculture

End-Use	Existing Technologies	Emerging Technologies
Water Extraction, Pressurization, and Delivery	• Low pressure sprinkler nozzle • Sprinkler to Micro Irrigation Conversion • Irrigated scheduling systems • Water filters • Flush lines/automatic flushing systems (for filters) • Flow meters • Booster pumps • Hand-move sprinklers • Slide roll sprinklers • Moisture sensors	• Advanced water well design and construction • Advanced long-lasting materials for pumping plant components • Improved irrigation system design to reduce pump discharge pressures

7.4 Utility Programs

Existing IOU programs offer water management education and training services, free or subsidized pump tests,[81] and incentives to repair and increase pumping plant efficiency. Table 9 provides a summary of past IOU programs offered to the irrigated agriculture sector.

Table 9. Current & Historical IOU Programs for Irrigated Agriculture

Program Name	Year	Manager	Measures Offered	Statistics

[80] Burt, 2011
[81] SDG&E: http://www.sdge.com/business/rebatesincentives/programs/opus.shtml

SCE Agricultural Energy Efficiency Program[82]	2006	SCE	Hydraulic testing services (expanded existing program to ag. market	• Implementation rate: 33% • Over 9,500 pumps were tested between 2006 and 2008 7% of these received an incentive to implement pump improvements • Over 70% of pumps tested were either turbine well or turbine booster pumps. • Fewer than 5% were either submersible booster or positive displacement pumps
2004-2005 Agricultural Pumping Efficiency Program (APEP II)[83]	2004-2005	CPUC (PG&E, SCE and SoCalGas)	Information and financial incentives to growers & turf managers for energy-efficient pumping systems	• 116 electrical pump repairs were accepted into the APEP II program from 2004-2005 • 4 natural gas pump repairs • The provided a little over two-thirds of expected net electric energy impacts, exceeded the net therm impacts by 50 percent and completed 76 percent of the pump tests planned"
2002 Pump Test and Hydraulic Services Program[84]	2002	SCE	Testing of hydraulic pumps for non-residential customers	41 percent of the 64 participants surveyed made changes to improve their pumping system efficiency, 27 percent of the participants represent free-ridership. 91% of pump test customers, 58% of energy efficiency contact customers and 54% of nonparticipants were aware of the Program prior to 2002 (31% of surveyed non-participants were not aware of the program and had not had their pumps tested prior to 2000)

Although pump tests offer only one data point to assess irrigation pumping plant efficiency, associated hardware repairs may result in efficiency improvements at a new start date. Current rebates do not encourage investments in new pump materials that, for example, might extend the duration of the benefits from the repair and replacement project. Beyond pumping equipment parts and motor efficiency, the overall efficiency of well water extraction also is influenced by the quality and integrity of the well's construction and infrastructure.[85] IOU programs could incorporate well design, construction and maintenance standards into existing incentive programs offered to customers.

7.5 Summary of Observations

- Pursuing energy and water conservation simultaneously. The challenge for energy conservation and efficiency programs administered by IOUs is to offer products and services to meet the farmer's need to conserve water yet also achieve energy savings. Policies driven solely by water conservation encourage farmers to utilize energy intensive irrigation systems to achieve desired water savings. The change from surface irrigation practices to drip and micro irrigation technologies has increased on-farm pumping demand in the East side of the San Joaquin Valley and other irrigated agricultural

[82] Cullen, Gary, Swarts, Deborah and Mengelberg, Ulrike (Summit Blue Consulting) 2009. Process Evaluation Report for the SCE Agricultural Energy Efficiency Program. Irwindale, Calif.: Southern California Edison. CALMAC Study number SEC0287.01. http://www.calmac.org/warn_dload.asp?e=0&id=2721

[83] Equipose Consulting, Inc. 2006. *Evaluation of the Center for Irrigation Technology, 2004-2005 Agricultural Pumping Efficiency Program*. California Public Utilities Commission. Publication No. 1418-04, 1428-04, 1434-04. http://www.calmac.org/publications/CIT_APEP_2004_2005_Final_Impact_Report_V2.pdf

[84] Itron, Inc. 2010. *2006-2008 Evaluation Report for the Southern California Industrial and Agricultural Contract*. San Francisco, Calif.: California Public Utilities Commission. Publication No. CPU0018.01. http://www.calmac.org/publications/SCIA_06-08_Eval_Final_Report.pdf

[85] C. Burt, 2011 personal conversation

regions of the state. An increase in energy demand results from additional use of ground water sources and the use of booster pumps.

- There is insufficient empirical research data to determine the total technical potential to achieve additional energy conservation and efficiency in California's irrigated agriculture. There also is potential for increased use of electricity from "conversion acres" in the San Joaquin Valley region. If irrigation district cannot deliver flexible water to farms adopting drip and micro irrigation systems, increased use of ground water sources will increase energy demand. IOUs would benefit from research studies to predict outcomes and assess unintended consequences from this trend, possibly providing guidance to design future programs addressing these issues.

- Embedded energy savings. To measure potential energy conservation and engineering efficiency improvements in irrigated agriculture requires an understanding of crop production systems, where tillage practices can affect water distribution, soil water retention and other planting options. As an example, the use of transplants should be considered an energy conservation practice as it enhances the performance of total agricultural water use and also achieves diesel fuel use savings and avoided air pollution emissions. These savings have yet to be rewarded under current California Public Utility Commission energy efficiency programs.

- New programs may be designed to offer a holistic resource management approach where farms can receive incentives for both direct and indirect energy savings, water use efficiency improvements, greenhouse gas emission reductions, reduced run-off and other environmental benefits. These savings have yet to be rewarded under current California Public Utility Commission energy efficiency programs. New program evaluation metrics would be needed to calculate overall energy savings that account for both direct and indirect energy, as well as electricity and diesel fuel consumption.

- Lack of studies on trends and adoption rates of irrigation systems. Although there is evidence that farms continue to adopt pressurized drip/micro irrigation systems to replace surface irrigation practices, there are no academic studies available to account for trends and adoption rates. Research should be conducted to evaluate the energy efficiency benefits, measured in product produced per unit of energy used, from the adoption of water conservation emerging technologies. Evaluation metrics could be developed to calculate total energy savings resulting from reduction or efficiency improvements from the use of both direct and indirect energy.

- Other direct energy saving opportunities. Other energy conservation or efficiency improvements could be evaluated for future program incentives. In particular, an evaluation of the energy implications of groundwater well design, construction and maintenance standards; and how to reduce pump discharge pressures through improved irrigation system design.

- Energy associated with non-pumping electricity use and gas pumping. Because electrical pumping dominates the energy use in irrigated agriculture, utility programs have focused attention there. However, gas-fired pumping may provide previously unexplored opportunities as might electricity used for non-pumping end-uses. There is limited knowledge of how and why energy is used in these areas and IOU programs that target irrigated agriculture customers could benefit from exploring the potential in these less evident end-uses.

8 Greenhouses & Nurseries

8.1 Industry Overview

California leads the nation in sales of greenhouse and nursery products, and is a dominant producer of cut flowers and greens (58 percent of national sales) and nursery transplants (74 percent of national sales).[86] Greenhouses and nurseries serve an important role in California's agricultural industry as producers of food crops, key suppliers of landscaping plants, major producers of flowers, and suppliers of plugs, garden and household plants, and vegetable transplants.

Table 10 provides a summary of the Greenhouses & Nurseries segment in terms of number of farms engaged in producing these crops, total production footprint in terms of square footage under glass and acres in open, and value of sales (in 2007) from each crop. The U.S. Department of Agriculture's data from the 2007 Agricultural Census were organized into these segments using the North American Industry Classification System (NAICS) definitions. The NAICS segments differ from the available literature, which tends to aggregate floriculture and nursery products. It is not clear whether the aggregation of floriculture and nursery products within the literature stems from the vertical integration of these industries or for another reason. Wherever possible, this Literature Review will distinguish the segments based on their NAICS codes but this is not always possible.

From an energy perspective, the NAICS code segmentations appear to be more useful for this Study than the groups in the available literature: greenhouse crops and floriculture tend to use more energy than nurseries because of their space conditioning and cold storage requirements.[87] Thus, the Greenhouses & Nurseries segment is most logically divided into greenhouse crops (vegetables), floriculture, nurseries (vegetable transplants, vegetable stock), and mushrooms.

Another important distinction for energy use, which is reflected in the U.S. Agricultural Census data in Table 10, is between crops grown under cover ("glass") and those grown in the open, conditions which affect the amount the space conditioning and/or lighting needed across the production cycle. In general, greenhouse food crops are produced under cover in conditioned spaces while nursery plants can be produced under cover in unconditioned spaces, or in the open. Mushrooms are produced entirely in conditioned environments. Flowers, while mostly produced under cover, may also be grown in the open, and typically require cold storage after harvest, regardless of how they were grown.

Table 10. Summary of Greenhouse & Nursery Farm Statistics for Key Subsegments[88]

Segment		NAICS Code[89]	# of Farms	Sq.Ft Under Glass	Acres in Open	Value of Sales†	
						# of Farms	Value
Mushrooms		**111411**	55	5,483,804	0	53	$223,457,225
Floriculture Products		**111422**	1,870	103,139,657	12,017	1,865	$1,222,371,503
Greenhouse Crops	***Vegetables**[a]*	**111419**	182	12,927,882	0	181	$112,284,392
	Tomatoes		*81*	*6,008,943*	0	*81*	*$51,016,687*

[86]Based on sales by subsegments provided in the 2007 U.S. National Agriculture Census, sales used to allow comparison across greenhouse and nursery subsegments, which are highly diverse.
http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_US_State_Level/st99_2_035_035.pdf

[87] Mushroom production has similar requirements to greenhouse crop production but since mushroom production is not aggregated in any of the data sets, this is not an issue for that subsegment.

[88] NASS, 2009.

