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Attachment 2:

Industrial/Agricultural Market Saturation Study

2021 Potential and Goals Study

Prepared for:

California Public Utilities Commission

Submitted by:

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Summary

The California Public Utilities Commission (CPUC) sets energy efficiency (EE) goals for the California's major investor-owned utilities (IOUs). To inform this goal-setting process, the CPUC conducts a Potential and Goals Study (PG Study), which forecasts the remaining future opportunity for EE in IOU service territories. The PG Study requires data on the current conditions of the market as a key input. The CPUC requires recent, California-specific market data to increase the accuracy of the PG Study forecast.

Background and Objectives

The CPUC conducted public workshops in October 2019 and identified a need to fill key gaps in the industrial and agricultural sectors to improve future PG studies.

This Industrial/Agricultural Market Saturation Study meets the identified need by collecting primary data on the industrial and agricultural sectors. The study focused on six prioritized industrial and agricultural subsectors. Within these subsectors, the study further focused on three technologies/systems with the greatest potential for future energy savings.

The research objectives for this study include:

- Quantifying the market saturation of these selected technologies/systems.
- Collecting other information about these selected technologies/systems useful for the industrial/agricultural component of the PG Study model, including:
    - Average energy savings.
    - Proportion of facility energy consumption impacted by these EE technologies/systems.
    - Percentage of applications where the technology/systems might not be suitable.
- Determining factors that prevent the wider adoption of the EE measures, including whether customers opt for other energy investments such as self-generation.
- Collecting information about industrial and agricultural customers, such as their willingness to adopt EE technologies with and without program interventions, and their interest in demand responses programs, that was used for other parts of the PG Study model or by other teams conducting studies for the CPUC.

The Approach

The Industrial/Agricultural Market Saturation Study's data collection strategy involved gathering a variety of market actor perspectives and secondary sources. This strategy guided the team's development of the study because it illuminated the EE technology role in targeted California industrial and agricultural markets. Primary and secondary information sources included:

- **Subsector expert interviews:** The market study team completed in-depth interviews with 60 individuals with specialized knowledge of energy consumption patterns and energy savings potential in the six California industrial and agricultural subsectors. These experts included program evaluators and implementers, specialists from the federal energy labs, California university professors who study EE, and representatives from the California Program Administrators (PAs) who help deliver programs in the targeted subsectors.

- **Equipment vendor interviews:** The team completed in-depth interviews with 61 vendors who sell the specific EE technology/systems this study targets to the six prioritized California industrial and agricultural subsectors.
- **End user interviews:** The team completed in-depth interviews with 50 California industrial and agricultural customers who operate in these subsectors.
- **Literature/database review:** The team completed a literature review of published reports and databases that provide information on energy consumption patterns and energy savings potential in the six targeted California industrial and agricultural subsectors.

California's industrial and agricultural sectors are so large and diverse that it would have been impossible to study them both broadly and deeply within the study's budget limits. Historically, previous attempts to study these California sectors experienced challenges in recruiting participants. For these reasons, the market study team instead chose to explore three industrial and three agricultural subsectors. The six subsectors selected were Electronics Manufacturing, Food Production, Chemical Manufacturing, Dairies, Water Pumping for Agriculture, and Greenhouses. The main criterion for selecting these subsectors was their contribution to California's future energy consumption as measured by forecasts coming from the California Energy Commission's (CEC's) Integrated Energy Policy Report (IEPR) model.[1]

The next step required identifying the three most promising EE measures for each of the six subsectors. The team conducted both a literature/database review and in-depth interviews with subsector experts to identify:

1. Which technologies/systems use the most energy in these industrial/agricultural subsectors
2. Which technologies/systems have the greatest potential for future energy savings

The market study team identified 18 promising EE measures from the literature review and the expert interviews.

Subsequent project steps included vendor and end user interviews to further answer the research objectives. These interviews contributed a representative outlook of the targeted subsectors, informing the team's understanding of each subsector's challenges, existing conditions, and potential for EE.

The final step involved using information from the Industrial/Agricultural Market Saturation Study about energy savings, technology density, technology efficiency level, and technical suitability as key PG Model inputs. The PG Model team used the findings from the Industrial/Agricultural Market Saturation Study as inputs to the industrial and agriculture measure characterization in the model. The saturation study provided 18 new characterizations for the model. In some cases, this involved the introduction of an EE measure that had previously not been in the model (e.g., low pressure drop HEPA/ULPA filters). In other cases, the measure was already in the model, but at a higher level of aggregation and the Industrial/Agricultural Market Saturation Study allowed the EE measure to be

[1] IEPR: 2017 Ag-Com-Ind 6-digit North American Industry Classification System data by IOU from the CEC.

modelled at a finer level. For example, heat recovery in the Chemical Manufacturing sector could now be modelled separately from more generic heat recovery.

Summary of Key Findings and Recommendations

Key findings from the Industrial/Agricultural Market Saturation Study include the following:

- **Selected measures offer the promise of significant energy savings:** The market study team asked equipment vendors to estimate the average energy savings for the equipment or services they sell. Vendors reported average end use energy savings estimates over 30 percent for five of the selected measures and average energy savings estimates over 20 percent for five others. All 17 measures for which the vendors provided savings estimates had double-digit levels of end use energy savings. The market study team experts review of the savings estimates are in line with their experience and the literature.[2]
- **Opportunities for improved customer education:** With respect to the EE technologies most relevant for their industries, only 20 percent of the chemical manufacturing end users were familiar with the advanced automation and optimization measure and only 40 percent of the electronics manufacturing end users were familiar with the chiller-plant optimization measure. In addition, only 57 percent of the chemical manufacturing end users were familiar with VFDs and 60 percent of the water pumping for agriculture customers were familiar with the sensors and controls measure.
- **Sizable opportunities for EE improvements exist in the industrial and agricultural subsectors:** Table 1 shows the measure saturation estimates from the end users and the vendors as well as the averages of the two estimates The table shows that only one of the 17 EE measures had saturation levels above 60 percent and seven of the measures had saturation levels below 40 percent. Saturation describes the percent of applicable equipment that is energy efficient.
- **Common factors/barriers constraining EE measure implementation:** The most common factors/barriers across all the subsectors were concerns about disrupting production, concern about the initial cost of EE measures, and lack of knowledge of EE measures and benefits. The market study team also asked the EE vendors whether the investments their customers make in EE compete with other energy management decisions or technologies. Most of the vendors said there was competition, but they had differing opinions as to the degree of competition.

Table 1: EE Measure Saturation

Subsector	EE Measure	End User Estimates	Vendor Estimates	Average Estimate
Electronics	Chiller plant optimization	6%	24%	15%

[2] While it was possible that some vendors might exaggerate the energy savings benefits of the technologies or services they sell, the market study team tried to mitigate these potential biases by: 1) comparing the energy savings estimates provided by the vendors with energy savings estimates from the literature review (where available), 2) comparing the energy savings estimates across multiple vendors to better identify and reject any outlier estimates, 3) asking the vendors for the sources and basis of their energy savings estimates, and 4) relying on the experience and professional judgement of the DNV GL and Guidehouse engineers as “reality checks” for these estimates.

Subsector	EE Measure	End User Estimates	Vendor Estimates	Average Estimate
Manufacturing	Retro-commissioning (RCx)	44%	No estimates provided[3]	44%
	Low pressure drop cleanroom filters	39%	36%	38%
Food Production	Refrigeration system optimization	62%	24%	43%
	Boilers and heat recovery	19%	11%	15%
	VFDs on pumps and motors	68%	No estimates provided	68%
Chemical Manufacturing	Heat recovery	30%	12%	21%
	Advanced automation and optimization	29%	33%	31%
	VFDs	40%	51%	46%
Dairies	Refrigeration system heat recovery	19%	29%	24%
	VFDs on pumps	31%	32%	32%
	EE fans and ventilation	62%	48%	55%
Water Pumping for Agriculture	Efficient pumps and motors	63%	42%	53%
	Sensors and controls	59%	44%	52%
Greenhouses	LED grow lights	38%	41%	40%
	EE HVAC	42%	46%	44%
	Energy Curtains	42%	60%	51%

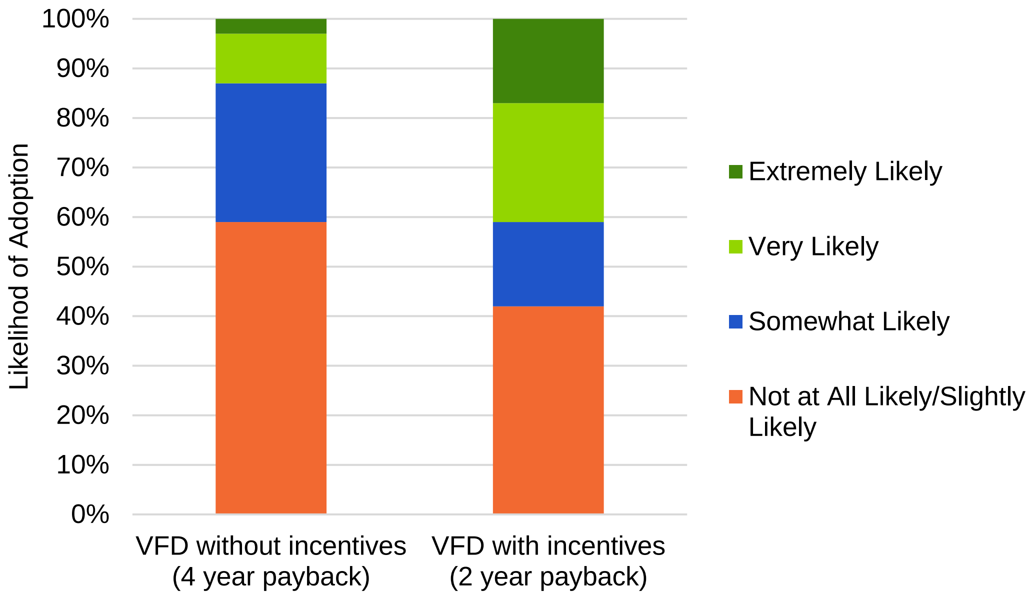
Source: DNV GL Analysis

- **Program participation was low in the Food Production and Water Pumping for Agriculture subsectors:** While rebate awareness was high across all subsectors, program participation was low in the Food Production (27 percent of respondents) and Water Pumping for Agriculture (30 percent of respondents) subsectors.
- **EE incentives can be very influential:** The market study team provided end users with information about the incremental costs of high-efficiency boilers and variable frequency drives (VFDs) as well as their potential energy savings and payback periods. End users responded about their willingness to purchase such equipment if program EE incentives reduce these payback periods. Figure 1 shows that when the incentives reduced payback period for VFDs from four years to two years, the likelihood of adoption increased significantly.

[3] While no vendor provided precise market estimation estimates for RCx, one gave the estimate "less than half" and another RCx vendor said: “Not seeing a lot of RCx in electronics manufacturing. Done a lot of [RCx in] labs, but not in semiconductor facilities.” Other vendors said the market saturation for RCx was difficult to estimate because there was a wide range of RCx actions that facilities could take and that it was “too binary” to ask about RCx vs. no RCx when there were meaningful differences in the level of RCx activity that must be accounted for.

This may be related to the finding from the end user interviews that the median payback period was 3.5 years as the threshold for their companies approving EE projects. Fifty-six percent of the companies with threshold payback periods had periods of 3.5 years or less.

Figure 1: The Influence of EE Incentives on Likelihood of VFD Adoption



Source: DNV GL Analysis

- **Higher agricultural solar installations than in the industrial subsectors:** The market study team asked end users if they had onsite generation and, if they did, what type it was. End users in the Water Pumping for Agriculture subsector reported the highest frequency of solar installations at 60 percent of respondents in that subsector. Other subsectors ranged from 10 to 36 percent as Table 2 shows.

Table 2: Solar Saturation by Subsector

Subsector	% of End Users with Solar Installations
Electronics Manufacturing	10%
Food Production	36%
Chemical Manufacturing	14%
Dairies	25%
Water Pumping for Agriculture	60%
Greenhouses	25%

Source: DNV GL Analysis

- **Demand response participation was low except for the Water Pumping for Agriculture subsector:** The market study team asked the end users if they had participated in a demand response program. End users in the Water Pumping for Agriculture subsector reported the highest frequency of demand response program participation (60 percent) compared to 0-25 percent for the other five subsectors (Table 3). The California PAs have long offered time-of-use rates and programs for customers with water pumps.

Table 3: Demand Response Participation by Subsector

Subsector	% of End Users Participating in Demand Response Programs
Electronics Manufacturing	10%
Food Production	18%
Chemical Manufacturing	18%
Dairies	25%
Water Pumping for Agriculture	60%
Greenhouses	0%

Source: DNV GL Analysis

The following are recommendations from the Industrial/Agricultural Market Saturation Study, which Section 2 describes in more detail.

- *Completing in-depth interviews with distributed generation experts and equipment vendors:* The market study team recommends that the CPUC support additional interviews with distributed generation experts and equipment vendors to get a fuller picture of distributed generation saturation in the six industrial and agricultural subsectors targeted by this study, as well as other industrial, agricultural, or commercial subsectors. This effort can also uncover synergies or competition in customer adoption of demand side management technologies.
- *Conducting a broader and deeper analysis of the NEM database:* There would be value in expanding the scope of the NEM database analysis from the six subsectors covered in this study to other industrial, agricultural, and commercial subsectors. Such an analysis would identify areas of untapped potential for the distributed generation market. It would also identify subsectors where there has been a lot of distributed generation activity, which might indicate lower uptake of EE opportunities due to competition for capital resources within companies.
- *Using billing data to identify distributed generation activity:* The CPUC's Group E research group has a database of California nonresidential billing data that could be mined for information on the prevalence of net metering projects.
- *Studying the impacts of greenhouse expansion on the lighting mix in the California agricultural sector:* For the model inputs, the PG Study team assumed that the large majority of agricultural lighting was outdoor but noted that more research on this indoor/outdoor mix should be considered due to the apparent rapid growth of indoor growing facilities in California, especially due to the expansion of the cannabis industry.
- *Interviewing additional greenhouse end users:* Difficulties reaching greenhouse end users due to the wildfires and the harvest caused the market study team to decide, with the agreement of the CPUC, to suspend data collection with this group after only four interviews were completed. Considering that indoor growing facilities appear to be multiplying in California, partly driven by the cannabis industry, it would be useful to complete more interviews with these end users.

- *Increasing customer education for certain EE technologies:* Increasing customer awareness of an EE measure is one of the first steps in increasing its adoption. This study showed that there were opportunities for targeted customer education by California's EE programs.

Generally, the industrial and agricultural market sectors are a hard to reach market for research and data. Crowd-sourcing across organizations and studies may be an efficient way over multiple years to get a longitudinal assessment of these sectors and sufficient data sets to draw robust conclusions. These efforts can provide more insight on the best approach to address barriers and understanding existing saturation and potential for EE.

1. Introduction

1.1 Background

This Industrial/Agricultural Market Saturation Study is one of several studies being conducted under California Public Utilities Commission (CPUC) Energy Efficiency Evaluation Contract for Group E Sectors: Potential and Goals (PG) and Industry and Market Studies (Group E). The Group E contract consists of a variety of efforts that are all related to the process of forecasting energy efficiency (EE) savings including:

- Collecting data that informs forecasts
- Developing forecasts to inform the investor-owned utility (IOU) EE goal-setting process managed by the CPUC and the California Energy Commission *Integrated Energy Policy Report* (CEC IEPR) process
- Coordinating with other forecasting related efforts at the CPUC (such as demand response and integrated resource planning)
- Exploring alternate methods of forecasting beyond those that have been used historically
- Providing forecasts in a format that can be useful for other state planning processes, program administrators (PAs), and program implementors

Historically, the PG Study did not collect any primary data and largely relied on secondary datasets and assumptions vetted with stakeholders. However, CPUC workshops from October 2019 identified a need to fill key gaps identified by stakeholders, including:

1. Market adoption characteristics
2. Industrial and agricultural market characterization

This study addresses the second of those primary data collection needs, while also collecting information to inform market adoption characteristics for the industrial and agricultural sectors.

1.2 Objectives

The research objectives for the Industrial/Agriculture Market Saturation study include:

- Identifying up to three technologies/systems with greatest potential for future energy savings in six prioritized industrial and agricultural subsectors.
- Quantifying the market saturation of these selected technologies/systems.
    - Collecting other information about these selected technologies/systems useful for the Industrial/Agricultural component of the PG Study model including:
        - Average energy savings
        - Proportion of facility energy consumption used by the end uses impacted by these EE technologies/systems
        - Percentage of applications where the technology/systems might not be suitable

- Determining factors preventing the wider adoption of the EE measures including whether customers opt for other demand side options such as self-generation.
- Collecting information about industrial and agricultural customer willingness to adopt EE technologies with and without program interventions to inform the market adoption component of the PG Study model. The study also collected information on the level of interest of industrial and agricultural customers in demand response programs.

1.3 Approach

This section summarizes the study's approach for data collection to fulfill the research objectives.

1.3.1 *Data Collection Strategy*

The PG Study's data collection strategy involved gathering a variety of market actor perspectives and secondary sources. This strategy guided the team's development of the PG Study because it illuminated the role of EE in targeted California industrial and agricultural markets. Primary and secondary information sources included:

- **Subsector expert interviews:** The team completed in-depth interviews with 60 individuals with specialized knowledge of energy consumption patterns and energy savings potential in the six California industrial and agricultural subsectors. These experts included program evaluators and implementers, specialists from the federal energy labs, California university professors who study EE, and representatives from the California PAs who help deliver programs in the targeted subsectors.
- **Equipment vendor interviews:** The team completed in-depth interviews with 61 vendors who sell the specific EE technology/systems this study targets to the six prioritized California industrial and agricultural subsectors.
- **End user interviews:** The team completed in-depth interviews with 50 California industrial and agricultural customers who operate in these subsectors. The intent of these interviews was for a representative outlook of the targeted subsectors to gain an understanding of each subsector's challenges, existing conditions, and potential for EE.
- **Literature/database review:** The team completed a literature review of published reports and databases that provide information on energy consumption patterns and energy savings potential in the six targeted California industrial and agricultural subsectors.

Table 1-1 maps these sources to the research objectives and notes if they are the primary or supplementary information source used to address the objective.

Table 1-1: Mapping Information Sources to Research Objectives

Information Sources	Literature and Database Review	Subsector Expert Interviews	Equipment Vendor Interviews	End User Interviews
Identifying Technologies/ Systems with High Energy Savings Potential	●	●	○	
Identifying Current Market Saturation of Key Technologies/Systems			●	●
Collecting Other Information about the Key Technology/ Systems for the PG Study Model	○	○	●	○
Determining Barriers to Wider Adoption of Key Technologies/Systems	○	●	●	●
Collecting Information about Willingness to Adopt EE Technologies	○	○	○	●

● - primary information source
○ - supplementary information source
Source: DNV GL Analysis

1.3.2 *Selecting Subsectors*

California's industrial and agricultural sectors are so large and diverse that it would have been impossible to study them both broadly and deeply within the study's budget limits. The market study team instead chose to do a deeper exploration of three industrial and three agricultural subsectors. The first criterion for selecting these subsectors was their contribution to California's future energy consumption. Table 1-2 shows the top five California industrial subsectors based on their average share of forecasted electric and gas consumption over the 2020-2030 period. The forecasts come from the CEC's IEPR model.[4]

[4] IEPR: 2017 Ag-Com-Ind 6-digit North American Industry Classification System data by IOU from the CEC.

Table 1-2: Top Five California Industrial Subsectors
Based on Forecasted 2020-2030 Electric and Gas Consumption

Subsector	Percent of Electric Consumption	Percent of Gas Consumption
Petroleum	19%	52%
Food Services/Production	16%	18%
Chemical Manufacturing	10%	11%
Electronics/Semiconductor	13%	1%
Stone-Glass-Clay	7%	6%

Source: CEC IEPR projections

The market study team chose to focus on three of the top five of these subsectors: Food Services/Production, Chemical Manufacturing, and Electronics/Semiconductor. While the Petroleum subsector was the largest, COVID-19-related impacts on the industry concerned the team as they studied the subsector when it was not operating normally. For example, petroleum end users might discount the importance of EE more than they would in a normal year because their industry faced more immediate, daunting challenges from pandemic-related impacts. If petroleum facilities were doing furloughs due to the drop in gasoline consumption, it might be more difficult to reach end users for interviews. The team chose not to study the California aerospace industry due to the impacts of the pandemic on reduced air travel and the severe economic impacts this had on the industry.[5]

Although Table 1-2 shows that the Stone-Glass-Clay subsector is comparable to Electronics/ Semiconductor subsector in its level of projected energy consumption (when one adds together the electric and gas shares), the market study team chose to review the Electronics/Semiconductor subsector. The team anticipated that the Stone-Glass-Clay subsector encompassed a more heterogeneous group of companies than the Electronics/Semiconductor subsector. This heterogeneity makes generalizing findings across the subsector more difficult and less meaningful for individual companies within the subsector.

To select three agricultural subsectors for the study, the market study team looked at CEC IEPR forecasts for 2025, as a representative year, of California agricultural electric and gas consumption (Table 1-3). Here the problem of subsector heterogeneity is more pronounced since the IEPR categories combine different activities (e.g., fishing and dairy farming).

[5] During the subsector scoping process, the market study team and the CPUC both considered the California aerospace industry for study because it was one of the top five employers in California.

Table 1-3: Top Agricultural Subsectors for Forecasted 2025 Electric and Gas Consumption by Utility

Program Administrator	Agricultural Subsector	Percent of Electric Consumption	Percent of Gas Consumption
PG&E	Dairies, Fishing and Hunting	17%	10%
	Irrigated Agriculture, Vineyards, Forestry and Greenhouses	50%	85%
	Water Pumping	32%	4%
SCE	Dairies, Fishing and Hunting	9%	
	Irrigated Agriculture, Vineyards, Forestry and Greenhouses	73%	
	Water Pumping	4%	
SCG	Dairies, Fishing and Hunting		15%
	Irrigated Agriculture, Vineyards, Forestry and Greenhouses		64%
	Water Pumping		21%
SDG&E	Dairies, Fishing and Hunting	4%	1%
	Irrigated Agriculture, Vineyards, Forestry and Greenhouses	21%	77%
	Water Pumping	75%	22%

Note: The Dairies, Fishing and Hunting subsector most closely maps with the North American Industry Classification System (NAICS) codes 112 (Animal Production and Aquaculture) and 114 (Fishing, Hunting, and Trapping). The Irrigated Agriculture, Vineyards, Forestry and Greenhouses subsector most closely maps with NAICS codes 111 (Crop Production) and 113 (Forestry and Logging). The NAICS code 22131 (Water Supply and Irrigations Systems) is the closest match with Water Pumping.

Source: DNV GL Analysis

After considering these factors and discussing with the CPUC, the market study team selected the Greenhouses, Dairies, and Water Pumping for Agriculture subsectors for further study. Reasons for selection included:

- **Greenhouses:** The Greenhouses subsector is the primary source of natural gas consumption in the agricultural sector and is a significant contributor to electric consumption. There are also a variety of EE technologies that are applicable to greenhouses ranging from LED lighting to boiler economizers and building shell measures. The cannabis industry has contributed to increasing demand for greenhouse capacity in recent years.
- **Water Pumping for Agriculture:** The Water Pumping subsector is the largest contributor to agricultural electric consumption. In addition, the CPUC was interested in more research on the relationship between water pumping demand and high yield, water-intensive California crops such as almond production.

- **Dairies:** Although the Dairies subsector is not projected to be as large a contributor to future California agriculture electric consumption as water pumping, it can benefit from a wider variety of EE measures. In addition, the team's high-level search of California EE program evaluations and market studies indicated that the dairy subsector is understudied.

Table 1-4 lists the six industrial and agricultural subsectors that the market study team selected for further review (using the subsector names this report uses). It also describes the customers that make up each subsector.

Table 1-4: Selected Industrial and Agricultural Subsectors

Subsector	NAICS Code*	Subsector Description
Electronics Manufacturing	334	Manufactures computers, computer peripherals, communications equipment, and similar electronic products.
Food Production	311 and 312	• Converts livestock and agricultural products into products for intermediate or final consumption. Activities in this subsector include: animal food manufacturing, grain and oilseed milling, sugar and confectionery product manufacturing, fruit and vegetable preserving, animal slaughtering and processing, seafood product production and packaging, bakeries and tortillas manufacturing, and manufacturing of other foods such as peanut butter, coffee, tea, syrups, mayonnaise, and spices. • Manufactures beverages and tobacco products. These include breweries, wineries, distilleries, soft drink manufacturers, and tobacco manufacturers.
Chemical Manufacturing	325	Transforms organic and inorganic raw materials by a chemical process and the formulation of products. This subsector includes both companies that produce basic chemicals and those that manufacture intermediate and end products produced by further processing of basic chemicals. It excludes industries that process chemicals as part of mining operations or as part of the refining of crude petroleum.
Dairies	112120	Involved in milking dairy cattle and milk production. It excludes farmers who raise beef cattle.
Water Pumping for Agriculture	11133	Many different agricultural subsectors pump water for irrigation and other agricultural end uses. For this study, the market study team chose to focus on water pumping use by California non-citrus fruit and nut farmers.[6] The non-citrus fruit and nut farming subsectors includes apple orchards, grape vineyards, strawberry farming, farming of other berries, and tree nut farming.

[6] During the scoping discussions for this study, the CPUC had expressed special interest in agricultural subsectors like the almond industry which are very water intensive.

Subsector	NAICS Code*	Subsector Description
Greenhouses	1114	Includes the Greenhouse, Nursery, and Floriculture Production companies that grow crops under covers such as greenhouses, cold frames, cloth houses, and lath houses. The crops grown in this subsector include vegetables, mushrooms, flowers, cannabis, and nursery plants.

* The US Census assigns codes to categorize industries in its NAICS.

Source: DNV GL Analysis

1.3.3 *Selecting Technologies*

The market study team next identified the three most promising EE measures for each of the six subsectors. The team conducted a literature/database review and in-depth interviews with subsector experts to identify:

- Which technologies/systems use the most energy in these industrial/agricultural subsectors
- Which technologies/systems have the greatest potential for future energy savings

Based on the literature review and the expert interviews, the market research identified 18 promising EE measures in total across the six subsectors. Table 1-5 shows these measures. Appendix B details the selection criteria for each measure.

Table 1-5: Summary Table of Recommended Industrial/Agricultural EE Measures

Measure	Justifications
Food Services/Production	
Refrigeration System Optimization	• Single largest electric energy consuming end use • Highest response from expert interviews • A top 10 recommended EE measure for this subsector by Industrial Assessment Center (IAC) database • Legacy refrigeration systems not designed for efficient application and likely in need of control system upgrades
Heat Recovery	• High energy consuming end use for gas • This measure was among the most mentioned in the expert interviews • A top 10 recommended EE measure for this subsector by IAC database
VSDs on Fans and Pumps	• Motors account for a substantial share of electric consumption in this subsector • Among the most mentioned in the expert interviews • A top 10 recommended EE measure for this subsector by IAC database • Fluctuations in motor load • Cost-effectiveness has increased for smaller motors sizes

Measure	Justifications
Chemical Manufacturing	

Heat Recovery	• Most frequently cited by interviewed experts
	• Sector has many processes and equipment that generate significant amounts of excess heat. Strategies include:
	  ◦ Heat recovery from stack gases
	  ◦ Recovery or reuse of low pressure steam and condensate
	  ◦ Heat recovery from compressors and exothermic processes

Advanced Automation and Optimization	• Second-most-cited EE measure by interviewed experts • Typically, energy and cost savings are around 5 percent or more for many industrial applications of monitoring and control systems • Plant-wide monitoring and automated control systems
Variable Speed Drives (VSDs)	• Third-most-cited measure by interviewed experts • High potential for energy saving per IAC database • Replacing constant speed drives with VSDs where practical
Electronics Manufacturing	

Optimize air change rates with VSDs in cleanroom spaces	• Most frequently mentioned measure in the literature reviewed and expert interviews
	• This measure saves electrical energy in semiconductor fabrication facilities, specifically in the HVAC end use of that subsector; this is important because:
	  ◦ The DOE's Manufacturing Energy Consumption Survey (MECS) data shows that semiconductor manufacture facilities account for 72 percent of the energy usage in the electronics manufacturing subsector in the Western region of the US
	  ◦ The MECS data shows that the largest end use at semiconductor facilities is HVAC

Low Cost O&M Retrocommissioning (RCx)	• Measures, such as RCx, that have short payback periods (1-2 years) are more likely to be implemented • Each semiconductor facility is unique and has different opportunities, RCx by nature is tailored to identify savings opportunities in a customized setting and can occur at any facility, impact any system, and result in electricity and gas savings
Low pressure drop High Efficiency Particulate Air (HEPA)/Ultra Low Particulate Air (ULPA) filters in cleanroom spaces	• Reducing HVAC consumption in semiconductor facilities is important because, as noted, such facilities account for nearly three-quarters of the energy usage in the West Coast electronic manufacturing subsector and HVAC is the largest end use at semiconductor facilities
Greenhouses	
LED Grow Lights	• Advances in semiconductor technology have made LED grow lights a viable alternative to High Pressure Sodium lamps and Metal Halides for greenhouse farming • Current LED grow light adoption is low overall across the greenhouse sector

Measure	Justifications
Efficient HVAC Equipment and Controls	• High efficiency heating systems such as condensing boilers are a good option when combined with below bench heating, below bench heating is more EE and effective compared to forced air systems • Some renewable technologies that have the technical potential but are yet to see increased adoption are geothermal heat pumps
Energy Curtain	• Energy curtains are being widely adopted in certain parts of Southern California • Energy curtains are becoming increasingly common in new construction greenhouses and less so in older facilities • A good energy curtain can sometimes be more effective in energy conservation than even a high efficiency heating system like a condensing boiler
Water Pumping for Agriculture	
Efficient Pumps and Motors	• Experts reported that California irrigation systems have many older, less efficient motors that would benefit from being brought up to code (which California allows if there is good justification that the upgrade would not have happened soon without program intervention) • A newer pump/motor opens the door for additional EE measures in the irrigation systems
Sensors and Controls	• Prevent overwatering and the energy usage associated with pumping that water • Optimize flow rates and irrigation schedule based on real-time data, thereby saving energy • Identify inefficiencies in pumping system

Comprehensive Program	• Programs exist for various parts of the pumping system, but none have a holistic approach
	    • Encourages farmers to implement EE measures on all parts of their pumping system by offering a comprehensive incentive on projects with measures from all three parts of the system/end use
	    • Educates farmers on all aspects of their irrigation system, how they interact with each other and the environment as well as the possibilities available for EE
	• Such holistic approaches are important because isolated EE improvements can sometimes be offset by inefficient equipment or operations elsewhere in the system

Dairies	
Refrigeration Systems Heat Recovery	• Biggest user of energy, thus biggest savings opportunity • Lots of market opportunity (low saturation) • Uses scavenged heat to pre-heat wash water or cow drinking water
Pump VSD	• Large energy consumer • Lots of market opportunity (low saturation) • Current practice is constant-velocity pump motor with manually adjustable orifice; inefficient at partial loads

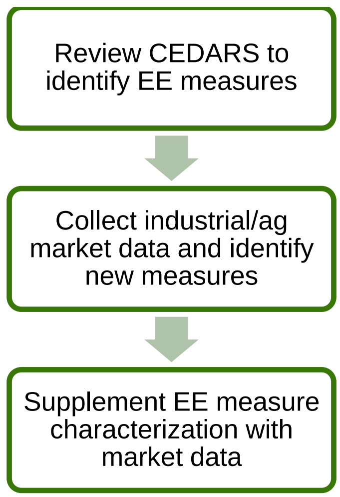
Measure	Justifications
Fans & Ventilation (HVLS fans, fan maintenance)	• Lots of market opportunity (low saturation) • Technologies are well understood and readily available • Use less energy and improve herd comfort

Source: DNV GL Analysis

1.3.4 *Incorporating the Information into the PG Study Model*

The information from the Industrial/Agricultural Market Saturation Study directly contributed to data inputs for the PG Study model. Figure 2 shows how this information fit into the broader effort to characterize the PG Study EE measures.

Figure 2: Process for Updating PG Study Inputs



Source: DNV GL

The information about these EE measures provided by the Industrial/Agricultural Market Saturation Study included:

- *Energy savings:* The EE measure's estimated energy savings and the applicability of this savings (e.g., which equipment is saving the energy)
- *Technology density:* The percentage of sites with equipment that could benefit from the EE measure
- *Technology efficiency saturation level:* The percentage of sites that have the equipment which could benefit from the EE measure in the baseline condition
- *Technical suitability:* The percentage of sites that are willing and able to install a given technology

For information that the Industrial/Agricultural Market Saturation study did not collect, such as incremental cost information, the PG Study relied on other sources such as the CEDARS database.

In cases where the Industrial/Agricultural Market Saturation study had identified EE measures which the PG Study model had not previously identified, the PG Study model analyzed these new EE measures alongside EE measures already in the PG Study model. If there was potential overlap between an EE measure that the Industrial/Agricultural Market Saturation study had identified and a measure already in the PG Study, such as VFDs, the EE measure data from the Industrial/ Agricultural Market Saturation Study replaced the pre-existing information.[7]

The Industrial/Agricultural Market Saturation Study also contributed to the market adoption algorithms by providing input to willingness to adopt curves used in the achievable potential analysis. The PG Study report explains the specific analysis and use of the survey data.

[7] One exception was the LED grow lights measure for the Greenhouse subsector. The Industrial/Agricultural Market Saturation study did not collect any information on the mix of indoor vs. outdoor lighting in the California Agriculture sector. For the model inputs, the PG Study team assumed that the large majority of agricultural lighting was outdoor, but noted that more research on this indoor/outdoor mix should be considered due to the apparent rapid growth of indoor growing facilities in California.

2. Key Findings and Recommendations

This section summarizes the report's key findings. Section 2.9 describes these findings in more detail by segment and measure. The following topics cover the key findings for EE measures:

- Potential energy savings
- Measure saturation
- End user awareness
- Barriers to adoption
- Program/rebate awareness and participation
- Onsite generation
- Demand response participation

The PG Study model requires measure characterization inputs to calculate EE potential. When characterizing industrial and agricultural measures, unit energy savings are expressed as a percent of energy consumption. Measures are further characterized by documenting the percent technology applicability and existing saturation. The remaining topics in this study provide qualitative inputs to address the market adoption assumptions over time.

2.1 Unit Energy Savings for the Selected EE Measures

One of the most important inputs to the PG Study model is the unit energy savings, defined as the average energy savings yielded by a typical installation of the selected EE measure. The market study team asked EE equipment vendors to estimate the average energy savings for the equipment or services they sell. Table 2-1 shows the average of their savings estimates for the selected EE measures.

