Measure, Application, Segment, Industry (MASI):

Agriculture

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Reference No.: 170661
March 31, 2015

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Executive Summary

This Agriculture Measure, Application, Segment, and Industry (MASI) study details findings from Navigant Consulting, Inc.'s (Navigant's) research into the current equipment installation, usage, and maintenance practices in the California agricultural industry. Navigant focused on current practices in the California agricultural market, with the goal of helping utilities understand equipment and systems installation and usage patterns. Navigant also explored energy-related market trends, drivers, and barriers to energy-efficiency adoption, as well as growers' decision-making processes with respect to energy usage and equipment installation. Navigant has provided recommendations to help program planners in future program design efforts.

Based on project scoping discussions with the California investor-owned utilities (IOUs), Navigant focused its research on the following two distinct market segments:

» Greenhouse equipment and installation practices (greenhouses)

» Agricultural irrigation design and usage (irrigated agriculture)

For the greenhouse portion of this study, Navigant conducted primary and secondary research to identify current and emerging installation practices in California greenhouses. With input from the California IOUs, Navigant identified the following measures listed in Table ES-1 as key areas of focus.

Table ES-1. High-Level Greenhouse Technology List for Review

End Use	Technology Type
Greenhouse [process-related] building shell measures	Shade cloths
	Infrared film
	Shell insulation and glazing
	Thermal or heat curtains
Greenhouse [process-related] HVAC measures	Boilers
	Condenser fans
	Unit heaters
	Geothermal heat pumps
	Bench (radiant) heating
	Pumps and motors
	VFDs
Irrigation measures	Domestic water heaters
	Water recycling

Source: Agriculture MASI Scope of Work

For the irrigated agriculture portion of the study, Navigant and the California IOUs developed the following list of key areas of focus given in Table ES-2.

Table ES-2. High-Level Irrigation Technologies

End Use	Technology Type
Irrigation System Components	Irrigation delivery systems
	Water purification systems
	Moisture level sensors
	Pumps and motors
	VFDs
Pump System Maintenance	Pump efficiency testing

Source: Agriculture MASI Scope of Work

Key Findings

This section summarizes key findings from Navigant's research efforts. The main body of the report provides additional context and further findings pertaining to greenhouses and irrigated agriculture.

General Findings

For both the greenhouse and irrigated agriculture market segments, the commodity drives growers' equipment installation and usage practices. While growers consider water and energy efficiency to an extent, their primary concern is the health and yield of their crops. Growers will select equipment based on the needs of the crop that they are growing. This may mean that growers will forgo systems that are more efficient because the crop requires more water to grow. For example, rice requires high amounts of water; therefore, rice growers may continue to use flood irrigation for these crops, as low-flow systems may hurt the crop or decrease a farmers' yield.

The source of an operation's irrigation water can also play a large role in growers' equipment decisions, particularly in irrigated agriculture operations. For example, farms with access to a municipal water source or close proximity to a river will have fewer expenses related to water pumping than farms that require drilling new wells or pumping water long distances. When approaching a grower with programs and information, utilities should consider the operation's crop types and water sources rather than categorizing an operation by its acreage, square footage, or energy consumption. Addressing the market by crop type could help utilities to distinguish between late adopters and farmers who use water-intensive systems because their crops require it. Utilities can then address these late adopters directly to identify barriers to technological adoption.

Growers remain very cost-constrained in their operations, and continue to rely on rebates for many of their energy-efficiency upgrades. The agricultural industry is moving toward efficiency; however, growers report that this is largely out of necessity. Many growers continue to struggle financially, and a number of greenhouses have gone out of business within the last decade. Rebates for high-efficiency equipment play a critical role in growers' ability to install high-efficiency equipment, and can help them to stay in business. Grower interviews suggest this may apply to both large and small operations. Because of the importance of the agricultural market to California's economy, and because of the tenuous financial situation of many agricultural operations, utility incentives can provide some financial relief to growers who are otherwise unable to install efficient equipment.

Greenhouse Findings

California's greenhouse and nursery segment is increasingly facing competition from other markets, particularly in South America. For example, in the last decade, California's rose industry has shrunk considerably throughout the state. This decline has occurred primarily due to price competition with countries such as Ecuador and Mexico, where the cost of production is significantly lower than that of California roses. While some growers have gone out of business due to this market loss, others have mitigated the impact by shifting focus to other products, such as Gerbera daisies. The increasing competition from international markets has created uncertainty in the market, and has caused some growers to be increasingly cost-conscious and risk averse.