[89] U.S. Census Bureau, North American Industry Classification System, Code 1114 (Greenhouse, Nursery & Floriculture Production). available: http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007

	Other Vegetables		*140*	*6,915,939*	*0*	*139*	*$61,267,525*
Nursery Plants & Trees	***Vegetable Transplants***	**111421**	68	14,291,522	193	68	$90,985,384
	Nursery Stock		1,655	25,179,297	31,889	1,626	$1,682,234,080
	Sod		55	0	19087	55	$252,476,652
	Christmas trees [b]		400	0	4,033	0	N/A
	Bulbs, Corms, Rhizomes, and Tubers		86	95,985	823	86	$38,208,034
	Other Nursery Crops		79	154,166	294	78	$7,207,180
Cuttings, Seedlings, Liners, Plugs		**111421/111422**	128	4,426,391	177	128	$84,376,862

Notes:
† Sales data reflects information provided by farms that responded to this question on the Agricultural Census, and may not reflect data from all farms that responded to the Census.
[a] The total for tomatoes and other vegetables cannot be summed as there is cross-over between farms that grow tomatoes and other plants.
[b] For 2007, of the total 4,033 acres cultivated only 1,487 acres were irrigated.

Most of the state's greenhouses and nurseries are concentrated along the Central and Southern coasts due to favorable climates that allow for year-round production.[90] For flowers, foliage and nursery crops, the majority of production occur in these counties: San Diego, Ventura, Monterey, Riverside, Santa Barbara, Orange, Los Angeles, San Mateo, and Santa Cruz, with San Diego county accounting for 30 percent of the overall state total.[91] Although much of the production is consumed within state, approximately 40 percent of the flowers and 20 percent of the nursery products are shipped out of state.[92]

California is ranked first in the nation for production of cut flowers, potted flowering plants, and bedding plants, second in the nation for foliage plant and cut cultivated greens production, and third for production of propagation materials.[93] The total value of these products is around 1 billion dollars per year and represents roughly 25 percent of total national production.[94] The total number of producers has fluctuated significantly over the past five years, suggesting some degree of volatility in the industry[95], and potentially a reflection of the housing market given the importance of ornamentals and house plants in this segment.

Overall, the number of producers is small compared with the total value of production of floriculture and nursery products – ranging from a high of $2.4 million average sales per producer in 2010 to a low of $2.0 million in 2006—suggesting that the floriculture subsegment is dominated by large companies.[96] California's mushroom production represents about 23 percent of the national total and is second only to Pennsylvania.[97] The California industry is highly concentrated yet profitable, with just 55 farms—likely

[90] Joshel, Christine and Rick Meinicoe, *Crop Timeline for California Greenhouse Grown Ornamental Annual Plants*, U.S. Environmental Protection Agency, 2004. Available: http://pestdata.ncsu.edu/croptimelines/pdf/canursery.pdf
[91] USDA NASS, Summary of California County Agricultural Commissioners' Reports, 2008-2009. Available: http://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/200910cavtb00.pdf
[92] http://pestdata.ncsu.edu/croptimelines/pdf/canursery.pdf
[93] USDA NASS, *California Floriculture Report*, Volume 2 No. 1, April 28, 2011, http://www.nass.usda.gov/Statistics_by_State/California/Publications/Field_Crops/201104florarv.pdf
[94] USDA NASS, *California Floriculture Report*
[95] NASS, 2009.
[96] USDA, *Floriculture and Nursery Crops Yearbook. FLO-2007*, Economic Research Service, September 2007. http://www.ers.usda.gov/Publications/Flo/2007/09Sep/FLO2007.pdf

owned by an even smaller number of companies—responsible for about $223.5 million dollars in sales, an average of over $4 million per farm.[98] Figures for local production, consumption versus export, and total value of crops for mushrooms and other food crops were not found in the course of this literature review. In general, current information regarding California's vegetable greenhouse production and mushroom production were not found in the course of this literature review. The latest available information for these areas was from the mid- to late 1990s. There is a significant gap in available data and industry knowledge related to these subsegments.

Beyond economic statistics, there is limited information available information on the California greenhouses and nurseries industry. The floriculture and nursery industries are generally better understood than vegetable crop production and mushroom production. Overall the industry does not appear to be the subject of much analysis from an energy and water use perspective. This segment would likely yield significant opportunity for utility programs, especially gas programs, to provide customers with energy-reducing, water conserving, cost-saving measures.

8.2 Energy

The Greenhouses & Nurseries segment is an energy-intensive sector. For mushrooms, floriculture, and greenhouse food crops, key energy end-uses include lighting, space conditioning (cooling, heating, humidification), sorting, packing, cold storage and irrigation-related (pumping, sprinklers). Mushroom production also requires energy for sanitization and cleaning. Key energy end-uses for nurseries are mostly irrigation-related, and for enclosed spaces, include lighting. Key water end-uses include irrigation, pressurized pumping, and drainage for nursery and tree production, and watering, washing, and cleaning for mushrooms, food crops, and flowers. However, the specifics of the energy use and water use in these subsegments are not well understood.

Important information to understand for each subsegment includes the following: energy intensity per square foot of covered growing area or open acreage (therms and kilowatt-hours), energy use by end-use by sector (therms and kilowatt-hour), sector-specific process and equipment requirements, baseline equipment data, penetration of efficient, emerging technologies and practices, water requirements for each sector and available conservation techniques. Efficient and emerging technology options for lighting, motors, building insulation, HVAC, refrigeration equipment and pumps are well understood, and could be implemented in this sector if the utilities knew where to focus their attention.

Many of these opportunities could be revealed through baseline surveys of the sector. Furthermore, this sector is a heavy user of gas, presumably for its space conditioning needs, which presents an opportunity for the IOUs to address natural gas use, typically harder to reach than electricity savings.

Other opportunities may become evident once the utilities have a better understanding of specific needs and production requirements of the individual subsegments within this sector. For instance, mushroom production may offer unique energy efficiency opportunities available through process and/or operational shifts in addition to new and better technologies. For example, an energy audit of Rolland Farms, a mushroom producer in Canada that is one of the largest producers in North America, provided the company with technology and process improvement ideas that resulted in a 9.5 percent reduction in electricity use, primarily through improvements to the cooling and chiller system, an 18 percent

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[97] NASS, 2007 Agricultural Census http://www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1,_Chapter_2_US_State_Level/st99_2_035_035.pdf

[98] NASS, 2007 Agricultural Census

reduction in natural gas consumption by 18 percent, through boiler system upgrades and process efficiency improvements.[99]

8.3 Technologies

A limited number of technologies were identified for this segment and are summarized in Table 11. Additional sector-specific technologies are expected to exist but have not been identified due to the lack of knowledge related to end-use and process specific energy consumption.

Table 11. Examples of Energy Efficiency Technologies for Greenhouses & Nurseries

Purpose	Subsegment	Existing Technologies	Emerging Technologies/Practices
Energy Management	Greenhouses Floriculture	• Greenhouse roofing materials • Shading curtains for greenhouses • Infrared film for greenhouses • Automated temperature control systems	
	Mushrooms	• Air handling units with heat exchangers[100]	• LED lighting for mushroom growing[101] • Underground mushroom production with passive fresh air exchange system[102]
Water Management	All	• Automated drip irrigation • Low pressure sprinklers	

8.4 Utility Programs

PG&E, SDG&E and SoCalGas offer greenhouses rebates for heat curtains and infrared film and PG&E and SDG&E also offer customers rebates for efficient sprinkler systems. SCE does not currently offer rebates specifically targeting the greenhouses and nurseries segment. Table 12 provides a summary of these measures. No existing or historical IOU programs were specifically identified for this segment. Also, this table does not include rebates for general measures targeting motors or lighting, which may be accessed by these customers, or custom programs that some customers may choose to access through their utility.

Table 12. Measures Offered by the IOUs

Measure	Measure Type	Rebate Amount	IOU	Segment
Greenhouse Heat Curtain	Gas	$0.20/square foot	PG&E SDG&E (Suspended as of July 25, 2011)	Greenhouse
Infrared Film for Greenhouses	Gas	$0.05/sq ft	PG&E Southern California Gas, Co.[103] SDG&E (Suspended as of July 25, 2011)	Greenhouse
Sprinkler to Drip Irrigation	Electric	$44.00/Acre	PG&E SDG&E	All
Low Pressure Sprinkler Nozzle	Electric	$1.15/nozzle	PG&E SDG&E	All

[99] Natural Resources Canada, Canadian Indsutry Program for Energy Conservation, "10 Companies That are Making a Difference", 2007. Available: http://oee.nrcan.gc.ca/publications/infosource/pub/cipec/annualreport-2008/companies.cfm?attr=24#thinking

[100] http://www.modernmushroomfarms.com/news.html

[101] http://www.mushroomvideos.com/Mountain-Mushroom-Farm

[102] http://www.mushroomvideos.com/Mountain-Mushroom-Farm

[103] http://www.socalgas.com/for-your-business/rebates/general-equipment.shtml

8.5 Summary of Observations

- Lack of basic industry information about the Greenhouses & Nurseries segment and subsegments: The industry has not been well studied in California and basic information regarding the key players, industry and market drivers, and other issues are not available.
- High-intensity energy and water requirements cannot be addressed without establishing baseline information: Floriculture, greenhouses and mushroom production facilities are of particular interest for the utilities as these subsegments are considered energy intensive due, in large part, to space conditioning requirements for large warehouse-type facilities. Floriculture production can occur partly outdoors but food crops are grown exclusively within conditioned spaces, and many of these crops require post harvest cold storage facilities. Mushroom production occurs entirely within conditioned spaces, and there are significant energy needs related to proper sanitation, as well as cold storage requirements. All of these crops require significant water resources and would benefit from better pumps, irrigation techniques, and most measures that apply to other types of irrigated agriculture. However, efficiency opportunities for the industry cannot be properly evaluated without an understanding of baseline equipment (efficiencies and penetration) and the options for efficient and emerging equipment. Some subsegments may present opportunities for process efficiency improvements but this also requires establishing a fundamental understanding of the energy and water use consumption, production requirements, and customer needs.

9 Vineyards & Wineries

California produces 90% of American wine and holds the 4th spot in global wine production (behind France, Italy and Spain).[104] In 2009, the retail value of California's domestic wine sales was $18.5 billion with export revenue reaching $1.14 billion.[105] California's emergence as a major force on the national and international wine is a recent phenomenon: in 1960, the state had about 250 wineries, in 1990 there were around 800 and by 2010, over 3,360.[106]

The rise of California's profitable wine industry is the story of a successful partnership between vineyards and wineries. Winegrape farmers develop the land to cultivate high quality wine varietal grapes for wine makers to transform into award winning wines. The wine industry is rooted in the work of winegrape growers delivering quality winegrapes for winemakers to crush into quality products. The wine industry has long-standing ties to the state's university system, developing the educational foundation to earn viticulture and enology degrees, conducting research to develop improved varietals, all of which is supported by the technology transfer infrastructure of the UC Cooperative Extension Service.