The table shows that the potential energy savings for these measures is significant. Five of the measures have average end use energy savings estimates over 30 percent and another five have average end use energy savings estimates over 20 percent. All the measures have double-digit levels of energy savings.

Section 4 of the report provides more details on these energy savings estimates. These details include the range of energy savings estimates, the factors that can influence the range of energy savings, and the number of vendors providing the savings estimates.

Table 2-1: Average End Use Energy Savings for the Selected EE Measures

Subsector	EE Measure	Average End Use Energy Savings	End Use or Equipment Type
Electronics Manufacturing	Chiller plant optimization	19%	Chiller plants
	RCx	11%	Facility operations which can benefit from RCx[8]
	Low pressure drop filters in cleanroom spaces	31%	HVAC systems used for the cleanrooms
Food Production	Refrigeration system optimization	29%	Refrigeration systems
	Boilers and heat recovery	18%	Boilers/Water heaters providing the heat which the scavenged waste heat is replacing
	VFDs on pumps and motors	33%	Pumps or motors
Chemical Manufacturing	Heat recovery	20%	Boilers/Water heaters providing the heat which the scavenged waste heat is replacing
	Advanced automation and optimization	25%	Facility operations which can benefit from advanced automation[9]
	Mechanical drives/VSDs	29%	Pumps or motors
Dairies	Refrigeration system heat recovery	45%	Boilers/Water heaters providing the heat which the scavenged waste heat is replacing
	VFDs on pumps	13%	Pumps or motors
	EE fans and ventilation	39%	Baseline fans
Water Pumping for Agriculture	Efficient pumps and motors	15%	Pumps or motors
	Sensors and controls	14%	Pumps or motors
Greenhouses	LED grow lights	44%	Grow lighting
	EE HVAC	29%	Baseline HVAC systems
	Energy curtains	29%	HVAC systems used for heating or dehumidification

Source: DNV GL Analysis

[8] The vendors estimated, on average, that 69 percent of a facility's operating systems could benefit from RCx.

[9] The vendors estimated, on average, that 55 percent of a facility's operating systems could benefit from advanced automation.

2.2 End User Awareness of the Selected EE Measures

The first step in increasing adoption of EE measures is building customer awareness. The market study team asked the end users if they were familiar with the selected EE measures relevant to their subsector. Table 2-2 shows their reported level of awareness. Interestingly, the agricultural end users had a higher average level of awareness than the industrial end users.

The table shows opportunities for improved customer education. Only 20 percent of the chemical manufacturing end users were familiar with the advanced automation and optimization measure and only 40 percent of the electronics manufacturing end users were familiar with the chiller plant optimization measure. In addition, only 57 percent of the chemical manufacturing end users were familiar with VFDs and 60 percent of the water pumping for agriculture customers were familiar with the sensors and controls measure.[10]

Table 2-2: End User Awareness of the Selected EE Measures

Subsector	EE Measure	Percent End User Awareness
Electronics Manufacturing	Chiller plant optimization	40%
	RCx	90%
	Low pressure drop filters in cleanroom spaces	80%
Food Production	Refrigeration system optimization	91%
	Boilers and heat recovery	91%
	VFDs on pumps and motors	73%
Chemical Manufacturing	Heat Recovery	100%
	Advanced Automation and Optimization	20%
	Mechanical drives/VFDs	57%
Dairies	Refrigeration system heat recovery	75%
	VFDs on pumps	100%
	EE fans and ventilation	100%
Water Pumping for Agriculture	Efficient pumps and motors	100%
	Sensors and controls	60%
Greenhouses	LED grow lights	100%
	EE HVAC	100%
	Energy curtains	100%

Source: DNV GL Analysis

[10] Some of these responses are surprising, however, the research team believes they spoke to the right interviewees since they were able to respond to other technical questions with appropriate knowledge and understanding of the subject matter.

2.3 EE Measure Saturation

An important input to the PG Study model is the percentage of equipment currently at the EE level. This estimate indicates the remaining opportunity for EE.

The market study team used two methods to estimate measure saturation. First, they asked end users what percentage of their equipment already had the EE enhancements. For example, if the EE measure was installing VFDs on pumps or motors, the team asked end users what percentage of their pumps or motors already had VFDs installed. Second, the team asked the vendors to estimate what percentage of the relevant equipment they had seen in California had the EE measure installed in the past couple of years. For example, the market study team asked water pump vendors what percentage of the agricultural water pumps they had seen in California with VSDs installed.

Table 2-3 shows the measure saturation estimates from the end users and the vendors as well as the averages of the two estimates, which were the inputs into the PG Study model. The table shows sizable opportunities exist for EE improvements. Only one of the 17 EE measures had saturation levels above 60 percent and seven of the measures had saturation levels below 40 percent.

The sample sizes for both the end users and the vendors for each segment were small and so these market saturation estimates should be interpreted with caution.[11] However, Table 2-3 shows that, with one exception (refrigeration system optimization), the end user and vendor measure saturation estimates were reasonably close (within 20 percentage points of each other). That two different market actors came to similar estimates of market saturation should increase confidence in the reliability of these estimates. Section 2.9 provides more details on these measure saturation estimates, including the number of end users and vendors providing the estimates.

Table 2-3: EE Measure Saturation

Subsector	EE Measure	End User Measure Saturation	Vendor Measure Saturation Estimates	Average Measure Saturation Estimate
Electronics Manufacturing	Chiller plant optimization	6%	24%	15%
	RCx	44%	No estimates provided	44%
	Low pressure drop filters in cleanroom spaces	39%	36%	38%
Food Production	Refrigeration system optimization	62%	24%	43%
	Boilers and heat recovery	19%	11%	15%
	VFDs on pumps and motors	68%	No estimates provided	68%

[11] To improve the representativeness of the small number of customers in the end user samples, the market study stratified them with a targeted minimum number of large customers (ratio weighting), as described in Appendix A. Stratification and targeting help ensure that samples are more representative than could be achieved through simple random selection.

Subsector	EE Measure	End User Measure Saturation	Vendor Measure Saturation Estimates	Average Measure Saturation Estimate
Chemical Manufacturing	Heat recovery	30%	12%	21%
	Advanced automation and optimization	29%	33%	31%
	Mechanical drives/VSDs	40%	51%	46%
Dairies	Refrigeration system heat recovery	19%	29%	24%
	VFDs on pumps	31%	32%	32%
	EE fans and ventilation	62%	48%	55%
Water Pumping for Agriculture	Efficient pumps and motors	63%	42%	53%
	Sensors and controls	59%	44%	52%
Greenhouses	LED grow lights	38%	41%	40%
	EE HVAC	42%	46%	44%
	Energy Curtains	42%	60%	51%

Source: DNV GL Analysis

The team used ratio estimation methods to develop California-level estimates of measure saturation from the estimates from the study's sample. Ratio methodology is a common statistical approach where the weights are calculated using the number of subjects in the sample compared to the number of subjects in the population, and relevant known values for characteristics in the sample and the population such as number of employees or energy consumption. It allows the researchers to make survey results from a sample more representative of the underlying population than could be achieved through stratification alone. Appendix A details the calculation of these ratios.

2.4 Barriers to EE Measure Adoption

The market study team asked the subsector experts, equipment vendors, and end users about factors or barriers that might discourage end users from installing the selected EE measures. The most common factors across all the subsectors were concerns about disrupting production, concerns about the initial cost of EE measures, and lack of knowledge of EE measures and benefits among facility managers and farmers. However, there were many subsector-specific and EE measure-specific factors that Section 2.9 discusses.

The market study team asked EE vendors whether the investments their customers make in energy efficiency compete with other energy management decisions or technologies. Most of the vendors said there was competition, but they had differing opinions as to the degree of competition and impact on pursuing EE.

2.5 EE Program/Rebate Awareness and Participation

The market study team asked end users whether they were aware that their electric and natural gas utilities offered rebates and incentives for their company to save energy. It then asked the rebate-aware end users whether they had participated in these utility rebate programs. Table 2-4 shows their responses by subsector. The table shows that while rebate awareness was high across all subsectors, program participation was low in the Food Production and Water Pumping for Agriculture subsectors. For more information about relevant barriers, look in the sub-sections below corresponding to each subsector.

Table 2-4: EE Program/Rebate Awareness and Participation

Subsector	Percent of End Users Aware of the EE Rebates	Percent of End Users Participating in the EE Programs
Electronics Manufacturing	80%	60%
Food Production	91%	27%
Chemical Manufacturing	71%	71%
Dairies	100%	75%
Water Pumping for Agriculture	90%	30%
Greenhouses	100%	75%

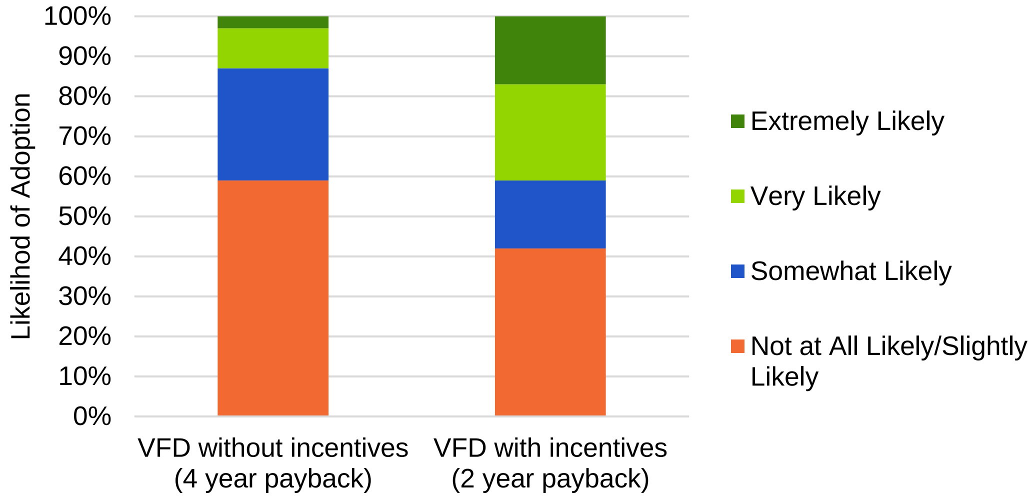
Source: DNV GL Analysis

2.6 The Influence of EE Incentives

The market study team provided end users with information about the incremental costs of high efficiency boilers and VFDs as well as their potential energy savings and payback periods.[12] They then asked end users about their willingness to purchase such equipment if program EE incentives reduce these payback periods. Figure 3 and Figure 4 show that when the incentives reduced the payback period for VFDs from 4 years to 2 years, and for high efficiency boilers from 5 years to 2 years, the likelihood of adoption increased significantly. End user interviews revealed that the median payback period threshold was 3.5 years for their company to approve EE projects.

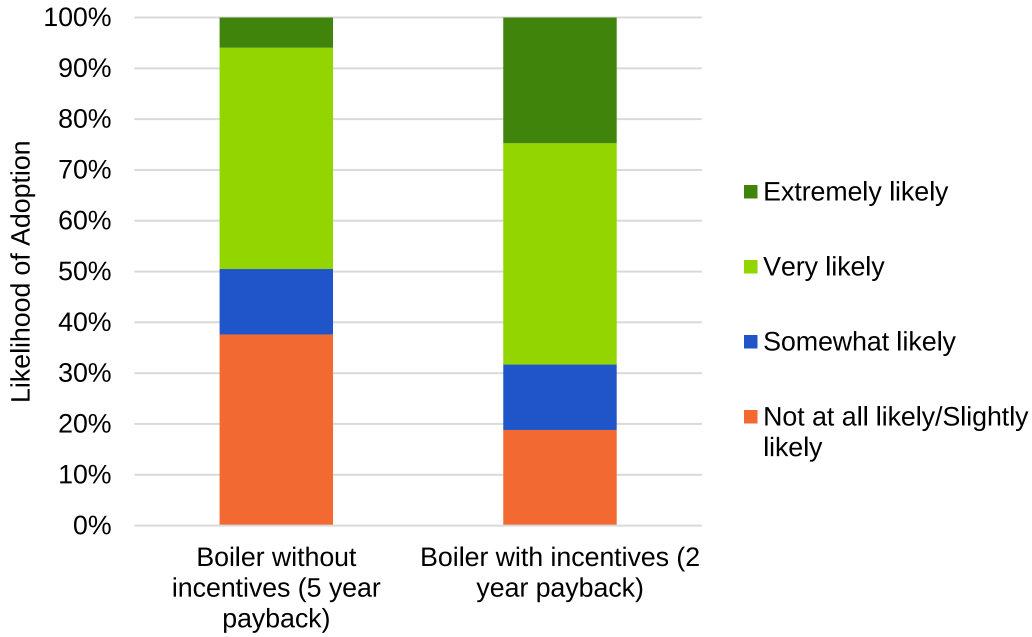
[12] Due to the length of the survey and concerns about respondent fatigue, the market study team limited these "willingness to purchase" questions to only two EE measures (VFDs and high efficiency boilers). The team selected these two measures due to their widespread use.

Figure 3: The Influence of EE Incentives on Likelihood of VFD Adoption



Source: DNV GL Analysis

Figure 4: The Influence of EE Incentives on Likelihood of High EE Boiler Adoption



Source: DNV GL Analysis

2.7 Onsite Generation

The market study team asked the end users if they had onsite generation and if they did, what type. Table 2-5 shows the percentage of end users who reported having solar installations by subsector. The non-citrus fruit and nut farmers, who made up the end users in the Water Pumping for Agriculture subsector, reported the highest frequency of solar installations.

Table 2-5: Solar Saturation by Subsector

Subsector	Percent of End Users with Solar Installations
Electronics Manufacturing	10%
Food Production	36%
Chemical Manufacturing	14%
Dairies	25%
Water Pumping for Agriculture	60%
Greenhouses	25%

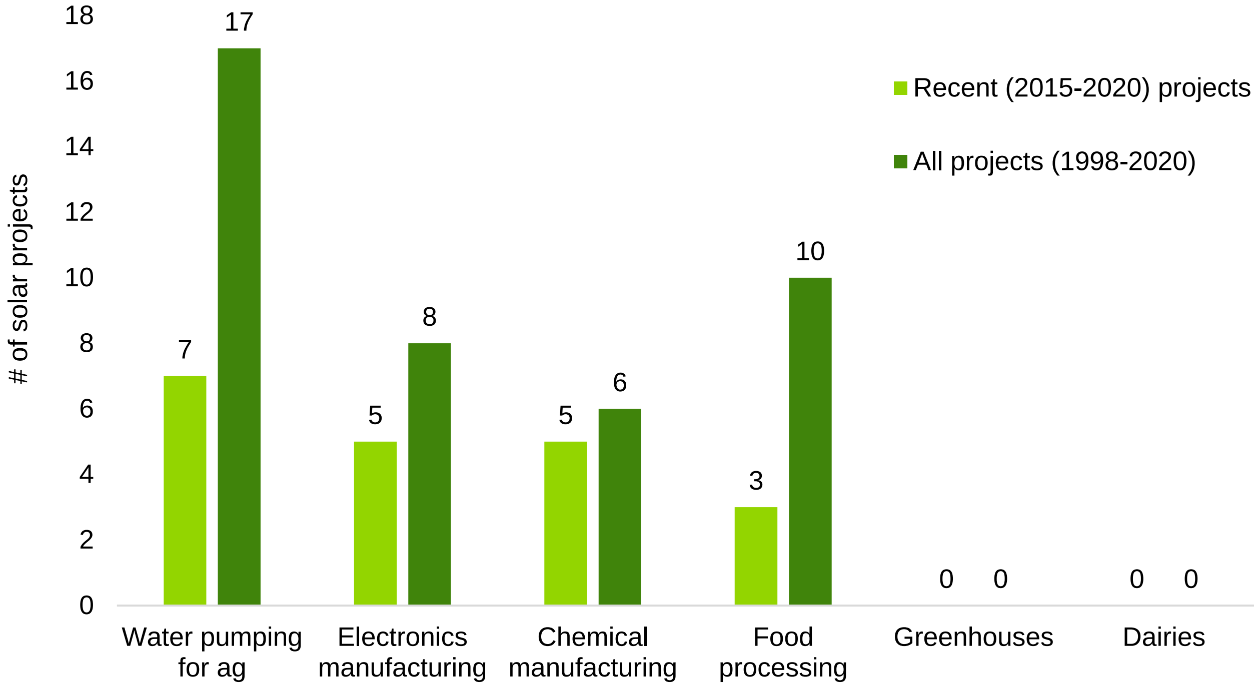
Source: DNV GL Analysis

The market study team also reviewed California's Net Energy Metering (NEM) database to see whether facilities in the six targeted subsectors had reported onsite generation projects.[13] The team looked at projects that had North American Industry Classification System (NAICS) codes matching these subsectors and installation dates. Although the database showed a variety of distributed generation technologies including fuel cells, advanced energy storage, microturbines, and wind; solar was, by far, the most common.

Figure 5 displays recent (2015-2020) solar projects and those installed over a longer period (1998-2020). It shows that the Water Pumping and Food Production subsectors have a longer-term history with solar projects while most of the solar activity in the Electronic Manufacturing and Chemical Manufacturing subsectors has been relatively recent. Solar power has practical appeal for farmers because it allows them to operate water pumps in locations distant from conventional power sources.

[13] https://www.californiadgstats.ca.gov/downloads/

Figure 5: Number of Solar Projects in NEM Database from Targeted Subsectors



Source: DNV GL Analysis

The market study team was unable to find any solar activity for the Dairy or Greenhouse subsectors in the NEM database. However, it did find other distributed generation projects for these subsectors (two advanced energy storage projects and one internal combustion engine project).

Although the NEM database contains the vast majority of California solar projects, it does not include them all. Some solar, and other distributed generation projects, interconnect under a tariff other than the NEM. A 2020 report estimated that 7 percent of the installed California solar capacity was not in the NEM database.[14]

The team's objective in reviewing this NEM data was to check if there was significant onsite generation occurring in the industrial/agricultural subsectors, which may indicate tradeoffs between their pursuit of the onsite generation projects and EE projects. The data indicates that these subsectors are not pursuing a substantial volume of onsite generation projects.

2.8 Demand Response Participation

The market study team asked end users if they had participated in a demand response program and, if they did, what type it was. Table 2-6 shows the percentage of end users who reported having participated in a demand response program. The Water Pumping for Agriculture subsector end users reported the highest frequency of demand response programs. The California PAs have long offered

[14] See CPUC 2020 California Solar Initiative, Annual Program Assessment, June 2020, p. 25. As discussed later in the report, discrepancies between the number of distributed generation projects for these six subsectors in the NEM database and the quantity of distributed generation projects reported by end users may also be due to inconsistencies in the ways that the IOUs assigned NAICS codes to projects in the NEM database.

time-of-use (TOU) rates and programs for customers with water pumps. The operation of most irrigation systems can be easily controlled by technology ranging from simple timers to more sophisticated Weather Based Irrigation Controls. Furthermore, schedules for crop irrigation can be more easily shifted than can schedules for manufacturing and dairy production without adverse effect to the end product.

Table 2-6: Demand Response Participation by Subsector

Subsector	Percent of End Users Participating in Demand Response Programs
Electronics Manufacturing	10%
Food Production	18%
Chemical Manufacturing	18%
Dairies	25%
Water Pumping for Agriculture	60%
Greenhouses	0%

Source: DNV GL Analysis

2.9 Recommendations

While conducting this study, the market study team identified some opportunities for further research including:

- *Completing in-depth interviews with distributed generation experts and equipment vendors:* As mentioned in this report, the market study team selected the subsector experts and equipment vendors for their knowledge of energy efficient measures rather than their distributed generation expertise. Therefore, it is likely that many of these lacked an in-depth knowledge of the level of renewable energy or demand response activity in these subsectors, although they would be aware of circumstances where renewable energy and demand response competed with energy efficiency. The market study team recommends that the CPUC support additional interviews with distributed generation experts and equipment vendors to get a fuller picture of distributed generation saturation in the six industrial and agricultural subsectors targeted by this study, as well as other industrial, agricultural, or commercial subsectors.

- *Conducting a broader and deeper analysis of the NEM database:* In the summer of 2020 the CPUC asked the California PAs to append NAICS codes to the projects listed in the NEM database. The Industrial/Agricultural Market Saturation study used this new NAICS code information to analyze distributed generation activity in the six industrial and agricultural subsectors it was focusing on. However, there would be value in expanding the scope of the analysis to other industrial, agricultural, and commercial subsectors. Such an analysis would identify areas of untapped potential for the distributed generation market. It would also identify subsectors where there has been a lot of distributed generation activity, which might indicate lower uptake of EE opportunities due to competition for capital resources within companies.

- *Using billing data to identify distributed generation activity:* The CPUC's Group E research group has a database of California nonresidential billing data that could be mined for information on the prevalence of net metering projects. This billing data has both net metering flags and NAICS code information and could be used as a check on the information contained in the NEM database.

DNV GL recently successfully conducted a very limited analysis of these data to test the feasibility of identifying these net metering flags.

- *Studying the impacts of greenhouse expansion on the lighting mix in the California agricultural sector.* The Industrial/Agricultural Market Saturation study did not collect any information on the mix of indoor versus outdoor lighting in the California Agriculture sector. For the model inputs, the PG Study team assumed that the large majority of agricultural lighting was outdoor but noted that more research on this indoor/outdoor mix should be considered due to the apparent rapid growth of indoor growing facilities in California, especially due to the expansion of the cannabis industry.

- *Interviewing additional greenhouse end users:* As mentioned in the report, the Greenhouse end users were particularly impacted by the wildfires that were ongoing when the market study team attempted to interview them in August and September 2020. For greenhouse end users who had open field crops, September was also the harvest season and therefore a difficult time to complete phone interviews. For these reasons the market study team decided, with the agreement of the CPUC, to suspend data collection with this group after only four interviews were completed. Considering that indoor growing facilities appear to be multiplying in California, partly driven by the cannabis industry, it would be useful to complete more interviews with these end users when they are more available for such interviews.

- *Increasing demand response education to farmers:* The team asked farmers in the Water Pumping for Agriculture subsector who were not participating in demand response programs about possible barriers to demand response program participation such as “adjusting your demand in response to demand response events from your utility” and “disruptions to operational processes and perceived productivity losses.” The nonparticipants reported these as being either “major barriers” (5 on a 5-point severity scale) or “considerable barriers” (4 on 5-point severity scale). Such responses suggest a need for more education for farmers about demand response programs since schedules for crop irrigation can be easily shifted with minimal impact on production, especially with newer technologies, and since other farmers in this subsector have successfully participated in such programs.

- *Increasing customer education for certain EE technologies:* Increasing customer awareness of an EE measure is one of the first steps in increasing its adoption. This study showed that there were opportunities for targeted customer education by California’s EE programs. For example, only 20 percent of the chemical manufacturing end users were familiar with the advanced automation and optimization measure and only 40 percent of the electronics manufacturing end users were familiar with the chiller plant optimization measure.

  Generally, the industrial and agricultural market sectors are a hard to reach market for research and data. Crowd-sourcing across organizations and studies may be an efficient way over multiple years to get a longitudinal assessment of these sectors and sufficient data sets to draw robust conclusions. These efforts can provide more insight on the best approach to address barriers and understanding existing saturation and potential for energy efficiency.

3. Detailed Findings

The detailed findings for each subsector include the data collection and analysis for each measure. The section is organized with the following information:

- A capsule summary of the subsector and why it was selected.
- A description of the EE measures with the greatest potential in the subsector including:
    - How the EE measures were selected.
    - A description of the EE measures and their potential energy savings.
    - Awareness of the EE measures among end users in the subsector.
    - An estimation of EE measure saturation within the subsector's California population.
    - A summary of factors/barriers hindering adoption of the EE measures as reported by subsector experts, vendors, and end users.
    - EE program/rebate awareness and participation among subsector end users.
- A description of other demand side energy management within the subsector, including:
    - A description of the subsector's level of activity for renewables, demand response, onsite energy storage, and other onsite generation, such as combined heat and power. This description includes a summary of factors/barriers hindering adoption of these other demand side energy management projects beyond EE.
    - A discussion of possible competition between other demand side management activities and EE, and opportunities to leverage these activities.

3.1 Subsector: Electronics Manufacturing

3.1.1 *The Electronic Manufacturing Subsector*

The Electronics Manufacturing subsector (NAICS code 334) includes companies that manufacture computers, computer peripherals, communications equipment, and similar electronic products. The market study team and the CPUC selected this industrial subsector for study due to its importance to the California economy and its energy consumption level. According to the CEC's IEPR forecast, this industry will account for 13 percent of California's industrial electric consumption over the 2020-2030 period, the third highest share of any California industrial subsector.

3.1.2 *EE Measures in the Electronics Manufacturing Subsector*

3.1.2.1 Selection of EE Measures

In the EE Technology Selection phase, the team interviewed experts on the Electronics Manufacturing subsector and conducted an extensive literature review. Through these interviews and the literature review, the team identified many promising EE measures. Per the research for this subsector, cleanrooms are a significant energy user and so the biggest focus for this subsector. From this longer list of measures, the market study team selected three technologies that held the greatest promise:

1. Optimizing air change rates in cleanroom spaces with VFDs
2. Low cost retrocommissioning (RCx)
3. Low pressure drop HEPA/ULPA filters in cleanroom spaces

The team selected these EE measures because of the frequency with which the subsector experts and literature review sources mentioned them and the knowledge that cleanrooms consume the most energy in electronics manufacturing facilities. Expert interviews also revealed that electronic manufacturing facilities are much less likely to move forward on projects with simple payback periods greater than 2 years. These longer payback period projects are viewed as capital projects, which must compete with more attractive projects involving production enhancements. Appendix B details the EE measure selection process for this subsector.

Several experts recommended low cost RCx since this EE measure can have payback periods of 1 year or less. The experts also mentioned flexibility as another benefit of the RCx measure. They noted each electronics manufacturing facility is unique with different energy savings opportunities. RCx is inherently tailored to identify low cost savings opportunities at each site individually. RCx can occur at any facility, impact any system, and result in both electricity and gas savings.[15]

During the initial measure identification phase, the market study team selected optimizing air change rates in cleanrooms with VFD measures. However, in the market saturation phase of the study, the market study team replaced the optimizing air change rates measure with a chiller plant optimization measure. Interviews with electronic manufacturer representatives informed this decision when; they pointed out significant barriers to this measure’s industry adoption:

1. **Sensor costs:** One representative reported significant costs for the air quality sensors needed for functioning demand based flow control measures
2. **Quality control process costs:** The cost of the change validation quality control process (to maintain industry standards) needed to accommodate the measure
3. **Risk aversion to new technologies:** One manufacturer representative characterized electronic manufacturing as “a very conservative industry” where no company wanted to be the “guinea pig” with this new measure.

These manufacturer representatives suggested that the optimizing air change rates measure might be viable in scientific cleanrooms that do not operate 24/7 like those in electronics manufacturing facilities. They also suggested it might be feasible in the portions of cleanrooms that do not have to be as clean as the main microchip manufacturing areas. An ASHRAE study of this EE measure is expected to finish in 2021.

[15] One expert observed that while traditionally efficiency measures have focused on non-process related equipment with the assumption that facility personnel are their own experts, industrial RCx can also be applied to the industrial processes. He observed that facility-wide control/monitoring systems are becoming more common at industrial facilities and these can serve as the starting points for process-side low-cost RCx improvements. This expert also said that some strategic energy management (SEM) consultants are looking at the process opportunities, which can result in significant savings on top of the traditional non-process related opportunities.

Table 3-1 describes the three EE measures the team ultimately selected.

Table 3-1: Descriptions of Selected EE Measures for Electronics Manufacturing

<table>
<tr><th>EE Measure</th><th>Description</th></tr>
<tr><td>Chiller plant optimization</td><td>Chilled water plant optimization consists of adding or updating hardware and control sequences to an existing chilled water system to reduce energy consumption associated with the chiller plant as a whole, which can consist of chillers, pumps, and cooling tower fans. Measures that can be categorized under chilled water plant optimization include but are not limited to:
• Changing chiller plant configuration (e.g., from primary-secondary to variable primary)
• Installing new, more efficient chillers
• Installing VFDs on pumps or cooling tower fans
• Installing deeper cooling coils with more rows to increase temperature drop across coil, to reduce pumping energy
• Optimizing chiller, pump, cooling tower staging
• Incorporating reset control logic on chiller/condenser water temperatures and pressures
Incorporating or tuning of waterside economizer operation</td></tr>
<tr><td>RCx</td><td>RCx involves making low and no-cost energy performance improvements to a system or process, resulting in short payback periods. Typical activities include reviewing trend data within the building automation systems, performing functional testing, and identifying control enhancements, such as:
• Improved scheduling of equipment or identification of scheduling programming errors
• Improved control sequences such as temperature/pressure resets or trim and respond control logic, or identification of errors in control sequence logic
• Identifying and fixing errors associated with sensors, such as mis-mapping of sensors with their stored parameters in the automation system, or sensor calibration issues</td></tr>
<tr><td>Low pressure drop HEPA/ULPA filters in cleanroom spaces</td><td>The cleanrooms in electronics manufacturing facilities use many filters to purify the air. If these filters get too clogged, they can cause the fans which drive the airflow in the cleanrooms to work harder. Lower pressure drop filters have greater dirt holding capacity than standard filters. This is due to their greater media surface area with deeper-pleated filters and closer pleat spacing. This greater dirt holding capacity reduces filter pressure drop and results in less fan energy use for the same airflow rate.</td></tr>
</table>

Source: DNV GL Analysis

3.1.2.2 Estimating Energy Savings for Electronics Manufacturing EE Measures

The market study team asked the vendors to estimate the annual energy savings their customers could expect from installing the selected measures. If vendors provided a range of energy savings for a given measure, the team asked them what factors or applications would drive this range. Table 3-2 shows these energy savings estimates and the factors that can influence the range of energy savings.

Table 3-2: End Use Energy Savings Estimates for Electronics Manufacturing EE Measures

EE Measure	End Use Energy Savings Estimate	Factors Influencing the Range of Energy Savings
Chiller plant optimization	Average energy savings: 19 percent of chiller plant usage Range of energy savings estimates: 8 to 33 percent Number of vendors providing savings estimate: Five	• The size of the chiller plant: Larger chillers offer greater savings opportunities than smaller chillers. • The age of the chiller plants: Older chiller may have different control options than new systems. For example, with some older chillers it is not possible to do condenser water resets. • The configuration of the systems: Chiller auxiliary equipment and process characteristics may impact EE opportunities. For example, chillers and cooling towers have minimum requirements for condenser water flow. In some cases, VFDs can only be installed in chillers if the contractor also installs two-way valves downstream. Also, some systems might not be able to do chilled water resets because they need chilled water all the time.

EE Measure	End Use Energy Savings Estimate	Factors Influencing the Range of Energy Savings
Retrocommissioning (RCx)	Average energy savings: 11 percent of facility operations which can benefit from RCx[16] Range of energy savings estimates: 3 to 20 percent Number of vendors providing savings estimate: Four	• The scope of the RCx: Some customers look for RCx opportunities throughout the plant and others only look for RCx opportunities within certain systems (e.g., HVAC). • Whether the RCx changes impact the cleanrooms: Cleanrooms are the most energy-intensive parts of electronic manufacturing facilities. Vendors said that there are opportunities to optimize temperature setpoints in cleanrooms that can result in substantial HVAC energy savings. • Facility size and the presence of a dedicated energy manager: According to our vendor interviews facilities that lack a dedicated energy manager are less likely to realize the full potential of RCx energy savings. In addition, larger facilities are more likely to have the in-house expertise to maximize RCx opportunities as compared to smaller, less sophisticated facilities.
Low pressure drop HEPA/ULPA filters in cleanroom spaces	Average energy savings: 31 percent of cleanroom HVAC use Range of energy savings estimates: 10 to 50 percent Number of vendors providing savings estimate: Four	• The design and configuration of the filters: The material used in the filter, the depth of its pleats, and the density of its pleating can all impact the savings percentage. • How the cleanrooms are being used: Vendors noted that energy savings can vary depending on how clean the rooms must be and their load profile (e.g., whether they are being used 24/7 like many electronics manufacturing facilities or less frequently).

Source: DNV GL Analysis

3.1.2.3 EE Measure Awareness and Market Saturation in Electronics Manufacturing

If end users did not report having a given EE measure installed, the market study team asked them: “Prior to my mentioning EE Measure X, were you familiar with EE Measure X?” Table 3-3 shows

[16] The vendors estimated, on average, that 69% of a facility’s operating systems could benefit from RCx.

respondents have high awareness of RCx and the low pressure drop filters; however, less than half of the respondents were aware of the chiller optimization measure.

Table 3-3: Awareness of Electronics Manufacturing EE Measures

EE Measure	End User Awareness of EE Measure (n=10)
Chiller plant optimization	40%
RCx	90%
Low pressure drop HEPA/ULPA filters in cleanroom spaces	80%

Source: DNV GL Analysis

Table 3-4 shows the market saturation estimates for the three EE measures based on end user self-reports and vendor estimates of the California market. The end user market saturation was estimated using ratio weights d to the whole California market based on a sample of 10 electronics manufacturing facility representatives.[17]

Two vendors provided the chiller plant optimization measure saturation estimate and two vendors provided the measure saturation estimate for the low pressure drop filters. The estimates in the table's vendor column represent the average.

End users and vendors reported chiller plant optimization market saturation to be very low. Reported market saturation for RCx and the low pressure drop filters was higher but still below 50 percent. For the EE measures that had measure saturation estimates from end users and vendors, the market study team used the average of these estimates for the inputs into the PG Study model.

Table 3-4: Measure Saturation for Electronics Manufacturing EE Measures

EE Measure	End User Measure Saturation	Vendor Measure Saturation Estimates
Chiller plant optimization	6%	24%
RCx	44%	No estimates provided[18]
Low pressure drop HEPA/ULPA filters in cleanroom spaces	39%	36%

Source: DNV GL Analysis

[17] As noted, ratio methodology is a common statistical approach where the weights are calculated using the number of subjects in the sample compared to the number of subjects in the population, and relevant known values for characteristics in the sample and the population such as number of employees or energy consumption. It allows the evaluator to make survey results from a sample more representative of the underlying population than could be achieved by sample stratification alone.

[18] Vendors were unable or unwilling to estimate measure saturation percentages for this RCx measure since it is made up of wide range of actions and the implementation of this measures varies widely from site to site.

The market study team also used the ratio estimation method to calculate measure saturation estimates for the electronics facilities differentiated by company size.[19] Larger companies were more likely to report installing the chiller plant optimization and low pressure drop filter measures, but less likely than small companies to do RCx.