Energy saving opportunities exist within the greenhouse sector, particularly with respect to the building shell. Interviews for this MASI study indicated that in the absence of utility programs, growers likely would revert to installing single-layer polyethylene film as replacement measures. According to

SME interviews, some greenhouse growers are so cost-conscious that they will occasionally buy used materials from a neighboring greenhouse if the other greenhouse is retrofitting their buildings. One large grower confirmed this, stating that if there is no rebate available for upgrading his greenhouse material, he will "scavenge" walls from another area in his greenhouse that require less heat. This may not be the case for new construction greenhouses, for which all but one, large grower installed at least double-layer polyethylene plastic. However, there are higher-efficiency materials available for greenhouse shells that may be under-incentivized when compared to the materials that utilities currently incentivize. This is especially true when considering the measure life of the different materials. There may be opportunities to increase efficiency by promoting rebates for higher-efficiency materials, such as polycarbonate or acrylic. Other shell measures, such as heat curtains and shade cloths, may present additional energy saving opportunities. Navigant's interviews suggested that growers may choose to use these materials based on the needs and sensitivity of their crop, and these rebates therefore may be more applicable for certain crop types rather than for the industry as a whole.

Although large growers tend to have more capital to invest in efficiency opportunities than small growers do, the volume of equipment that large must replace can place cost constraints on large growers' efficiency efforts, as well. . Large growers arguably have more available funding to pursue energy efficiency than small growers have. However, because of the sheer amount of equipment that they must repair or upgrade regularly, large growers must pace their upgrades due to cost constraints. Grower and subject matter expert (SME) interviews revealed that many large growers will put off equipment upgrades or will revert to lower-efficiency options if there is no incentive available because they cannot afford to install higher-efficiency equipment. If utilities were to discontinue rebates for large greenhouse growers, the industry may revert to low-efficiency equipment or practices.

The use of variable frequency drives (VFDs) is becoming more common in greenhouses. However, growers interviewed typically only use VFDs on large well pumps. There may be efficiency opportunities in offering VFDs on pumps and motors within the greenhouses themselves. With the increasing penetration of water recycling and purification systems, and with the potential for increased use of conveyance for moving plant beds, VFDs may offer increased efficiency for these pumps and motors. However, VFDs are not appropriate on all motors, so utilities should consider conducting targeted research into VFDs in greenhouses to pinpoint realistic savings opportunities for this measure.

As growers turn toward automated vent controls and other automated systems, the industry may see a corresponding increase in use of small motors. Many growers also use small fans for air movement. Growers reported that they typically do not repair these fans, as the labor costs are too high to warrant regular repair. Growers stated that they replace these fans regularly, and did not appear to prioritize energy efficiency in small fans.

Irrigated Agriculture Findings

Irrigated agriculture growers are increasingly aware of energy-efficiency opportunities, but cost concerns drive their equipment decisions. Grower interviews suggest that farmers who pursue efficiency measures do so either because they understand the long-term savings that they will achieve with the installation, or because there was an incentive available to make high-efficiency measures cost-competitive. Farmers rely heavily on their contractors for information about potential savings and rebates. However, according to growers, contractors and utility staff now have less time to discuss efficiency opportunities with them due to increased interest in efficient measures across the industry. Some growers claimed that they are "at the whim" of contractors, and that contractors' schedules may not always align with those of the farmers. Due to time constraints, some farmers have begun installing their own equipment. If this continues, it may result in missed opportunities in efficiency, as growers' top priority is to get their equipment running rather than focus on system optimization or efficiency. There may be opportunities for utilities to perform system optimization reviews beyond the standard pump efficiency testing to ensure that farmers have properly designed and installed their systems.

Farmers are increasingly aware of the benefits of VFDs, although VFDs are more common in large farms and on larger pumps. According to grower interviews, small- and medium-sized growers are less likely to have VFDs on their pumps, and are also less likely to see the benefits of VFDs. Educating and offering incentives to smaller farms may therefore present an opportunity for future potential savings. This opportunity will be particularly relevant if the market continues to move away from gravity-based systems and toward pressurized systems such as drip because pressurized systems may require increased pumping. Utilities should consider conducting targeted research into VFD applications to determine which equipment on small farms is appropriate for VFDs.

The industry is trending toward low-flow, pressurized irrigation systems. However, some utility staff expressed concerns about the exclusion of microsprinklers from the utilities' rebate package. The Pacific Gas and Electric Company (PG&E) recently removed incentives for microsprinklers for tree crops and vineyards due to ISP concerns, although the incentive is still available for field crops. Utility account executives, however, stated that these estimates failed to take into account certain factors related to usage, and that the utility should continue to include them as an agricultural incentive. According to United States Department of Agriculture (USDA) data, the use of microsprinklers has actually declined since 2008, and therefore there may be energy savings available in this technology. Utilities may want to consider reevaluating potential savings for this technology and reconsider its inclusion in program offerings.