The vineyards grow winegrape cultivars from winery-owned vineyards and from independent wine grape growers supplying fruit to regional wineries. Wineries crush and ferment grapes and produce and store wine in tanks, barrels, and cold storage facilities. Wine grapes are predominantly grown in the Central San Joaquin Valley, the Central Coast, Napa and the Northern Coastal Mountain Range regions (see **Error! Reference source not found.** for the geographical distribution and aggregation of California's winegrape growing districts).

[104] Wine Institute, "California Wine Profile 2010", http://www.wineinstitute.org/files/CA_EIR_Flyer_2011_Apr15.pdf
[105] Wine Institute, "California Wine Profile 2010".
[106] Wine Institute, "California Wine Profile 2010".

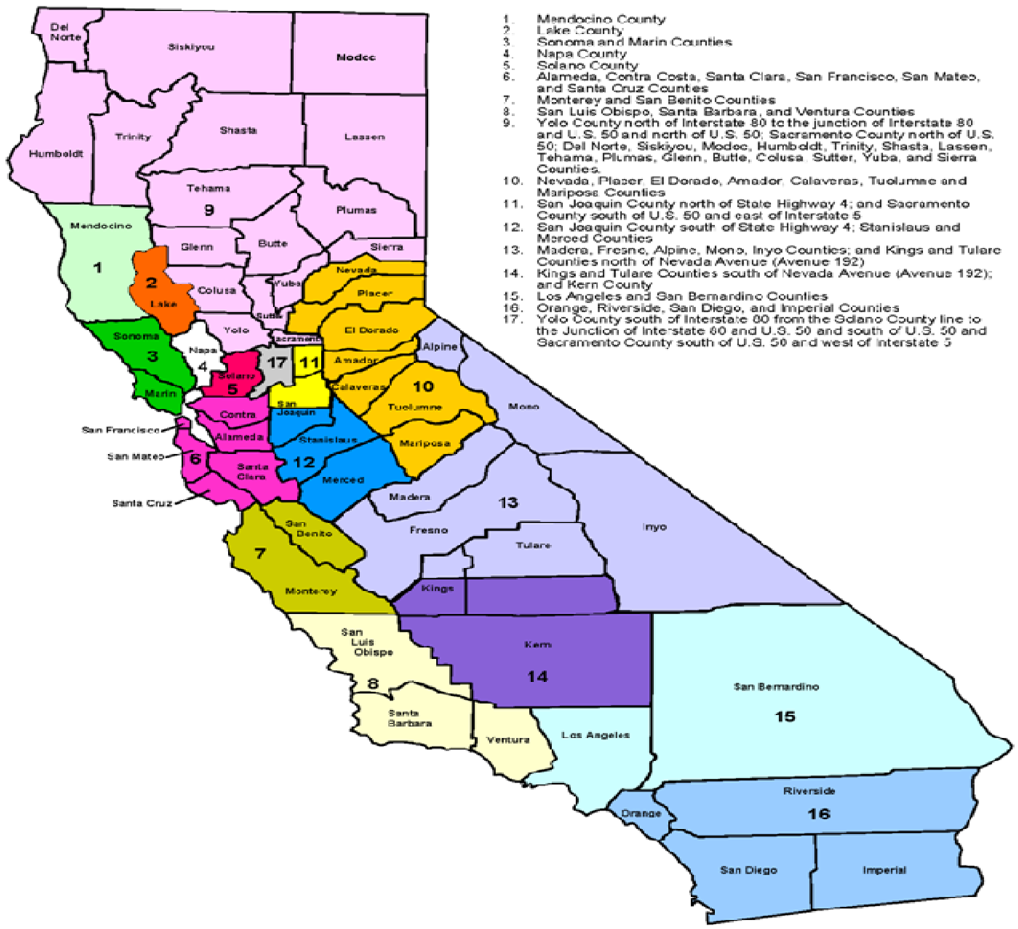

Figure 3. California Wine Growing Districts[107]

9.1 Industry Overview

Vineyards

Thousands of vineyards grow table, wine and raisin grape varietals, occupying a combined 789,000 acres of cultivated irrigated land. In 2010, winegrapes were grown in 489,000 of the total grape acreage.[108] Raisin and table grape grown varietals at times are added to the winegrape crush. Most vineyards have adopted drip irrigation systems, soil and weather monitoring technologies and the use of software to adopt Irrigation Scheduling (IS) practices. The rate of technology adoption depends on the wine growing region of the state. The Napa Valley and the Central Coast wine growing regions are almost entirely using drip irrigation.[109]

Although this Study makes a distinction between vineyards and other irrigated crops (including other grape crops) based on the organization of the industry around wine production, the issues, barriers and opportunities described in the section of this report devoted to Irrigated Agriculture of this report apply to vineyards. Please refer to that section for further detail.

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[107] USDA, NASS. 2011b, California Wine Growing Districts. Available: http://www.nass.usda.gov/Statistics_by_State/California/Publications/Grape_Crush/Prelim/2010/201002gcbtb00.pdf

[108] California Department of Food and Agriculture, California Agricultural Production Statistics, Fruit & Nut Crops, 2010-2011. Available: http://www.cdfa.ca.gov/statistics/

[109] Dr. Charles Burt, CalPoly SLO, ITRC 2011.

Wineries

California's 3,364 bonded wineries[110] crushed 3.7 million tons of fruit in 2010[111], delivering 241.8 million cases of wine to the U.S. market and for export to 125 countries.[112] Many of California's wineries are small businesses that produce fewer than 5,000 cases per year. Demand for these small-batch producers can be strong, sometimes with long waiting periods, and may yield good profit margins for the wineries.[113] However, by volume, the vast majority of California's wine production is concentrated with just a few companies such E.J. Gallo. Constellation Wines (Robert Mondavi, Franciscan, Simi), and The Wine Group (Franzia, Glen Ellen, Canconnon), Bronco.

Table 13 shows the total tons of wine grapes crushed in 2010 by USDA Wine Growing Districts (some counties are part of more than one district). The crush is widely distributed across the state but Districts 13 and 11 are the leaders. Wineries in District 13, which include most of the Ernest and Julio Gallo Wineries, are the single largest crushers of wine grapes in the state. The Sacramento and San Joaquin counties (District 11) account for the second largest wine grape crush district, mostly from vineyards associated with the Lodi-Woodbridge Commission.

Table 13. 2010 Winegrape Crush by County[114]

USDA Wine Growing Districts	Counties	Total Crush (tons/yr)
1	Mendocino	59,617
2	Lake	31,623
3	Marin, Sonoma	212,675
4	Napa	142,752
5	Solano, Sacramento*	19,272
6	Alameda, Contra Costa, San Mateo, Santa Clara, Santa Cruz	26,925
7	Monterey, San Benito	264,848
8	San Luis Obispo, Santa Barbara, Ventura	216,936
9	Butte, Colusa, Glenn, Humboldt, Sacramento*, Shasta, Siskiyou, Sutter, Tehama, Trinity, Yolo*, Yuba	60,142
10	Amador, Calaveras, El Dorado, Mariposa, Nevada, Placer, Tuolumne	18,192
11	Sacramento*, San Joaquin*	770,101
12	Merced, San Joaquin*, Stanislaus	316,063
13	Fresno, Kings*, Madera, Tulare*	1,074,821
14	Kern, Kings*	347,297
15	San Bernardino, Los Angeles	1,078
16	Orange, Riverside, San Diego	3,841
TOTAL	**CALIFORNIA**	**3,702,530**

9.2 Energy

Wineries are industrial facilities utilizing process energy to wash, clean and crush wine grapes, and to process grape juice to create wine products. Electricity is used to power pumps to extract well water and to discharge and treat wastewater residues, usually using pond aerators. Electricity and natural gas are used for building conditioning and lighting, motors for crushers and presses, process heat for the

[110] Wine Institute, "Number of California Wineries", http://www.wineinstitute.org/resources/statistics/article124
[111] CDFA, 2011, Available: http://www.nass.usda.gov/Statistics_by_State/California/Publications/Grape_Crush/Reports/index.asp
[112] Wine Institute, "California Wine Profile 2010".
[113] Rachael E. Goodhue, et. al., *Current Economic Trends in the California Wine Industry*, U.C. Davis Giannini Foundation of Agricultural Economics, 6. Available: http://giannini.ucop.edu/media/are-update/files/articles/v11n4_2.pdf
[114] USDA, NASS. 2011b, California Wine Growing Districts; CDFA, 2011.

fermentation vats, motor-driven bottling equipment, and post-bottling cooling storage and refrigeration. California's winemaking industry uses 400 GWh of electricity every year, in addition to the consumption of natural gas and propane.[115]

The majority of the electricity is used for cooling and cold storage refrigeration, in addition to compressors, pumps and motors. Hot water is used to heat red wine fermentation vats and yeast generator tanks and for washing and cleaning storage barrels. Additional fresh water is used to wash and clean equipment, bottling lines, cellars and crushing areas. Figure 4 shows the distribution of energy resources for the production of wine. Refrigeration and lighting combined utilize 56 percent of total energy in a typical winery, and motors represent an additional 16% of total electricity use.