3.1.2.4 Barriers to EE Measure Adoption in Electronics Manufacturing

The market study team asked the subsector experts, equipment vendors, and the end users about barriers or factors that might prevent electronic manufacturing facilities from installing the three EE measures the study focused on. They identified a wide range of factors, as Table 3-5 shows.

All three groups of interviewees (experts, vendors, and end users) cited concerns about disrupting production, especially for measures that impacted cleanrooms, as a factor that would limit installation of EE measures. “Facility folks do not want to jeopardize the process,” said one subsector expert. “A breach in cleanliness would be very costly, so facility folks will not make any changes unless directed to do so from top management.”

All three groups also identified concerns about the initial cost of EE measures as a factor. When asked why they had not installed an EE measure that they were aware of, one end user said, “Primarily cost. We have to be cash conservative at this point.” Another end user said, “Our company is in a ramp-up cash-tight phase.” One of the vendors said the popularity of RCx stemmed from its low cost. “You have finite amount of funding, that is why RCx is so attractive, because typically it doesn't need that much money to make good energy savings happen,” they said.

The subsector experts and the end users mentioned energy savings not being a priority as a factor that would limit EE measure installation. “Energy is not a priority at these [electronic manufacturing] facilities, production is, and energy is just an afterthought,” said one subsector expert. “There is a tendency to rely on status quo—not wanting to make a change, since that could affect production negatively, and cost a lot of money.”

Table 3-5 shows the relative importance of the limiting factors, which varied with the EE measure discussed. Lack of awareness was a major factor for the lack of implementation of the chiller plant optimization measure. Concerns about initial costs were significant factors limiting the installation of the of low pressure drop filters.

[19] Because the distribution of company sizes varies by subsector, the market study team chose to vary the definition of a large vs. small company depending on the subsector. For the Electronics Manufacturing subsector the team defined a large company as one that had greater than 250 employees.

Table 3-5: Factors Limiting EE Measure Adoption in Electronics Manufacturing

Factors	Subsector Experts	Equipment Vendors	End Users
Concern about disrupting production	X	X	X
Concern about initial cost of EE measure	X	X	X
Energy savings is not a priority:	X		X
Perception that EE program participation is onerous	X		
Concern about availability of EE equipment		X	
Constraints from capital budget cycles		X	
Lack of financing		X	
Competition from other energy-related projects (e.g., renewables)		X	
Lack of EE measure awareness			X
Facility is too old or too new to justify equipment changes			X

Source: DNV GL Analysis

3.1.2.5 EE Program/Rebate Awareness and Participation among Electronics Manufacturers

The market study team asked the 10 electronic manufacturing end users about EE program awareness and participation. Table 3-6 shows that rebate/awareness participation was higher than that for the technical assistance.

Table 3-6: EE Program/Rebate Awareness and Participation

Question	Metric	Percentage
Are you aware that your electric and natural gas utilities offer rebates and incentives for your company to save energy?	Awareness of Rebate Programs	80%
Has your company ever received a rebate or incentive for EE equipment at your facility?	Participating in EE programs	60%
Are you aware that your electric and natural gas utilities and their contractors also offer technical assistance to help companies like yours to implement EE projects?	Aware of EE technical assistance	60%
Has your company ever received such technical assistance from your electric and gas utilities or their contractors?	Receiving technical assistance	30%

Source: DNV GL Analysis

Finally, the team asked the electronic manufacturing end users what more was needed besides incentives or technical assistance from EE programs to get their company to adopt some of the EE measures discussed earlier in the interview. Only two of the eight EE program-aware respondents offered suggestions.

One suggested more clarity in the program communications. “This world is so polluted with hucksters that it’s difficult to sort out noise from legitimate offers,” he explained. The other suggested that the programs “could advertise more that they offer those things.”

3.1.3 *Other Demand Side Energy Management in the Electronics Manufacturing Subsector*

Although energy efficiency was the main focus of the study, the market study team also asked the subsector experts, equipment vendors, and end users about the Electronic Manufacturing subsector’s level of activity in renewable energy, CHP/cogeneration, onsite energy storage, and demand response programs. The market study team also asked them whether they thought these other demand side energy management activities might be competing with energy efficiency for company resources.[20]

3.1.3.1 Fuel Cells

The market study team asked the electronics manufacturing end users whether their companies had ever received a rebate or incentive for distributed generation equipment:

- Two of the respondents said their companies had received incentives for the installation of fuel cells.
- One respondent said their fuel cell was a 3 MW capacity system and their company was using about 80 percent of the system’s power onsite while selling the remaining 20 percent back to the grid.
- Another respondent said they had two fuel cells with one generating electricity for onsite use and the second for harmonic streaming to improve power quality.

One of the subsector experts said that fuel cells not only offered power quality and reliability benefits, but also could have economic benefits for the electronics manufacturing facilities. He mentioned one electronics manufacturing facility which had deployed a 5-MW fuel cell not for power reliability reasons, but to lock in a low electricity price.

3.1.3.2 Solar

Only one of the 10 end users reported that their company installed a PV solar system; however, two others said that their companies had near-term plans for solar installations. A couple of the subsector experts also said they have seen some limited solar use in the Electronics Manufacturing subsector, sometimes driven by corporate sustainability goals. The market study team’s analysis of the California

[20] It is important to note that the many of the subsector experts and most of the equipment vendors were targeted primarily for their knowledge of energy efficient opportunities and equipment. Therefore, it is likely that many of these lacked an in-depth knowledge of the level of renewable energy or demand response activity in these subsectors, although they would be aware of circumstances where renewable energy and demand response competed with energy efficiency.

NEM database found five electronics manufacturing facilities had installed solar systems in the recent 2015-2020 period and eight over the longer 1998-2020 period.

3.1.3.3 Demand Response

The subsector experts said that demand response program participation was uncommon in the Electronic Manufacturing subsector because the long and sensitive production processes were not conducive to power interruption. “Demand response is not a viable path as the semiconductor facilities will not regulate the most intensive energy consumption portion of manufacturing based on the demand of the electric grid,” said one expert.

The end users confirmed this expert assessment of the incompatibility of electric manufacturing and demand response. The market study team asked the 10 electronics manufacturing end users whether they had heard of demand response programs and whether their companies were participating in such programs. Table 3-7 shows that participation was low and four of the end users had not heard of a demand response program.

Table 3-7: Demand Response Program Awareness and Participation

Percent Aware of Demand Response Programs	Percent Participation in Demand Response Programs
60%	10%

Source: DNV GL Analysis

When asked about various possible barriers to demand response program participation, five of the 10 respondents (50 percent) said concerns about “disruptions to operations/processes and perceived productivity losses” were “major barriers” (5 on a 5-point severity scale) and a sixth said it was a “considerable barrier” (4 on a 5-point severity scale). When given descriptions of a various demand response programs, most end users said their companies were unlikely to participate in these programs.

3.1.3.4 CHP/Cogeneration

Interviews with subsector experts and the literature review indicated the Electronics Manufacturing subsector does very little CHP/cogeneration (0.6 percent out of 6,831 NAICS 334 facilities) as reported by the US Energy Information Administration’s 2014 Manufacturing Energy Consumption Survey (MECS).

Subsector experts explained that there is a lack of large enough and sustained heating demand load to make CHP/cogeneration economically attractive; the high capital costs for CHP/cogeneration compete for capital with other facility improvements, such as new production tools; and energy costs are a small portion of the total expenditure for these facilities compared to equipment, personnel, and raw materials.

3.1.3.5 Onsite Energy Storage

Of the 10 electronics manufacturing end users, none said that their companies received incentives for energy storage. Only one of the respondents said they have onsite energy storage, which was one of the benefits of their fuel cell.

3.1.4 *Interaction Between EE and Other Demand Side Management*

The market study team asked the vendors of EE equipment in the Electronics Manufacturing subsector whether the investments their customers make in energy efficiency compete with other energy management decisions or technologies.[21] Four of the six vendors who responded to this question said there was competition. Some representative quotes included:

- "Absolutely, it's all about maximizing initial and lifecycle costs when these facilities are designed or modified, so it's always looking at all options, and choosing the best option."
- "Yeah, [competition between energy management technologies] is probably true, customers have finite budgets."
- "No one has all the budget to do everything they want."

Vendors observed competition between energy management technologies including:

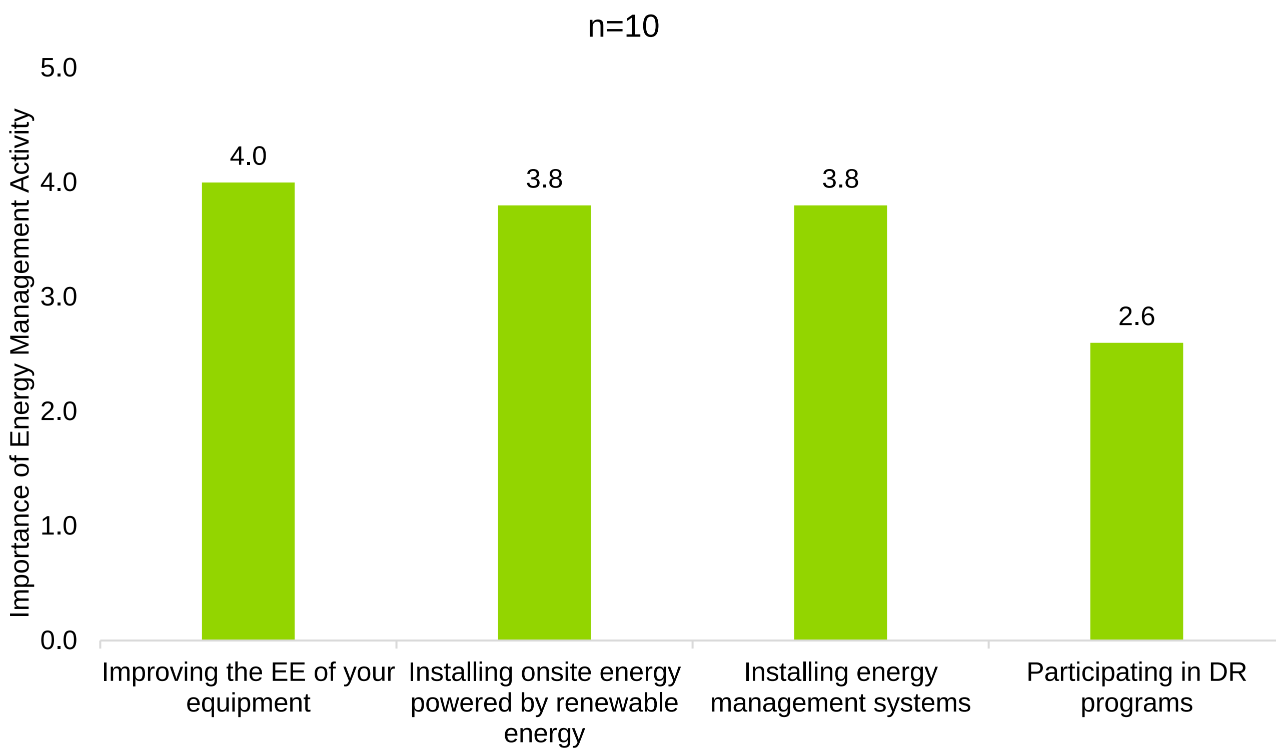
- **Split company decision-making:** One vendor observed that the decisions between EE and renewables projects often come from different parts of the company. "As to what we are explicitly competing against, it's very customer- and site-dependent. When you look at solar, it's not necessarily coming from the same group. Solar might come from headquarters, [other technologies] come from facility managers."
- **Project size considerations:** One end user said that who in the company made the decision depended on the size of the project. "Right now, given the state of the economy, I'm not going to undertake anything of any size," he said. "Large projects would have to come from corporate folks. At a local site, we would not likely take that on right now."
- **Synergies between energy management technologies**: Two vendors pointed out synergies between energy efficiency and other demand side management activities. One recalled a company that reinvested the payments it received from its demand response program into energy efficiency. Another noted that energy efficiency can benefit a renewables investment by reducing the size of the system required.

The market study team asked the electronics manufacturing EE equipment vendors whether their companies provide services that integrate energy efficiency with solar, wind, or demand response. Five of the 11 vendors said they offered these integrated services. One vendor said they commission newly installed solar systems to make sure they are integrating correctly with the customer's electric system. Others mentioned working on the integration of EE and demand response solutions.

[21] The full question was: "Do the investments your customers make in energy efficiency compete with other energy management decisions or technologies? For example, have you encountered scenarios with customers where their level of interest in your energy efficient products or services is being impacted by their interest in other energy management options such renewable energy, energy storage, demand response, CHP, etc.?"

The market study team asked end users to rate the relative importance of various energy management options using a five-point scale where 5 equaled “very important” and 1 equaled “not important at all.” Figure 6 shows that energy efficiency remains the most popular energy management option based on average scores. However, the perceived importance of renewables and energy management systems was close to that for energy efficiency. Demand response was the least popular option, which is consistent with the discussion in the previous subsection.

Figure 6: The Relative Importance of Energy Management Options for Electronics Manufacturers



Source: DNV GL Analysis

3.2 Subsector: Food Production

3.2.1 *The Food Production Subsector*

According to the CEC, the Food Production subsector uses more energy than any other industrial subsector in California except for the Petroleum subsector. The CEC’s IEPR forecast estimates that the Food Services/Production subsector will account for 16 percent of California’s industrial electric consumption and 18 percent of its natural gas consumption over the 2020-2030 period.

The Food Production subsector includes:

- **Companies that convert livestock and agricultural products into products for intermediate or final consumption (NAICS code 311):** Activities in this subsector include animal food manufacturing, grain and oilseed milling, sugar and confectionery product manufacturing, fruit and vegetable preserving, animal slaughtering and processing, seafood product production and packaging, bakeries and tortillas manufacturing, and manufacturing of other foods such as peanut butter, coffee, tea, syrups, mayonnaise, and spices.

- **Companies that manufacture beverages and tobacco products (NAICS code 312):** These include breweries, wineries, distilleries, soft drink manufacturers, and tobacco manufacturers.

3.2.2 *EE Measures in the Food Production Subsector*

3.2.2.1 Selection of EE Measures

In the EE Technology Selection phase of the study, the team interviewed experts on the Food Production subsector and conducted an extensive literature review. Through these interviews and the literature review, the team identified many promising EE measures for this subsector. From this longer list of measures, it selected three technologies that hold the greatest promise:

- Refrigeration system optimization:
  - Refrigeration is the second-largest end use in this subsector.[22]
  - Refrigeration systems are often old and built-up with equipment from various vendors over the years. This creates inefficiencies due to poor integration of the various systems and lack of controls.
- Boilers and heat recovery:[23]
  - There are many inefficient boilers and underused heat recovery measures. In the last 10 years of DOE's Industrial Energy Assessment audits in California, eight of the top 10 recommended natural gas measures were applicable to boilers and heat recovery.
  - The previous (2015) study of this California subsector found that awareness and adoption of heat recovery technologies was limited.[24]
- VFDs on pumps and motors:
  - The motors end use is the largest one in this subsector.
  - The top measure recommended was VFDs on pumps and fans, both in frequency of recommendation and projected energy savings, by the Industrial Assessment Center audits conducted in California food facilities over the last 10 years.[25]

Appendix B details the EE measure selection process for this subsector. Table 3-8 describes the three EE measures that the team ultimately selected.

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[22] According to EIA's latest MECS study, Machine Drives account for 43% of electric consumption in food facilities and Process Cooling and Refrigeration account for 26%.

[23] Heat recovery is a process where excess (waste) heat - generated through fuel combustion, gas compression, and exothermic chemical reactions - is typically exhausted into the environment but can be recovered, via heat exchangers and economizers, and utilized in other systems requiring heat input, potentially lowering the amount of fuel required to heat processes.

[24] "Measure, Application, Segment, Industry (MASI): Motors Baseline and Opportunities in the Industrial, food Processing, and Agricultural Sectors, and Early Motor Retirement in Refineries", Navigant Consulting Inc.; ASW Engineering, 2/2015, http://www.calmac.org/publications/MASI_Motors_Opportunities_Final_Report.pdf

[25] 2019 Guidehouse internal analysis of Industrial Assessment Center audits.

Table 3-8: Descriptions of EE Measures for Food Production

EE Measure	Description
Refrigeration system optimization	Includes a variety of smaller measures to improve the energy efficiency of refrigeration systems mostly through controls. These include head pressure adjustments, adjustment of suction pressure, sequencing of refrigeration compressors, temperature adjustments, improving insulation, adding VFDs to compressors and the installation of new more EE compressors.
Boilers and heat recovery	Includes low cost boiler EE improvements such as measuring boiler system performance based on condensate return, improving insulation of the boiler system and loops, boiler controls, and boiler system tune-ups. The measure also includes opportunities for heat recovery via heat exchangers, from process heat (e.g., used in canning tomatoes), compressors, boilers, and hot water systems.
VFDs on pumps and motors	The installation of VFDs on pumps and motors produces energy savings because many motors in this subsector operate well below the design load. This is especially true for facilities that have large seasonal swings in production. VFD savings can also be further enhanced by moving to smart controls. However, expertise in complex controls systems is needed.

Source: DNV GL Analysis

3.2.2.2 Estimating Energy Savings for Food Production EE Measures

The market study team asked the vendors of the selected EE measures to estimate the annual energy savings their customers could expect from installing the measures. If vendors provided a range of energy savings for a given measure, the team asked them what different factors or applications would drive this range. Table 3-9 shows these energy savings estimates and the factors that can influence the range of energy savings.

Table 3-9: Energy Savings Estimates for Food Production EE Measures

EE Measure	End Use Energy Savings Estimate	Factors Influencing the Range of Energy Savings
Refrigeration system optimization	Average energy savings: 29 percent of refrigeration system consumption Range of energy savings estimates: 13 to 55 percent Number of vendors providing savings estimate: Four	• The size and use of the system: A couple of vendors noted that the efficiency of a system can depend on how the food production facility uses the refrigeration. For example, many wineries and canning facilities have refrigeration systems that are oversized so they can handle large loads for a small part of the year even though they are operating at low loads for the rest of the year. • Whether the system uses VFDs or high EE motors. The potential energy savings from the optimization measures would be reduced if the end user had already made these improvements to the refrigeration system.
Boilers and heat recovery	Average energy savings: 18 percent of the process boilers and water heaters Range of energy savings estimates: 10 to 25 percent Number of vendors providing savings estimate: Three	• The level of facility production: One vendor observed that the energy savings can be higher when the facility is at peak production and everything is going “full throttle,” because there is greater opportunity to reuse the waste heat during the production process.
VFDs on pumps and motors	Average energy savings: 33 percent Range of energy savings estimates: 25 to 40 percent Number of vendors providing savings estimate: Two	• The partial load operation of the motor: When motors are only partially needed, throttles or other inefficient means are used to operate the motor at partial load. The larger the frequency of partial operation, the greater the potential energy savings from the installation of the VFD.

Source: DNV GL Analysis

3.2.2.3 EE Measure Awareness and Market Saturation in Food Production

If the end users did not report having a given EE measure installed, the market study team asked them, “Prior to my mentioning EE Measure X, were you familiar with EE Measure X?” Table 3-10 shows that awareness of refrigeration system optimization and boiler/heat recovery measures was nearly universal, but three of the respondents were unfamiliar with VFDs as a measure opportunity.

Table 3-10: Awareness of Food Production EE Measures

EE Measure	End User Awareness of EE Measure (n=11)
Refrigeration system optimization	91%
Boilers and heat recovery	91%
VFDs on pumps and motors	73%

Source: DNV GL Analysis

Table 3-11 shows the measure saturation estimates for the three EE measures based on end user self-reports and vendor estimates of the California market. Both end users and vendors reported boiler and heat recovery measure saturation to be very low. This low market saturation was consistent with findings from the literature review.

Table 3-11: Measure Saturation Estimates for Food Production EE Measures

EE Measure	End User Measure Saturation	Vendor Measure Saturation
Refrigeration system optimization	62%	24%
Boilers and heat recovery	19%	11%
VFDs on pumps and motors	68%	No estimates provided

Source: DNV GL Analysis

The market study team estimated the end user market saturation in Table 3-11 using ratio weights to the whole California market based on the self-reports of a sample of 11 food production facility representatives.[26] Four vendors provided market saturation estimates for boilers and heat recovery and three vendors provided estimates for refrigeration system optimization. The estimates in the vendor column of the table represent the average of the vendor estimates. For the EE measures that had measure estimation estimates from end users and vendors, the market study team used the average of these estimates for the inputs into the PG Study model.

To calculate measure estimation estimates for the food production facilities differentiated by company size, the market study team also used the ratio estimation method.[27] Larger companies were more likely to report installing the refrigeration system optimization and VFD measures. Heat recovery measure saturation was similar for both the larger and smaller companies.

The market study team speculated that the large difference between the end user and vendor measure saturation estimates for refrigeration optimization might be due to different interpretations as to the breadth of what constitutes refrigeration optimization. As described, the refrigeration system optimization measure encompasses a half dozen smaller measures. It is possible that the vendors interpreted that refrigeration system optimization meant a package of these measures sold as a

[26] As discussed earlier, ratio methodology is a common statistical approach where the weights are calculated using the number of subjects in the sample compared to the number of subjects in the population, and relevant known values for characteristics in the sample and the population such as number of employees or energy consumption. It allows the evaluator to make survey results from a sample more representative of the underlying population

[27] For the Food Production subsector, the team defined a large company as one that had greater than 250 employees.

comprehensive service. In contrast, the end users may have viewed the implementation of any one of these smaller measures as constituting refrigeration system optimization. This looser definition would explain the higher measure saturation estimate from the end users.

3.2.2.4 Barriers to EE Measure Adoption in Food Production

The market study team asked the subsector experts, equipment vendors, and the end users about barriers or factors that might prevent food production facilities from installing the three EE measures which the study was focusing on. The experts identified the following barriers/factors:

- **Lack of EE knowledge among subsector operators and management:** Experts observed that while larger, more sophisticated companies are using advanced controls for motor system optimization, other facilities lack the knowledge to implement these optimization strategies. Some experts claimed that there are not enough technical educators who can convince key decision makers of the benefits of current best practices. They noted that many operators in the Food Production subsector do not have the time to learn about EE opportunities.
- **Seasonal/episodic production schedules complicate the economics of EE investments:** Research revealed that the Food Production subsector is susceptible to seasonality changes and the run hours of process equipment varies greatly throughout the year. For example, it is common to have only 4 months of operation for vegetable processing. These lower hours-of-use can make owners hesitant to upgrade to more EE systems because of longer payback periods and reduced cost-effectiveness.
- **First cost barriers, especially for smaller companies:** Experts observed that many smaller facilities (micro-breweries or small wineries) do not have the capital resources to invest in EE upgrades of equipment. The replacement of large refrigeration systems is cost-prohibitive for companies of many sizes.
- **Large refrigeration systems require customized solutions:** The research found that refrigeration systems in the Food Production subsector are often old and built-up with equipment from various vendors over the years. One-size-fits-all remedies are usually not feasible and customized solutions are needed. However, some operators in this subsector are reluctant to pursue custom projects because they are expensive to develop and are subject to a higher level of scrutiny than more prescriptive measures.
- **The challenge of scheduling maintenance so as not to interrupt production:** Food facilities often operate 24/7 while in production and so are reluctant to halt production and lose revenue during these periods for EE-related maintenance. Companies must determine the right time to conduct maintenance so it will have the least impact on revenue. One expert proposed enhanced sensors and building empirical computer models to determine when these maintenance repairs should be made.
- **Reluctance to change out familiar equipment:** Some experts also said that many operators do not want to make changes to the systems and components they are accustomed to using with known results.
- **Lack of time to plan and implement EE projects:** Some experts noted that even when operators in the Food Production subsector are knowledgeable about EE opportunities, they often lack the time to plan and implement the EE projects.

Vendors and end users also identified additional barriers, as Table 3-12 shows. Over half the food production facility representatives mentioned factors preventing their adoption or expansion of the heat recovery measures. These included not having a use for the waste heat or the heat source (e.g., boiler) being too far from where they could use the waste heat.

Table 3-12: Factors Limiting EE Measure Adoption in Food Production

Factors	Subsector Experts	Equipment Vendors	End Users
Concern about disrupting production	X	X	
Concern about initial cost of EE measure	X	X	X
Lack of knowledge of EE measures and benefits among facility managers	X		X
Seasonal/episodic production schedules complicating the economics of EE investments	X		
Low energy costs/consumption for some facilities	X		
Reluctance to change out familiar equipment	X		
Lack of time to plan and implement EE projects:	X		
Large refrigeration systems require customized solutions:	X		
Constraints from capital budget cycles		X	
Lack of financing		X	
Competition from other energy-related projects (e.g., renewables)		X	
No ways to use waste heat in the facility (relevant to heat recovery measure)	X		X
Motors are too old or small to benefit from VFDs			X

Source: DNV GL Analysis

3.2.2.5 EE Program/Rebate Awareness and Participation among Food Production Facilities

The market study team asked the 11 food production end users about EE program awareness and participation. Table 3-13 shows that participation in EE programs was low.

Table 3-13: EE Program/Rebate Awareness and Participation

Question	Metric	Percentage

Are you aware that your electric and natural gas utilities offer rebates and incentives for your company to save energy?	Aware of the EE rebates	91%
Has your company ever received a rebate or incentive for EE equipment at your facility?	Participating in EE programs	27%
Are you aware that your electric and natural gas utilities and their contractors also offer technical assistance to help companies like yours to implement EE projects?	Aware of EE technical assistance	55%
Has your company ever received such technical assistance from your electric and gas utilities or their contractors?	Receiving technical assistance	27%

Source: DNV GL Analysis

The team asked the food production end users what was needed besides incentives or technical assistance from EE programs to get their company to adopt some of the EE measures discussed earlier in the interview. Only two of the 10 EE program-aware respondents offered suggestions:

- One end user was disappointed with his EE program experiences. “I'm not happy with the utilities at all,” he said, “there have been multiple occurrences of projects and financials being difficult to understand and it has led to distrust.” He cited one project that “was doubled in cost by accident.”
- The other end user said that participating in EE programs was not easy for companies that did not own the building they were operating in. He said that in such lease situations, the EE programs should “focus on bridging the gap to make it easier and beneficial for both parties.”

3.2.3 *Other Demand Side Energy Management in the Food Production Subsector*

While energy efficiency was the main focus of the study, the market study team also asked the subsector experts, equipment vendors, and end users about the Food Production subsector’s level of activity in renewable energy, CHP/cogeneration, onsite energy storage, and demand response programs. The team also asked them whether they thought these other demand side energy management activities might be competing with energy efficiency for company resources.

3.2.3.1 CHP/Cogeneration

One subsector expert reported that some food production companies examining their peak load are considering CHP/cogeneration and batteries to reduce costs. The literature review of the DOE’s Manufacturing Energy Consumption Survey (MECS) also found that the Food Production subsector had the fourth highest use of cogeneration among industries in the US West Region.[28] However, none of the Food Production end users in this study reported having CHP/cogeneration facilities.

[28] The top three industries for cogeneration use were Petroleum and Coal Products, Paper, and Chemical.,

3.2.3.2 Solar

Subsector experts said while some food production companies used renewables as a branding strategy, they estimated these companies represent a small proportion of the subsector. These experts observed that some of the same barriers that hinder EE projects (e.g., the unwillingness to interrupt production processes and a lack of staff/time to implement new projects) also deter renewable energy projects.

As Section 3.2.4 discusses, the market study team asked EE equipment vendors whether they thought energy efficiency competed with other energy management decisions or technologies. Of the five vendors who believed that there was competition between energy efficiency and these other energy technologies, three of the five mentioned solar as a competing technology.

The market study team asked the food production end users whether their companies had any onsite generation and whether they ever received a rebate or incentive for distributed generation equipment. Four of the 11 respondents (36 percent) said that they had done solar installations at their facility. All four said that their companies were using the solar to power their facilities and selling some of the power back to the grid. Three of the four end users said they had received financial incentives for these installations.

The team's analysis of the California NEM database found that three food processing facilities had installed solar systems in the recent 2015-2020 period and 10 had installed them over the longer 1998-2020 period.

The market study team also asked end users whether they had any near-term plans to install onsite generation. Only two of the 11 respondents said that they did, with one planning a solar project and the second planning a biodiesel project.

3.2.3.3 Demand Response

Only two of the 11 (18 percent) end users reported having participated in a demand response program. In addition, four of the 11 (36 percent) end users said they had not even heard of demand response programs.

When asked about various possible barriers to demand response program participation, eight of the 10 respondents (80 percent) said concerns about "disruptions to operations/processes and perceived productivity losses" were "major barriers" (5 on a 5-point severity scale) and a ninth said it was a "considerable barrier" (4 on a 5-point severity scale). Given descriptions of various demand response programs, most of the end users said their companies were unlikely to participate in these programs. "Demand response doesn't come up much [in conversation] because companies require their refrigeration 24/7," one EE equipment vendor explained.

3.2.3.4 Other Demand Side Energy Management

None of the 11 food production end users reported doing any energy storage projects. One end user indicated they had a biodiesel project in their near-term plans.

3.2.4 *Interaction Between EE and Other Demand Side Management*

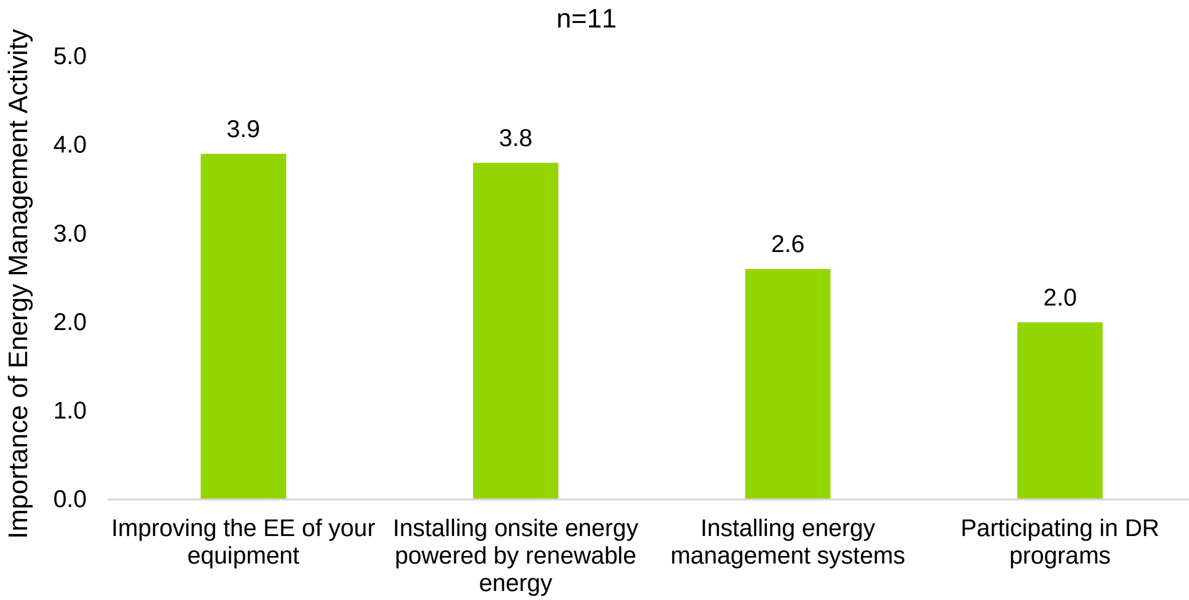
The market study team asked EE equipment vendors in the Food Production subsector whether the investments their customers make in energy efficiency compete with other energy management decisions or technologies. Five of the seven vendors who responded to this question said there was competition. EE equipment vendors view solar as their biggest competition. One suggested this was due to the popularity of solar. “Customers might look at the more popular ways to reduce energy before looking into heat recovery,” he said. Another vendor said that solar projects could get the edge on economics grounds. “Heat recovery is often not cost-effective without incentives, and so customers may elect to install solar before heat recovery for this reason,” he explained.

However, some vendors cited examples where food production companies had installed EE improvements and solar at the same time. One vendor identified a large brewery and one of California’s largest mushroom producers as having installed EE refrigeration and solar at the same time. “Sometimes solar is paired with refrigeration and heat exchanger installation,” said another vendor.

The market study team asked the food production EE equipment vendors whether their companies provide services that integrate energy efficiency with solar, wind, or demand response. None of the seven vendors said they offered these integrated services.

The market study team asked the food production end users to rate the relative importance of various energy management options using a five-point scale where 5 equaled “very important” and 1 equaled “not important at all.” Figure 7 shows that energy efficiency remains the most popular energy management option based on average scores. However, the perceived importance of renewables and energy management systems was close to that for energy efficiency. Demand response was the least popular option, which is consistent with the discussion in the previous subsection.

Figure 7: The Relative Importance of Energy Management Options for Food Producers



Source: DNV GL Analysis

3.3 Subsector: Chemical Manufacturing

3.3.1 *The Chemical Manufacturing Subsector*

This subsector energy includes all companies involved in the transformation of organic and inorganic raw materials by a chemical process and the formulation of products (NAICS code 325). It includes companies that produce basic chemicals and those that manufacture intermediate and end products produced by further processing of basic chemicals. The Chemical Manufacturing subsector does not include industries that process chemicals as part of mining operations or as part of the refining of crude petroleum.

According to the CEC, this subsector uses the third most energy among the industrial subsectors in California, exceeded only by the Petroleum and Food Services/Production subsectors. The CEC's IEPR forecast estimates that the Chemical Manufacturing subsector will account for 10 percent of California's industrial electric consumption and 11 percent of its natural gas consumption over the 2020-2030 period.

3.3.2 *EE Measures in the Chemical Manufacturing Subsector*

3.3.2.1 Selection of EE Measures

In the EE Technology Selection phase, the market study team conducted an extensive literature review and interviewed experts on the Chemical Manufacturing subsector. Through these interviews and the literature review, the team identified many promising EE measures for this subsector. From this longer list of measures, it selected three technologies that hold the greatest promise: 1) heat recovery, 2) advanced automation and optimization, and boilers and heat recovery, and 3) mechanical drives/VSDs.

The reasons for selecting these EE measures included:

- The frequency with which the subsector experts and literature review sources mentioned these measures
- How frequently DOE's Industrial Energy Assessment audits in California listed these as recommended measures
- This subsector has processes and equipment that generate significant amounts of excess heat (for the heat recovery measure)

Appendix B details the EE measure selection process for this subsector. Table 3-14 describes the three EE measures the team selected.