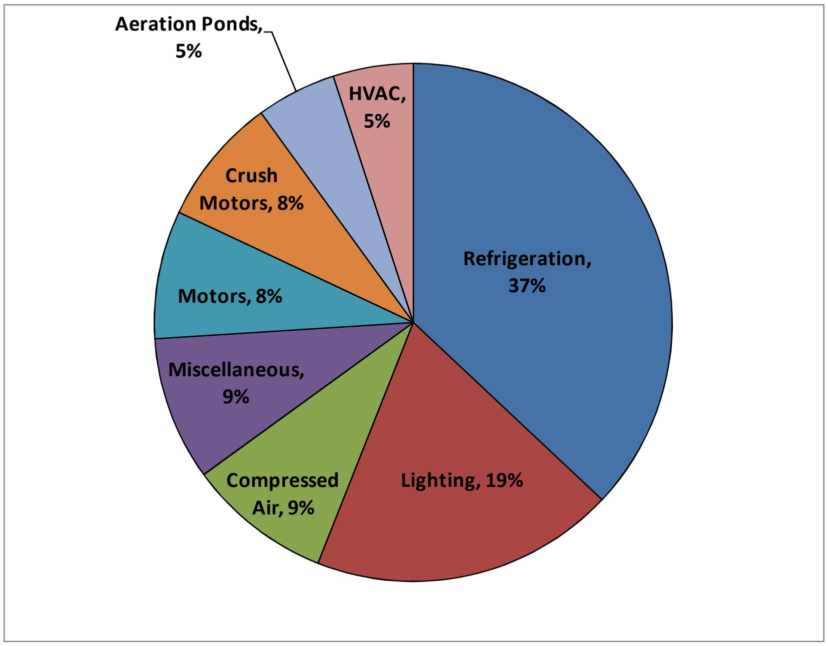

Figure 4. Typical Winery Energy Use[116]

Historically, California wineries have voluntarily adopted energy management practices to increase efficiencies and reduce the energy intensity of winemaking. Although there is no documentation to establish a comparison for efficiency improvements achieved, individual wineries can calculate their energy and water intensity using benchmarking tools. Winery production managers can use a California based benchmark tool developed to compare their resource intensity to a best winery index. The tool offers energy efficiency options and allows for before and after comparisons.

CASE STUDY: BEST-Winery Tool.[117] BEST-Winery is a software tool designed to evaluate the energy and water efficiency at a winery, and to help assess the environmental and financial impacts of potential improvement strategies. Given the necessary data, BEST-Winery calculates an energy intensity index (EII) and water intensity index (WII), performance indicators that compare the user's winery to a benchmark or reference facility, incorporating information about winery-

[115] LBNL, 2005, BEST Winery Energy Tool, http://best-winery.lbl.gov/

[116] For illustrative purposes only, PG&E, Clem Lee, "Reducing Wineries' Climate Impact: How PG&E's Energy Efficiency Programs Assist", presentation at Eco-winegrowing Symposium, July 19, 2011, Available: http://www.mendowine.com/files/Lee%20EcoWinegrowing%20Symposium_PGE%20Presentation.pdf

[117] LBNL, 2005, BEST – *Winery: Benchmarking Energy and Water Efficiency Tool* Energy Tool, http://best-winery.lbl.gov/

specific process steps and characteristics affecting energy and water use and volumes processed by the winery. BEST Winery also allows the user to evaluate preliminary opportunities for energy and water efficiency improvement, to assess the impact on the performance of the facility, and to evaluate operation costs. This can help the user in developing a preliminary implementation plan for energy and water efficiency improvement.

Although the process of wine making is energy intensive, there are no California based studies that have estimated the energy and water intensity of producing a bottle of wine. Each winery can use the BEST tool to establish their own metrics, from which they can compare savings from adopting new efficiency measures. Figure 5 illustrates the steps used in the wine making process and the major energy assets.

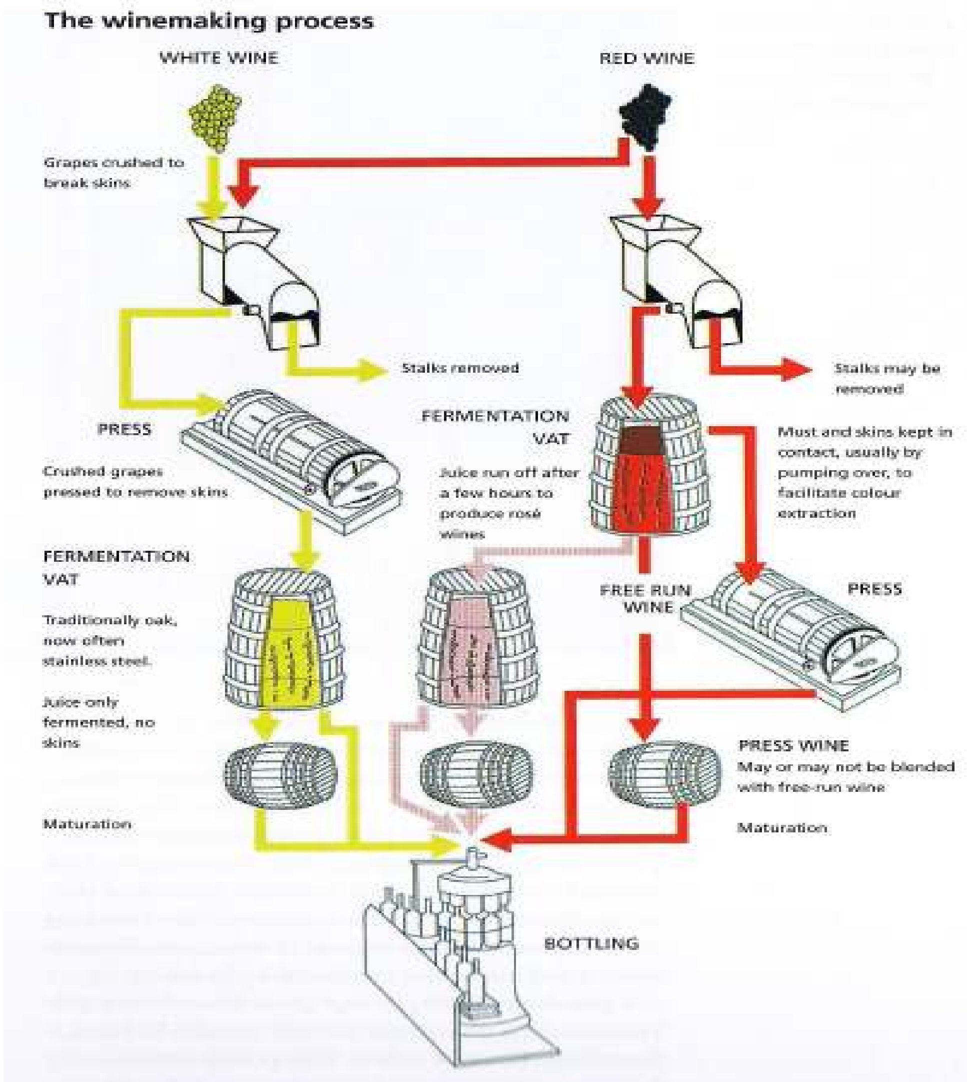

Figure 5. The Winemaking Process[118]

[118] Winegraphy.com, "Wine Making Process (Vinification)", Available: http://www.winegraphy.com/wine-making-process/wine-making-process-red-and-white-wine.html

Waste as Energy
Both liquid and solid residues are generated from the crushing of wine grapes and production of wine. Wineries discharge wastewater on land using land discharge permits from their Regional Water Quality Districts as well as to holding aerated ponds. A few very large wineries discharge wastewater to local WWTFs. The pomace (grape skins, seeds and stems) remains after the grape crush. Pomace is a compostable soil amendment and animal feed supplement, but it can also be used in anaerobic digesters to extract biogas. Currently the amounts of pomace can be very high leading to disposal and storage constraints.[119]

9.3 Utility Programs

Table 14 provides detail on the rebates currently offered to vineyards and wineries by PG&E and SDG&E. Specific programs targeting this segment were not found for SCE or SoCalGas.

Table 14. Measures Offered by IOUs

Measure Name	Measure Type	Rebate Amount	IOU	Segment
Low Pressure Sprinkler Nozzle	Electric	$1.15/nozzle	PG&E SDG&E	Vineyards
Sprinkler to Drip Irrigation	Electric	$44.00/acre	PG&E SDG&E	Vineyards
Wine Tank Insulation	Insulation	• $2.25/sq ft Indoor Tank • $3.00/sq ft Outdoor Coastal Tank • $3.75/sq ft Outdoor Inland Tank; Outdoor Coastal Valley	PG&E SDG&E	Wineries
Pumping Measures	Refer to Table xx for general agriculture measures			
Lighting Measures	Refer to Table xx for general agriculture measures			

PG&E's Wine Industry Efficiency Solutions (WIES) program offers a comprehensive menu of energy management services to medium and small sized wineries. These services include pricing plans, energy audits, energy efficiency rebates, new construction, retrofit, retro-commissioning, agricultural pump testing and repair, demand response, solar and other self-generation rebates, education and training, and the Climate Smart Program. Program offerings for the 2010-2012 program cycle include financial incentives for wine tank insulation and on-site audits.[120]

In addition to these services, PG&E has identified specific energy efficiency rebates and incentives for the purchase of variable frequency drives, qualified higher efficiency motors, wine tank insulation, high bay lighting, refrigeration, and compressed air system controls, listed in Table 2. A 2009 program evaluation by The Cadmus Group reported 3,739 MWh of electricity savings and 105,660 therms of natural gas savings.[121] The Cadmus Group's recent evaluation of PG&E's wine industry program shows

[119] Amón, 2011, unpublished
[120]PG&E WIES program information available here:
http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/agriculture/AgFood-EM_Wineries_Fact_Sheet.pdf
[121] Cadmus, 2009, Process Evaluation of PG&E's Agricultural and Food Processing Program, July 27, 2009, Final Report, CALMAC Study ID PGE0276.01

that since 2006, some 150 wineries have received energy efficiency rebates. Over 85 wineries have installed PV solar power generating renewable energy. Wineries participated almost 60 percent of the time upgrading motor and pumping systems, including waste water facilities. Tank insulation is the second largest with 16 percent of the electric powered measures available for IOU rebates. The use of control systems reaches 7 percent with the rest distributed among variable frequency drives, lights and sensors, compressed air and chiller refrigeration. It is noticeable that chiller and refrigeration systems have a low 2 percent participation in the 2010 review.[122]

> **CASE STUDY:** E.J. Gallo Winery.[123] The E. & J. Gallo Winery has historically participated in PGE's Energy Efficiency programs. Energy-efficiency improvements at the Fresno winery have included retrofits to the refrigeration system, process boilers, and an oversized high-capacity condenser, saving 4.7 million kilowatt hours of electricity, 144,000 therms of natural gas and a reduction of 1,000 kilowatt of electricity demand. The winery facility has received nearly a half million dollars in rebates from PG&E over several years. In 2001, Gallo received a comprehensive energy audit identifying recommendations for upgrades to lighting and air compressors, and installing variable speed drives (VSD) on its cooling towers. These projects resulted in an additional energy savings of 5.7 million kilowatt hours.

9.4 Policies, Barriers, Issues & Opportunities

Policies

The winery industry has invested in sustainability marketing and adoption efforts to be interested in the final details of the California Air Resources Board Cap and Trade Program green house gas emissions reduction program. The adoption rules for this program can influence future investments in energy efficiency, water conservation, the use of solar power technologies and the potential to install distributed generation bioenergy systems for vineyards and wineries.

Barriers

The P&GE WIES program has raised awareness with the target population through direct customer contact, educational workshops, audits and other outreach efforts.[124] Considering that the electricity savings achieved are higher than the forecasted savings by 1,429 MWh, may be an indication that electro-technology adoption is being encouraged by the program. The opposite happened to the adoption of natural gas measures with 56,812 therms not achieved from the forecast.

It would be advisable to conduct consultations with PGE third party providers and company customer representatives to evaluate customer needs and interest to further participate in these programs, identify barriers to adoption and develop technology transfer strategies. These activities and other evaluation studies should attempt to ascertain adoption rates of prescribed measures and the use of energy management options. IOU energy efficiency programs encounter institutional barriers that limit their involvement with wineries to only achieve electricity or natural gas use reductions or efficiency improvements. This barrier limits the IOU from potentially impacting additional desired winery resource use improvements, like water conservation.

Issues

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[122] Cadmus, 2009.

[123] PG&E, Integrated Case Study: E.J. Gallo Winery, Energy Efficiency and Demand Response, Available: http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/demandresponse/cs/Wineries_Gallo_Integrated_CaseStudy.pdf

[124] PG&E, Clem Lee, 2011.

The *California Association of Winegrape Growers* has proposed the establishment of a research-only marketing order given the significant reduction in public research funding. The winery industry, as well as many other agricultural commodity boards, "called for sustained public investment to ensure the future of agriculture in California", as an important issue affecting their industry.[125] Publicly funded agricultural research investments are considered paramount to the progress achieved by California's vineyards and wineries. Other issues of concern include water resource availability and cost, and environmental regulations.

Opportunities

Vineyard and wineries in California have consistently demonstrated a willingness and desire to be leaders in sustainability and efficiency. With the support of UC Cooperative Extension Specialists and Farm Advisors, the principles of Integrated Pest Management practices have been widely adopted in the wine industry. These efforts are recognized for supporting the adoption of sustainable agricultural practices in vineyards as well at the wineries. The winery industry has actively participated in IOU efficiency and renewable programs receiving incentives from the Public Goods Charge funds and California Solar Initiative. In particular, the funds that PGE is dedicating supporting wineries to adopt energy efficiency, demand response, energy management and Continuous Improvement (CI) methods.

There is an opportunity to measure and validate achievements and to estimate the technical potential to further adopt energy efficiency technologies. The 2011, release of ANSI's ISO 50001, Energy Management Standard may provide a catalyst for IOUs to encourage wine industry managers to adopt these standards and advance their sustainability principles. Promoting resource management practices offers the potential to reduce energy and water use in wineries. Wineries could also increase the use of solar PV and thermal systems, and possibly convert grape pomace to distributed bioenergy sources.

The opportunity may exist for the wine industry to successfully adopt green house gas (GHG) emission reductions given the improvements achieved to date. Under a cap and trade program, biomass to energy may be considered Carbon neutral, thus providing carbon credit allocations for the reduction of GHG emissions. These credits may be monetized, encouraging large grape crushing winery facilities to install cost effective bioenergy systems.

The winery industry may also benefit from IOU programs that reward embedded energy savings in process water. As much as possible IOU programs could be neutral to how wineries achieve energy and other resource use reductions and efficiency improvements. Wineries could use benchmark tools to establish their energy and water use intensity per unit of wine produced. From that point forward, the winery management will collect data and evaluate the performance of adopting Energy Management Standards, Best Practices, Continuous Improvements and other methods to achieve resource intensity reductions, receiving incentives based on performance against the benchmark.

9.5 Technologies

The PGE WIES program has identified the following technologies to qualify for the rebate program: wine tank insulation, strip curtains, fluorescent lights, occupancy sensors, steam or water process boilers, pipe insulation for boiler systems, attic and roof insulation, wall insulation, and commercial and industrial steam traps.[126] Additional customized retrofit measures include: energy efficient motors, VFD cooling and heating circulation pumps, glycol pumps, air handler and condenser fans, controls floating

[125] Waterhouse, Andrew et al, Impact of Innovation: A Call to Action, Insight and Opinion, WBM, 2009.

[126] PG&E, Clem Lee, 2011.

head pressure and suction pressure, aerators for wastewater ponds, dissolved oxygen, sensors for wastewater ponds, air compressor upgrades and replacements, and glycol pipe insulation.

The use of electrodialysis for wine processing emerged in California with a field demonstration project funded by the California Energy Commission's PIER program in the mid-2000s. Since then a viable private sector business was established offering the use of ion exchange membrane technology for both tartrate stabilization and pH adjustment. Winesecrets demonstrated an energy efficient tartrate stabilization system without refrigeration that resulted in energy savings of 139,200 kWh per year for a 600 gallon per hour unit operating 4,000 hours. At the time of the evaluation these savings represented $13,200 saved per year.[127] There is no evidence that this technology is eligible to participate in the PGE winery program.
The use of solar powered aeration pumps on wastewater discharge lagoons also emerged in the early 2000s. There is insufficient information to determine the extent to which wineries are purchasing solar pumps to replace electric power aeration pumps.

9.6 Summary of Observations

- Winegrape growers are encouraged to adopt water conservation practices to achieve conservation and improved varietal quality.

- Wineries have received significant attention from PG&E's Agricultural and Food Industry Energy Efficiency Program providing comprehensive products and services to achieve energy savings and efficiency improvements.

- Insufficient information is available to ascertain program participation rates, the rate of prescribed technology adoption and the technical potential for future energy savings. Considering that PG&E has designed and supported a targeted program, it is advisable to wait for a more comprehensive program evaluation to identify barriers to adoption or other improvements to the program offering.

- Both vineyards and wineries would benefit from efficiency programs that encourage overall energy savings, including liquid fuels and energy embedded in water, fertilizers, and agricultural chemicals. Encouraging The California Public Utilities Commission may consider these savings part of the total public good benefits.

- A resolution to the future cost of GHG emissions will support the desire to offer efficiency programs using a whole systems approach to resource utilization.

[127] California Energy Commission, Emerging Energy Technologies
http://www.energy.ca.gov/process/agriculture/loan_solicitation/02_ETabstracts.PDF

10 Post Harvest Processing

California's agricultural industry has achieved significant resource productivity gains in crop production and post harvest processing of vine, fruit and vegetable crops. These gains result from progressive disciplined adoption of improved varietals, best cultural practices, water management, and labor efficient harvest practices. The agricultural industry's partnership with the Land Grant University of California Cooperative Extension Service has advanced scientific post-harvest business management practices for fruits, vegetables, nuts and fiber crops.

Post harvest activities like cleaning, hulling and shelling, irradiation, drying, grinding, fumigation, and cold storage depend on the crop. Fresh market fruits and vegetables require fast cooling to preserve quality and shelf life; dried tomatoes, prunes, peaches and other vegetables and stone fruits are dried using passive solar practices or with the use of heat tunels. Grapes for raisins, figs and other fruits are dried using post harvest practices. Almonds are hulled and shelled post harvest and delivered to processing facilities for marketable products. Walnuts are dried and stored in-shell. Pistachios are hulled, roasted and also stored in-shell.

This section will evaluate post harvest activities in three section: cooling activities for fresh market fruits and vegetables, fruit and vegetable drying practices, and nut post harvest activities.

10.1 Post Harvest Cooling

California's fruit and vegetable crops are quickly cooled after harvest before shipping to consumer markets or refrigerated warehouses for storage. The process to achieve fast after harvest cooling of fruits and vegetables is paramount to ensuring produce safety and quality. Any delay to achieve fast cooling can result in quality deterioration because of water loss, excessive respiration rates and increased decay development.[128] Thompson confirms that companies in this industry would never entertain "delaying cooling to reduce peak period electricity use.[129]"

10.1.1 Industry Overview

California fruit and vegetable farms have improved in-field harvesting, sorting and cleaning to deliver boxed commodity for post harvest crop cooling. Melons, fruits and vegetables are grown in the Central Coast, San Joaquin Valley region, Imperial Valley and other production micro-climate regions. The largest proportion of fruits and vegetables are grown by a few large agricultural business companies like Tanimura & Antle, Mission Ranches, and Ocean Mist Farms. These farms are vertically integrated to operate year-round production systems utilizing land resources in both California and Arizona or shipping from northern Mexico.

10.1.2 Energy

The mobile trailer units that transport on-farm pre-cooling equipment are major energy end users. These units operate in the field before produce is delivered by refrigerated transport to centralized cold storage facilities. All cooling activities demand high peak electricity loads and consume significant hours of operation. Thompson and Singh report in their 2008 study *Status of Energy Use and Conservation Technologies Used in Fruit and Vegetable Cooling Operations in California* for the California Energy

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[128] Thompson, James and Singh, Paul (University of California, Davis) 2008. Status of Energy Use and Conservation Technologies Used in Fruit and Vegetable Cooling Operations in California. *California Energy Commission*, *PIER Program*. CEC-400-1999-00. http://ucce.ucdavis.edu/files/datastore/234-1165.pdf.