Table 3-14: Descriptions of EE Measures for Chemical Manufacturing

EE Measure	Description
Heat Recovery	Includes the installation of heat exchangers, also known as economizers. • Stack economizers may recover heat energy from flue gases, instead of exhausted to the atmosphere, and use it to pre-heat boiler feedwater, which can save 1 percent of fuel for every 45°F (25°C) reduction in exiting gas temperature. • Installing economizers in industrial boilers-can increase boiler efficiency by 2.5 to 4 percent, dependent on the number of tubes, the addition of tube fins, allowable pressure drop, and mostly dependent on the boiler feedwater temperature. • Low pressure steam and condensate can be used to pre-heat low energy process streams (feedwater) Low pressure steam can also be recompressed to increase its energy and then used to heat other feed streams or endothermic processes. • Many facilities generate excess heat, via compressors (which give off heat) and other exothermic chemical reactions (acid-base, polymerization). That excess heat can pre-heat other feed streams or endothermic processes decreasing the amount of fuel used for process heating.

EE Measure	Description
Advanced Automation and Optimization	• *Plant-wide monitoring and automated control systems:* These systems use machine learning and analytics to understand their production data and to automatically optimize processes. o Many facilities have Supervisory Control and Data Acquisition (SCADA) systems that enable real-time or interval process monitoring. However, existing systems are typically focused on discrete systems or processes in a plant, and they require manual optimization of systems or processes. o Recent advancements in machine learning allow for SCADA systems that automatically identify drifting parameters and adjust them back to desired ranges. These automated monitoring and controls systems can quickly adjust parameters for many systems and processes to optimize plant-wide operations across a variety of loads. • *Variable flow primary loop systems for cooling:* In a variable flow primary pumping system, the condenser, chiller, and chilled water loop all work together to maximize efficiency and performance via automated monitoring and control of VSDs through the system. For example, the chiller varies its cooling capacity to maintain a desired chiller leaving water temperature, which saves compressor energy at part-load conditions. • *Fuel to air controls for combustion systems:* Combustion systems are often not sufficiently optimized for excess air and many operate at unnecessarily low combustion efficiencies. These systems are typically manually tested and optimized annually. o Most existing systems use constant speed drives and require manual optimization of excess air. o Newer systems use VSDs and advanced controls to automate optimization.
Mechanical drives/VFDs	• *Replacing constant speed drives:* Replacing single speed drives with VFDs results in average speed reductions of 10 to 60 percent. • *Replacing single-stage systems with multi-stage systems:* Single-stage systems typically use oversized motors or pumps with constant speed drives. These systems are very inefficient during non-steady state operations. Multi-stage systems use two or more efficient VFD drives modulating their speed with the load to achieve optimum performance during part-load conditions. These systems can offer significant energy savings across all load profiles.

Source: DNV GL Analysis

3.3.2.2 Estimating Energy Savings for the EE Measures

The market study team asked the vendors of the selected EE measures to estimate the annual energy savings their customers could expect from installing the measures. If vendors provided these estimates, the team asked what information the estimates were based upon. If vendors provided a range of energy savings for a given measure, the market study team asked them what different factors or applications would drive this range. Table 3-15 shows these energy savings estimates and the factors that can influence the range of energy savings.

Table 3-15: Energy Savings Estimates for Chemical Manufacturing EE Measures

EE Measure	Energy Savings Estimate	Factors Influencing the Range of Energy Savings
Heat Recovery	Average energy savings: 20 percent Range of energy savings estimates: 10 to 40 percent of process heating boilers and water heaters Number of vendors providing savings estimate: Seven	The design and use of the system: One vendor said that the savings from heat recovery varies with system design, how the waste heat will be reused, and possible safety considerations.
Advanced Automation and Optimization	Average energy savings: 25 percent of facility operations which can benefit from advanced automation[29] Range of energy savings estimates: 13 to 45 percent Number of vendors providing savings estimate: Five	• Scope of the automation: One vendor said the range of savings depends on what proportion of the facility the company chooses to automate.

[29] The vendors estimated, on average, that 55% of a facility’s operating systems could benefit from advanced automation.

EE Measure	Energy Savings Estimate	Factors Influencing the Range of Energy Savings
Mechanical drives/VSDs	Average energy savings: 29 percent of pump/motor consumption Range of energy savings estimates: 13 to 40 percent Number of vendors providing savings estimate: Four	• Which application the VSD is being used on: Multiple vendors said that the level of energy savings was highly dependent on which application or process is powered by the pump/motor being controlled by the VSD. One vendor observed that there are some parts of chemical manufacturing plants where it would not be safe to operate a VSD. • Load characteristics: Multiple vendors noted that the full load or operating torque range as well as the operating hours of the equipment being controlled can influence the level of energy savings.

Source: DNV GL Analysis

3.3.2.3 EE Measure Awareness and Market Saturation in Chemical Manufacturing

If the end users did not report having a given EE measure installed, the market study team asked, "Prior to my mentioning EE Measure X, were you familiar with EE Measure X?" Table 3-16 shows that, while awareness of the heat recovery measure was universal, only slightly more than half of the end users were aware of the VSD measure, and awareness of the advanced automation measure was very low.

Table 3-16: Awareness of Chemical Manufacturing EE Measures

EE Measure	End User Awareness (n=7)
Heat Recovery	100%
Advanced Automation and Optimization	20%
Mechanical drives/VFDs	57%

Source: DNV GL Analysis

Table 3-17 shows the measure saturation estimates for the three EE measures based on end user self-reports and vendor estimates of the California market. The end user market saturation was estimated using ratio weights to the whole California market based on the self-reports of a sample of seven chemical manufacturing facility representatives.[30] Five vendors provided market saturation estimates for VFDs, four provided estimates for advanced automation, and three offered estimates for heat recovery. Both end users and vendors reported heat recovery and advanced automation

[30] As discussed earlier, ratio methodology is a common statistical approach where the weights are calculated using the number of subjects in the sample compared to the number of subjects in the population, and relevant known values for characteristics in the sample and the population such as number of employees or energy consumption. It allows the evaluator to make survey results from a sample more representative of the underlying population

measure saturation to be very low. The market study team used the average of end user and vendor estimates for the inputs into the PG Study model.

The market study team used the ratio estimation method to calculate measure saturation estimates for the chemical manufacturing facilities differentiated by company size.[31] None of the smaller companies reported installing heat recovery or advanced automation measures. The smaller companies did report installing VFDs but had a much lower measure saturation (14 percent) than the large companies (67 percent).

Table 3-17: Measure Saturation Estimates for Chemical Manufacturing EE Measures

EE Measure	End User Measure Saturation	Vendor Measure Saturation
Heat Recovery	30%	12%
Advanced Automation and Optimization	29%	33%
Mechanical Drives/VSDs	40%	51%

Source: DNV GL Analysis

3.3.2.4 Barriers to EE Measure Adoption in Chemical Manufacturing

Expert interviews and the literature review revealed several barriers to EE implementation in the Chemical Manufacturing subsector, including:

- Competition for capital especially from process-related projects: Some experts noted that most chemical companies are investor-owned and so they do not want to spend capital for energy efficiency gains that may be minimal, especially if it means they will accrue debt or lose out on more lucrative opportunities that will generate profit for their investors such as process-related improvements.
- Low energy costs: While chemical manufacturing is an energy-intensive industry, experts observed that energy costs are still cheap, so shutting down plants for incremental efficiency gains or optimizing their plants beyond the required levels to meet demand is not attractive to most operators.
- Concerns over lost production due to the downtime required to install and commission more EE systems.
- Concerns about possible negative impacts of EE technology on product quality or yield.
- Decision makers' lack of understanding of the benefits of energy efficiency.

Of the barriers the experts identified, the vendors and end users mentioned two most frequently: competition for capital especially from process-related projects and lack of knowledge of EE measures and benefits among facility managers. "At this facility we're just doing it as we can," said

[31] For the Chemical Manufacturing subsector, the team defined a large company as one that had 100 or more employees.

one end user. "Without incentives we can't get a good payback [on a VFD measure] and have to compete with process engineers. They make more product and get preferential treatment."

Several vendors also mentioned the barrier of facility managers being unaware of the EE technologies, Table 3-16 evidences this. The vendors and end users also identified barriers that the experts had not. Vendors identified concern about initial cost of EE measures as a significant barrier with all seven vendors rating it as an extreme barrier. Table 3-18 shows the factors/barriers identified by all three groups of interviewees.

Table 3-18: Factors Limiting EE Measure Adoption in Chemical Manufacturing

Factors	Subsector Experts	Equipment Vendors	End Users
Concern about disrupting production	X	X	X
Concern about initial cost of EE measures		X	X
Lack of knowledge of EE measures and benefits among facility managers	X	X	X
Low energy costs/usage	X		
Competition for capital especially from process-related projects	X	X	X
Concerns about negative impacts of EE technology on product quality or yield.	X		X
Lack of awareness of EE incentives		X	
Lack of financing		X	
Competition from other energy-related projects (e.g., renewables)		X	

Source: DNV GL Analysis

3.3.2.5 EE Program/Rebate Awareness and Participation among Chemical Manufacturing Facilities

The market study team asked the seven chemical manufacturing end users about EE program awareness and participation. Table 3-19 shows their responses. EE program participation in this subsector was higher (71 percent) than the other two industrial subsectors (Electronics Manufacturing [60 percent] and Food Production [27 percent]).

Table 3-19: EE Program/Rebate Awareness and Participation

Question	Metric	Percentage
Are you aware that your electric and natural gas utilities offer rebates and incentives for your company to save energy?	Aware of the EE rebates	71%

Question	Metric	Percentage
Has your company ever received a rebate or incentive for EE equipment at your facility?	Participating in EE programs	71%
Are you aware that your electric and natural gas utilities and their contractors also offer technical assistance to help companies like yours to implement EE projects?	Aware of EE technical assistance	57%
Has your company ever received such technical assistance from your electric and gas utilities or their contractors?	Receiving technical assistance	43%

Source: DNV GL Analysis

The market study team also asked the chemical manufacturing end users what more was needed (besides incentives or technical assistance) from EE programs to get their company to adopt some of the EE measures discussed earlier in the interview. Only one respondent offered a suggestion: that the programs provide some rebates for batteries for energy storage.

3.3.3 *Other Demand Side Energy Management in the Chemical Manufacturing Subsector*

The market study team also asked the subsector experts, equipment vendors, and end users about the Chemical Manufacturing subsector's level of activity in renewable energy, CHP/cogeneration, onsite energy storage and demand response programs. The team asked whether they thought that these other demand side energy management activities might be competing with energy efficiency for company resources.

3.3.3.1 CHP/Cogeneration

The Chemical Manufacturing experts indicated that CHP was the most common demand side activity beyond energy efficiency in this subsector. They said CHP systems are being installed because they have >80 percent thermal efficiency. The literature review revealed that in the last decade the Chemical Manufacturing subsector has, on a national basis, spent $200 billion to expand production capacity and CHP systems are standard technologies in most of these new facilities.

3.3.3.2 Solar

Subsector experts said many chemical companies have purchase agreements with independent providers for wind or solar to fulfill corporate sustainability goals. However, experts indicated that most chemical manufacturers still rely heavily on traditional grid power and shy away from generating their own energy and running their own microgrids. The experts said that most of these manufacturers do not want to take on the responsibility of generating power themselves because they do not think it is a profitable investment for their capital.

The market study team asked chemical manufacturing end users whether their companies had any onsite generation and if they had ever received a rebate or incentive for distributed generation equipment. Only one of the seven respondents (14 percent) said that they had done solar installations at their facility. This end user said the solar system, for which his company received a rebate, covered

30 to 40 percent of their onsite consumption and while his company would have liked to install storage, it determined it to be too expensive. The evaluations team's analysis of the California NEM database found five chemical manufacturing facilities had installed solar systems in the most recent 2015-2020 period and a total of six facilities had installed them over the longer 1998-2020 period.

The market study team also asked the end users whether they had any near-term plans to install onsite generation. Two of the seven respondents (28 percent) said they did, with both planning solar projects. One of the planned projects would involve solar PV with battery storage in the initial phase and then solar heating in the second phase.

3.3.3.3 Demand Response

The experts said that demand response programs are popular in California for those chemical manufacturers whose operations can tolerate part-loads and non-steady state conditions. Only one of the seven (18 percent) end users reported having participated in a demand response program. In addition, three of the seven (43 percent) end users said they had not even heard of demand response programs.

When asked about possible barriers to demand response program participation, four of the seven respondents (57 percent) said concerns about "disruptions to operations/processes and perceived productivity losses" were "major barriers" (5 on a 5-point severity scale). Given descriptions of various demand response programs, most of the end users said their companies were unlikely to participate in these programs.

3.3.3.4 Other Demand Side Energy Management

None of the seven chemical manufacturing reported using onsite energy storage. However, one end user reported near-term plans for a solar installation with storage and another end user mentioned offering incentives for energy storage as one way that the California energy management programs could improve.

3.3.4 *Interaction Between EE and Other Demand Side Management*

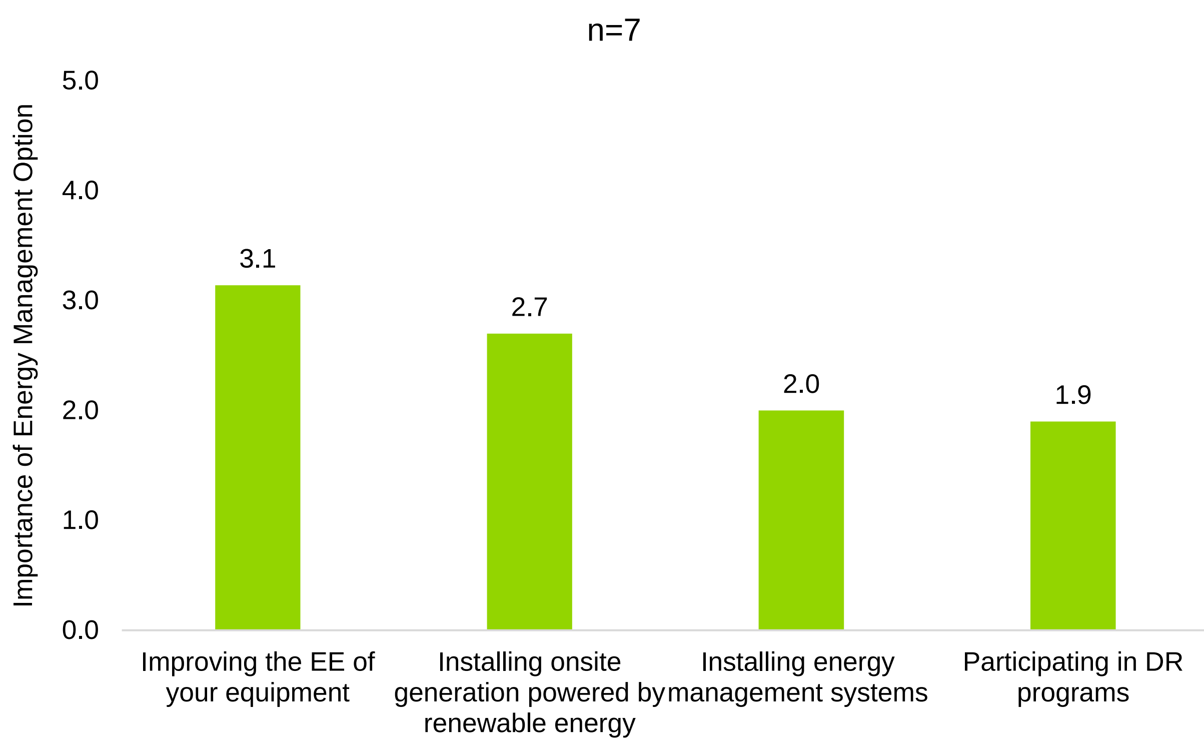
The team asked vendors of EE equipment in the Chemical Manufacturing subsector whether the investments their customers make in energy efficiency compete with other energy management decisions or technologies. Four of the seven vendors said there was competition but one of them said this competition occurs rarely. These vendors said the chemical manufacturers would judge EE projects and non-EE projects using criteria such as ROI, impacts on productivity, and safety. "Safety is the major factor, as they don't want anyone getting hurt because it's a lawsuit, and it's potentially a loss of production," said one vendor. One vendor said that onsite generation projects may have an edge over EE projects in facilities which operate in more remote locations where reliable power is more questionable.

A couple vendors identified situations where energy efficiency and other energy management technologies are complementary. One example of this is where EE improvements at the facility allow for the size of the solar system to be reduced. Another example is where the implementation of advanced automation or the installation of a VFD enables demand response opportunities that were not previously possible.

The market study team asked the chemical manufacturing EE equipment vendors whether their companies provide services that integrate energy efficiency with solar, wind, or demand response. Three of the seven vendors said they did, with two saying they offered services integrating energy efficiency with solar and one reporting that his company also integrated energy efficiency with wind energy.

Chemical manufacturing end users rated the relative importance of various energy management options using a five-point scale where 5 equaled “very important” and 1 equaled “not important at all.” Figure 8 shows that energy efficiency was the most popular energy management option based on average “importance” scores. Demand response was the least popular option.

Figure 8: The Relative Importance of Energy Management Options for Chemical Manufacturers



Source: DNV GL Analysis

3.4 Subsector: Dairies

3.4.1 *The Dairies Subsector*

The Dairies subsector energy includes all California companies involved in the milking of dairy cattle and milk production (NAICS code 112120). It does not include farmers who raise beef cattle.

The CEC’s IEPR 2025 forecast combines dairies with other subsectors into a larger Dairies, Fishing, and Hunting subsector. Table 3-20 shows that this combined subsector accounted for 4 to 17 percent of the California IOUs’ agricultural electric consumption and 1 to 15 percent of their agricultural gas consumption.

Table 3-20: Forecasted 2025 Electric and Gas Consumption for the Dairies, Fishing, and Hunting Subsector by Utility

Program Administrator	% of Electric Consumption	% of Gas Consumption
PG&E	17%	10%
SCE	9%	
SCG		15%
SDG&E	4%	1%

Source: DNV GL Analysis

In addition to these contributions to California's agricultural energy consumption, the market study team and the CPUC selected this subsector for the following reasons:

- A high-level search of California EE program evaluations and market studies indicated that the dairy subsector is less studied than other California agricultural subsectors
- It is a subsector that can benefit from a wider variety of EE measures

3.4.2 *EE Measures in the Dairies Subsector*

3.4.2.1 Selection of EE Measures

In the EE Technology Selection phase, the team conducted an extensive literature review and interviewed experts on the Dairies subsector. Through these interviews and the literature review, the team identified many promising EE measures. From this longer list of measures, it selected three technologies that hold the greatest promise and the highest frequency with which the subsector experts and literature review sources mentioned these measures. The measures and reasons for selecting these EE measures follow:

- **Refrigeration system heat recovery:** The experts identified milk pumping and refrigeration systems as the top two sources of energy consumption on dairy farms.
- **VFDs on pumps:** The pumps used in milking and collection systems are mostly constant speed models which typically run well below capacity, wasting most of the pump's motor power.
- **EE fans and ventilation:** The experts identified the market for EE fans as a newer market that was expanding quickly.

Appendix B details the EE measure selection process for this subsector. Table 3-21 describes the three EE measures the team selected.

Table 3-21: Descriptions of EE Measures for Dairies

EE Measure	Description
Refrigeration system heat recovery	Dairy refrigeration systems keep raw milk cool and the heat removed by these refrigeration systems is typically rejected to the environment. Installation of a heat recovery system (a heat exchanger on the condensing unit) allows waste heat to be recovered for pre-heating water for cleaning processes, which is another large energy use on a dairy farm. The experts claimed that this measure is underused in the Dairies subsector.
VFDs on pumps	The milking and collection system pumps milk through the milking system from cow to cooling tank. Current practice is a constant speed pump with a manually adjusted orifice to maximize the vacuum level in the system. As a result, systems typically run well below capacity, wasting most of the pump motor's power. A VFD allows the system to adjust optimize vacuum levels on the fly, reducing pump power when not under full load conditions. One expert claimed that this pumping process was the highest-energy-consuming and least-energy efficient process on a dairy farm.
EE fans and ventilation	High efficiency fan blades are made from lighter materials and reduce overall power consumption. A variety of fan sizes are now available, and the experts said that this was a newer market that was expanding quickly. Experts noted routine blade cleaning can improve fan efficiency without part replacement.

Source: DNV GL Analysis

3.4.2.2 Estimating Energy Savings for EE Measures

The market study team asked the vendors of selected EE measures to estimate the annual energy savings their customers could expect from installing the measures. If vendors provided a range of energy savings for a given measure, the team asked what different factors or applications would drive this range. Table 3-22 shows these energy savings estimates and the factors that influence the range of energy savings.

Table 3-22: Energy Savings Estimates for Dairy EE Measures

EE Measure	End Use Energy Savings Estimate	Factors Influencing the Range of Energy Savings
Refrigeration system heat recovery	Average energy savings: 45 percent of the boilers and water heaters providing the heat which the scavenged waste heat is replacing Range of energy savings estimates: 40 to 50 percent Number of vendors providing savings estimate: Two	Amount of hot water used: The waste heat from the refrigeration systems are commonly used to heat water that is used for washing out stalls or (in colder parts of California) for warming up drinking water for cows. The more hot water the farm uses, the greater the energy savings.
VFDs on pumps	Average energy savings: 13 percent of the pump's electric consumption Range of energy savings estimates: 8 to 18 percent Number of vendors providing savings estimate: Two	• Size of dairies: One vendor said that in bigger dairies with large milking parlors, there is a bigger savings benefit by installing the VFDs at the milk receiver, as opposed to putting it on the milk vat to pump through a plate cooler. Another vendor thought the VFDs were not the most cost-effective option for smaller dairy farms. • Type of pump being controlled: One vendor said that energy savings from a VFD can be greater when installed on an irrigation pump compared to one installed on a milk vacuum pump.
EE fans and ventilation	Average energy savings: 39 percent of the baseline fan's electric consumption Range of energy savings estimates: 13 to 40 percent Number of vendors providing savings estimate: Three	• Amount of preexisting ventilation: One vendor said that savings will be greater for a dairy farmer which does not have a lot of preexisting ventilation versus one which is just trying to fill some gaps in their ventilation system. • Type of barn: Vendors said that high velocity low speed (HVLS) fans are most effective in four-wall barns versus free stalls.

Source: DNV GL Analysis

3.4.2.3 EE Measure Awareness and Market Saturation in Dairies

If end users did not report having a given EE measure installed, the market study team asked, "Prior to my mentioning EE Measure X, were you familiar with EE Measure X?" Table 3-23 shows that awareness of the VFDs on pumps and EE ventilation measures among the eight dairy farmers was universal, with three-quarters of the respondents being aware of the heat recovery measure.

Table 3-23: Awareness of Dairy EE Measures

EE Measure	End User Awareness (n=8)
Refrigeration system heat recovery	75%
VFDs on pumps	100%
EE fans and ventilation	100%

Source: DNV GL Analysis

Table 3-24 shows the measure saturation estimates for the three EE measures based on end user self-reports and vendor estimates of the California market. The end user market saturation was estimated using ratio weights to the whole California market based on the self-reports of a sample of eight dairy farmers.[32] Five vendors provided market saturation estimates for heat recovery and four vendors provided estimates for each of the other two measures. The estimates in the table's vendor column represent the average. End users and vendors reported refrigeration system heat recovery and VFD measure saturation to be very low with EE ventilation adoption rates somewhat higher. The market study team used the average of end user and vendor measure saturation estimates for the inputs into the PG Study model.

The market study team also used the ratio estimation method to calculate measure saturation estimates for the dairy operations differentiated by company size.[33] Larger dairy operations were much more likely (55 percent average measure saturation) to use heat recovery than the smaller operations (6 percent average measure saturation). The measure saturation of VFDs was also twice as high in the large dairy operations as it was in the small operations. However, the measure saturation of the EE fans was similar in large and small operations.

Table 3-24: Measure Saturation for Dairy Measures

EE Measure	End User Measure Saturation	Vendor Measure Saturation
Refrigeration system heat recovery	19%	29%
VFDs on pumps	31%	32%
EE fans and ventilation	62%	48%

Source: DNV GL Analysis

[32] As discussed earlier, ratio methodology is a common statistical approach where the weights are calculated using the number of subjects in the sample compared to the number of subjects in the population, and relevant known values for characteristics in the sample and the population such as number of employees or energy consumption. It allows the evaluator to make survey results from a sample more representative of the underlying population

[33] For the Dairies subsector, the team defined a large company as one that had 20 or more employees based on the distribution of company sizes in the subsector.

3.4.2.4 Barriers to EE Measure Adoption in Dairies

Expert interviews and the literature review revealed several barriers to EE implementation in the Dairies subsector including:

- **Inability to afford the high first cost of some EE improvements:** Experts identified this as a significant barrier to EE implementation in the Dairy subsector.
- **Incompatibility of older pumps:** The experts observed that older pumps may not be VFD-compatible, which increases installation costs.
- **Lack of time for EE knowledge implementation:** Some experts noted that dairy farmers often cannot afford to take downtime to learn about energy efficiency opportunities or implement these upgrades.

One of the vendors said that the lack of EE knowledge among dairy farmers was sometimes due to difficulty deviating from traditional practices. “Dairies are so used to setting up systems in an ‘old fashioned’ way with X fans per 60 feet,” said one vendor. “Dairies need to approach [ventilation] with a technical advanced controlling mindset where initial investment in ‘smart’ controls of ventilation systems can save a whole lot on the back end and improve cow's comfort and production.”

The vendors and end users also identified additional limiting factors, as Table 3-25 shows. All three interviewee groups identified initial cost as a factor.

Table 3-25: Factors Limiting EE Measure Adoption in Dairies

Factors	Subsector Experts	Equipment Vendors	End Users
Concern about disrupting production		X	
Concern about initial cost of EE measures	X	X	X
Lack of knowledge of EE measures and benefits	X	X	
Concern about the availability of EE equipment		X	
Lack of financing		X	
Competition from other energy-related projects (e.g., renewables)		X	
Older pumps that cannot benefit from VFDs	X		
Farm power/voltage issues that make EE fan installation more expensive		X	

Source: DNV GL Analysis

3.4.2.5 EE Program/Rebate Awareness and Participation among Dairies

The market study team asked the eight dairy farmers about EE program awareness and participation. Table 3-26 shows their responses. EE program awareness was universal among the respondents and program participation was high.

Table 3-26: EE Program/Rebate Awareness and Participation

Question	Metric	Percentage
Are you aware that your electric and natural gas utilities offer rebates and incentives for your company to save energy?	Aware of the EE rebates	100%
Has your company ever received a rebate or incentive for EE equipment at your facility?	Participating in EE programs	75%
Are you aware that your electric and natural gas utilities and their contractors also offer technical assistance to help companies like yours to implement EE projects?	Aware of EE technical assistance	63%
Has your company ever received such technical assistance from your electric and gas utilities or their contractors?	Receiving technical assistance	50%

Source: DNV GL Analysis

The team asked the dairy end users what more was needed besides incentives or technical assistance from EE programs to get their company to adopt some of the EE measures discussed earlier in the interview. The respondents had no suggestions, although one expressed dissatisfaction with his utility.

3.4.3 *Other Demand Side Energy Management in the Dairies Subsector*

The market study team asked the subsector experts, equipment vendors, and end users about the Dairies subsector's level of activity in renewable energy, CHP/cogeneration, onsite energy storage, and demand response programs. The team also asked these groups whether they thought these other demand side energy management activities might be competing with energy efficiency for company resources.

3.4.3.1 Solar

Dairy subsector experts said that competition with energy efficiency from solar PV opportunities was small-to-moderate and that wind energy options offered little competition with energy efficiency. They observed that dairy farmers are more likely to lease their land to utilities for solar arrays or wind turbines than to install their own generation equipment.

The market study team asked dairy end users whether their companies had any onsite generation and had ever received a rebate or incentive for distributed generation equipment. Four of the eight respondents said that they had onsite generation with two of them reporting solar/PV installations at their farms. However, the team's analysis of the California NEM database found no dairies had installed solar systems over the 1998-2020 period.

The market study team found it puzzling that the two solar projects identified by the dairy end users were not captured by the NEM database analysis. One possibility is that the IOUs, which assigned NAICS codes to the NEM projects in response to a CPUC request, might have assigned non-dairy NAICS codes to these projects and therefore the analysis never identified them as being dairy projects. It is also possible that the projects were not in the NEM database because they were implemented under a different tariff. As discussed above, about 7 percent of the solar capacity in California is not implemented through the NEM tariff. Another possibility is that the end users were identifying solar projects that their company implemented outside of California or in a California utility service territory that was not one of the three large IOUs.

3.4.3.2 Biodiesel

The California Department of Food and Agriculture spent nearly $102 million in grant funding for dairy methane reduction projects across the state. Two of the dairy farms in this study's sample said that they had methane digesters on their farm to convert manure into fuel. A third dairy farm reported they received a grant for a methane-powered fuel cell that had yet to be installed.

3.4.3.3 Demand Response

Two of the eight (25 percent) end users reported having participated in a demand response program. In addition, three of the eight (38 percent) end users said they had not even heard of demand response programs.

When asked about various possible barriers to demand response program participation, five of the six (83 percent) end users who were not already participating in demand response programs said concerns about "disruptions to operations/processes and perceived productivity losses" were "major barriers" (5 on a 5-point severity scale). Given descriptions of various demand response programs, most of the end users said their companies were unlikely to participate.

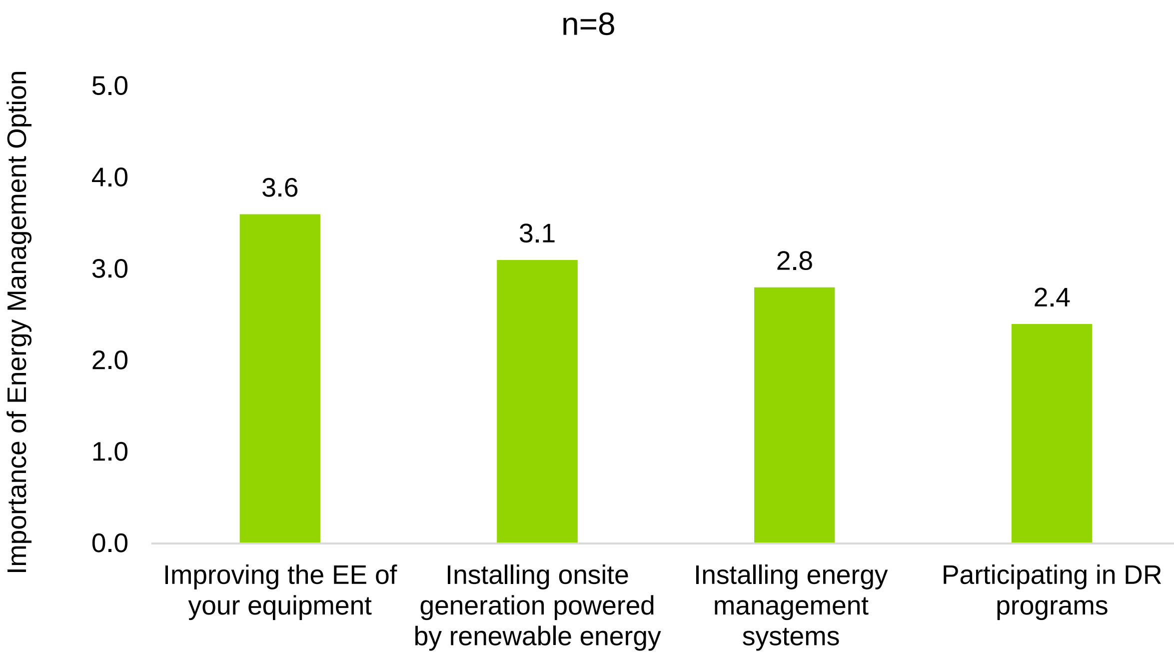
3.4.4 *Interaction Between EE and Other Demand Side Management*

The market study team asked EE equipment vendors in the Dairies subsector whether the investments their customers make in energy efficiency compete with other energy management decisions or technologies. Three of the seven vendors said there was competition. All three said solar was the biggest competitor with energy efficiency, two also mentioned biogas as a competitive technology. One vendor claimed that customers with solar "are less worried about wasting electricity and therefore not concerned about 'smart' or efficient ventilation." Another vendor said that although EE ventilation faced some competition from solar, it faces greater competition from other EE technologies such as EE lighting and refrigeration.

The team asked dairy EE equipment vendors whether their companies provide services that integrate energy efficiency with solar, wind, or demand response. None said they offered these integrated services.

Dairy end users rated the relative importance of various energy management options using a five-point scale where 5 equaled "very important" and 1 equaled "not important at all." Figure 9 shows that energy efficiency remains the most popular energy management option based on average importance scores with demand response being the least popular option.

Figure 9: The Relative Importance of Energy Management Options for Dairies



Source: DNV GL Analysis

3.5 Subsector: Water Pumping for Agriculture

3.5.1 *Water Pumping for Agriculture*

Many different agricultural subsectors pump water for irrigation and other agricultural end uses. The market study team chose to focus on water pumping use by California non-citrus fruit and nut farmers (NAICS code 11133). During the scoping discussions for this study, CPUC expressed special interest in agricultural subsectors like the almond industry, which are water-intensive. The non-citrus fruit and nut farming subsectors includes apple orchards, grape vineyards, strawberry farming, farming of other berries, and tree nut farming.

According to the IEPR's 2025 forecast, water pumping for agriculture will account for 32 percent of PG&E's agricultural electric consumption, 4 percent of SCE's electric agricultural consumption, and 75 percent of SDG&E's agricultural electric consumption.

3.5.2 *EE Measures in the Water Pumping for Agriculture Subsector*

3.5.2.1 Selection of EE Measures

In the EE Technology Selection phase, the market study team interviewed experts on the Water Pumping for Agriculture subsector and conducted an extensive literature review focusing on this subsector. Through these interviews and the literature review, the team identified many promising EE measures for this subsector. From this longer list of measures, the team selected three technologies that hold the greatest promise, with a high frequency of subsector experts and literature review sources mentioning efficient pumps and motors, sensors and controls, and a comprehensive program for improving water pump energy efficiency.

The reasons for selecting these EE measures included:

- High efficiency motors provide the required discharge pressure for pumps for a fraction of the energy consumption of standard efficiency models.
- The expert interviews and the literature review indicated that older, less efficient water pumps are prevalent in California agriculture.
- Several subsector experts advocated for a comprehensive program that looks at the water pumping system as a whole and offers farmers an increased incentive or comprehensive bonus if they implement EE measures within all parts of the system.

Appendix B details the EE measure selection process for this subsector. Table 3-27 describes the three EE measures the team selected.