[129] Thompson and Singh, 2008

Commission that the use of these systems is highly energy intensive. Calculations from this report show that there are 150 half-car units carrying 350 horse power electric loads, with another 50 full-car units carrying 700 horse power electric loads.[130] The total load is calculated at about 66 MW from these post harvest cooling units and the annual power consumption is calculated with a base of 12 hours per day, during 220 days per year, operating at 50 percent utilization.[131] The report estimated total electricity consumption at about 87 GWh.[132] For 2006, the baseline year in the study, cooling and short-term storage of California's 17.7 million tons of fresh fruits and vegetables utilized 1.1 million kWh of electricity, calculated as representing 5.5 percent of the total electricity used by agriculture and 0.4 percent of the state's total consumption.[133]

10.1.3 Technologies

The post harvest cooling process can be improved in many ways. Some improvement opportunities to increase energy efficiency in post harvest cooling operations include[134]:

- Hydro-cooler pumps appear to operate at greater water flow than is needed for rapid cooling and research is needed to determine optimum water flow rates.
- Potential options for reduced electricity use in vacuum coolers include using a common refrigeration system for multiple vacuum tubes, minimizing the time water is sprayed in the water spray operation, using high-speed vacuum pumps, and installing direct expansion or flooded evaporators.
- Peak period electricity demand could be reduced by partial cooling certain items during the peak period and then finishing the cooling after the peak period ends. Based on a limited test, strawberries do not appear to be suited to two-stage cooling, but a number of other produce items are likely to be good candidates for this method. More research is needed to verify the list of fruits and vegetables that can withstand two-stage cooling.
- An option for reducing electricity demand without restricting the amount of product entering the cooler is to stop cooling when product reaches a temperature of 45° to 50°F. This temperature is not the final 32°-34°F temperature needed for most commodities, but it is much cooler than product temperatures at harvest that range from 70° to near 100°F.

Vacuum, forced air, liquid-ice cooling systems and hydro cooling technologies are commercially available. Thompson amd Singh report that the lettuce industry favors the use of precooling mobile vacuum systems equipped with water sprays. Most fruits and vegetables produced for fresh market are precooled. The 2008 report identified systems that integrate vacuum tube with utility trailers and are moved to cold storage locations to be grid connected. The survey also revealed that the systems installed in the Central Coast from April to November are moved to the south San Joaquin Valley regions of California and also to Yuma, Arizona during the winter months.[135]

The Thompson and Singh study identified several conservation options that have been used successfully in commercial facilities with different levels of market penetration, among them:

- Installing control software to maximize refrigerant suction pressure.
- Adding condenser heat exchange capacity with improved refrigerant discharge pressure control.

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130 Thompson and Singh, 2008
131 Thompson and Singh, 2008
132 Thompson and Singh, 2008
133 Thompson and Singh, 2008
134 Thompson and Singh, 2008
135 Thompson and Singh, 2008

- Adding speed control and using software for proper screw compressor sequencing.
- Applying high reflectivity surface coatings.
- High efficiency motors can save small amounts of electricity but only are cost effective for new installations and when equipment is replaced.

10.2 Post Harvest Drying

10.2.1 Industry Overview

California's dehydrated fruit and vegetable industry consists of dozens of dehydrating facilities working two to three months per year drying apricots, plums, raisins, and other fruits. "Dehydrated" fruits and vegetables are defined as food that has had the moisture content reduced to a level below which microorganisms can grow (8 to 18 percent moisture).[136] After harvest, fruit and vegetable crops are quickly cleaned, sorted and collected in drying trays for controlled drying process. The industry uses passive solar for dried tomatoes, blanching of vegetables, and forced air drying of plums using heat tunnels. Most of the equipment still used was installed in the 1960's and 1970's during the development of the dried fruit and vegetable industry. Cooperatives like Sun Sweet Growers are the predominant player with ten facilities to process dried fruits in the Central Valley Region. SunMaid Growers process grape raisins and Gills Onions is the largest onion processor in the state.

Issues

Companies have limited financial incentives, due to the short drying season, to invest in new energy efficient equipment to replace existing natural gas or propane powered heat tunnels. Some companies have purchased irradiation machines to process specialty products.

Opportunities

There is insufficient published information about energy efficiency opportunities for this industry. It may be appropriate to conduct surveys to assess the interest in energy management and technology adoption needs of this industry.

The Energy Commission's PIER program is funding a research project to develop and demonstrate an infrared dry-blanching and drying system for fruits or vegetables that results in high quality products. The sequential infrared and freeze-drying (SIRFD) method is estimated to reduce energy use by 40 percent compared to traditional freeze-drying methods. The simultaneous infrared dry-blanching and dehydration (SIRDBD) method eliminates the water or steam used in traditional blanching and reduces energy use.[137]

The California Air Resources Board funded the demonstration of solar crop drying systems at five commercial drying operations: Sunsweet Growers drying prunes; Carriere & Sons and Keyawa Orchards drying walnuts; Korina Farms drying pecans; and Sonoma County Herb Exchange drying herbs. The energy savings and economic benefits of these demonstration projects cannot be determined with currently available information.

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[136] Midwest Research Institute 1995. Emission Factor Documentation for AP-42: Dehydrated Fruits and Vegetables. Research Triangle Park, North Carolina: *US Environmental Protection Agency*. EPA contract number 68-D2-0159. http://www.epa.gov/ttnchie1/ap42/ch09/bgdocs/b9s08-2.pdf

[137] US Department of Food and Agriculture 2011. New Energy Efficient Infrared Drying and Blanching Technologies for Fruits and Vegetables. *California Energy Commission.* PIER Program Grant Award Number. PIR-09-005. http://www.esource.com/esource/getpub/public/pdf/cec/CEC-FS-5_InfraredDryingBlanching.pdf

10.2.2 Energy

Accesible energy use data for dehydrator companies is lacking. A companion study to the Thompson 2008, for post harvest cooling is not available for fruit and vegetable dehydrators. The customer data provided by IOU sources will be searched to aggregate relevant information from this industry.

Waste as Energy

Post-harvest drying operations generate significant low moisture organic solid residues and limited waste water discharges. Companies have to acquire land discharge permits from their Regional Water Quality Control Boards to dispose of wastewater. These residues can be converted to bioenergy using anaerobic digestion technologies. Companies are adopting sustainability practices to reduce production waste by-products. Sunsweet Growers is reducing the amount of packaging used in their products, recycling all packaging waste, glass, fiber and cans, utilizing energy-efficient lighting and steam power in their factory facilities and developing ways to utilize production residues. These residues are currently used in composting and feed for livestock.[138]

10.2.3 Technologies

More efficient modern equipment is available to optimize the post harvest blanching and drying process. The Ernest Orlando Lawrence Berkeley National Laboratory (LBNL) conducted an ENERGY STAR®, evaluation of energy efficient measures for blanching and drying technologies and practices.[139]

Energy Efficiency Measures for Blanching

Blanching equipment may have a useful life of 15 years or more.[140] The replacement of old steam blanchers with new, more efficient designs can typically lead to significant energy savings. Most modern steam blanchers are equipped with design features that help to retain heat, minimize steam losses, and efficiently circulate heat throughout the product stream. Common energy efficiency features of modern steam blanchers include:[141]

- Steam seals, which help to minimize steam leakage at the blancher entrance and exit. Typical types of steam seals include water spray curtains at the blancher entrance and exit, hydrostatic seals that enclose the steam chamber, and rotary locks.
- Insulation of the steam chamber walls, ceiling, and floor to minimize heat losses.
- Forced convection of steam throughout the product depth using internal fans or steam injection, which provides more efficient and even heating of product and helps to reduce blanching times.
- Process controls that optimize the flow of steam based on such variables as product temperature, blanching time, and product depth.
- Recovery of condensate for use in water curtain sprays or for product cooling.

Other heat and hold techniques are included in the LBNL report.[142] In traditional blanching, products are continuously subjected to the heating medium until a specified product core temperature is reached. In contrast, blanchers using the heat and hold technique expose products to just the minimum amount of steam required for blanching, via the use of a heating section and a holding section. In the

[138] Sunsweet. "Sunsweet Growers: Green Efforts." Modified 2011. http://www.sunsweet.com/about/green.html
[139] Masanet, Eric, Worrell, Ernst, Graus, Wina and Galitsky, Christina (Ernst Orlando Lawrence Berkeley National Laboratory) 2008. Energy Efficiency Improvement and Cost Saving Opportunities for the Fruit and Vegetable Processing Industry. *US Environmental Protection Agency*. Publication number LBNL-59289. http://www.energystar.gov/ia/business/industry/Food-Guide.pdf
[140] Lung, 2006 as cited in Masanet, 2008
[141] Rumsey, 1986a, FMCITT, 1997 and FIRE, 2005f as cited in Masanet, 2008
[142] Masanet, 2008

heating section, products are exposed to just enough steam to heat the surfaces of the product to the necessary temperature for blanching. The product then proceeds to an adiabatic holding section, in which the product's surface heat is allowed to penetrate to its core, which raises the entire product to the required blanching temperature without the use of additional steam. Heat and hold blanchers have been reported to reduce blanching times by up to 60 percent and blanching energy intensity by up to 50 percent.[143]

> **CASE STUDY**: **Stahlbush Island Farms.**[144] In 2003, Stahlbush Island Farms, a grower, canner, and freezer of fruits and vegetables in Corvalis, Oregon, replaced an aging and inefficient blancher used for processing pumpkins with an ABCO heat and hold blancher. In addition to heat and hold features, the ABCO blancher also incorporated curtains and water sprays to minimize steam losses, a condensate recovery system, an internal steam recirculation system, a fully insulated steam chamber, and programmable logic controls. Stahlbush Island Farms reported annual natural gas savings of 29,000 therms (a 50 percent reduction compared to their previous blancher) and $16,000 in annual energy savings.[145] Project costs (which included the blancher, a feed conveyor, and a vibratory shaker) totaled $202,000, and with an Oregon energy efficiency tax credit of $70,855, the final simple payback period was 8 years.

Heat Recovery from Blanching Water or Condensate
Heat can be recovered from the discharge water of hot water blanchers via a heat exchanger. Similarly, in steam blanchers where condensate is not recycled internally, it might be possible to recover heat from the hot condensate exiting the blancher. Where fouling is manageable, in both cases heat can be recovered using a heat exchanger and used to pre-heat equipment cleaning water or boiler feed water.[146] Steam Recirculation. Some steam blanching systems with forced convection also are capable of recirculating and reusing the steam that does not condensate on the product at first pass, thus reducing the steam inputs into the blanching chamber.