Table 3-27: Descriptions of EE Measures for Water Pumping for Agriculture

EE Measure	Description
Efficient pumps and motors	Within the agriculture water pumping subsector, the pumps and motor account for approximately 90 percent of the system's energy consumption. According to experts, many of the motors and pumps in use are old and, in some cases, have not been examined in over 30 years. In terms of the system operation and energy usage, this means farmers, instead of pulling the pump, chose to just increase the pump's speed to compensate for reduction in water supply pressure, an act that increases their energy consumption. This results in a well pump running inefficiently and, according to one expert, sometimes at more than double their rated capacity. Often, this equipment was not sized appropriately for their application, the application has since changed, or the water table has shifted so much that the equipment is struggling to overcome the change in head its now seeing. According to Southern California Edison, premium efficiency motors offered savings upwards of 4 percent when compared to standard efficiency motors. Based on expert interviews, most motors are 15-30 years old and probably do not meet standard efficiency motors efficiency levels. When comparing premium efficiency motors to the motors that are installed and considering that motors make up a significant portion of the energy associated with water pumping in the agricultural setting, a large quantity of savings could be realized from the installation of premium efficient motors.

EE Measure	Description
Sensors and controls	Irrigation often is done manually and based on rule of thumb, as farmers know on average how much water a certain crop needs and adjust their pumping schedule to fit that demand. In these cases, crops are often over- or under-irrigated, which can have a negative impact on the crop's yield and the pumps' energy consumption. Use of sensors to monitor soil moisture content would help avoid over or underwatering. It would also minimize energy costs associated with pumping as a control system would optimize operation and so reduce water and energy consumption. All the experts in this subsector offered sensors and controls as a promising EE technology. Additionally, a study commissioned by the CEC found an average of 13 percent energy savings and 9 percent water savings across a variety of crops and geographies. Finally, sensors and controls help to identify faulty areas within the irrigation system that need to be resolved and places the overall system operation at the farmer's fingertips.
Comprehensive program	The irrigation system is made up of three parts, pump/well hydraulics, electric to hydraulics conversion, and the discharge or water distribution system. While energy incentives are available for each part of the system, a number of subsector experts advocate for a program that looks at the entire system as a whole and offers farmers an increased incentive or bonus if they implement EE measures within all parts of the system. Studies show that improving pumping efficiency can reduce energy consumption by 19 to 34 percent on average. However, when such a measure is implemented on its own within such a closely knitted system, it may just shift inefficiencies to the next part of the system. For example, an EE motor or pump will not work as intended if that piece of equipment is still expected to meet a high discharge pressure on a system that over irrigates because no moisture sensors have been deployed or the water is being distributed through an old, inefficient and leaking aluminum pipe system instead of a more efficient yellow mine system.

Source: DNV GL Analysis

3.5.2.2 Estimating Energy Savings for EE Measures

The market study team asked vendors of selected EE measures to estimate the annual energy savings their customers could expect from installing the measures. If vendors provided a range of energy savings for a given measure, the team asked them what factors or applications would drive this range. Table 3-28 shows these energy savings estimates and the factors that can influence the range of energy savings.

Table 3-28: Energy Savings Estimates for Water Pumping for Agriculture EE Measures

EE Measure	Energy Savings Estimate	Factors Influencing the Range of Energy Savings
Efficient pumps and motors	Average energy savings: 15 percent of pump/motor electric consumption Range of energy savings estimates: 3 to 35 percent Number of vendors providing savings estimate: Five	• The height of the water table: Vendors said that drops in the height of the water table can reduce pump efficiency because water needs to be pumped from greater depths. Vendors said that the water table has been getting lower in many parts of California. • The amount of sand in the water: Vendors said that more sand in water will wear out pumps and make them less efficient. • The age and efficiency of the pump being replaced. • The size and flow rate of the pump being replaced. • The application of the pump: Vendors said that energy savings can vary depending on whether the water is being pumped for distribution or into a reservoir.
Sensors and controls	Average energy savings: 14 percent of pump/motor electric consumption Range of energy savings estimates: 5 to 30 percent Number of vendors providing savings estimate: Four	
Comprehensive program	No estimates provided. This is a proposed program and has not yet been implemented	

Source: DNV GL Analysis

3.5.2.3 EE Measure Awareness and Market Saturation for Water Pumping in Agriculture

If the end users did not report having a given EE measure installed, the market study team asked them: “Prior to my mentioning EE Measure X, were you familiar with EE Measure X?” Table 3-29 shows that, while awareness of EE pumps and motors was universal, only 60 percent were aware of the sensors and controls measures. Since the comprehensive program has yet to be introduced, none of the end users were aware of it.

Table 3-29: Awareness of Water Pumping EE Measures

EE Measure	End User Awareness of EE Measure (n=10)
Efficient pumps and motors	100%
Sensors and controls	60%
Comprehensive program	0%

Source: DNV GL Analysis

Table 3-30 shows the measure saturation estimates for the three EE measures based on end user self-reports and vendor estimates of the California market. The market study team used the ratio estimation method to estimate the end user market saturation for the whole California market based on the self-reports of a sample of eight dairy farmers.[34] Five vendors provided market saturation estimates for EE pumps/motors and four vendors provided estimates for sensors and controls. The estimates in the vendor column of the table represent the average. The end user measure saturation estimates were slightly higher compared to those from the vendors. The market study team used the average of end user and vendor measure saturation estimates for the efficient pumps and motors and sensors and controls measures for inputs into the PG Study model. Nothing was input into this model for the comprehensive program since this measure has yet to be offered.[35]

Table 3-30: Measure Saturation for Water Pumping for Agriculture Measures

EE Measure	End User Measure Saturation	Vendor Measure Saturation Estimates
Efficient pumps and motors	63%	42%
Sensors and controls	59%	44%
Comprehensive program	0%	0%

Source: DNV GL Analysis

3.5.2.4 Barriers to Adoption of Water Pumping for Agriculture EE Measures

Expert interviews and the literature review revealed barriers to EE implementation in the Water Pumping for Agriculture subsector, including:

- **Cost barriers for motor and pump replacement:** The major barrier to the installation of this measure is cost. To pull a well pump a farmer usually must pay on average $40,000. Coupled with the fact that a single farm could have about 10 wells, this explains why farmers are reluctant to shoulder the financial burden and instead opt to leave the pumps in.

[34] Ratio methodology is a common statistical approach where the weights are calculated using the number of subjects in the sample compared to the number of subjects in the population, and relevant known values for characteristics in the sample and the population such as number of employees or energy consumption. It allows the evaluator to make survey results from a sample more representative of the underlying population

[35] The June 2020 technology selection memo acknowledged that: "It will be difficult to get a market saturation estimate [for the comprehensive program] because this measure is new and is not typically offered as an EE program." However, the market study team still chose to ask the end users and equipment vendors about this measure to gauge their awareness of it and to learn about possible barriers to its implementation.

- **Farmers lack the time to learn about the benefits of EE options:** Often farmers are unaware of the incentives at their disposal and how various energy saving measures operate individually and together.

Vendors and end users identified additional barriers, as Table 3-31 shows. All three interviewee groups identified the barriers of initial cost and lack of knowledge of the EE technology (primarily regarding the controls and the comprehensive program). Many vendors pointed to declining water tables in California as a factor that makes pumps, whether old or new, work harder and become less efficient. Although not listed here as a barrier, a few farmers indicated that they had no desire to replace their older pumps because they were working fine and their operating costs were not too high.

Table 3-31: Factors Limiting EE Measure Adoption in Water Pumping for Agriculture

Factors	Subsector Experts	Equipment Vendors	End Users
Concern about disrupting production		X	
Concern about initial cost of EE measures	X	X	X
Lack of knowledge of EE measures and benefits	X	X	X
Concern about the availability of EE equipment		X	
Lack of financing		X	
Competition from other energy-related projects (e.g., renewables)		X	
Low water tables		X	
Split incentives (farmer leases land and has limited incentive to upgrade equipment)		X	
Preference to use a variety of vendors (barrier to implementation of comprehensive program)		X	
Space constraints (some farmers do not have space to house VFDs)		X	

Source: DNV GL Analysis

3.5.2.5 EE Program/Rebate Awareness and Participation Among Water Pumping for Agriculture

The market study team asked the 10 Water Pumping for Agriculture subsector end users about EE program awareness and participation. Table 3-32 shows their responses. The table shows that while respondents were more aware of the EE rebates than the EE technical assistance, their EE technical assistance participation rates were higher.

Table 3-32: EE Program/Rebate Awareness and Participation

Question	Metric	Percentage
Are you aware that your electric and natural gas utilities offer rebates and incentives for your company to save energy?	Aware of the EE rebates	90%
Has your company ever received a rebate or incentive for EE equipment at your facility?	Participating in EE programs	30%
Are you aware that your electric and natural gas utilities and their contractors also offer technical assistance to help companies like yours to implement EE projects?	Aware of EE technical assistance	60%
Has your company ever received such technical assistance from your electric and gas utilities or their contractors?	Receiving technical assistance	50%

Source: DNV GL Analysis

The market study team asked the Water Pumping for Agriculture end users what more was needed besides incentives or technical assistance from EE programs to get their company to adopt some of the EE measures discussed earlier in the interview. Most of the suggestions concerned improving the economics of EE projects. “The bottom line is cost is the major thing for most farmers, I can’t think of anything else more important,” one farmer noted.

One farmer suggested it would be useful to have a breakdown table of the typical ROI of various agricultural EE measures so they could bring this information to their managers to determine which measures should be prioritized. Another suggested providing more information on which incentives were available for which equipment. A third farmer said that utility costs needed to be reduced.

3.5.3 *Other Demand Side Energy Management in the Water Pumping for Agriculture Subsector*

The market study team asked subsector experts, equipment vendors, and end users about the Water Pumping for Agriculture subsector’s level of activity in renewable energy, CHP/cogeneration, onsite energy storage, and demand response programs. The team also asked them whether they thought these other demand side energy management activities might be competing with energy efficiency for company resources.

3.5.3.1 Solar

The Water Pumping for Agriculture subsector experts said that there was some use of solar for water pumping and for meeting the power needs of other farm areas. The equipment vendors confirmed this but said that the integration of solar with water pumping was infrequent. One pump vendor claimed that he had come across only two cases of solar being integrated with water pumping among the thousands of customers his company interacted with in recent years. “It’s not very common, but it may start to trend depending on how solar technology develops," he said. "Some customers have used solar to run monitoring systems for pumps, just small panels, but it's not very common," said another pump vendor. "I've only seen solar with power pumps in locations where connection to the grid is not readily available," said a third vendor.

Interviews with non-citrus fruit and nut farmers indicated that the use of solar power for water pumping may be more common than the experts and vendors suggested. The market study team asked farmers whether they had any onsite generation and had ever received a rebate or incentive for distributed generation equipment. Six of the 10 respondents (60 percent) said that they had onsite generation with all six of them saying it was solar. Three of the farmers indicated that their solar panels were being used to power water pumps among other loads. None of the farmers reported receiving incentives for these solar installations. Most of the farmers were using the majority of their solar-generated power onsite while selling the remainder to the grid to their solar providers.

In addition, two farmers indicated plans for new solar installations in the near term. One farmer planned to lease some of his ranchland to a solar company. While he planned to use a little of the solar-generated power for his farm, most of it would be sold back to the solar company.[36] Another farmer planned to get PV panels to power his well.

The evaluations team's analysis of the California Net Energy Metering (NEM) database also found the most solar projects of all the industrial and agricultural subsectors in this Water Pumping for Agriculture subsector. This included seven projects in the most recent (2015-2020) period and 17 over the longer 1998-2020 period.

3.5.3.2 Demand Response

Both the subsector experts and the equipment vendors had indicated that many farmers with water pumping participate in demand response programs – primarily time-of-use (TOU) The interviews with the agricultural water pumping end user programs confirmed this with six of 10 respondents (60 percent) reporting participation in a demand response program. In addition, only one of the 10 (10 percent) end users said they had not heard of demand response programs.

The team asked the four farmers who were not participating in demand response programs about various possible barriers to demand response program participation such as "adjusting your demand in response to demand response events from your utility" and "disruptions to operational processes and perceived productivity losses." Three of the four said these were either "major barriers" (5 on a 5-point severity scale) or "considerable barriers" (4 on 5-point severity scale). Given descriptions of various demand response programs, these demand response nonparticipants said their companies were unlikely to participate in these programs. This perceived barrier suggests that there may be an opportunity to educate farmers on the actual impact of shifting irrigation load to off peak hours in order to cut costs and reduce peak load.

3.5.3.3 Other Demand Side Energy Management

None of the 10 farmers reported doing any energy storage projects. One pump vendor said a few customers have integrated wind energy with water pumping.

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[36] It should be noted that the current NEM tariff does limit the size of a distributed generation project to a customer's annual load (https://www.cpuc.ca.gov/NEM/).

3.5.4 *Interaction Between EE and Other Demand Side Management*

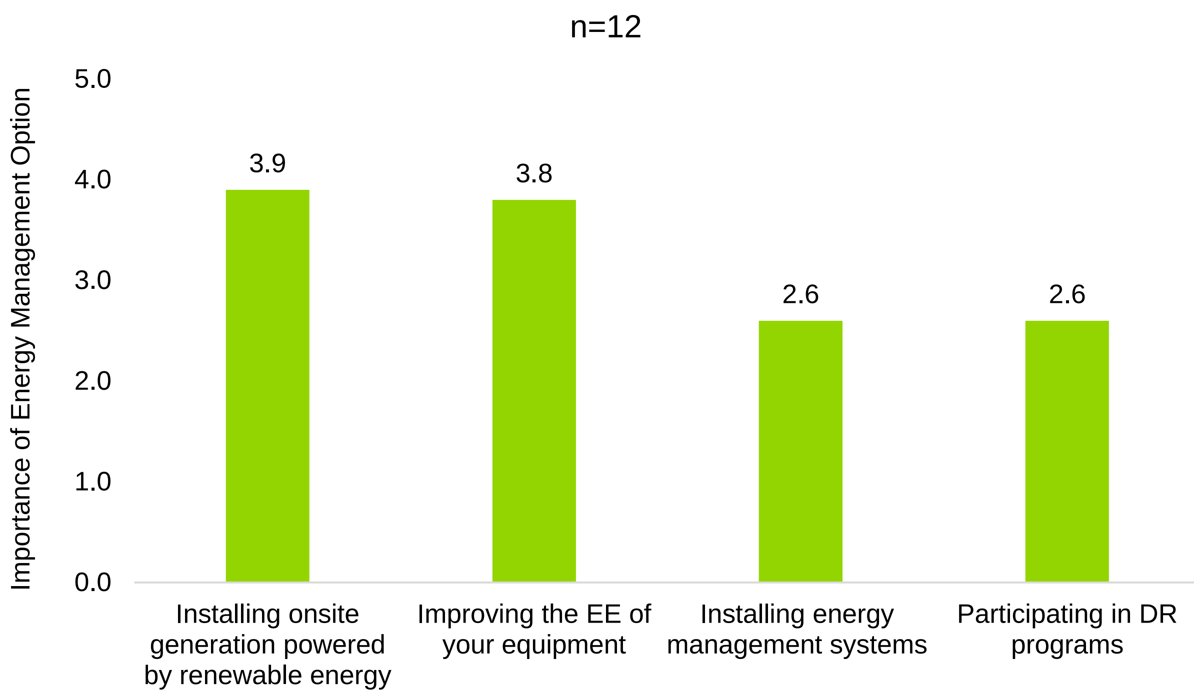
The market study team asked EE equipment vendors in the Water Pumping for Agriculture subsector whether the investments their customers make in energy efficiency compete with other energy management decisions or technologies. Four of the 12 vendors (33 percent) said there was competition. Two mentioned solar as a competing energy management technology. “Some farmers have been opting to install solar panels because they have the acres and are trying to cut costs by sourcing energy separate from the grid, but it is rare, only 5 percent now,” said one pump vendor. “But the percentage is likely increasing as solar becomes more popular or viable.”

The two other vendors mentioned demand response competes with energy efficiency to some degree. “I have seen situations where farmers were worn out from the complexity of some demand response or time-of-use programs and this exhaustion seems to reduce their interest in other EE programs,” said one of these vendors. It is possible that some end users conflate demand response and EE programs, thereby confusing the requirements of one program with those of another. Future research in these subsectors could explore more deeply these sources of possible confusion.

The market study team asked the vendors whether their companies provide services that integrate energy efficiency with solar, wind, or demand response. Four of the 12 (33 percent) said they did. One vendor said they offer consulting services to farmers and “recommend various avenues for the customer to follow.” Another said most farmers with VFDs are participating in demand response programs, so their company gets involved with both. A third vendor said that the electric motor shop in their company sells line voltage conditioners for customers who have solar installed.

The Water Pumping for Agriculture end users rated the relative importance of various energy management options using a five-point scale where 5 equaled “very important” and 1 equaled “not important at all.” Figure 10 shows their responses. The Water Pumping for Agriculture subsector was the only one that gave a higher importance rating to renewables than it did for energy efficiency.

Figure 10: The Relative Importance of Energy Management Options for Water Pumping for Agriculture



Source: DNV GL Analysis

3.6 Subsector: Greenhouses

3.6.1 *Greenhouses*

The Greenhouses subsector includes California companies included in the Greenhouse, Nursery, and Floriculture Production NAICS classification (NAICS code 1114). This subsector includes companies that grow crops under covers such as greenhouses, cold frames, cloth houses, and lath houses. The crops grown in this subsector include vegetables, mushrooms, flowers, cannabis, and nursery plants.

The market study team selected the Greenhouses subsector because it is the primary source of natural gas consumption in the California agricultural sector and a significant contributor to electric consumption. There are a variety of EE technologies that are applicable to greenhouses ranging from LED lighting to boiler economizers and building shell measures. The cannabis industry has also led to increasing demand for greenhouse capacity in recent years.

3.6.2 *EE Measures in the Greenhouses Subsector*

3.6.2.1 Selection of EE Measures

The team interviewed experts on the Greenhouses subsector and conducted an extensive literature review focusing on this subsector. Through these interviews and the literature review the team identified many promising EE measures for this subsector. From this longer list of measures, it selected three technologies that hold the greatest promise: LED grow lights, EE HVAC, and energy curtains.

The reasons for selecting these EE measures included:

- The frequency with which the subsector experts and literature review sources mentioned these measures
- Adoption of LEDs for grow lighting is low across the sector, although its use is increasing in cannabis production
- The significant energy savings offered by high efficiency HVAC equipment such as condensing boiler
- The great potential energy savings offered by energy curtains.

Appendix B details the EE measure selection process for this subsector. Table 3-33 describes the three EE measures the team selected.

Table 3-33: Descriptions of EE Measures for Greenhouses

EE Measure	Description
LED grow lights	Expert interviews and the literature review led the market study team to recommend LED lighting as a key EE measures for the Greenhouses subsector. The following are observed trends in the Greenhouse sector regarding LEDs: • LED lighting technology can now be considered a viable, EE alternative to 1,000 W high pressure sodium (HPS) and 1,000 W metal halide lamps which are currently the industry baseline. Recent advances in semiconductor technology include doping LEDs with certain elements and increasing the UV-C output of the light. LEDs have seen increased rates of adoption in the cannabis industry and are used as grow lights. • LEDs are a tried and tested technology in other industrial and commercial applications, where the lamps provide the same light output while drawing a lower wattage. However, early LEDs that catered to the cannabis subsector were not as effective and the technology was not fully developed therefore resulting in lower adoption in the industry. • Since the market saturation has been low so far, potential for adoption remains because the cannabis subsector has a heavy lighting load, which has even caused a shift in the grid’s load in certain parts of the country. The shift toward an EE alternative could begin with replacing HPS lamps with LEDs. It should be noted that the lighting loads in a greenhouse vary with location and type of crop being cultivated. Greenhouses growing vegetables or other high value crop do not have significant lighting loads. However, cannabis greenhouses have a considerably large lighting load. Market saturation and adoption depend on multiple factors such as crop being cultivated, geography, and greenhouse size.

EE Measure	Description

EE HVAC	Expert interviews and the literature review led the market study team to recommend various HVAC system measures for the Greenhouses subsector. The following trends have been observed in this subsector regarding HVAC systems:
	• There is consensus that HVAC is the biggest energy consuming system in a greenhouse. The most prevalent systems used are package units and chilled water systems. Some sites also use ductless split systems. The heating system consists of hot water boilers, which are sometimes equipped with flue gas condensers. The most common types of boilers used are high efficiency condensing boilers, which are integrated with below bench heating systems for effective root-level heating. The baseline equipment used is either standard efficiency boilers integrated with forced air systems.
	• Controls are an integral part of the HVAC system. Although most small-scale growers do not have sophisticated climate control systems, they use simpler controls like a setback thermostat. Larger growers have sophisticated controls that monitor temperature, relative humidity, and vapor pressure deficit.
	• Advanced controls started adopting large-scale use of agriculture-specific sensors and faster computing technologies to reduce the operating cost. AI, machine learning, robotics, and computer visioning have been adopted in large greenhouses to reduce labor costs.
	• Some other measures can be installed along with EE HVAC systems that can increase overall effectiveness of the HVAC system and increase the EE potential includes:
	    o Structural changes to the envelope such as double- or triple-layered polycarbonate walls.
	    o Insulation, which was observed to be a frequently neglected measure, but is easier to install and has a shorter payback period.
	One expert said that conventional greenhouse HVAC systems are not best suited for greenhouse applications, especially in the cannabis subsector because they are designed for a different purpose—comfort cooling for people loads rather than plant loads. Additionally, psychrometric requirements of the cannabis plant typically require the HVAC system to operate at different conditions than what they normally operate at because plants need different internal climate conditions compared to comfort cooling for humans.

EE Measure	Description
Energy Curtains	The expert interviews and the literature review led the market study team to recommend energy curtains as a measure for the Greenhouses subsector. The team observed the following trends in this subsector regarding energy curtains: • Depending on the geographical location of the greenhouses, energy curtains have varying levels of adoption. Greenhouses in southern California have a higher rate of installing energy curtains than in other territories. Energy curtains are generally effective in saving energy and help maintain internal environmental conditions. • Some experts believe that an energy curtain would be more effective in realizing energy savings by reducing heat loss to the external environment compared to installing a higher efficiency heating system like a condensing boiler. Experts observe that the energy curtain would have a lower initial cost and a shorter payback period than the boiler. • While energy curtains are not standard practice in the US, they are in other countries with significant greenhouse activity, such a Canada.

Source: DNV GL Analysis

3.6.2.2 Estimating Energy Savings for EE Measures

The market study team asked vendors of the selected EE measures to estimate the annual energy savings their customers could expect from installing the measures. If vendors provided a range of energy savings for a given measure, the team asked them what different factors or applications would drive this range. Table 3-34 shows these energy savings estimates and the factors that can influence the range of energy savings.

Table 3-34: Energy Savings Estimates for Greenhouse EE Measures

EE Measure	Energy Savings Estimate	Factors Influencing the Range of Energy Savings
LED grow lights	Average energy savings: 44 percent off the electric consumption of baseline grow lighting Range of energy savings estimates: 25 to 68 percent Number of vendors providing savings estimate: Nine	Factors the vendors cited that could influence the range of savings included: • The baseline lighting system • Hours of daylight • Whether lighting has controls • Type of crop
EE HVAC	Average energy savings: 29 percent off the electric consumption of baseline HVAC systems Range of energy savings estimates: 3 to 50 percent Number of vendors providing savings estimate: Seven	Factors the vendors cited that could influence the range of savings included: • Whether the HVAC system has controls • The type of crop: Some crops require hotter and drier ambient air and others require cooler and less dry ambient air • The thickness of the greenhouse walls: Single wall greenhouses have different humidity control and HVAC needs than greenhouses with double walls • The climate where the greenhouse is located
Energy Curtains	Average energy savings: 29 percent off the electric consumption of baseline HVAC systems used for heating and dehumidification Range of energy savings estimates: 3 to 55 percent Number of vendors providing savings estimate: Four	Some factors which vendors cited which could influence the range of savings included: • The baseline envelope material and type • The greenhouse's environment setup for temperature and dehumidification • What areas of the greenhouse the energy curtain covers (e.g., just walls, roof plus walls) • The size of the greenhouse

Source: DNV GL Analysis

3.6.2.3 EE Measure Awareness and Market Saturation for Water Pumping in Agriculture

The market study team asked the four end users whether they were aware of the three EE measures the study focused on. While it was a small sample, Table 3-35 shows that all the greenhouse end users reported they were aware of these measures.

Table 3-35: Awareness of Greenhouse EE Measures

EE Measure	End User Awareness of EE Measure (n=4)
LED Grow Lights	100%
EE HVAC	100%
Energy Curtains	100%

Source: DNV GL Analysis

Table 3-36 shows the measure saturation estimates for the three EE measures based on end user self-reports and vendor estimates of the California market.[37] Nine vendors provided market saturation estimates for LED grow lights, six provided estimates for EE HVAC, and three vendors provided estimates for energy curtains. The estimates in the table's vendor column represent the average. End user and vendor measure saturation estimates were similar for the LED grow lights and EE HVAC measures. The market study team used the average of end user and vendor measure saturation estimates for inputs into the PG Study model.

Table 3-36: Measure Saturation for Greenhouse EE Measures

EE Measure	End User Measure Saturation	Vendor Measure Saturation Estimates
LED Grow Lights	38%	41%
EE HVAC	42%	46%
Energy Curtains	42%	60%

Source: DNV GL Analysis

3.6.2.4 Barriers to Adoption of Greenhouse EE Measures

The expert interviews and the literature review revealed several barriers to EE implementation in the Greenhouse subsector, including:

- **Greenhouse cultivation is highly customized:** The consensus among the expert interviewees was that greenhouses run highly customized processes when it comes to cultivating their crops. There is no generally accepted industry standard practice that the industry has adopted—there is no one-size-fits-all approach. Each greenhouse has adopted systems tailored toward their crop requirements and yield. If a grower wants to replace existing HPS lamps with LED grow lights, then the grower would need at least two to three crop cycles to readjust all the other systems in the facility to work in conjunction with the lighting system (such as heating, pumping,

[37] Because of the small size of the greenhouse end user sample (n=4), the market study team did not try to ratio estimate this sample to the whole California market, as it did for the other industrial and agricultural subsectors. Instead it used an average of the four end user estimates that was weighted based on company size.

and other systems). This could result in increased loss of crop yield, which most growers are not willing to risk, making adoption of LEDs much slower.

- **Greenhouses typically have lower margins on their produce and so have little capital to invest in EE technologies:** Expert interviews indicated that adverse market conditions and uncertainty make it more difficult for them to make such investments. Some experts said that the higher capital cost involved in greenhouse farming is making farmers resort to high market volume cash crops such as tomatoes, greens, cucumbers, peppers, and market greens. These crops also are labor-intensive and labor is becoming more expensive in California. Experts also observed consumers are looking for inexpensive produce and so greenhouse farmers face competition from cheaper produce outside of California. Cost can be considered a barrier. Additionally, financing the project (through loans, etc.) can be a challenge due to conflicting federal and state laws regarding cannabis cultivation.
- **Lack of awareness of LED benefits:** Experts said that many greenhouse growers are not aware of the effectiveness of LEDs or their EE benefits.
- **Unwillingness to change current processes:** Experts said most growers have processes tailored to suit their needs and are reluctant to upgrade systems due to the re-adjustment of their operations, which could take multiple growing cycles. The risk of lost crop yield is a significant barrier.
- **Energy curtains can be difficult to retrofit:** Retrofit options for energy curtains are difficult and so are installed mostly in new construction projects.

Vendors and end users also identified additional barriers, as Table 3-37 shows. Initial cost was the only factor/barrier all three interviewee groups identified.

Table 3-37: Factors Limiting EE Measure Adoption in Greenhouses

Factors	Subsector Experts	Equipment Vendors	End Users
Concern about disrupting production	X	X	
Concern about initial cost of EE measures	X	X	X
Lack of knowledge of EE measures and benefits	X	X	
Concern about the availability of EE equipment		X	
Capital budget cycles		X	
Lack of financing		X	
Competition from other energy-related projects (e.g., renewables)		X	
Customer concerns that EE products may adversely impact the quality and yield of their crop		X	
Energy curtains can be difficult to retrofit	X		

Factors	Subsector Experts	Equipment Vendors	End Users
Their crop type will not benefit from the suggested EE measure			X
They are only installing EE lighting when old lighting burns out			X

Source: DNV GL Analysis

3.6.2.5 EE Program/Rebate Awareness and Participation among Greenhouse Subsector

The market study team asked the four Greenhouse subsector end users about EE program awareness and participation.[38] Table 3-38 shows their responses. EE program awareness was universal and all the end users who were aware of EE technical assistance took advantage of it.

Table 3-38: EE Program/Rebate Awareness and Participation

Question	Metric	Percentage
Are you aware that your electric and natural gas utilities offer rebates and incentives for your company to save energy?		100%
Has your company ever received a rebate or incentive for EE equipment at your facility?	Participating in EE programs	75%
Are you aware that your electric and natural gas utilities and their contractors also offer technical assistance to help companies like yours to implement EE projects?	Aware of EE technical assistance	75%
Has your company ever received such technical assistance from your electric and gas utilities or their contractors?	Receiving technical assistance	75%

Source: DNV GL Analysis

The team asked the Greenhouse subsector end users what was needed besides incentives or technical assistance from EE programs to get their company to adopt some of the EE measures discussed earlier in the interview. No respondents had suggestions.

[38] The Greenhouse end users were particularly impacted by the wildfires that were ongoing when the market study team attempted to interview them in August and September 2020. Several establishments were closed during this period with recorded messages citing the wildfires. Several Greenhouse end users whom the market study team was able to reach by phone also said the fires and the COVID pandemic had caused them to be short-staffed and stressed out and therefore they did not have the time to complete the interview. For greenhouse end users who had open field crops, September was also the harvest season and therefore a difficult time to complete phone interviews. For these reasons the market study team decided, with the agreement of the CPUC, to suspend data collection with this group after four interviews were completed.

3.6.3 *Other Demand Side Energy Management in the Greenhouse Subsector*

The market study team asked the subsector experts, equipment vendors, and end users about the Greenhouse subsector's activity in renewable energy, CHP/cogeneration, onsite energy storage, and demand response programs. The team also asked whether they thought that these other demand side energy management activities might compete with energy efficiency for company resources.

3.6.3.1 Solar

The Greenhouse subsector experts said that solar PV options have been explored in the Greenhouse subsector but currently market saturation is low. One barrier they cited was the availability of real estate, which can be expensive in parts of southern California (rooftop solar is not feasible for most greenhouses due to the blocking of useful light and so solar panels would need to be placed on adjoining land).[39] The EE equipment vendors did not report much use of solar in the Greenhouse subsector. One vendor noted a greenhouse that installed a solar array but commented that, "solar PV was not the primary concern of the grower but was installed later as an afterthought." The evaluations team's analysis of the California NEM database found no solar projects installed in the 1998-2020 period by companies using the Greenhouses NAICs code.

The market study team asked greenhouse end users whether they had any onsite generation and had ever received a rebate or incentive for distributed generation equipment. Only one of the four respondents (25 percent) said they had onsite generation (a solar installation) for which they did not receive a rebate. When asked about future onsite generation projects, no end users reported any near-term plans in California, although one said that its Texas location was building a solar installation.

3.6.3.2 CHP

The Greenhouse subsector experts said that CHP/cogeneration is a technology with high technical potential but low market potential. This is because the greenhouse facilities would need very good access to natural gas, which many do not have. Two EE equipment vendors reported encountering a few greenhouses that were using CHP. "There are growers who use CHP and use the excess CO_2 as fertilizer. Some of the large growers supply power to the grid as well," said one of these vendors. However, none of the greenhouse end users reported using CHP.

3.6.3.3 Demand Response

The Greenhouse subsector experts said that greenhouses are taken advantage of TOU rate structures. However, EE equipment vendors said that demand response program participation could be difficult for some end users. "Demand response is going to be hard sell," said one vendor. "But if the payment from demand response is high enough, then the growers are ready to curtail their lighting for a few hours for couple of days as it does not affect the growing as much."

None of the four greenhouse end users said they were participating in a demand response program and one of the four respondents said they had not previously heard of demand response programs. The market study team asked end users about various possible barriers to demand response

[39] It should be noted that research is being done on transparent solar panels that would solve this light blocking dilemma (see https://modernfarmer.com/2020/02/could-solar-panels-make-greenhouses-energy-neutral/)

program participation such as “adjusting your demand in response to demand response events from your utility” and “disruptions to operational processes and perceived productivity losses.” Three of the four said these were major barriers” (5 on a 5-point severity scale). Given descriptions of various demand response programs, these demand response nonparticipants said their companies were unlikely to participate in these programs.

3.6.3.4 Other Demand Side Energy Management

The Greenhouse subsector experts said that compost heating, biogas steam heating, and geothermal heating are some other demand-size energy management approaches that are gaining traction. Experts cited costs and uncertainty about crop impacts as barriers to wider adoption. The risks of pest damage and damage due to wider temperature fluctuations in crops dissuade farmers from adapting to a more compost-heated greenhouse. Sometimes auxiliary or supplementary heating by portable systems is required for occasional cold bouts in non-greenhouse-controlled environments and growers prefer that as a low-risk alternative.

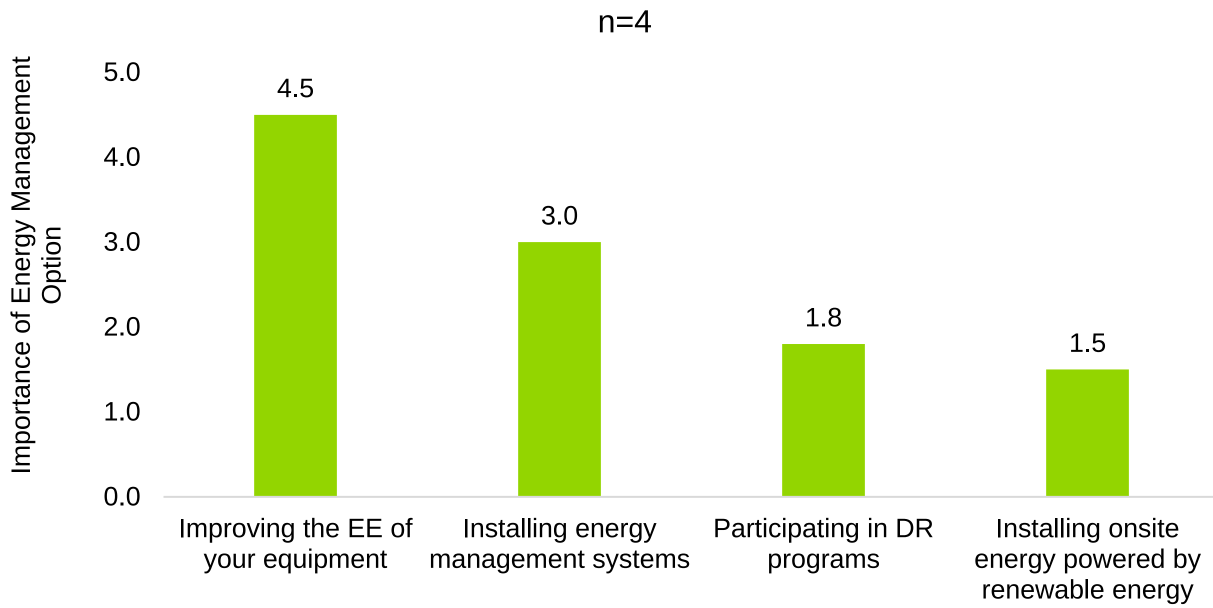
3.6.4 *Interaction Between EE and Other Demand Side Management*

The market study team asked the vendors of EE equipment in the Greenhouse subsector whether the investments their customers make in energy efficiency compete with other energy management decisions or technologies. Eight of the 13 vendors (62 percent) said there was competition and a couple of these mentioned renewables and CHP as competing with energy efficiency. The other vendors indicated that many greenhouses use energy management software that usually recommends energy actions based on project cost criteria. In the past, this software has favored energy efficiency due to its lower cost. Some vendors indicated these energy management systems are being used less often.

The market study team asked the vendors whether their companies provide services that integrate EE with solar, wind, or demand response. Four of the 13 vendors (31 percent) said they did. Two of these vendors said their company’s products come with built-in HVAC control systems that can be integrated with demand response programs.

The four Greenhouse subsector end users rated the relative importance of various energy management options using a five-point scale where 5 equaled “very important” and 1 equaled “not important at all.” Figure 11 shows their responses. They were the only end users to rate energy management and demand response participation higher than onsite generation from renewables.

Figure 11: The Relative Importance of Energy Management Options for Water Pumping for Agriculture



Source: DNV GL Analysis

Appendix A. Study Methodology

This section describes the methods the study used for data collection and analysis.

Literature Review

The market study completed a literature review of published reports and databases which provide information on energy consumption patterns and energy savings potential in the six large California industrial and agricultural subsectors. The information sources it reviewed included:

- Energy Information Administration's Manufacturing Energy Consumption Survey (MECS)
- Any published CPUC or CEC studies
- CEC's Integrated Energy Policy Report (IEPR) model.
- U.S. Department of Energy's (DOE's) Industrial Assessment Center (IAC) audit database[40]
- California IOU Emerging Technology Reports
- California's Net Energy Metering (NEM) database
- Reports from the Emerging Technologies Coordinating Council
- DOE's Energy Efficiency & Renewable Energy Emerging Technologies Database
- Conference papers from energy efficiency organizations such as ACEEE and IEPEC
- Publications from DOE's Advanced Manufacturing Office
- Information from the U.S. DOE's Better Plants Initiative including its ISO 50001 Ready Program
- Publications from federal energy research labs
- California agricultural statistics
- Published energy efficiency evaluation reports focusing on the industrial and agricultural sectors
- Other relevant conference/white papers from online searches.

The memorandum in Appendix C lists the major secondary sources that the market study team used.

Subsector Expert Interviews

The market study team completed in-depth interviews with 60 individuals who had specialized knowledge of energy consumption patterns and energy savings potential in the six large California industrial and agricultural subsectors. These subsector experts included:

[40] The database currently includes 19,105 assessments, 1,314 of which took place in California. Counting only the most recent assessments (2014 or later) there are 2,837 total assessments with 205 of these having been completed in California.

- Energy efficiency program evaluators and implementers
- Energy efficiency specialists from the federal energy labs
- California university professors who study energy efficiency
- Representatives from the California Program Administrators (PAs) who help deliver programs in the targeted subsectors

The subsector expert interviews addressed the following topics:

1) Which technologies used the most energy in the subsector
2) Which technologies had the greatest energy savings potential in the subsector
3) What would be the energy-efficient and baseline/standard efficiency versions of these technologies
4) What types of product vendors would be best able to estimate market saturation of EE technologies in this subsector
5) What other kinds of demand side technologies were these subsectors using to manage their energy consumption besides EE and what were the impacts of these technologies on EE implementation

The memorandum in Appendix C lists most of the interviewed subsector experts (some experts preferred not to be listed).

Equipment Vendor Interviews

After the literature review and the subsector expert interviews had identified the 18 EE measures that the study would focus on, the market study team identified companies who sold these EE measures. There were four sources for the equipment vendor sample frame including:

1) Internet research
2) Vendor lists from the California PAs
3) Vendors identified from the subsector expert interview
4) Vendors identified by competing vendors[41]

Following the development of the initial equipment vendor list from these four sources, the market study team winnowed down the list to only include equipment vendors who sold EE measures in the target industrial or agricultural subsector. For example, for the Food Production subsector, the team could only complete interviews with VFD vendors who sold VFDs into the Food Production subsector.

The team completed interviews with 61 equipment vendors. There were significant challenges in completing the interviews. The COVID-19 pandemic meant that key contacts were difficult to reach because companies were closed or short staffed or had staff working at home. The August-

[41] One of the questions in the equipment vendor interview guide was: “Finally, we would like to interview other companies who sell products and services that are like yours. Which companies do you view as your main competitors?”

September 2020 data collection period also coincided with the worst wildfire season in California history which exacerbated the problems caused by the pandemic. Even when the team was able to reach key contacts, they were often unwilling to do the interviews due to being short-staffed and not having the time or simply due the stress caused by the COVID-19 and wildfire crises.

Table A-1 shows the sample frame and disposition for the interviews by EE measure type. The total completed interviews in the table is greater than 61 because some vendors sold more than one EE measure and therefore were able to answer questions about multiple measures. The chiller plant optimization measure for the Electronic Manufacturing subsector is not listed in the table because it was not one of the original selected measures. It was a late replacement for the “optimize air change rates with VSDs in cleanroom spaces” measure when vendor interviews indicated that measure was unlikely to be adopted by electronics manufacturing facilities. Four vendors completed interviews for the chiller plant optimization measure.

Table A-1: Equipment Vendor Sample Frame and Disposition

Measure	Sample Frame	Completed Interviews
Food Services/Production		
Refrigeration System Optimization	26	4
Heat Recovery	10	5
VSDs on Fans and Pumps	5	2
Chemical Manufacturing		
Heat Recovery	10	4
Advanced Automation and Optimization	6	6
Variable Speed Drives (VSDs)	7	7
Electronics Manufacturing		
Optimize air change rates with VSDs in cleanroom spaces	19	5
Low-Cost O&M Retro-commissioning (RCx)	11	7
Low pressure drop HEPA/ULPA filters in cleanroom spaces	9	8
Greenhouses		
LED Grow Lights	20	9
Efficient HVAC Equipment and Controls	21.	7
Energy Curtain	18	4
Water Pumping for Agriculture		
Efficient Pumps and Motors	129	10
Sensors and Controls	14	7
Comprehensive Program	6	3
Dairies		
Refrigeration Systems Heat Recovery	5	5
Pump VSD	12	5

Measure	Sample Frame	Completed Interviews
Fans & Ventilation (HVLS fans, fan maintenance)	9	5

The primary topics covered by the equipment vendor interviews included:

- The saturation of recommended EE measures as observed among their client base
- Factors/barriers impacting the implementation of these EE measures
- Whether energy efficiency projects in the subsectors faced competition from other demand side management options such as renewables or demand response
- Estimates of the average energy savings from these EE measures and explanations for any range of estimate energy savings
- Estimates for other inputs to the PG Study model such as the % of total site energy consumption accounted by the equipment which is being made more efficient by the recommended EE measures

The full equipment vendor interview guide appears in Appendix D.

End User Interviews

Market study team revised the targets to get a minimum of two large end user interviews completed in each subsector, although the interviewees were encouraged to get more than this, if possible. Table A-2 shows that the team was able to hit these revised targets for large end users for all the subsectors except Water Pumping for Agriculture.

Table A-2: End User Interview Sample Design and Disposition

1 Subsector	2 NAICS Code*	3 Company Size*	4 # of Companies in Sample Frame	5 Target # of Completed Interviews	6 # of Completed Interviews
Electronics Manufacturing	334	Large	22	2-7	4
		Small	300	3-8	6
Food Production	311, 312	Large	17	2-5	3
		Small	909	5-8	8
Chemical Manufacturing	325	Large	13	2-8	3
		Small	113	2-8	4
Dairies	112120	Large	21	2-7	5
		Small	72	3-8	3
Water Pumping for Agriculture	11133	Large	35	2-6	1
		Small	1,070	4-8	9
Greenhouses	1114	Large	41	2-6	4
		Small	804	4-8	0

* Because the distribution of company sizes varies by subsector, the market study team chose to vary the definition of a large vs. small company depending on the subsector. For larger industrial subsectors such as Electronics Manufacturing and Food Production the team defined a large company as one that had greater than 250 employees. For smaller agricultural subsectors such as Dairies, the team defined a large company as one that had greater than 20 employees.

The primary topics covered by the end user interviews included:

- The saturation of recommended EE measures within /in their own facility
- Factor/barriers impacting their implementation of these EE measures
- Payback/ROI criteria for EE projects
- Their awareness of and participation in EE, distributed generation, and demand response programs/rebates
- The likelihood of their purchasing EE equipment based on example incremental costs & incentive levels
- Their Involvement in distributed generation and its impacts on their willingness to invest in EE
- The impact of the COVID-19 on their operations

The full end user interview guide appears in Appendix D.

Ratio Estimation

To estimate measure saturation the market study team wanted to use ratio estimation to expand the self-reported measure saturation from the study sample for each subsector into representations of the California population for each subsector. Ratio methodology is a common statistical approach where the weights are calculated combining the number of subjects in the sample compared to the number of subjects in the population, and relevant known values for characteristics in the sample and the population such as number of employees or energy consumption.

The team started with the infogroup commercial database described in the previous subsection. The infogroup data included information on the number of employees for each company in the subsector populations as indicators of company size. The team also collected information from the end users as to whether they had installed the EE measure on the applicable equipment and what percentage of total facility energy use was accounted for by the applicable equipment.

In summary, after completing the interviews, the following variables were available for each respondent j and measure m:

E_j Number of employees as reported by InfoSource
I_{mj} Measure m is installed, yes or no
p_{mj} % of applicable equipment measure m is installed on

The sample expansion followed these steps:

1. Sampling cells are defined by the combination of subsector and size bin. These sampling cells are shown in the fourth column of Table A-2. We refer to each of these cells by their combination of characteristics. The shorthand to describe each cell that goes through the weighting process is “k”. In Table A-2, k represents “electronics manufacturing, large” in the first row, “electronics manufacturing, small” in the second row, etc.

   For each cell k defined by subsector and size bin, calculate the sample expansion weight W_k .

   $$W_k = N_k/n_k$$

   This is the ratio of the number N_k of cases in the frame for the target subsector and size bin (column 4 of Table A-2), to the corresponding number n_k of respondents (column 6).

2. For each completed interview j calculate the relevant employment E_j~.

   $$E_j\sim = E_j x F_j$$

   This is the establishment employment E_j multiplied by the fraction F_j of the establishment that works in the target subsector.

3. The estimated percent p_m of subsector equipment that has the measure is calculated as the following ratio.

   $$p_m\hat{} = [\Sigma_k\ \Sigma_j\ p_{mj} * E_j\sim * W_k\ ]/\ [\Sigma_k\ \Sigma_j\ E_j\sim * W_k\ ]$$

These percentages were calculated for the following subsectors: Chemical Manufacturing, Dairy, Electronics Manufacturing, Food Production, and Water Pumping. The end user sample sizes were small and therefore these market saturation estimates should be interpreted with caution. Greenhouses were not estimated because the attained sample size (four respondents) was insufficient to estimate these ratios. To estimate measure saturation for the Greenhouse subsector the market study team used a weighted average of the four end user self-reported installation estimates based on company size.

Appendix B. Energy Efficient Technology/System Identification Memo

Memo to: Lisa Paulo, CPUC		**Date:** **From:**	07/7/2020 Christopher Dyson, DNV GL
Copied to: Karen Maoz, Dustin Bailey, Amul Sathe Guidehouse; Miriam Goldberg, DNV GL		**Prep. By:**	Christopher Dyson and Jennifer Childs, DNV GL

Industrial/Agricultural Market Saturation Study: Findings from The Energy Efficient Technology/System Identification Stage

This final memorandum (memo) summarizes the findings from the Energy Efficient Technology/System Identification Stage of the Industrial/Agricultural Market Saturation Study. It incorporates edits and comments from the California Public Utilities Commission (CPUC) and other stakeholders on a draft version of this memo that was submitted on 6/22/20.

Research Objectives

The Energy Efficient Technology/System Identification Stage of the Industrial/Agricultural Market Saturation Study included a literature/database review and in-depth interviews with subsector experts to identify the following researchable questions:

1. Which technologies/systems currently use the most energy in these industrial/agricultural subsectors?
2. Which technologies/systems have the greatest potential for future energy savings: This would be limited to technologies which already have some quantifiable baseline?
3. What would be the energy efficient and baseline/standard efficiency versions of these technologies/systems to document savings (and if the efficient version is preferred over standard)?[42]
4. What would be best way to estimate the market potential of energy efficient technologies for a given California subsector?
5. What barriers might delay or discourage installation of promising energy efficient technologies including end user consideration of other demand side options (e.g., demand response, self-generation)?

This memo summarizes the findings corresponding to researchable questions 1, 2, and 5. The information gathered for researchable questions 3 and 4 will feed into the later market saturation analysis and report.

[42] An industry standard practice assessment is not in scope.

The Technologies/Systems with the Greatest Energy Savings Potential

Based on the in-depth expert interviews and the literature/database review, the market study team members selected the three most promising energy efficient measures for each of the preselected six subsectors: Food Service/Production, Chemical Manufacturing, Electronics/Semiconductor Manufacturing, Greenhouses, Dairies, and Water Pumping (for agriculture). Table B-1 shows all the measures recommended for these six subsectors.

Table B-1: Summary of Recommended Industrial/Agricultural Energy Efficient Measures

<table>
<tr><th>Measure</th><th>Justifications</th></tr>
<tr><td colspan="2">Food Services/Production</td></tr>
<tr><td>Refrigeration System Optimization</td><td>• Single largest electric energy consuming end use.
• Highest response from expert interviews.
• Top 10 recommended energy efficient measures for this subsector by Industrial Assessment Center (IAC) database.
• Legacy refrigeration systems not designed for efficient application and likely in need of control system upgrades.</td></tr>
<tr><td>Heat Recovery</td><td>• High energy consuming end use for gas.
• This measure was among the most mentioned in the expert interviews.
• Top 10 recommended energy efficient measures for this subsector by IAC database.</td></tr>
<tr><td>Variable Speed Drives (VSDs) on Fans and Pumps</td><td>• Motors account for a substantial share of electric consumption in this subsector.
• Among the most mentioned in the expert interviews.
• Top 10 recommended energy efficient measures for this subsector by IAC database.
• Fluctuations in motor load.
• Cost-effectiveness has increased for smaller motors sizes.</td></tr>
<tr><td colspan="2">Chemical Manufacturing</td></tr>
<tr><td>Heat Recovery</td><td>• Most frequently cited by interviewed experts.
• Sector has many processes and equipment that generate significant amounts of excess heat. Strategies include:
- Heat recovery from stack gases
- Recovery or reuse of low pressure steam and condensate
- Heat recovery from compressors and exothermic processes</td></tr>
<tr><td>Advanced Automation and Optimization</td><td>• Second-most-cited energy efficiency measure by interviewed experts.
• Typically, energy and cost savings are around 5% or more for many industrial applications of monitoring and control systems.
• Plant-wide monitoring and automated control systems.</td></tr>
<tr><td>VSDs</td><td>• Third-most-cited measure by interviewed experts.
• High potential for energy saving per IAC database.
• Replacing constant speed drives with VSDs where practical.</td></tr>
</table>

Measure	Justifications
Electronics Manufacturing	
Optimize air change rates with VSDs in cleanroom spaces	• Most frequently mentioned measure in the literature reviewed and expert interviews. • This measure saves electrical energy in semiconductor fabrication facilities, specifically in the HVAC end use of that subsector. This is important because: - The DOE's Manufacturing Energy Consumption Survey (MECS) data shows that semiconductor manufacture facilities account for 72% of the energy usage in the electronics manufacturing subsector in the Western region of the US. - The MECS data shows that the largest end use at semiconductor facilities is HVAC.
Low Cost O&M Retrocommissioning (RCx)	• Measures, such as RCx, that have short payback periods (1-2 years) are more likely to be implemented. • Each semiconductor facility is unique and has different opportunities. RCx by nature is tailored to identify savings opportunities in a customized setting. RCx can occur at any facility, impact any system, and result in electricity and gas savings.
Low pressure drop HEPA/ULPA filters in cleanroom spaces	• Reducing HVAC consumption in semiconductor facilities is important because, as noted, such facilities account for nearly three-quarters of the energy usage in the West Coast electronic manufacturing subsector and HVAC is the largest end use at semiconductor facilities.
Greenhouses	
LED Grow Lights	• Advances in semiconductor technology have made LED grow lights a viable alternative to High Pressure Sodium lamps and Metal Halides for greenhouse farming. • Current LED grow light adoption is low overall across the greenhouse sector.
Efficient HVAC Equipment and Controls	• High efficiency heating systems such as condensing boilers are a good option when combined with below bench heating. Below bench heating is more energy efficient and effective compared to forced air systems. • Some renewable technologies that have the technical potential but are yet to see increased adoption are geothermal heat pumps.
Energy Curtain	• Energy curtains are being widely adopted in certain parts of southern California. • Energy curtains are becoming increasingly common in new construction greenhouses and less so in older facilities. • A good energy curtain can sometimes be more effective in energy conservation than even a high efficiency heating system like a condensing boiler.

Measure	Justifications
Water Pumping for Agriculture	
Efficient Pumps and Motors	• Experts reported that California irrigation systems have many older, less efficient motors that would benefit from being brought up to code (which California allows if there is good justification that the upgrade would not have happened soon without program intervention). • A newer pump/motor opens the door for additional energy efficient measures in the irrigation systems.
Sensors and Controls	• Prevent overwatering and the energy usage associated with pumping that water. • Optimize flow rates and irrigation schedule based on real-time data, thereby saving energy. • Identify inefficiencies in pumping system.
Comprehensive Program	• Programs exist for various parts of the pumping system, but none have a holistic approach: - Encourages farmers to implement energy efficiency measures on all parts of their pumping system by offering a comprehensive incentive on projects with measures from all three parts of the system/end use. - Educates farmers on all aspects of their irrigation system, how they interact with each other and the environment as well as the possibilities available for energy efficiency. • Such holistic approaches are important because isolated energy efficiency improvements can sometimes be offset by inefficient equipment or operations elsewhere in the system.
Dairies	
Refrigeration Systems Heat Recovery	• Biggest user -> biggest savings opportunity. • Lots of market opportunity (low saturation). • Uses scavenged heat to preheat wash water or cow drinking water.
Pump VSD	• Large energy consumer. • Lots of market opportunity (low saturation). • Current practice is constant-velocity pump motor with manually adjustable orifice; very inefficient at partial loads.
Fans & Ventilation (HVLS fans, fan maintenance)	• Lots of market opportunity (low saturation). • Technologies are well understood and readily available. • Use less energy and improve herd comfort.

Food Service/Production

Table B-2 shows the three most promising energy efficient technologies identified by the team for the Food Production subsector and a summary of its justification for selecting them. The subsequent subsections detail these recommendations.

Table B-2: Recommended Energy Efficiency Measures for the Food Service/Production Subsector

Measure	Justifications
Refrigeration System Optimization	• Single largest electric energy consuming end use • Highest response from expert interviews • Top 10 recommended energy efficient measures for this subsector by IAC database • Legacy refrigeration systems not designed for efficient application and likely in need of control system upgrades
Heat Recovery	• High energy consuming end use for gas • This measure was among the most mentioned in the expert interviews • Top 10 recommended energy efficient measures for this subsector by IAC database
VSDs on Fans and Pumps	• Motors account for a substantial share of electric consumption in this subsector • Among the most mentioned in the expert interviews • Top 10 recommended energy efficient measures for this subsector by IAC database • Fluctuations in motor load • Cost-effectiveness has increased for smaller motors sizes

Food Services/Production Measure 1: Refrigeration System Optimization

Over half of the 11 subsector experts listed refrigeration as one of their top three recommended measures with the highest energy savings potential. Food processing has large refrigeration loads since many facilities frequently heat up the food products and then rapidly cool them down or flash freeze.

Expert interviews and other information indicated that refrigeration systems in the Food Services/Production subsector are often old and built-up with equipment from various vendors over the years. This creates inefficiencies due to poor integration of the various systems and lack of controls. These problems are exacerbated by the fact that a single food processing plant will need different loads and temperatures for different processes, which creates complexity in the system design.

Many wineries and canning facilities have refrigeration systems that are oversized so they can handle large loads for a small part of the year even though they are operating at low loads for the rest of the year.

- The proposed measure will characterize refrigeration system optimization. Optimization may vary from system to system and may include the following measures:
  - Variable speed drives (VSDs) on evaporative fans
  - Setpoint adjustments
  - Envelope upgrades (e.g., high speed doors; insulation improvements)
  - Compressor staging controls

Food Services/Production Measure 2: Heat Recovery

Expert interviews and industrial audit data indicated that heat recovery is one of the largest untapped sources of natural gas savings in the Food Services/Production subsector. Three of the top four recommended gas-saving measures in the IAC database for the Food and Beverage sector were heat recovery measures.[43] Some of the most-recommended heat recovery measures included:

- Recover waste heat from equipment
- Use heat from boiler blowdown to preheat boiler feed water
- Use waste heat from hot flue gases to preheat
- Use waste heat from compression equipment

Food Services/Production Measure 3: VSDs, Fans and Pumps

The expert interviews and other research also led the team to select VSDs on pumps, and to a lesser extent fans, as offering great energy savings potential for the Food Service/Production subsectors. Multiple experts listed VSDs on pumps and fans as one of their top recommended energy efficiency measures. This was also the top measure recommended by the IAC audits conducted in California over the last 10 years (in terms of frequency of recommendation and projected energy savings).

Motor systems are used for a variety of applications related to process, refrigeration, and distribution systems. Typically, these motors operate well below the design load. One specific application that has a significant potential for this subsector is evaporator fan motors. Standard practice for this application is to operate fans at 100% speed even though typical demand is much lower. This is especially true for facilities that have large seasonal swings in production. These low load operating conditions make VSDs cost-effective. Historically, VSDs were only cost-effective for large motor systems. However, prices have decreased, making even small VSDs cost-effective for motors that might not have been considered ordinarily.

The expert interviews revealed that motor controls are the critical factor for saving energy with this measure. One expert commented that VSDs do not guarantee efficiency by themselves and if used improperly can even increase electricity usage. This expert emphasized that motor system optimization is the critical path to obtain total efficiency. VSD savings can be further enhanced by moving to smart controls. However, expertise in complex controls systems is

[43] One of the reviewers on the draft version of this memo commented that: "One of our engineers have found that these heat recovery recommendations from IAC are not always technically or economically feasible, or well investigated. These need to be carefully considered for each site application."

needed. Top performing facilities in the industry do use VSDs controls throughout the processing production line to maintain competitiveness, marketability, and profitability. However, in other facilities this technology may be used in only limited applications.

Barriers to Energy Efficiency Implementation in the Food Services/Production Subsector

The expert interviews and the literature review revealed several barriers to energy efficiency implementation in the Food Services/Production subsector, including:

- **Lack of energy efficiency knowledge among subsector operators and management:** Experts observed that, while larger, more sophisticated companies are using advanced controls for motor system optimization. Other facilities lack the knowledge to implement these optimization strategies. They also noted that many operators in the Food Services/Production subsector do not have the time to learn about energy efficiency opportunities. Finally, some experts claimed that there are not enough technical educators in energy efficiency programs who can convince key decision makers of the benefits of current best practices.
- **Seasonal/episodic production schedules complicate the economics of energy efficiency investments:** Research revealed that the food processing industry is susceptible to seasonality changes and the run hours of refrigeration equipment can be used heavily for months and then not needed for months. For example, for vegetable processing, it is common to have only 4 months of operation. These lower hours-of-use can make owners hesitant to upgrade to more energy efficient systems because of longer payback periods and reduced cost-effectiveness.
- **First cost barriers, especially for smaller companies:** The experts observed that many smaller facilities (micro-breweries or small wineries) do not have the capital resources to invest in energy efficient upgrades of equipment. The replacement of large refrigeration systems is cost-prohibitive for companies of many sizes.
- **Large refrigeration systems require customized solutions:** The research found that refrigeration systems in the Food Services/Production subsector are often old and built-up with equipment from various vendors over the years. Therefore, one size fits all remedies are usually not feasible and customized solutions are needed. However, some operators in this subsector are reluctant to pursue custom projects because they are expensive to develop and are subject to a higher level of scrutiny than more prescriptive measures.
- **Reluctance to change out familiar equipment due to perceived risk:** The experts said that the primary concern of many food processors is that changes in equipment/operations might disrupt the process in a way that would affect the quality of the product. They also mentioned a related concern—that food processors are hesitant to change systems that they understand and that seem to be performing adequately.
- **Lack of time to plan and implement energy efficient projects:** Some experts noted that even when operators in the Food Services/Production subsector are knowledgeable about energy efficiency opportunities, they often lack the time to plan and implement the energy efficiency projects.

Other Demand Side Activity in the Food Services/Production Subsector

The Food Service/Production subsector experts did not think that the subsector had significant demand side activity other than energy efficiency or that other demand side projects were seriously competing with energy efficiency. They reported that renewable generation was not widespread across the industry.[44] While some companies used renewables as a branding strategy, they estimated that these companies made up a small proportion of their energy portfolio. These experts observed that some of the same barriers that hinder energy efficiency projects (e.g., the unwillingness to interrupt production processes and a lack of staff/time to implement new projects) also deter renewable energy projects.

One expert noted that some companies examining their peak load are considering combined heat and power (CHP) generation and batteries to reduce costs. Some facilities are going to electrical charging forklifts, using passive solar sky lights, and have signed some demand response contracts.

Chemical Manufacturing

Table B-3 shows the three most promising energy efficient technologies that the team identified for the Chemical Manufacturing subsector and a summary of its justifications for selecting them. The subsequent subsections provide more details on these recommendations.

Table B-3: Recommended Energy Efficiency Measures for the Chemical Manufacturing Subsector

Measure	Justifications
Heat Recovery	• Most frequently cited by interviewed experts. • Sector has many processes and equipment that generate significant amounts of excess heat. Strategies include: - Heat recovery from stack gases - Recovery or reuse of low pressure steam and condensate - Heat recovery from compressors and exothermic processes
Advanced Automation and Optimization	• Second-most-cited energy efficiency measure by interviewed experts. • Typically, energy and cost savings are around 5% or more for many industrial applications of monitoring and control systems. • Plant-wide monitoring and automated control systems.
Variable Speed Drives	• Third-most-cited measure by interviewed experts. • High potential for energy saving per IAC database. • Replacing constant speed drives with variable speed where practical.

Chemical Manufacturing Measure 1: Heat Recovery

Excess (waste) heat generated through fuel combustion, gas compression, and exothermic chemical reactions is typically exhausted into the environment but can be recovered and used in

[44] In reviewing this memo, the CPUC staff cited a recent interview with a contractor delivering a California food processing Strategic Energy Management (SEM) program in which the contractor reported that two of the six food processing facilities in the cohort had bio-gas systems.

other systems requiring heat input, potentially lowering the amount of fuel required to heat processes:

- Stack economizers recover heat energy from flue gases, which are exhausted to the atmosphere, and use it to preheat boiler feedwater which can save 1% of fuel for every 45°F (25°C) reduction in exiting gas temperature. Installing economizers in industrial boilers can increase boiler efficiency by 2.5%-4%, dependent on the number of tubes, the addition of tube fins, and allowable pressure drop, but it is most dependent on the boiler feedwater temperature.
- Low pressure steam and condensate can be used to preheat low energy process streams (feedwater, etc.) Low pressure steam can also be recompressed to increase its energy and then utilized to heat other feed streams or endothermic processes. A heat exchanger potentially reduces the energy consumption for the heating process.
- Many facilities generate excess heat via compressors (which give off heat) and other exothermic chemical reactions (acid-base, polymerization, etc.) that is rejected to the atmosphere. That excess heat can be recovered via heat exchangers and used to preheat other feed streams or endothermic processes, decreasing the amount of fuel used for process heating. Industrial heat pumps with high coefficients of performance can also be used for heat recovery or to elevate temperature of fluid streams from the recovery heat exchangers.

Chemical Manufacturing Measure 2: Advanced Automation and Optimization

Some of the key advanced automation and optimization measures for the Chemical Manufacturing subsector include:

- **Plant-wide monitoring and automated control systems:** These systems use machine learning and analytics to understand their production data and to automatically optimize processes.
  - **Baseline:** Many facilities have SCADA systems that enable real-time or interval process monitoring. However, existing systems are typically focused on discrete systems or processes in a plant, and they require manual optimization of systems or processes.
  - **Efficient:** Recent advancements in machine learning allow for SCADA systems that automatically identify drifting parameters and adjust them back to desired ranges. These automated monitoring and controls systems can quickly adjust parameters for many systems and processes to optimize plant-wide operations across a variety of loads.

Chemical Manufacturing Measure 3: Variable Speed Drives

Replacing constant speed drives: Replacing single speed drives with VSDs results in average speed reductions of 10%-60% which corresponds to lower energy usage during part-load conditions. The US Department of Energy estimates that up to 25% of installed motor systems can benefit from retrofitting VSD technology.

- VSDs are an economically viable application with payback periods less than one-third of the average motor life (15-20 years).

- VSDs offer tremendous benefits, including pump size reductions, lower energy costs and improved efficiency across all load profiles.

Barriers to Energy Efficiency Implementation in the Chemical Manufacturing Subsector

The expert interviews and the literature review revealed several barriers to energy efficiency implementation in the Chemical Manufacturing subsector, including:

- **Competition for capital:** Some experts noted that most chemical companies are investor owned and so they do not want to spend capital for energy efficiency gains that may be minimal, especially if it means they will accrue debt or lose out on more lucrative opportunities that will generate profit for their investors.
- **Low energy costs:** While chemical manufacturing is an energy-intensive industry, experts observed that energy costs are still cheap, so shutting down plants for incremental efficiency gains or optimizing their plants beyond the required levels to meet demand is not attractive to most operators.
- **Concerns over lost production:** Due to the downtime required to install and commission more energy efficient systems.
- **Perceived risks:** Concerns about possible negative impacts of energy efficient technology on product quality or yield.
- **Lack of knowledge:** Decision makers' lack of understanding of the benefits of energy efficiency.

Other Demand Side Activity in the Chemical Manufacturing Subsector

Chemical Manufacturing experts indicated that this subsector has some demand side activity beyond energy efficiency, with CHP systems being the most common. Many CHP systems are used across this sector because they have >80% thermal efficiency and have large natural gas-based heating loads. CHP systems have been the most significant reason (50%) for the decrease in energy intensity per unit (and greenhouse gas) of output.45 In the last decade, the subsector has, on a national basis, spent $200 billion to expand production capacity and CHP is standard technology in most of these new facilities.

The experts said that demand response programs are popular in California for those chemical manufacturers whose operations can tolerate part-loads and non-steady state conditions. They also reported that many chemical companies have purchase agreements with independent providers for wind or solar to fulfil corporate sustainability goals. However, the experts also indicated that most chemical manufacturers still use electricity mostly generated from fossil fuels rather than alternative energy sources.

Electronics Manufacturing

Table B-4 shows the three most promising energy efficient activities that the team identified for the Electronics Manufacturing subsector and a summary of its justifications for selecting them. The subsequent subsections provide more details on these recommendations.

[45] While this number seems like a high percentage, the study's end user interviews will obtain more detailed context for this subsector

Table B-4: Recommended Energy Efficiency Measures for the Electronic Manufacturing Subsector

Measure	Justification
Optimize air change rates with VSDs in cleanroom spaces	• Most frequently mentioned measure in the literature reviewed and expert interviews. • This measure saves electrical energy in semiconductor fabrication facilities, specifically in the HVAC end use of that subsector. This is important because: - The DOE's MECS data shows that semiconductor manufacture facilities account for 72% of the energy usage in the electronics manufacturing subsector in the Western region of the US. - The MECS data shows that the largest end use at semiconductor facilities is HVAC.
Low Cost O&M Retrocommissioning (RCx)	• Measures, such as RCx, that have short payback periods (1-2 years) are more likely to be implemented. • Each semiconductor facility is unique and has different opportunities. RCx by nature is tailored to identify savings opportunities in a customized setting. RCx can occur at any facility, impact any system, and result in both electricity and gas savings.
Low pressure drop HEPA/ULPA filters in cleanroom spaces	• Reducing HVAC consumption in semiconductor facilities is important because such facilities account for nearly three-quarters of the energy usage in the West Coast electronic manufacturing subsector and HVAC is the largest end use at semiconductor facilities.

Electronics Manufacturing Measure 1: Optimizing Air Change Rates with VSDs in Cleanroom Spaces

This measure involves adjusting air change rates using VSDs to reduce airflow through cleanrooms when doing so does not adversely impact the cleanliness of the cleanroom. Contamination sources are lower during periods of low production or low occupancy, meaning that the air changes in the cleanroom can be reduced while maintaining the necessary cleanliness standards. This measure can involve using particle counters or other gas-phase contamination measurement devices combined with scheduling controls to automatically or manually adjust/optimize the air change rates during certain times. The primary savings are due to reduced fan energy use and reduced cooling load due to the motors running at slower speeds.

Electronics Manufacturing Measure 2: Low Cost O&M Retrocommissioning

Low Cost O&M Retrocommissioning (RCx) involves making low and no-cost energy performance improvements to a system or process. RCx typically involves reviewing trend data within the building automation systems, performing functional testing, and identifying control enhancements such as:

- Improved scheduling of equipment or identification of scheduling programming errors

- Improved control sequences such as temperature/pressure resets or trim and respond control logic, or identification of errors in control sequence logic
- Identifying and fixing errors associated with sensors, such as mis-mapping of sensors with their stored parameters in the automation system, or sensor calibration issues

Flexibility is one advantage of this measure. According to multiple interviewees, each electronics manufacturing facility is unique and has different opportunities. RCx is tailored to identify savings opportunities in a customized setting. RCx can occur at any facility, impact any system, and result in both electricity and gas savings.