The U.S. DOE sponsored the development of the Turbo-Flo blancher, which features a steam recirculation system in addition to hydrostatic seals, a fully insulated steam chamber, and blanching process controls. As of 2002, 40 units have been installed in food processing facilities in the United States. Reser's Fine Foods, an Oregon based processor of vegetables and specialty foods, has installed five Turbo-Flo blanchers at its processing facilities. According to the company, the Turbo-Flo blancher at its Beaverton, Oregon, facility increased product throughput by 300 percent while reducing the floor space required for blanching dramatically. At the California Prune Packing Company in Live Oak, California, a TurboFlo blancher installed in 1997 was reportedly four times more efficient than its predecessor.[147] Estimated payback periods are under two years.[148]

Energy Efficiency Measures for Drying and Dehydrating

143 Rumsey, 1986a and FIRE, 2005f as cited in Masanet, 2008
144 Masanet, 2008
145 FIRE, 2005f as cited in Masanet, 2008
146 Lund, 1986 as cited in Masanet, 2008
147 CADDET 2000b as cited in Masanet, 2008
148 U.S. 2002e as cited in Masanet, 2008

- **Maintenance.** Improper maintenance of drying and dehydrating equipment can increase energy consumption by up to 10 percent.[149] An effective maintenance program should include the following actions, which should be performed on a regular basis[150]:
  - Checking burner and combustion efficiency.
  - Checking heat exchangers for fouling, excessive pressure drops, and leaks.
  - Cleaning filters at fans.
  - Checking for belt slippage and fan speeds.
  - Avoiding air leaks through checks and repairs of doors and seals.
  - Checking and repairing insulation on burners, heat exchangers, duct work, and the body of the dryer.
  - Checking thermocouples and humidity sensors for fouling.
  - Monitoring heat transfer efficiency.
  - Ensuring that fuel and air ports and flues are clear of debris.
  - Checking and repairing utility (i.e., steam, natural gas, and compressed air) supply lines.

- **Insulation.** Any hot surfaces of drying equipment that are exposed to air, such as burners, heat exchangers, roofs, walls, ducts, and pipes, should be fully insulated to minimize heat losses. Insulation should also be checked regularly for damage or decay. Different insulation materials such as mineral wool, foam, or calcium silicate can be applied to various drying system components, depending on temperature.[151] Foam can be used for low temperature insulation while ceramics are useful under high temperature conditions.

- **Mechanical Dewatering.** Mechanical dewatering of fruits and vegetables prior to drying can reduce the moisture loading on the dryer and save significant amounts of energy. As a rule of thumb, for each 1 percent reduction in feed moisture, the dryer energy input can be reduced by up to 4 percent.[152] Mechanical dewatering methods include filtration, use of centrifugal force, gravity, mechanical compression, and high velocity air.[153]

  CASE STUDY: **British Sugar part 1.**[154] At the British Sugar beet factory in Wissington, England, six screw presses were employed to mechanically dewater wet beet pulp prior to dehydration in a rotary dryer. Each screw press had specific energy use of 23 kilojoules (kJ)/kg of water removed, compared to a specific energy use of 2,907 kJ/kg for the rotary dryer. By using the six screw presses for mechanical dewatering, British Sugar found that its energy costs in drying the beet pulp were 40 times less than they would have been if they had used the rotary dryers alone.

- **Direct Fired Dryers.** Direct fired dryers are generally more energy efficient than indirect heated dryers, because they remove the inefficiency of first transferring heat to air and then transferring heat from air to the product. Direct fired dryers can reduce primary fuel use by 35 percent to 45 percent compared to indirect (i.e., steam-based) heating methods.155

[149] ISU 2005 as cited in Masanet, 2008
[150] ISU 2005, BEE 2004, Traub 1999b and EEBPP 1996 as cited in Masanet, 2008
[151] BEE 2004 as cited in Masanet, 2008
[152] [152] BEE 2004 as cited in Masanet, 2008
[153] ISU Extension 2005, as cited in Masanet, 2008
[154] EEBPP 1996 as cited in Masanet, 2008
[155] BEE 2004 and ISU 2005 as cited in Masanet, 2008

- **Exhaust Air Heat Recovery.** A simple form of heat recovery in retrofit applications is to utilize the exhaust air of a dryer to preheat the inlet air stream, thereby saving energy. The success of this measure depends on the available space for additional duct work near the dryer.[156] Either the exhaust air can be directly injected into the inlet air stream, or a recuperation (i.e., heat exchanger) system can be employed to indirectly heat the inlet air stream using exhaust air.[157] In the former approach, the saturation of the exhaust air might limit the effectiveness of heat recovery (highly saturated exhaust air may raise the humidity of incoming air and reduce its drying capacity).[158] If there is not sufficient room for additional duct work around the dryer, heat can be recovered from exhaust gases using "run-around coils," which contain a heating medium such as water to transfer heat to the inlet air stream via a heat exchanger.[159]

- **Using Dry Air.**: The use of dry air reduces the amount of moisture in the air that requires heating and vaporization. Thus, by removing this moisture, the heating load on the dryer is reduced. Air can be dried using desiccants or dehumidifying techniques, but, in general, this measure is only practical for dryers with small volumes of air.[160]

- **Heat Recovery from the Product.** In cases where products are deliberately cooled using forced air after drying, it might be feasible to recycle the resulting warm air, either directly into the dryer or through a heat exchanger to preheat the inlet air stream.[161] However, for products that don't require cooling, the cooling fan and heat recovery system cost might be greater than the energy cost savings associated with the recovered heat.[162]

- **Process Controls.** Process controls, such as feedback controllers, feed forward controllers, and model-based predictive controllers, can help to minimize dryer energy consumption by more precisely controlling energy inputs to meet the needs of the product being processed. Common sensors used in drying process control include thermocouples and resistance thermometers (for air temperature), infrared pyrometers (for product surface temperatures), and wet-bulb and dry-bulb thermometers, resistance sensors, and absorption capacitive sensors (for air humidity).[163]

> **CASE STUDY**: **British Sugar part 2.**[164] At the British Sugar beet sugar factory in Wissington, England, sugar is extracted from the beets and the remaining spent beet pulp is dried using rotary dryers to produce cattle feed. The company chose to install a model-based predictive control system to more accurately control the process performance of its rotary dryers. Following installation, the company reported saving £32,900 per year ($54,290 in 1997 U.S. dollars), which was comprised of £18,900 ($31,185 in 1997 U.S dollars) in dryer energy savings and £14,000 ($23,100 in 1997 U.S

156 ISU 2005 as cited in Masanet, 2008
157 EEBPP, 2996 as cited in Masanet, 2008
158 Traub, 1999a as cited in Masanet, 2008
159 ISU Extension, 2005 as cited in Masanet, 2008
160 Traub, 1999b as cited in Masanet, 2008
161 EEBPP, 1996 as cited in Masanet, 2008
162 Traub, 1999b as cited in Masanet, 2008
163 CADDET, 1997b, ISU Extension, 2005, and BEE, 2004 as cited in Masanet, 2008
164 Masanet, 2008

dollars) per year in downstream energy cost savings.[165] Furthermore, increased yields boosted savings by another £61,600 ($101,640 in 1997 U.S dollars) per year, enabling a payback period of just 17 months.

10.3 Post Harvest Nut Hulling and Shelling

10.3.1 Industry Overview

California's almond industry produced some 800,000 tons of almonds in 2009, harvested between August and December.[166] The Counties of Kern, Fresno, Stanislaus, Merced and Madera combined produce 77.4 percent of the state's almond crop. An additional 432,334 tons of walnuts were also produced in 2009.[167]

There is a large infrastructure of small and medium sized huller and nut processing facilities and a few large nut handlers that process these crops. Hulled and shelled almonds are further processed at product manufacturing facilities. Walnuts are dried and stored in-shell at fumigated warehouses or non-fumigated refrigerated facilities.

10.3.2 Energy

Accessible energy use data for nut hulling and shelling facilities is lacking. A companion study to the Thompson 2008, for post harvest cooling is not available for nut processing. The customer data provided by IOU sources will be searched to aggregate relevant information from this industry.

Waste as Energy

The process to hull and shell almonds generates significant low moisture organic residues that could be used for bioenergy generation. However, almond hulls are a valued animal feed commodity to dairyman and not readily available for bioenergy conversion.[168] Almond Shells can be burned at biomass power plants for energy, manufactured into fire place logs, used as glue filler for laminate board, or used as raw material for other wood board production. Dairy farms also use shells for animal bedding.

Walnut hulls are not collected or used for animal feed but shells are supplied to biomass power plants and for industrial abrasives. Walnut growers and processors are interested in the use of walnut shells to fuel distributed generation bioenergy systems using thermo-chemical conversion technologies. Senate Bill 489, the Renewable Energy Equity Act, if signed by the Governor, would "enable all eligible renewable energy types, including biomass and gas, to utilize California's Net Energy Metering program, which allows customers to offset some of their power usage with the energy they generate on site."[169]

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165 CADDET 1997b as cited in Masanet, 2008

166 Almond Board of California 2010. *The 2010 Almond Almanac*. http://www.almondboard.com/AboutTheAlmondBoard/Documents/2010%20Almanac%20FINAL.pdf

167 National Agricultural Statistics Service 2010. 2009 California Walnut Acreage Report. Sacramento, Calif.: *United States Department of Agriculture*. http://www.walnuts.org/tasks/sites/walnuts/assets/File/2009_California_Walnut_Acreage_Report.pdf

168 Amon, Ricardo 2011. "California Food Processing Industry Organic Residue Assessment." *California Biomass Collaborative.* Unpublished.

169 California State Senate Majority Caucus. "Clean, Renewable Energy." Modified 2011. http://sd05.senate.ca.gov/issues/clean-renewable-energy

10.3.3 Technologies

This Literature Review did not find information related to energy efficiency technologies for post harvest drying. Solar drying technologies are available for this segment.

10.4 Utility Programs

There was no information on utility programs specifically targeting this segment. Efficiency programs offering rebates for motors and VFD systems may apply for these customers.

10.5 Summary of Observations

Post Harvest Cooling

The accumulated effect of utilizing best practices and adopting continuous improvements deliver a highly productive agricultural industry. Post harvest being a critical link in the production chain to ensure quality, safety and marketability. Thompson's 2008 study identifies several areas for further research that hold potential for electricity use reduction in the use of post harvest coolers:

- Determining the minimum water flow needed in hydro-coolers.
- Optimizing airflow rates and reducing pressure drop in forced-air coolers.
- For vacuum coolers:
    - Using a common refrigeration system for multiple vacuum tubes.
    - Minimizing the time water is sprayed in the water spray operation.
    - Using high-speed vacuum pumps.
    - Installing direct expansion or flooded evaporators.