Electronics Manufacturing Measure 3: Low Pressure Drop HEPA/ULPA Filters in Cleanroom Spaces

The main function of low pressure drop filters are to reduce the pressure required for air to pass through the filter and adequately remove particulate matter. The suggested replacement filter has more surface area and provides deeper-pleated weaves to reduce pleat spacing, which reduces pressure requirements and increases dirt holding capacity. These low-pressure drop filters result in less fan energy use for the same airflow rate while maintaining or improving filtering capabilities.

HEPA/ULPA filters typically last for 10 years compared to conventional pre-filters that have to be changed out every 6 months. This avoids maintenance crews neglecting to replace dirty filters that reduce system efficiency. Installing new HEPA/ULPA filters requires shutting down the process and ensuring no leak-by is occurring around the HEPA/ULPA filters. If low pressure drop filters are being installed, space available in the ceiling may or may not be an issue, since low pressure drop filters are typically lower and deeper than standard HEPA/ULPA filters.

Barriers to Energy Efficiency Implementation in the Electronics Manufacturing Subsector

The expert interviews and the literature review revealed several barriers to energy efficiency implementation in the Electronics Manufacturing subsector including:

- **The fear of negatively impacting production:** Semiconductor facilities were primarily responsible for this barrier as any energy efficiency upgrade might create inefficiencies in their production and facilities are particular about which changes are allowed for processes and when. Experts named this as both a barrier and a primary barrier.
- **The cost of implementing the measure is too high:** Experts were more likely to achieve energy savings for measures with low payback periods. Some of the largest energy savers are also the projects with the highest payback periods, which significantly reduces the probability of implementation.
- **Energy savings is not a priority:** Some of the experts noted that energy is a small portion of the total expenditure for electronics manufacturing facilities compared with equipment, personnel, and raw materials. Due to the volatility of the semiconductor manufacturing process and securing optimal material tend to take precedent over energy efficiency. Some experts also referenced that semiconductor facilities are willing to use any amount of energy required to make the product to the highest quality.
- **The perception that participating in energy efficiency programs is too onerous and time-consuming:** Computer and semiconductor manufacturers on the process and

operations level monetize the value of minutes and seconds and may perceive energy efficiency programs as time-consuming.

There were other barriers that were each cited by only a single expert. These included not knowing if energy savings estimates were reliable and a lack of energy efficiency knowledge among end use customers.

Other Demand Side Activity in the Electronics Manufacturing Sector

Some interviewees reported that some electronics and semiconductor manufacturing facilities are installing large solar PV arrays, either because they have corporate goals to achieve net-zero carbon emissions within a certain timeframe, or because the cost of electricity from PV can be more attractive than grid-supplied electricity in some cases. One expert stated that one manufacturer installed a fuel cell system in conjunction with a contract that locked in low gas prices for the coming future.

The Electronics Manufacturing Sector makes almost no use of cogeneration. Table B-5 shows that few electronics manufacturing facilities in the US as of 2014 had cogeneration capabilities.

Table B-5: Electronic Facilities in US with Cogeneration Facilities According to MECS 2014

NAICS Code	NAICS Code Description	Facilities in US	Have Cogeneration Technologies
334	Computer and Electronic Products	6,831	0.06%
334413	Semiconductors and Related Devices	388	0.00%
335	Electrical Equip., Appliances, and Components	3,298	0.00%

The Electronics Manufacturing subsector experts indicated that the low adoption rate of cogeneration at electronics facilities can be due to the following reasons:

- Lack of gas consuming processes and the lack of large, sustained heating demand load makes cogeneration economically attractive.
- High capital costs for cogeneration that must compete for capital with other facility improvements, such as new production tools that can manufacture the next generation of better/faster computing components. The size of semiconductors is getting smaller, and new/different tools are continuously being needed to manufacture these smaller and faster chips.
- Energy is a small portion of the total expenditure for these facilities compared with equipment, personnel, and raw materials, so there is little motivation to invest large capital sums on new equipment with long paybacks. Many facilities do not know if they will be open in in 5-10 years, since technology moves so quickly, and they must continuously strive to stay up to date with the latest technologies to remain competitive in the global market.

Greenhouses

Table B-6 shows the three most promising energy efficient technologies that the team identified for the Greenhouse subsector and a summary of its justifications for selecting them. The subsequent subsections provide more details on these recommendations.

Table B-6: Recommended Energy Efficiency Measures for the Greenhouses Subsector

Measure	Justification
LED Grow Lights	• Advances in semiconductor technology have made LED grow lights a viable alternative to high pressure sodium lamps and metal halides for greenhouse farming. • Current LED grow light adoption is low overall across the greenhouse sector.
Efficient HVAC Equipment and Controls	• High efficiency heating systems such as condensing boilers are a very good option when combined with below bench heating. Below bench heating is more energy efficient and effective compared to forced air systems. • Some renewable technologies that have the technical potential but are yet to see increased adoption are geothermal heat pumps.
Energy Curtain	• Energy curtains are being widely adopted in certain parts of southern California. • Energy curtains are increasingly common in new construction greenhouses and less so in older facilities. • A good energy curtain can sometimes be more effective in energy conservation than even a high efficiency heating system like a condensing boiler.

Greenhouses Measure 1: LED Lighting

The expert interviews and the literature review led the team to recommend LED lighting as a key energy efficient measures for the Greenhouses subsector. The following trends were observed in the Greenhouse sector regarding LEDs:

- LED lighting technology can now be considered a viable, energy efficient alternative to 1,000 W high pressure sodium (HPS) and 1,000 W metal halide lamps, which are currently the industry baseline. Recent advances in semiconductor technology include doping LEDs with certain elements and increasing the UV-C output of the light. Therefore, LEDs have seen increased rates of adoption in the cannabis industry and are used as grow lights. Other benefits include the production yield in grams/watt, which are far better for LEDs. Also, LED light spectrum adjustability has the advantage of not needing to switch out lamps during different growth stages for growers who optimize the light intensity and color spectrum by growth stages.[46]

[46] One reviewer of the draft memo observed that LEDs can offer significant cooling savings over HPS lamps. This reviewer also claimed that the heating advantages of HPS lamps are overstated because the greatest heating needs for greenhouses occur when lights are out and that LEDs can also provide meaningful heat when lights are on.

- Early LEDs that catered to the cannabis subsector were not as effective and the technology was not fully developed, resulting in lower adoption in the industry. However, the greenhouse market saw lot of marketing from many grow LED lighting manufacturers that made the grower nervous of the effectiveness of these lighting. DLC listed them on its website along with their effectiveness, which helped streamline the grow LED lighting market. But there is still some debate on whether LEDs are better than HPS as HPS can work as both grow lighting and proving heat to the greenhouse space.
- Since the market saturation has been low the potential for adoption remains because the cannabis subsector has a very heavy lighting load, which has even caused a shift in the grid's load in certain parts of the country. The shift toward an energy efficient alternative could begin with replacing HPS lamps with LEDs.

The lighting loads in a greenhouse vary with location and type of crop being cultivated. Greenhouses growing vegetables or other high value crop do not have significant lighting loads. However, cannabis greenhouses have a considerably large lighting load. Therefore, market saturation and adoption would depend on multiple factors such as crop being cultivated, geography, size of the greenhouse, etc.

Greenhouses Measure 2: Efficient HVAC Equipment and Controls

The expert interviews and the literature review led the team to recommend various HVAC system measures for the Greenhouses subsector. The following trends have been observed in this subsector regarding HVAC systems:

- There is a consensus that HVAC is the biggest energy consuming system in a greenhouse. The most prevalent systems being used are package units and chilled water systems. Some sites also use ductless split systems. The heating system consists of hot water boilers sometimes equipped with flue gas condensers. The baseline can be either standard efficiency boiler or natural gas-fired overhead furnaces. For standard efficiency boilers, the efficient case is a condensing boiler and for overhead natural gas-fired furnaces, the efficient case is below bench heating systems.
- One expert said that conventional greenhouse HVAC systems are not best suited for greenhouse applications, especially in the cannabis subsector because they are designed for a different purpose—comfort cooling for people loads rather than plant loads. Additionally, psychrometric requirements of the cannabis plant typically require the HVAC system to operate at different conditions than what they normally operate at because plants need different internal climate conditions compared to comfort cooling for humans.
- Controls are integral to the HVAC system. Although most small-scale growers do not have sophisticated climate control systems, they use simpler controls like a setback thermostat. Larger growers have sophisticated controls that monitor temperature, relative humidity, the vapor pressure deficit (or VPD—the difference between the amount of moisture in the air and how much moisture the air can hold when it is saturated), etc. The baseline system does not have controls for HVAC and the fans operate at fixed speed and at ON or OFF mode. This results in either over or under supply of ventilation air.
- Advanced controls have started adopting large-scale use of agriculture specific sensors and faster computing technologies to reduce the operating cost. AI, machine learning, robotics, and computer visioning have been adopted in large greenhouses to reduce labor costs.

- Some other measures that can be installed along with energy efficient HVAC systems that can increase overall effectiveness of the HVAC system and increase the energy efficiency potential. Additionally, envelope changes may offer HVAC resizing opportunities and thus cost savings. Other measures include:
  - Structural changes to the envelope such as double or triple layered polycarbonate walls.
  - Insulation, which was observed to be a frequently neglected measure, but is easier to install and has a shorter payback period.

Greenhouses Measure 3: Energy Curtains

The expert interviews and the literature review led the team to recommend energy curtains as measure measures for the Greenhouses subsector. The following trends have been observed in this subsector regarding energy curtains.

- Depending on the geographical location of the greenhouses, energy curtains have varying levels of adoption. Greenhouses in southern California have a higher rate of installing energy curtains that in other territories. Energy curtains are generally effective in saving energy and help maintain internal environmental conditions.
- Some experts believe that an energy curtain, by reducing heat loss to the external environment, would be more effective in realizing energy savings than installing a higher efficiency heating system like a condensing boiler. In addition, they observe that the energy curtain would have a lower initial cost and a shorter payback period than the boiler.
- While energy curtains are not standard practice in the US, they are in other countries with significant greenhouse activity, such as Canada.

Barriers to Energy Efficiency Implementation in the Greenhouse Subsector

The expert interviews and the literature review revealed several barriers to energy efficiency implementation in the Greenhouse subsector including.

- **Greenhouse cultivation is highly customized:** The consensus among the expert interviewees was that greenhouses run highly customized processes when it comes to cultivating their crops. There is no generally accepted industry standard practice that the industry has adopted—there is no one size fits all approach. Each greenhouse has adopted systems that are tailored toward their crop requirements and yield. If a grower wants to replace existing HPS lamps with LED grow lights, then the grower would need at least 2-3 crop cycles to readjust all the other systems in the facility to work in conjunction with the lighting system (such as heating, pumping, and other systems). This could result in increased loss of crop yield, which most growers are not willing to risk, making adoption of LEDs much slower.
- **Lack of capital:** Greenhouses typically have lower margins on their produce and so have little capital to invest in energy efficient technologies. The expert interviews indicated that adverse market conditions and uncertainty make it more difficult for them to make such investments. Some experts said that the higher capital cost involved in greenhouse farming is making farmers resort to high market volume cash crops such as tomatoes, greens, cucumbers, peppers, and market greens. These crops also happen to be labor-intensive, which is becoming more expensive in California. They also observed that

consumers are looking for inexpensive produce and so greenhouse farmers face competition from cheaper produce from outside of California. Therefore, cost can be considered a barrier. Additionally, financing the project (through loans, etc.) can be a challenge owing to conflicting federal and state laws regarding cannabis cultivation.

- **Lack of awareness of LED benefits:** The experts said that many greenhouse growers are not aware of, or do not have confidence in, the effectiveness of LEDs or their energy efficiency benefits.
- **Unwillingness to change current processes:** The experts said that most growers have processes that are tailored to suit their needs and are reluctant to upgrade their systems due to the re-adjustment of their operations which could take multiple growing cycles. The risk of lost crop yield is a significant barrier.
- **Energy curtains can be difficult to retrofit:** Retrofit options for energy curtains are difficult and so these are installed mostly in new construction projects.

Other Demand Side Activity in Greenhouses

The Greenhouse experts indicated that this subsector has some demand side activity beyond energy efficiency. Some of the other demand side activity mentioned included:

- In many areas, greenhouses are taking advantage of time-of-use rate structures.
- The expert interviews and literature review indicated that CHP/cogeneration is a technology that has good potential for larger growers. The experts said that CHP would be a good technology to invest in for large greenhouse operations with a high level of HVAC/lighting requirements. The one California greenhouse with a CHP system that the literature review was able to identify was a large-scale tomato-growing operation. However, these experts also said that most greenhouses lack these economies of scale and operate with tight margins that would make such a large capital investment difficult. The fact that some areas of the greenhouse subsector (e.g., cannabis farming) are relatively new could also be an explanatory factor for the low rate of CHP adoption.
- Bio-gas production is adopted by a few large industrial scale farms where there are government subsidies available for energy conservation or bio-gas production and where there are state and federal environmental regulations that mandate animal effluent treatment in industrial scale farms.
- Solar PV options have been explored in the Greenhouse subsector but market saturation is low currently. One barrier is the availability of real estate, which can be expensive in parts of southern California. Other barriers to adoption are like those discussed above for CHP (e.g., some greenhouses lacking economies of scale for energy consumption, smaller greenhouses lacking funds to invest in such large capital projects, and the relative newness of some areas of the greenhouse subsector).
- Compost heating, bio-gas steam heating, and geothermal heating are some other approaches that are gaining traction. However, the market cost is often the primary barrier to wider adaptation. For example, the risks of pest damage and damage due to wider temperature fluctuations in crops dissuade farmers from adapting to a more compost-heated greenhouse. Sometimes auxiliary or supplementary heating by portable systems is required for occasional cold bouts in non-greenhouse-controlled environments and growers prefer that as a low risk alternative.

Water Pumping

Table B-7 shows the three most promising energy efficient technologies that the team identified for the Water Pumping (for Agriculture) subsector and a summary of its justifications for selecting them. The subsequent subsections provide more details on these recommendations.

Table B-7: Recommended Energy Efficiency Measures for the Water Pumping Subsector

Measure	Justification
Efficient Pumps and Motors	• Experts reported that California irrigation systems have many older, less efficient motors that would benefit from being brought up to code (which California allows if there is good justification that the upgrade would not have happened soon without program intervention) • A newer pump/motor opens the door for additional energy efficient measures in the irrigation systems
Sensors and Controls	• Prevent overwatering and the energy usage associated with pumping that water • Optimize flow rates and irrigation schedule based on real-time data, thereby saving energy • Identify inefficiencies in pumping system
Comprehensive Program	• Programs exist for various parts of the pumping system, but none have a holistic approach: - Encourages farmers to implement energy efficiency measures on all parts of their pumping system by offering a comprehensive incentive on projects with measures from all three parts of the system/end use. - Educates farmers on all aspects of their irrigation system, how they interact with each other and the environment as well as the possibilities available for energy efficiency. • Such holistic approaches are important because isolated energy efficiency improvements can sometimes be offset by inefficient equipment or operations elsewhere in the system

Water Pumping Measure 1: Efficient Pumps and Motors

Within the agriculture water pumping subsector, the pumps and motor accounts for approximately 90% of the system's energy consumption. According to experts, many of the motors and pumps currently in use are old and, in some cases, have not been examined in over 30 years. What that means in terms of the system operation and energy usage is that farmers, instead of pulling and replacing/repairing these older pumps, choose to increase the pump's speed to compensate for reduction in water supply pressure—an act that increases their energy consumption. This behavior results in a well pump running inefficiently and, according to one expert, sometimes at more than double their rated capacity. These equipment often were not set at their optimal efficiency level according to their respective motor curves, were not sized appropriately for their application, the application has since changed, or the water table has shifted so much that the equipment is struggling to overcome the change in head its now seeing.

According to Southern California Edison,[47] premium efficiency motors offered savings upwards of 4% when compared to standard efficiency motors. However, based on expert interviews, most motors are 15-30 years old and do not meet standard efficiency motors efficiency levels. This is usually due to the cost of installing new motors and the mentality that if it works, do not fix it. This measure should be offered as an early replacement program where savings can be claimed for bringing equipment up to code. When comparing premium efficiency motors to the motors that are currently installed and considering that motors comprise a significant portion of the energy associated with water pumping in the agricultural setting, a large quantity of savings could be realized from the installation of premium efficient motors.

Water Pumping Measure 2: Sensors and Controls

Irrigation controls often are operated manually and based on a rule of thumb as farmers know on average how many acres foot of water a certain crop needs and adjust their pumping schedule to fit that demand. In such cases, crops are often over- or under-irrigated, which can have a negative impact on the crop's yield and energy consumption of the pumps. The use of sensors to monitor soil moisture content would help avoid over or underwatering. It would also minimize energy costs associated with pumping as a control system would optimize operation and so reducing water and energy consumption.

All the experts in this subsector offered sensors and controls as a promising energy efficiency technology. Additionally, a study commissioned by the California Energy Commission stated the following:[48]

> *Eight to thirty-three percent in energy savings was observed from pump monitoring and irrigation optimization, with an average improvement in energy efficiency (energy savings for the same production level) of 13 percent across a variety of crops and geographies. Water use efficiency was improved by 9 percent. If this technology was installed for 20 percent of the 2.4 million acres cultivated in California for almond, pistachio, tomatoes, and alfalfa annual savings could be more than 66 gigawatt-hours of electricity and 120,000 acre-feet of water."*

Sensors and controls also help to identify faulty areas within the irrigation system that need to be resolved and places the overall system operation at the farmer's fingertips.

Water Pumping Measure 3: Comprehensive Program

The irrigation system is made up of three parts: pump/well hydraulics, electric to hydraulics conversion, and the discharge or water distribution system. While energy incentives are available for each part of the system, a number of subsector experts advocated for a comprehensive program that looks at the entire system as a whole and offers farmers an increased incentive or comprehensive bonus if they implement energy efficiency measures within all parts of the system.

[47] https://www.sce.com/sites/default/files/inline-files/25777_Arg_Pump_v8_WCAG.pdf, Accessed June 11, 2020.
[48] California Energy Commission, "Decision Support Tool to Reduce Energy and Water Consumption in Agriculture." March 2019.

Studies show that improving pumping efficiency can reduce energy consumption by 19%-34% on average.[49] However, when such a measure is implemented on its own within such a closely knitted system, it can just shift the inefficient component to the next part of the system. For example, an energy efficient motor or pump will not work as intended if that piece of equipment is still expected to meet a high discharge pressure on a system that over irrigates because no moisture sensors have been deployed or the water is being distributed through an old, inefficient, and leaking aluminum pipe system instead of a more efficient yellow mine system.

It will be difficult to get a market saturation estimate because this measure is new and is not typically offered as an energy efficiency program.

Barriers to Energy Efficiency Implementation in the Water Pumping Subsector

The expert interviews and literature review revealed several barriers to the implementation of energy efficiency measures in the Water Pumping (for Agriculture). The two most prominent barriers follow:

- **Cost barriers for motor and pump replacement:** The major barrier to the installation of this measure is cost. To pull a well pump a farmer usually must pay on average about $40,000. Coupled with the fact that a single farm could have about 10 wells, this helps explain why farmers are reluctant to shoulder the financial burden and instead opt to leave the pumps in.
- **Farmers lack the time to learn about the benefits of energy efficient options:** Farmers often are unaware of the incentives at their disposal and how various energy saving measures operate individually and together.

Other Demand Side Activity in the Water Pumping Subsector

Unlike other subsectors, equipment location/usage and workforce allocation may not be as centralized within the water pumping subsector. This has a positive effect on the subsector when dealing with things such as the COVID-19 pandemic but acts as more of an obstacle when dealing with the implementation of demand side technologies. The following lists demand side measures that various industry experts presented as effective in this environment.

- Curtailment
- PV water pumping
- Wind turbines couple with irrigation system
- Net metering
- Self-generation, primarily solar, but also includes fuel cells and batteries

49 Divya Handa, "The Efficiencies, Environmental Impacts and Economics of Energy Consumption for Groundwater-Based Irrigation in Oklahoma," MDPI, 2019, file:///C:/Users/rulant/Downloads/agriculture-09-00027.pdf.

Dairies

Table B-8 shows the three most promising energy efficient technologies that the team identified for the Dairies subsector and a summary of its justifications for selecting them. The subsequent subsections provide more details on these recommendations.

Table B-8: Recommended Energy Efficiency Measures for the Dairies Subsector

Measure	Justification
Refrigeration Systems Heat Recovery	• Biggest user -> biggest savings opportunity • Lots of market opportunity (low saturation) • Uses scavenged heat to preheat wash water or cow drinking water
Pump VSD	• Large energy consumer • Lots of market opportunity (low saturation) • Current practice is constant-velocity pump motor with manually adjustable orifice; very inefficient at partial loads
Fans & Ventilation (HVLS fans, fan maintenance)	• Lots of market opportunity (low saturation) • Technologies are well understood and readily available • Use less energy and improve herd comfort

Dairies Measure 1: Refrigeration System Heat Recovery

Dairies subsector experts identified refrigeration systems as either the highest or second-highest energy user on a dairy farm (excluding the energy needed to grow crops for cattle). Dairy refrigeration systems keep raw milk cool. The heat removed by these refrigeration systems is typically rejected to the environment. While heat recovery may not be strictly a refrigeration system measure, several experts felt that installation of a simple heat recovery system (allowing waste heat to be recovered for pre-heating cleaning water) offered fewer barriers than do more involved refrigeration measures and still offered significant savings opportunities. The experts also claimed that this measure is under-used in the Dairies subsector. In colder climate zones, recovered heat can also be used to heat cow drinking water during the winter, which increases milk production.

Dairies Measure 2: Pump VSDs

The milking and collection system pumps milk through the milking system from cow to cooling tank. Current practice is a constant speed pump with a manually adjusted orifice to maximize the vacuum level in the system. As a result, systems typically run well below capacity, wasting most of the pump motor’s power. A VSD allows the system to adjust optimize vacuum levels on the fly, reducing pump power when not under full load conditions. One expert claimed that this pumping process was the highest energy consuming and least energy efficient process on a dairy farm.

Dairies Measure 3: Fans and Ventilation

Installing high-velocity low-speed (HVLS), which use large fan blades, can reduce overall power consumption compared to conventional box fans while having the additional benefits of improving cow comfort by improving air circulation. A variety of fan sizes are now available, and the experts stated this was a newer market that was expanding quickly. In addition, the experts noted that routine blade cleaning can improve fan efficiency without parts replacement. Fan blade material can be altered to reduce load on the motor; however, this application is quite rare.

Barriers to Energy Efficiency Implementation in the Dairies Subsector

The expert interviews and the literature review revealed several barriers to energy efficiency implementation in the Dairies subsector, including:

- **Inability to afford the high first cost of some energy efficiency improvements:** The experts identified this as a significant barrier to energy efficiency implementation in the Dairy subsector.
- **Incompatibility of older pumps:** The experts observed that older pumps may not be VSD-compatible which increases installation costs.
- **Lack of time for energy efficient knowledge implementation:** Some experts noted that dairy farmers often cannot afford to take downtime to learn about energy efficiency opportunities or implement these upgrades.

Other Demand Side Activity in Dairy

Dairy subsector experts said that competition with energy efficiency from solar PV opportunities was small-to-moderate and that wind energy options offered little competition with energy efficiency. Most of the experts indicated that dairy farmers were more likely to lease their lower quality land to utilities for solar arrays or wind turbines than to install their own solar generation equipment. These experts claimed that most farmers wanted to concentrate on their dairy operations and did not want to complicate their lives by managing a PV system or signing a long-term lease with a solar provider when their own future viability was uncertain. However, one California-based expert claimed that dairy farmers were as likely to generate their own solar energy as sell it.

Appendix C. Summary of Literature Review Sources and Experts Interviewed

Memo to:		**Date:**	7/8/2020
Lisa Paulo, CPUC		**From:**	Christopher Dyson, DNV GL
Copied to:		**Prep. By:**	Jennifer Childs, DNV GL; Christopher Dyson, DNV GL; and DNV GL's Industrial/Agricultural Market Saturation Study Team
Karen Maoz, Dustin Bailey, Amul Sathe Guidehouse; Miriam Goldberg, DNV GL			

Background

This memorandum (memo) lists the information sources the Group E team used to support its recommendations of promising energy-efficient technology and systems for six industrial and agricultural subsectors (dairy, greenhouses, water pumping [for agriculture], chemical manufacturing, electronics/semiconductor manufacturing, and food processing). This research is part of the CPUC's Industrial/Agricultural Market Saturation Study.

The memo lists the following for each industrial/agricultural subsector:

- A list of subsector experts that the Industrial/Agricultural Market Saturation Study Team interviewed over the phone
- A list of published reports, conference papers, journal articles, and white papers that the team reviewed

The team completed the literature review and expert interviews between May and June 2020.

Agriculture

Dairy

Expert Interviews

- Daniel Ciolkosz, PhD, P.E., Assistant Research Professor of Agricultural and Biological Engineering, Pennsylvania State University, University Park, Pennsylvania
- Wayne Leonard, Senior Managing Consultant, Guidehouse
- Curt Andrews Gooch, PhD, Dairy Environmental Systems and Sustainability Engineer and Senior Extension Associate, Cornell Department of Animal Science, Cornell University, Ithaca, New York
- Mary Diebart, Agricultural Account Manager, PG&E
- Carlos Del Pozo, Senior Program Engineer, Field Engineering Services, PG&E
- Christine Forster, Agricultural/Food Processing Supervisor, PG&E

- Teresa Groppetti, Agricultural/Food Processing Customer Relationship Manager, PG&E

Literature Review

- Naranjo, A. Johnson, E. Kebreab, and H. Rossow, "Greenhouse gas, water, and land footprint per unit of production of the California dairy industry over 50 years," *Journal of Dairy Science*, February 7, 2020, https://www.sciencedirect.com/science/article/pii/S0022030220300746.
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Greenhouses

Expert Interviews

- Arian Agajanzadeh, Director of Agriculture, Bountiful Agriculture
- Bryan L Sherman, Owner, Innovative Energy Solutions
- Wayne Leonard, Engineer, Guidehouse
- Dan Ciolkosz, Professor (Outreach & Extension), Penn State
- Cindy Smith and Jesse Monn, Utility Representative and Engineer, SDG&E and Cascade Energy
- Tim Clinton, Customer Relationship Manager, AG/Food Processing, PG&E

- Cameron Tuttle, P.E., Senior Engineer, DNV GL
- Subhadarshi Nayak, PhD, P.E., Sarah Miller, Greenhouse owner and consultant for USDA Greenhouse Projects; CEO, President, Arhize Corporation, Lexington Kentucky, FSN - 4481, 4482
- Yeshpal Gupta, PhD, Director of Engineering, Lincus Inc. PG&E and SCE technical reviewer
- Wesley Whited and James Yerke, P.E., Senior Consultant and Senior Engineer, DNV GL
- Nadia Sabeh, PhD, P.E., Founder and President, Dr. Greenhouse, Inc.
- Julio Lopez, President, Enwise Solutions Inc.

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- Merle H. Jensen, *Controlled Environment Agriculture in Deserts, Tropics and Temperate Regions - A World Review*, University of Arizona.

Water Pumping (for Agriculture)

Expert Interviews

- Christine Foster, Agriculture and Food Process Manager, PG&E
- Justin Witte, Customer Relationship Manager, PG&E
- Floyd Keneipp, Principle at Tierra Resource Consultants, Tierra Resource Consultants
- Wayne Leonard, Program Evaluator, Guidehouse
- Arian Agajanzadeh, Head of Sustainability, Bountiful Agriculture
- Olivier Jerphagnon, Founder of Powwow Energy, Powwow Energy
- Daniel Ciolkosz, PhD, Research Associate Professor, Department of Agriculture and Bio Engineering, Penn State
- Dr. Scott Frazier, Associate Professor and CEM instructor for AEE, Biosystems and Agriculture Engineering, Ohio State

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Industrial

Chemical Manufacturing

Expert Interviews

- Owen Kean, Senior Director for Energy, The American Chemistry Council
- James Yereke, Senior Engineer, DNV GL
- Spencer Lipp, Director of Engineering and Strategy, TRC Companies, Inc.
- Julia Vetromile, Principle Engineer, David B. Goldstein & Associates
- Mark Jones, Executive External Strategy and Communications Fellow, Dow Chemical
- Peter Akinjiola, Chemical Engineer, Psage Research, Inc.

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Electronics/Semi-Conductor Manufacturing

Expert Interviews

- Steve Hambalek, Regional Technology Director, Japan, Mattson Technology, Inc.
- Ahmad Ganji, Mechanical Engineering Program Head & Professor of Mechanical Engineering-San Francisco State University, Industrial Assessment Center
- Samantha Reese, Senior Engineer/Analyst, National Renewable Energy Laboratory
- Sujit Das, Senior Researcher, Oak Ridge National Laboratory
- Spencer Lipp, Director of Engineering and Strategy, TRC
- James Yerke, Senior Energy Engineer, DNV GL

- Jeremy Zhang, Staff Thermal Modelling Engineer, Tesla
- Jingjing Liu, Program Manager, Lawrence Berkeley National Laboratory
- John Zwick, Account Manager, SDG&E
- Laura Elliot, Manager, High Tech/Real Estate Large Enterprise Accounts, PG&E
- Neema Yazdi, Account Manager, PG&E
- Jerry Hutchinson, Account Manager, PG&E
- Linda Barboza, Account Manager, PG&E

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Food Processing

Expert Interviews

- Ahmad Ganji, Director, AIC
- Cameron Guy, Program Manager for PG&E Dairy and Winery Program, PG&E
- Ann Marie Mastrippolito, Program Portfolio Manager for Industrial and Agricultural programs in CA, Clear Result
- Peter Therkelsen, Energy Efficiency Research Scientist, Lawrence Berkeley National Laboratory
- John Stier, Sustainability Mentor, Brewers Association
- Steven Nadel, Executive Director of Marking Energy Efficiency, ACEEE
- Glenda Towns, Program Manager, SoCalGas; Richard Hart, Senior SEM Couch, Cascade Energy; Siva Sethuraman, Director of Utility Engagement, Cascade Energy
- Justin Westmoreland, Senior Customer Care Program Engineer, PG&E
- Rob Neenan, President, California Food Producers
- Doug Scott, Founder and Manager, VaCom Technologies
- Genrick Gofman, Energy Efficiency Manager, PG&E

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Appendix D. Interview Guides

D.1 IN-DEPTH INTERVIEW GUIDE FOR INDUSTRIAL AND AGRICULTURAL SUBSECTOR EXPERTS

Interview Information

Interviewer		Survey Length (min)	
Completion Date			

Contact Information

Phone	
Email	

Call Tracking

Date/Time	Notes

INTRODUCTION

[NOTE: THE QUESTIONS IN THIS INTERVIEW GUIDE WILL NOT NECESSARILY BE READ VERBATIM BUT MAY BE MODIFIED TO SUIT THE INTERVIEW]

1. Hi, my name is X I am calling from DNV GL. As I indicated in my email, we are working on behalf of the California Public Utilities Commission to get a better understanding of the potential for greater energy efficiency in the Y subsector.

INTERVIEWEE BACKGROUND

First, I had a few background questions.

1. Please describe your current job title and a high-level summary of your current responsibilities at [COMPANY/ORGANIZATION].
2. How long have you been familiar with the Y subsector?
3. What aspects of Y subsector are you most familiar with?

SUBSECTOR TRENDS, CHALLENGES

4. Before I get into a discussion of energy use in [SUBSECTOR Y], I want to get your high-level perspective on how [SUBSECTOR Y] is doing economically. Please talk first about how it is doing during the current period, and then how it was doing before the COVID-19 pandemic.
    a. How is [SUBSECTOR Y] doing economically ***during*** the current time period?
    b. How was [SUBSECTOR Y] doing economically ***before*** the COVID-19 pandemic?
    c. Do you think there will be any long-term impacts in [SUBSECTOR Y] due to the COVID-19 pandemic?

[NOTE: IF THE INTERVIEWEE SEEMS LIKELY TO HAVE CALIFORNIA-SPECIFIC KNOWLEDGE, INCLUDE “CALIFORNIA” IN SUBSECTOR NAME – E.G., “THE CALIFORNIA DAIRY SUBSECTOR.” IF THE INTERVIEWEE HAS SUBSECTOR EXPERTISE BUT LACKS CALIFORNIA-SPECIFIC SUBSECTOR EXPERTISE, JUST USE THE GENERIC SUBSECTOR NAME (E.G., “THE DAIRY SUBSECTOR”).

5. What economic challenges has this subsector faced in recent years besides the COVID-19 pandemic?

ENERGY EFFICIENCY OPPORTUNITIES, BARRIERS

6. In [SUBSECTOR Y], what types of equipment or systems/processes consume the most energy?
7. One of the main goals of this study is to find out which energy efficient measures offer the greatest potential for future energy savings in [SUBSECTOR Y] in the California market. What do you think are the energy efficiency measures that offer the greatest potential energy savings in [SUBSECTOR Y]?

[RECORD ALL MEASURES IDENTIFIED IN TABLE 1. THE INTERVIEWEE DOES NOT HAVE TO IDENTIFY 7 MEASURES, BUT TRY TO GET THEM TO IDENTIFY AT LEAST THE TOP 3]

Table 1: EE Measures of Greatest Potential for [SUBSECTOR Y]

EE MEASURE X1	
EE MEASURE X2	
EE MEASURE X3	
EE MEASURE X4	

EE MEASURE X5	
EE MEASURE X6	
EE MEASURE X7	

[NOTE: IF NOT ALREADY MENTIONED AND RELEVANT, ASK THE INTERVIEWEE WHAT SORT OF APPLICATION THE EE MEASURE IS MOST COMMONLY USED FOR. FOR EXAMPLE, IF THE INTERVIEWEE MENTIONS A VFD, ASK THE INTERVIEWEE WHAT KIND OF APPLICATIONS THESE VFDS ARE MOST OFTEN USED FOR IN [SUBSECTOR Y]]

[ASK QUESTIONS 7A through 7E FOR EACH MEASURE MENTIONED IN TABLE 1 MAKE SURE THE RESPONSE MATRIX FOR EACH EE MEASURE IS COMPLETE (THE INTERVIEW GUIDE CURRENTLY ONLY HAS TABLES FOR 2 MEASURES BUT DUPLICATE THESE BLANK TABLES AHEAD OF THE INTERVIEW]

a. Why do you think [EE MEASURE X1] offers significant energy savings potential?

b. What would be the most common standard efficiency version of [EE MEASURE X1]?

   [NOTE: SOME INTERVIEWEES MAY BE MORE FAMILIAR WITH THE TERM “BASELINE TECHNOLOGY FOR” INSTEAD OF “STANDARD EFFICIENCY VERSION OF”.]

c. What types of equipment vendors or contractors would best be able to estimate how much [EE MEASURE X1] has penetrated into [SUBSECTOR Y]?

d. What factors or barriers prevent [EE MEASURE X1] from getting greater saturation into the [SUBSECTOR Y] market?

   [FOR EACH NAMED ASK IF THEY WOULD CONSIDER IT A FACTOR OR A BARRIER AND TAILOR TO COINCIDE] Would you classify this barrier or factor as:

   1. An Extreme Barrier or Factor?
   2. A Moderate Barrier or Factor?
   3. Somewhat of a Barrier or Factor?
   4. A Slight Barrier or Factor?
   5. Or Not a Factor?

Table 2: Response Matrix for Characteristics of [EE Measure [X1]

EE MEASURE X1 (FROM TABLE 1)	
Q7a) Why do you think [EE MEASURE X1] offers significant energy savings potential in [SUBSECTOR Y]?	
Q7b) What would be the most common standard efficiency version of [EE MEASURE X1]?	
Q7c) What types of equipment vendors or contractors would best be able to estimate how much [EE MEASURE X1] has penetrated into [SUBSECTOR Y]?	
Q7d) What factors or barriers prevent [EE MEASURE X1] from getting greater saturation into the [SUBSECTOR Y] market? [FOR EACH NAMED ASK IF THEY WOULD CONSIDER IT A FACTOR OR A BARRIER AND TAILOR TO COINCIDE]	
Barrier 1:	Would you classify this as: 1. An Extreme Barrier or Factor? 2. A Moderate Barrier or Factor? 3. Somewhat of a Barrier or Factor? 4. A Slight Barrier or Factor? 5. Or Not a Factor?
Barrier 2:	Would you classify this as: 1. An Extreme Barrier or Factor? 2. A Moderate Barrier or Factor? 3. Somewhat of a Barrier or Factor? 4. A Slight Barrier or Factor? 5. Or Not a Factor?
Barrier 3:	Would you classify this as: 1. An Extreme Barrier or Factor? 2. A Moderate Barrier or Factor? 3. Somewhat of a Barrier or Factor? 4. A Slight Barrier or Factor? 5. Or Not a Factor?

Table 3: Response Matrix for Characteristics of [EE Measure [X2]

EE MEASURE X2 (FROM TABLE 1)	
Q7a) Why do you think [EE MEASURE X1] offers significant energy savings potential in [SUBSECTOR Y]?	
Q7b) What would be the most common standard efficiency version of [EE MEASURE X2]?	
Q7c) What types of equipment vendors or contractors would best be able to estimate how much [EE MEASURE X2] has penetrated into [SUBSECTOR Y]?	
Q7d) What factors or barriers prevent [EE MEASURE X2] from getting greater saturation into the [SUBSECTOR Y] market? [FOR EACH NAMED ASK IF THEY WOULD CONSIDER IT A FACTOR OR A BARRIER AND TAILOR TO COINCIDE]	
Barrier 1:	Would you classify this as: 1. An Extreme Barrier or Factor? 2. A Moderate Barrier or Factor? 3. Somewhat of a Barrier or Factor? 4. A Slight Barrier or Factor? 5. Or Not a Factor?
Barrier 2:	Would you classify this as: 1. An Extreme Barrier or Factor? 2. A Moderate Barrier or Factor? 3. Somewhat of a Barrier or Factor? 4. A Slight Barrier or Factor? 5. Or Not a Factor?
Barrier 3:	Would you classify this as: 1. An Extreme Barrier or Factor? 2. A Moderate Barrier or Factor? 3. Somewhat of a Barrier or Factor? 4. A Slight Barrier or Factor? 5. Or Not a Factor?

Other Demand-side Options

Q8) [IF NOT ALREADY MENTIONED IN EARLIER RESONSES] How significant do you think customer selection of other demand-side options – such as distributed generation from renewables or demand response programs – has an impact on implementing energy efficiency projects?	
Q8a) What level of impact would you classify this factor as having on the selection of energy efficiency measures:	1. An Extreme impact? 2. A Moderate impact? 3. Somewhat of an impact? 4. A Slight impact? 5. Or No impact?
Q8b) Why do you say that?	

9. Finally, what other kinds of demand side technologies besides energy efficiency is [SUBSECTOR Y] installing in California? [IF NOT ALREADY MENTIONED, PROBE FOR DISTRIBUTED GENERATION (E.G. PV, BIOGAS, FUEL CELLS) AND DEMAND RESPONSE]

Thank you for your time.

D.2 IN-DEPTH INTERVIEW GUIDE FOR INDUSTRIAL AND AGRICULTURAL EQUIPMENT VENDORS

Interview Information

Interviewer		Survey Length (min)	
Completion Date			

Contact Information

Phone	
Email	

Call Tracking

Date/Time	Notes

Introduction

[NOTE: THE QUESTIONS IN THIS INTERVIEW GUIDE WILL NOT NECESSARILY BE READ VERBATIM BUT MAY BE MODIFIED TO SUIT THE INTERVIEW]

2. [USE THIS INTRO ONLY IF YOU HAVE NOT ALREADY SCHEDULED THE INTERVIEW VIA EMAIL] Hi, my name is [NAME] OF DNV GL. We are conducting a study on [EE MEASURE X] on behalf of the California Public Utilities Commission. According to our records, your company has experience installing or servicing [EE MEASURE X] and we would like to interview you to better understand the California market for [EE MEASURE X].

   [IF THEY ASK HOW LONG THE INTERVIEW WLL TAKE, SAY 15 MINUTES]

   [IF THEY REFUSE, THANK THEM FOR THEIR TIME AND HANG UP]

Company/Interviewee Background

First, I had a few background questions about you and your company.

8. What is your job title?
9. How many years have you been involved in selling or installing [EE MEASURE X]?
10. Approximately how many employees does your company have?

11. I know your company likely sells many different products and services. Roughly, [EE MEASURE X] accounts for what % of your company's annual sales in California? ___

EE Measure Energy Savings and Market Saturation

[NOTE TO INTERVIEWERS: IF THE INTERVIEW IS GOING TO COVER MULTIPLE SUBSECTORS AND/OR MULTIPLE MEASURES, PLEASE POPULATE THIS TABLE BEFORE THE INTERVIEW SO YOU CAN MAKE SURE YOU'RE COVERING All THE SUBSECTORS AND MEASURES. MAKE SURE TO ONLY INCLUDE SUBSECTORS FOR WHICH THESE MEASURES WERE ONE OF THE TOP 3 RECOMMENDATIONS]

Table 1: Subsectors and Measures Covered by Interview

Study Subsector #1	Study Subsector #2	Study Subsector #3	Study Subsector #4
Measure#1	Measure#1	Measure#1	Measure#1
Measure #2	Measure #2	Measure #2	Measure #2
Measure #3	Measure #3	Measure #3	Measure #3

12. Our study is especially interested in sales/installations of [EE MEASURE X] in certain industrial and agricultural subsectors. Does your company sell/install [EE MEASURE X] in any of the following subsectors? [PLEASE POPULATE THIS TABLE BEFORE THE INTERVIEW. ONLY INCLUDE SUBSECTORS FOR WHICH THESE MEASURES WERE ONE OF THE TOP 3 RECOMMENDATIONS]

Table 2: Study Subsector in Which Vendor Has Sales

Study Subsector #1	Study Subsector #2	Study Subsector #3	Study Subsector #4
Yes__ No __ Don't know ___	Yes__ No __ Don't know ___	Yes__ No __ Don't know ___	Yes__ No __ Don't know ___

13. If your customers install/use [EE MEASURE X] what range of annual energy savings can they expect from the operation of that [ENERGY-USING EQUIPMENT/SYSTEM Z]? ___%

    [NOTE: INTERVIEWERS WILL NEED TO CUSTOMIZE THIS QUESTION AHEAD OF TIME TO MAKE SURE THE APPROPRIATE WORDS ARE USED FOR [ENERGY-USING EQUIPMENT/SYSTEM Z] TO MATCH THE MEASURE. FOR EXAMPLE, IF THE MEASURE IS A VSD, THE APPROPRIATE [ENERGY-USING EQUIPMENT/SYSTEM Z] MIGHT BE A MOTOR OR PUMP. HOWEVER, IF THE MEASURE IS A CLEAN ROOM AIR FILTER, THEN THE APPROPRIATE [ENERGY-USING EQUIPMENT/SYSTEM Z] MIGHT BE THE CLEAN ROOM's HVAC SYSTEM, ETC.]

    a. [IF THEY PROVIDE SAVINGS %] What information are these energy savings estimates based on? [IF NOT ALREADY MENTIONED, PROBE FOR THE

BASELINE SCENARIO/ASSUMPTIONS WHICH THE SAVINGS ESTIMATES ARE BASED ON]

b. [IF THEY MENTIONED A RANGE OF SAVINGS %s] I noticed you said that energy savings would range between X% and Y%. What different factors or applications would drive this range in energy savings?

14. Do you know how much of a typical [STUDY SUBSECTOR] facility's annual energy use is consumed by [ENERGY-USING EQUIPMENT/SYSTEM Z]?

    a. [IF YES] What %? __%

    [NOTE: THE ENERGY-USING EQUIPMENT/SYSTEM Z REFERENCED HERE SHOULD BE THE ONE YOU REFERENCED IN Q6 (E.G. THE EQUIPMENT/SYSTEM THAT EE MEASURE X IS MAKING MORE EFFICIENT]

15. Of the [ENERGY-USING EQUIPMENT Z] you have seen in *California* in the past couple of years, about what % of them have [EE MEASURE X] installed? ___%

16. [IF THEY HAVE SALES TO THE STUDY SUBSECTORS (SEE Q5)] Of the [ENERGY-USING EQUIPMENT Z] you have seen in [STUDY SUBSECTOR Y] in the past couple of years, about what % of them have [EE MEASURE X] installed? ___ [FILL OUT TABLE 3 FOR ALL STUDY SUBSECTORS WHERE THEY HAVE SALES]

Table 3: EE Measure Saturation for Study Subsectors

Study Subsector #1	Study Subsector #2	Study Subsector #3	Study Subsector #4
% of [ENERGY-USING EQUIPMENT Z] which have [EE MEASURE X] installed __%	% of [ENERGY-USING EQUIPMENT Z] which have [EE MEASURE X] installed __%	% of [ENERGY-USING EQUIPMENT Z] which have [EE MEASURE X] installed __%	% of [ENERGY-USING EQUIPMENT Z] which have [EE MEASURE X] installed __%

17. Are there situations or applications where it's not technically suitable for customers to install [EE MEASURE X]?

    a. [IF NOT ALREADY MENTIONED] For which types of customers?

    b. [IF NOT ALREADY MENTIONED] For which situations or applications?

    c. For about what % of customers do you think the installation of [EE MEASURE X] is not technically suitable __% [NOTE: IF POSSIBLE (E.G. INTERVIEWEE DOES NOT SOUND FATIGUED) GET % ESTIMATES BY SUBSECTOR]

18. You estimated that __% of the [ENERGY-USING EQUIPMENT] you have seen in [CALIFORNIA/STUDY SUBSECTORS] have [EE MEASURE X INSTALLED] [REPEAT RESPONSES FROM Q8 AND Q9]. You also noted that in some cases the installation of [EE MEASURE X] is not technically suitable. What are some factors or barriers why [EE MEASURE X] is not being installed in places where it would be technically suitable to do

so? [IF THEY MENTION FACTORS/BARRIERS IN TABLE BELOW, CLICK "YES" IN MIDDLE COLUMN AND THEN ASK BARRIER CLASSIFICATION QUESTION IN 3RD COLUMN]

Factors/Barrier	Mentioned?	[IF THEY MENTIONED AS FACTOR/BARRIER, ASK:
Initial cost	Yes No	Would you classify this barrier as: 1. An Extreme Barrier? 2. A Moderate Barrier? 3. Somewhat of a Barrier? 4. A Slight Barrier? 5. Or Not a Barrier?
Disruption of work/production	Yes No	Would you classify this barrier as: 1. An Extreme Barrier? 2. A Moderate Barrier? 3. Somewhat of a Barrier? 4. A Slight Barrier? 5. Or Not a Barrier?
Concern about availability of energy-efficient equipment	Yes No	Would you classify this barrier as: 1. An Extreme Barrier? 2. A Moderate Barrier? 3. Somewhat of a Barrier? 4. A Slight Barrier? 5. Or Not a Barrier?
Capital budget cycles	Yes No	Would you classify this barrier as: 1. An Extreme Barrier? 2. A Moderate Barrier? 3. Somewhat of a Barrier? 4. A Slight Barrier? 5. Or Not a Barrier?
Lack of financing	Yes No	Would you classify this barrier as: 1. An Extreme Barrier? 2. A Moderate Barrier? 3. Somewhat of a Barrier? 4. A Slight Barrier? 5. Or Not a Barrier?

Competition from other energy-related projects (renewables, DR, etc.)	Yes No	Would you classify this barrier as: 1. An Extreme Barrier? 2. A Moderate Barrier? 3. Somewhat of a Barrier? 4. A Slight Barrier? 5. Or Not a Barrier?
Other factor/barriers mentioned (please described ________________________	Yes No	Would you classify this barrier as: 1. An Extreme Barrier? 2. A Moderate Barrier? 3. Somewhat of a Barrier? 4. A Slight Barrier? 5. Or Not a Barrier?

19. [IF NOT ALREADY MENTIONED] Do the investments your customers make in energy efficiency compete with other energy management decisions or technologies? For example, have you encountered scenarios with customers where their level of interest in your energy efficient products or services is being impacted by their interest in other energy management options such renewable energy, energy storage, demand response, CHP, etc.?
    a. [IF YES] What were these scenarios? [PROBE FOR TYPE OF DEMAND-SIDE TECHNOLOGY IF NOT ALREADY MENTIONED]
    b. [IF YES] How frequently has this occurred? Would you say it happens often, sometimes, rarely, or never?
20. Has your company had any projects that have integrated energy efficiency with renewable energy sources such as solar or wind or with demand response?
    a. [IF YES] Please describe these projects.
    b. [IF RESPONDENT MENTIONS DEMAND RESPONSE] To what extent does customer selection of energy efficient equipment (e.g., installing VSDs) influence their decision to participate in demand response programs?
        i. Extremely influential
        ii. Moderately influential
        iii. Somewhat influential
        iv. Slight influence
        v. Or No influence
    c. Why do you say that?

21. [IF NOT ALREADY MENTIONED IN RESPONSE TO Q13] Does your own company provide services that integrate energy efficiency with demand side renewable energy resources such as solar or wind and/or demand response?
    a. [IF YES] What are these services?
    b. Which kinds of customers use them?
    c. What % of your business provides these services?
22. Finally, we would like to interview other companies who sell products and services that are like yours. Which companies do you view as your main competitors?

That's all the questions I had. Thank you for helping us with this market research.

D.3 IN-DEPTH INTERVIEW GUIDE FOR INDUSTRIAL AND AGRICULTURAL END USERS

Interview Information

Interviewer		Survey Length (min)	
Completion Date			

Contact Information

Phone	
Email	

Call Tracking

Date/Time	Notes	

Introduction

[NOTE: THE QUESTIONS IN THIS INTERVIEW GUIDE WILL NOT NECESSARILY BE READ VERBATIM BUT MAY BE MODIFIED TO SUIT THE INTERVIEW]

IA. [USE THIS INTRO ONLY IF YOU HAVE NOT ALREADY SCHEDULED THE INTERVIEW VIA EMAIL] Hi, my name is [NAME] OF DNV GL. We are conducting a study of energy efficiency practices in the [STUDY SUBSECTOR Y] on behalf of the California Public Utilities Commission. Who at your company would be most familiar with how your company uses energy?

[IF ENERGY-KNOWLEDGEABLE CONTACT IS NOT IMMEDIATELY AVAILABLE, OBTAIN CONTACT INFORMATION FOR HIM/HER AND THEN ATTEMPT TO INTERVIEW ENERGY-KNOWLEDGEABLE CONTACT AT A LATER TIME/DATE USING INTRO IB.]

IB. [IF ENERGY-KNOWLEDGEABLE CONTACT IS IMMEDIATELY AVAILABLE, WAIT FOR CALL TO BE TRANSFERRED TO HIM/HER AND THEN SAY:] "Hi, my name is [NAME] OF DNV GL. We are conducting a study of energy efficiency practices in the [STUDY SUBSECTOR Y] on behalf of the California Public Utilities Commission. I was told that you're knowledgeable about how your company uses energy and would like to ask you some questions about its energy practices."

[IF THEY ASK HOW LONG THE INTERVIEW WLL TAKE, SAY 15 MINUTES]

[IF THEY REFUSE, THANK THEM FOR THEIR TIME AND HANG UP]

Company/Interviewee Background

First, I had a few background questions about you and your company.

23. What is your job title?
24. How many years have you worked for this company?
25. Approximately how many people work at this facility in [FACILITY LOCATION]?
26. [IF GREENHOUSES SUBSECTOR] About what is the total square footage of the greenhouses at this facility? ____
27. When deciding whether to approve a major energy savings-related investment, what financial factors does your organization consider? [NOTE TO INTERVIEWERS: CHECK ALL FACTORS THEY NAME AND AFTER THEY ARE DONE, ASK THEM THE IMPORTANCE SCALE QUESTION IN THE SECOND COLUMN OF THE TABLE FOR EACH FACTOR THEY'VE NAMED]

Financial Factor	[IF THEY MENTIONED FINANCAL FACTOR X] "You mentioned [FINANCIAL FACTOR X]. How important is [FINANCIAL FACTOR X] when your organization is deciding whether to approve a major energy-related investment? Please use a five-point scale where 5 equals "Very important" and 1 equals "Not important at all."
Upfront cost (including equipment, delivery & installation	
Operating & maintenance cost (including energy cost to operate)	
Payback period	
Return on investment (ROI)	[IF THEY MENTION THIS ONE, ALSO FOLLOW UP WITH: "WHAT IS YOUR TYPICAL REQUIRED ROI FOR A PROJECT TO MOVE FORWARD?"]
Depreciation	
Improved operations	
Increased productivity	
Program incentives or financing	

a. [IF THEY MENTIONED PROGRAM INCENTIES/FINANCING AS A FINANCIAL FACTOR] When you're estimating the Return on Investment for an energy efficiency project, are you typically including energy efficiency program incentives into that estimate or financing options?

   i. Why is this your standard practice?

28. What is the typical payback period that your organization uses to approve a major energy-related investment?

EE Measure Market Saturation

Now I would like to ask you about energy-saving equipment or services you may be using.

Study EE Measure #1

29. [PLEASE CUSTOMIZE THIS QUESTION BEFORE YOUR INTERVIEWS SO IT MAKES SENSE FOR YOUR SUBSECTOR AND EE MEASURE] One way for companies in [STUDY SUBSECTOR Y] to save energy is to install/use [STUDY EE MEASURE #1]. [PROVIDE A BRIEF DESCRIPTION OF STUDY EE MEASURE #1]. Do you have any [STUDY EE MEASURE #1's] installed in your facility?

    a. [IF YES] Do you have [STUDY EE MEASURE #1] installed on all the applicable equipment or only some of the applicable equipment [NOTE: IF "EQUIPMENT" IS NOT THE APPROPRIATE TERM FOR YOUR EE MEASURE, SUBSTITUTE APPROPRIATE LANGUAGE]

       i. [IF ONLY INSTALLED ON SOME OF THE EQUIPMENT] On about what % of the applicable equipment is [STUDY EE MEASURE #1] installed?

       ii. [IF ONLY INSTALLED ON SOME OF THE EQUIPMENT] Why do you have [EE MEASURE #1] installed on some of these pieces of equipment but not others?

    b. [IF INTERVIEWEE HAS MEASURE INSTALLED AT THEIR FACILITY AND MEASURES ARE VSDS] What types of equipment are these VSDs controlling?

       i. [IF EQUIPMENT CONTROLLED ARE PUMPS OR MOTORS] Roughly how many pumps/motors does your facility have?

       ii. [IF EQUIPMENT CONTROLLED ARE PUMPS OR MOTORS] What is the size range of these pumps or motors?

       iii. [IF EQUIPMENT CONTROLLED ARE PUMPS OR MOTORS] Roughly what % your pumps/motors have VSDs installed on them?

          1. [IF % IS LOW] Why do you have VSDs installed on some of these pieces of equipment but not others?

c. [IF INTERVIEWEE'S FACILITY DOES NOT HAVE MEASURE INSTALLED] Before I mentioned [STUDY EE MEASURE #1], had you heard of [STUDY EE MEASURE #1]?

1. [IF AWARE] Are there any particular reasons why you have not installed [STUDY EE MEASURE #1]?

a. [IF YES] What are these?

d. About what % of your facility's [STUDY SUBSECTOR Y]-related annual electric consumption is used by [ENERGY-USING EQUIPMENT]?

Study EE Measure #2

30. [REPEAT Q8 BUT WITH QUESTIONS CUSTOMIZED FOR STUDY MEASURE #2]

Study EE Measure #3

31. [REPEAT Q8 BUT WITH QUESTIONS CUSTOMIZED FOR STUDY MEASURE #3]

Program Awareness, Influence

32. Are you aware that your electric and natural gas utilities offer rebates and incentives for your company to save energy?

a. [IF YES] Has your company ever received a rebate or incentive for energy efficient equipment at your facility?

b. Has your company ever received a rebate or incentive for distributed generation equipment?

iv. [IF YES] If so for what kind of distributed generation equipment?

c. Has your company ever received a rebate or incentive for onsite energy storage?

d. Has your company ever participated in a demand response program?

33. Are you aware that your electric and natural gas utilities and their contractors also offer technical assistance to help companies like yours to implement energy efficiency projects?

a. [IF YES] Has your company ever received such technical assistance from your electric and gas utilities or their contractors?

34. [IF AWARE OF EE INCENTIVES OR TECH ASSISTANCE (EITHER Q6A OR Q7 = YES)] What more is needed besides incentives or technical assistance from energy efficiency programs to get your company to adopt some of the energy efficiency measures we discussed?

35. [IF THEY SAID "NO" TO 6A AND "YES" TO 6B, 6C, OR 6D] You mentioned that your company [IF 6B=YES, SAY: "RECEIVED A REBATE FOR DISTRIBUTED GENERATION"], [IF 6C=YES, SAY: "RECEIVED A REBATE FOR ONSITE ENERGY STORAGE"], [IF 6D=YES, SAY: "PARTICIPATED IN A DEMAND RESPONSE

PROGRAM"] but did not receive a rebate for an energy efficiency project. Do you know why your company sought rebates for these projects and not for energy efficiency projects?

a. [IF YES] Why did it do this?

36. Does your facility have a boiler?

a. [IF YES] If your organization needed to replace this boiler because it was broken, how likely would your organization purchase the high efficiency model given the following information:

The cost of a standard efficiency boiler of average commercial size is about $XXXX and the cost of a comparable high efficiency boiler is about $YYYYY. The high efficiency model could save up to $Z per year in energy costs and the payback period would be as low as W years.

1. Not at all likely
2. Slightly likely
3. Somewhat likely
4. Very likely
5. Extremely likely

b. What if a rebate was available to offset the cost and reduce the payback period? The rebate would be a one-time payment provided shortly after making the purchase. How likely would your organization be to purchase the high efficiency boiler if there was [READ RESPONSE IN TABLE FOR b AND MARK RESPONSE IN TABLE]?

c. What if there was [READ RESPONSE IN TABLE FOR c AND MARK RESPONSE IN TABLE]?

SINGLE RESPONSE]	**1 – Not at all likely**	**2 – Slightly likely**	**3 - Somewhat likely**	**4 – Very likely**	**5 – Extremely likely**
b. A rebate for HALF the additional cost of the high efficiency boiler which would lower the payback period to as low as X years.	○	○	○	○	○
c. A rebate for ALL the additional cost of the high efficiency boiler, which would lower the payback period to as low as x years.	○	○	○	○	○

37. [IF THEY ANSWERED THE BOILER QUESTION (Q14) SKIP TO Q16] Does your facility have pumps or motors?

a. [IF YES] A common way to make the operation of partial load pumps or motors more energy efficient is to install a variable speed drive or VSD.

How likely would your organization have a VSD installed if the average installation cost was $YYYYY. The VSD could save up to $Z per year in energy costs and the payback period would be as low as W years.

1. Not at all likely
2. Slightly likely
3. Somewhat likely
4. Very likely
5. Extremely likely

b. What if a rebate was available to offset the cost and reduce the payback period? The rebate would be a one-time payment provided shortly after making the purchase. How likely would your organization be to install the VSD. if there was [READ RESPONSE IN TABLE FOR b AND MARK RESPONSE IN TABLE]?

c. What if there was [READ RESPONSE IN TABLE FOR c AND MARK RESPONSE IN TABLE]?

SINGLE RESPONSE]	1 – Not at all likely	2 – Slightly likely	3 - Somewhat likely	4 – Very likely	5 – Extremely likely
b. A rebate for HALF the additional cost of the VSD which would lower the payback period to as low as X years.	○	○	○	○	○
c. A rebate for ALL the additional cost of the high efficiency VSD which would lower the payback period to as low as x years.	○	○	○	○	○

38. [AGRICULTURAL CUSTOMERS ONLY] What if a financing option were available that would allow your organization to pay some or all the cost over time through your monthly energy bills from your utility? With this on-bill financing option, you could choose how much to finance and for how long, and the monthly payments would be added to your energy bills.

a. [IF THEY ANSWERED THE BOILER QUESTION (Q14)] How likely would your organization purchase the high efficiency boiler in the scenario I just described if an on-bill financing option was available?

1. Not at all likely
2. Slightly likely
3. Somewhat likely
4. Very likely
5. Extremely likely

b. [IF THEY ANSWERED THE VSD QUESTION (Q15)] How likely would your organization purchase the VSD in the scenario I just described if an on-bill financing option was available?

1. Not at all likely
2. Slightly likely
3. Somewhat likely
4. Very likely
5. Extremely likely

Motivations and Barriers

39. Now I'm going to read you some statements about energy and the environment. For each one I read, please tell me to what extent you agree with the statement. Please use a 5-point scale where 5 means you strongly *agree* with the statement and 1 means you strongly *disagree* with the statement.

	1 – Strongly disagree	**2 – Somewhat disagree**	**3 - Neither**	**4 – Somewhat agree**	**5 – Strongly agree**
A. It is important for our customers and peers to see our organization as environmentally conscious.	○	○	○	○	○
B. If it means we can save energy costs in the long term, my organization will pay more upfront for energy efficient equipment or devices	○	○	○	○	○
C. My organization considers the environmental impacts of energy-related equipment or devices it purchases	○	○	○	○	○
D. My organization purchases energy efficient equipment only if it meets our financial criteria, such as payback or ROI.	○	○	○	○	○
E. It takes a lot of effort for my organization to be energy efficient	○	○	○	○	○
F. My organization likes to be one of the first among its peers and competitors to purchase the latest high-tech products and equipment	○	○	○	○	○
G. California businesses should do what they can to reduce their energy consumption	○	○	○	○	○

Other Demand-Side Options

We're almost done. Next, I have some questions about other ways you might be using energy.

40. Does your facility currently have any onsite electricity generation such as solar/PV, wind power, biogas, or cogeneration?

    a. [IF YES] Please describe the type of onsite generation you have:

    b. [IF YES] Is the output from this generation being used exclusively at your facility, being all sold to the grid, or being used both internally and sold to the grid?

    c. [IF YES] Please describe any type of energy storage system you might have for this onsite generation.

    d. [IF NO] Does your facility have any near-term plans to install onsite generation such as solar/photovoltaics, wind power, biogas, or cogeneration?

        2. [IF YES] Please describe the type of onsite generation you plan to install:

        3. [IF YES] Is the output from this generation going to be used exclusively at your facility, going to be all sold to the grid, or going to be used both internally and sold to the grid?

41. [IF THEY HAVE INSTALLED ONSITE GENERATION OR PLAN TO DO SO IN THE NEAR-TERM] Did/will the onsite generation [you've installed/plan to install] influence whether or not your facility will implement *energy efficiency* projects in the future?

    a. Please explain:

    b. Will it influence the future size of your energy efficiency projects?

        v. [IF YES] Please explain:

42. California offers demand response programs/rates which incentivize companies to modify their electric consumption based on grid needs. You may be called to reduce/shed your load during certain times when demand is high, or you could be incentivized to shift your load from peak to off-peak periods. The incentive level depends on your load commitment and your performance during demand response events. Some programs offer you additional incentives for your equipment to be demand-response-enabled at the time of participation. [IF NEEDED: SOME EXAMPLES ARE … [REFER TO TABLE BELOW]

Utility	DR Program Name	Notes
SCE	Ag and Pumping Interruptible Program	Only applies to Ag customers
PG&E, SCE, SDG&E	Base Interruptible program, Scheduled Load Reduction Program	Applies to all customers with >=100 kW average monthly peak demand
PG&E, SCE, SDG&E	Capacity Bidding Program	All customers
PG&E	Peak Day Pricing	All customers

Utility	DR Program Name	Notes
SCE, SDG&E	Critical Peak Pricing	All customers
SCE	Real Time Pricing	All customers

What best describes your level of familiarity with demand response programs?

1. Never heard of demand response programs
2. Heard of demand response programs but never participated
3. Participated in demand response programs before but not currently
4. Currently participating in demand response programs

43. [ASK IF THEY ARE NOT CURRENTLY PARTICIPATING IN DR PROGRAMS (15 < 4)]
How much would each factor below be a barrier for your company to participate in a demand response program?

[RANDOMIZE ALL ITEMS; SINGLE RESPONSE]	1 – Not a barrier	2 - Minor barrier	3 - Moderate barrier	4 - Considerable barrier	5 – Major barrier
A. Adjusting your demand in response to DR events from your utility	○	○	○	○	○
B. Disruptions to operations/processes and perceived productivity losses	○	○	○	○	○
C. Your level of familiarity or experience with a demand response program	○	○	○	○	○

44. [ASK IF THEY ARE NOT CURRENTLY PARTICIPATING IN DR PROGRAMS (Q20 < 4)]
How likely would you be to participate in a demand response program?

1. Not at all likely
2. Slightly likely
3. Somewhat likely
4. Very likely
5. Extremely likely

45. Next, consider that you were offered upfront incentives for enabling your **<u>site to automatically respond to DR event signals.</u>** This allows your site to respond and automatically adjust your facility's HVAC, lighting or process loads based on settings you established in advance. This upfront incentive is $200/kW. So, if you were to sign-up in the DR program and enable 20 kW load reduction at your site through installing, for example, variable speed drives on fans/pumps that can respond automatically to DR signals and shed load, you would receive $4,000 as an upfront technology incentive. In addition, you would receive additional incentives for agreeing to reduce your load when called.

How likely would you be to enroll in your utility's demand response program with the $200/kW upfront incentive for site enablement for automated demand response? [SCALE SHOWN BELOW]

[SINGLE RESPONSE]

1. Not at all likely
2. Slightly likely
3. Somewhat likely
4. Very likely
5. Extremely likely

46. How likely would you be to participate with the $200/kW site-enablement incentive (totaling $4,000 for 20 kW load reduction) and additional incentive payments for agreeing to reduce load when requested by your utility (known as DR events)?

For example, some demand response programs allow you to make monthly nominations to reduce your load. You are paid based on the amount of load you nominated and being available for load reduction, even if you are not called to reduce your load. The payment level can vary based on energy market prices. You may face penalties if you unable to reduce your nominated load when called.

Assume you nominated 20 kW load reduction for summer months and DR events are called for 40 hours for four summer months.

	1 – Not at all likely	**2 – Slightly likely**	**3 - Somewhat likely**	**4 – Very likely**	**5 – Extremely likely**
A. Around **$400** each summer your facility agrees to participate in high demand event days [you receive this even if no DR events are called].	○	○	○	○	○
B. [ASK IF Q18<5] Around **$800** each summer your facility participates in high demand event days [you receive this even if no DR events are called].	○	○	○	○	○

47. If you wanted to improve energy management at your facility how important would each of these options be. Please use a five-point scale where 5 equals “Very important” and 1 equals “Not important at all.”

Energy Management Option	**Level of Importance (5=”Very Important, 1=”Not Important at All”)**
Improving the energy efficiency of your equipment	
Installing onsite generation powered by renewable energy (e.g., solar, wind)	
Installing onsite generation powered by cogeneration	
Participating in demand response programs using efficient equipment with controls	
Installation of energy management systems to help various demand side technologies work more effectively / efficiently together.	
[IF MENTIONED] Other energy management options [PLEASE DESCRIBE OPTION THEY MENTIONED] ___________________	

COVID-19 Impacts

Finally, I have some questions about the impact of COVID-19 on your business

48. Overall, how much has the COVID-19 pandemic impacted the business at <ADDRESS> since March 2020?

    vi. It has had a *large negative* impact
    vii. It has had a *moderate negative* impact
    viii. It has had *little or no* impact
    ix. It has had *a moderate positive* impact
    x. It has had a *large positive* impact
    xi. Don't know

49. I'm going to ask you about how various aspects of your business's operations might been impacted by the COVID-19 pandemic or associated containment measures since March 2020. For each one I mention, please tell me if that aspect of your business operation has increased, decreased, or remained the same.

i. Revenue or profits	1 = Decreased 2 = No change 3 = Increased
ii. Availability of needed materials, products, or equipment	1 = Decreased 2 = No change 3 = Increased
iii. Number of employees or staff	1 = Decreased 2 = No change 3 = Increased
iv. Operating or working hours	1 = Decreased 2 = No change 3 = Increased
v. Capital spending or investments	1 = Decreased 2 = No change 3 = Increased
vi. Up-front cost and/or payback period thresholds used to make investment decisions	1 = Decreased 2 = No change 3 = Increased

50. Has the business fast-tracked, postponed, or cancelled any planned investment projects due to COVID-19? *Please select all that apply.*

    i. Fast-tracked or sped-up planned project(s)

ii. Postponed planned project(s)
iii. Cancelled planned project(s)
iv. Not applicable, the business did not have any planned projects
v. Don't know

51. Has your company changed the type or quantity of products it makes or modified its production in any way due to COVID-19?
    a. [IF YES] Please explain:

52. Suppose you needed to replace or upgrade an appliance or equipment at the facility at <ADDRESS> within the next few months. How comfortable or uncomfortable would you be having a contractor or technician come into the facility to install it, assuming they followed the latest safety guidelines for your area?
    i. Very comfortable
    ii. Somewhat comfortable
    iii. Somewhat uncomfortable
    iv. Very uncomfortable
    v. Don’t know, I would not be involved in such a decision

That’s all the questions I had. Thank you for helping us with this market research.