Post Harvest Drying

There is limited knowledge about post harvest drying energy use, potential for energy conservation or adoption rate of emerging technologies. Customer or county-based utility data is not available to assess electricity and natural gas consumption in this industry. Additional surveys or data mining efforts will be required to more completely characterize this industry.

Post Harvest Nut Hulling & Shelling

There is insufficient information to evaluate gaps and efficiency opportunities in this sub-segment. Research should be conducted to further understand energy use and efficiency improvement opportunities.

11 Appendix

To date, Navigant has identified the following California agriculture sector evaluations and reports related to and completed for the IOU's agricultural sector energy efficiency program offerings:

- Process Evaluation of PG&E's Agricultural and Food Processing Program, PG&E, *The Cadmus Group in collaboration with Nexus Market Research, Research Into Action, and Strategic Energy Group*, 2009
- 2006-2008 Evaluation Report for the Southern California Industrial and Agricultural Contract Group, CPUC, *Itron, Inc. with ASW Engineering, Energy and Resources Solutions, Energy Metrics, Helios Resources, Jai J Mitchell Analytics, Michael Engineering, PWP Inc., Katin Engineering, SDV/ACCI, and Warren Energy Engineering*, 2009
- Evaluation of the Certified Agri-Food Energy Efficiency (CAFEE) Program- 1473-04, for Global Energy Partners, *Quantec LLC*, 2006
- Evaluation, Measurement and Verification Report, California Multi Measure Farm Program, 1354-04 and 1360-04, California Public Utilities Commission and EnSave, Inc, *kW Engineering*, 2007
- Evaluation of the Center for Irrigation Technology, 2004-2005 Agricultural Pumping Efficiency Program, *Equipose Consulting, Inc. with California AgQuest Consulting, Inc., Ridge & Associates, and Vanward Consulting*, 2006
- Southern California Edison Company's Evaluation Measurement & Verification of the 2002 Pump Test and Hydraulic Services Program, SCE, *Equipose Consulting, Inc. in conjunction with Ridge & Associates, Vanward Consulting, and California AgQuest Consulting Inc.*, 2003
- Impact Evaluation of PG&E's 1997 Agricultural Programs Energy Efficiency Incentives Program: Pumping and Related End Use (Study ID 335A), Refrigeration End Use (Study IS 335B) and Greenhouse Heat Curtain End Use (Study ID 335C), *Equipoise Consulting with California AgQuest Consulting and Dr. Kirtida Parikh*, 1999
- 1997 Agricultural Energy Efficiency Incentives Program, First Year Load Impact Evaluation Final Report, Study ID 1022, San Diego Gas & Electric, *Xenergy, Inc.* 1999
- 1997 Agricultural Energy Efficiency Incentive Program Impact Study, Study ID 569, Southern California Edison, *Alternative Energy Systems Consulting, Inc. with Ridge & Associates, and KVDR, Inc.*, 1999

Table 15 provides a summary of existing and historical programs offered by the IOUs that target the agriculture industry in general. Segment specific programs are provided within the specific sections of this Report. Measures offered through the IOU's non-residential programs, custom and deemed, may also be available for agriculture customers.

Table 15. Existing & Historical IOU Programs for the Agriculture Sector

Program Name	Program Cycle	Program Offerings	Notes

PG&E's Agriculture & Food Processing Programs – Core Program[170]	Ongoing	Incentives, Energy Audits, Pump Testing, Engineering Support & Design Assistance, Energy Modeling Tools, Commissioning & Retrocommissioning Assistance, Access to market resources & benchmarking information	• The "Core Program" embodies PG&E's primary agricultural energy efficiency efforts • Applicable Segments: Agriculture; Dairies; Food Processing; Greenhouses; Irrigation; Refrigerated Warehouses; Wineries
PG&E's Industrial Refrigeration Performance Plus[171]	Ongoing	Retrofit of existing buildings, improvements of refrigeration systems, lighting, envelope, pumping, air handling	• Partnership with VaCom • Applicable Segments: Cold Storage & Food Processing (large facilities)
PG&E's Combined Approach to Solar and Efficiency (CASE) Program[172]	Ongoing	Large-scale solar power systems, energy balance analyses, industry benchmarking, equipment retrofits, project management services	• Partnership with SunPower Corporation • The project reported no savings in the 2006-2008 Program Cycle • Applicable Segments: General agriculture
PG&E's Industrial Cold Storage/Food Processing Efficiency Program[173]	2006-2008	Audits, cash incentives for completed projects; refrigeration retrofits, lighting retrofits for T-5 fluorescents, VFDs on process pumps and fans, compressed air systems	• Applicable Segments: Refrigerated Warehouses & Food Processing
PG&E's Certified Agri-Food Energy Efficiency (CAFEE) Program[174]	2004-2006	Educational activities, on-site energy audits, incentives and post-installation certification of measures	• 2004-2006 Cycle: Program implementers contacted 639 targeted customers to inform them of the program. Installers intended to conduct 73 customer energy audits and verify 73 installations. In actuality, they performed 72 energy audits and verified 63 installations. In actuality, they performed 72 energy audits and verified 63 installations. All claimed savings were achieved for the projects sampled. • Applicable Segments: All agricultural sectors

[170] Rock, Kerstin and Wong, Crispin (The Cadmus Group). 2009. *Process Evaluation of PG&E's Agriculture and Food Processing Program*. Portland, Oregon: Pacific Gas and Electric Company. CALMAC Study ID PGE0276.0. http://www.calmac.org/publications/PG%26E_AG_and_FP_Report_20090727.pdf; http://www.calmac.org/publications/PG&E_AFPEvaluation_Appendix.pdf

[171] Equipose Consulting, Inc. 2006. *Evaluation of the Center for Irrigation Technology, 2004-2005 Agricultural Pumping Efficiency Program*. California Public Utilities Commission. Publication No. 1418-04, 1428-04, 1434-04. http://www.calmac.org/publications/CIT_APEP_2004_2005_Final_Impact_Report_V2.pdf

[172] Rock, Kerstin and Wong, Crispin (The Cadmus Group). 2009. *Process Evaluation of PG&E's Agriculture and Food Processing Program*. Portland, Oregon: Pacific Gas and Electric Company. CALMAC Study ID PGE0276.0. http://www.calmac.org/publications/PG%26E_AG_and_FP_Report_20090727.pdf; http://www.calmac.org/publications/PG&E_AFPEvaluation_Appendix.pdf

[173] Rock, Kerstin and Wong, Crispin (The Cadmus Group). 2009. *Process Evaluation of PG&E's Agriculture and Food Processing Program*. Portland, Oregon: Pacific Gas and Electric Company. CALMAC Study ID PGE0276.0. http://www.calmac.org/publications/PG%26E_AG_and_FP_Report_20090727.pdf; http://www.calmac.org/publications/PG&E_AFPEvaluation_Appendix.pdf

[174] Lee, Allen, Seiden, Ken, Ogle, Rick and Wish, Sara (Quantec, LLC) 2006. Evaluation of the Certified Agri-Food Energy Efficiency (CAFEE) Program – 1473-04. Portland, Oregon: *Global Energy Partners*. http://www.calmac.org/publications/CAFEE_Report_091806_Final.pdf

2004-2005 IDEEA Constituent Program Evaluations[175]	2004-2005	Various programs. Agricultural activities included the Agricultural Ventilation Efficiency activity and the Refrigerated Warehouses activity	• Agricultural Ventilation Efficiency activity (livestock industries): program did not meet its kWh and kW goals. The technology was slow to penetrate the ag community, although post-installation satisfaction was high • Refrigerated Warehouse activity: Five measures were offered, the program met its energy savings goals and expended all available incentives to fund the projects (only 4 participants) - the kWh realization rate was 104% and kW realization rate was 100%
Agricultural Pumping Programs			
SCE's Pump Test and Hydraulic Services Program[176][177]	Ongoing	Free efficiency tests for water pumping services	An evaluation in 2002 showed 41 percent of the 64 participants surveyed made changes to improve their pumping system efficiency, 27 percent of the participants represent free-ridership. 91% of pump test customers, 58% of energy efficiency contact customers and 54% of nonparticipants were aware of the Program prior to 2002 (31% of surveyed non-participants were not aware of the program and had not had their pumps tested prior to 2000) Applicable Segments: All sectors with irrigation requirements
PG&E, SoCalGas & SCE's 2004-2005 Agricultural Pumping Efficiency Program (APEP I & II)[178]	Ongoing	Education and financial incentives to promote the installation & maintenance of high efficiency pump systems	Now Advanced Pumping Efficiency Program.[179] "The APEP II program provided a little over two-thirds of expected net electric energy impacts, exceeded the net therm impacts by 50 percent and completed 76 percent of the pump tests planned." Applicable Segments: All sectors with irrigation requirements

[175] Bronfman, Ben and West, Anne (Quantec) 2008. Southern California Edison 2004-2005 IDEEA Constituent Program Evaluations. Portland, Oregon: *Southern California Edison*. Report number SCE0234.01. http://www.calmac.org/publications/IDEEA_Constituent_Program_Evaluations_-_Vol_1_FINAL_072808.pdf; http://www.calmac.org/publications/IDEEA_Constituent_Program_Evaluations_-_Vol_2_FINAL_AppendicesES.pdf

[176] Cullen, Gary, Swarts, Deborah and Mengelberg, Ulrike (Summit Blue Consulting) 2009. Process Evaluation Report for the SCE Agricultural Energy Efficiency Program. Irwindale, Calif.: Southern California Edison. CALMAC Study number SEC0287.01. http://www.calmac.org/warn_dload.asp?e=0&id=2721

[177] Itron, Inc. 2010. *2006-2008 Evaluation Report for the Southern California Industrial and Agricultural Contract*. San Francisco, Calif.: California Public Utilities Commission. Publication No. CPU0018.01. http://www.calmac.org/publications/SCIA_06-08_Eval_Final_Report.pdf

[178] Equipose Consulting, Inc. 2006. *Evaluation of the Center for Irrigation Technology, 2004-2005 Agricultural Pumping Efficiency Program*. California Public Utilities Commission. Publication No. 1418-04, 1428-04, 1434-04. http://www.calmac.org/publications/CIT_APEP_2004_2005_Final_Impact_Report_V2.pdf

[179] http://www.pumpefficiency.org/