The irrigated agriculture market is moving toward the use of computerized systems to determine the timing and quantity of their irrigation and fertilization practices. Although farmers see the benefits of these systems, the upfront cost of the technology often prohibits farmers of all sizes from using these technologies on a broad scale. Farmers are typically only able to afford one or two moisture sensors, although they may have thousands of irrigated acres in operation. There may be energy saving opportunities present in computerized systems, but utilities should ensure that the products they incentivize are reliable, easy to use, and that the company is on-track to remain in business into the future. If utilities do promote these computerized systems, they should also ensure that growers understand how to use the systems; otherwise, they may not achieve the highest amount of savings possible.

Recommendations

Schedule program marketing around the growing season, and conduct field tests, verifications, installations, and rebates according to this schedule. Growers' primary concern is that their equipment is functioning properly during the planting, growing, and harvest seasons. Growers will therefore take any action necessary to ensure their equipment is running, including installing lower-efficiency equipment if it is available at the time they need it. If utilities do not align field tests with growers' schedules, growers will be far less likely to install equipment that requires these field tests. Furthermore, if growers must wait to install equipment until utilities can conduct a pre-inspection, then growers may forgo the incentive and install whatever equipment is available. This may lead to growers installing lower-efficiency equipment. By scheduling inspections and installations around the growing season, utilities are more likely to encourage growers to install higher-efficiency equipment.

Focus on educating contractors on efficiency opportunities, and develop relationships with these contractors. Contractors are an important source of information for agricultural growers when it comes to energy efficiency. However, not all contractors believe that measures such as VFDs offer energy savings. Furthermore, due to uncertainty surrounding rebate availability, some contractors avoid promoting utility programs, as any variance in the rebate amount or the time that it takes to receive a rebate can reflect poorly on the contractor. Utilities should work with contractors to ensure that they understand the benefits of efficient equipment. In doing so, utilities may gain increased trust from their contractors, and contractors, in turn, may be more inclined to promote high-efficiency measures.

Incorporate system optimization services into program offerings, in addition to pump efficiency testing. Most irrigated agriculture respondents stated that they use the operating pressures from the original system design. However, both utility staff and SMEs expressed concern over the original designs. Respondents suggested that designers might overestimate the operating pressures to compensate for error, which would unnecessarily increase energy use. Furthermore, settings may naturally alter with the operation of the system over time. Utilities should take a systemic approach to ensure that all components of a growers' irrigation system are working synergistically and efficiently. This may be more relevant for larger farms than for smaller farms; however, utilities should explore potential savings in each. Utilities could provide these services to both irrigated agriculture and greenhouse customers as an extension of their pump efficiency program. By offering system optimization services, utilities could achieve increased savings from the system as a whole, as well as gain a better understanding of how growers are designing their systems.

Consider incentivizing moisture sensors and other information-based technologies. Responses from the interviews in this MASI suggest that the market already may be moving toward incorporating computerized controls or information systems into their irrigation planning and systems operation. This is true both of irrigated agriculture and of greenhouse operators. However, because of cost constraints, some farmers who are interested in these technologies are having trouble incorporating moisture sensors and other technologies across their operations, particularly for irrigated agriculture farmers. Incentives from utilities could help farmers invest further in this equipment, which could result in both energy and water conservation. However, while these systems typically can monitor factors such as energy and water use, growers must account for other factors such as fertilization, weather, and other environmental concerns. Therefore, any monitoring system that utilities might promote to growers would need to incorporate tracking other key factors in addition to energy and water usage.

Look at small- and medium-sized pumps, as well as large pumps, for efficiency opportunities in irrigated agriculture. While there are obvious savings available in targeting efficiency measures for large pumps, both large and small growers often use smaller pumps, as well. In particular, smaller farms with smaller irrigated plots may use small to mediums sized pumps for irrigation. Large farmers also tend to operate plots that can be geographically distant from each other, and may therefore use small- to medium-sized pumps for these plots. By targeting small- to medium-sized pumps as an area for efficiency opportunities, rebates and efficiency information can apply to farmers of all sizes, rather than simply targeting larger farms. This program offering can increase participation, as it is relevant to the entire market segment.

Work with other utilities and agricultural entities to establish a database of system designs by crop and region. Despite individual reports that various groups have conducted over the years, the agricultural industry still lacks a comprehensive database of individual producers in the market, and their respective on-farm equipment components. The lack of a comprehensive database makes it difficult to establish baselines, to identify market trends, and to maintain communication with growers. Utilities and the California agriculture industry, as a whole, could benefit from an agricultural saturation study similar to California's Residential Appliance Saturation Study (RASS) or Commercial End-Use Survey (CEUS). California's IOUs should work with the CPUC, municipal and irrigation district utilities, agricultural extensions, and trade associations to establish a framework for a study such as this, taking into account the need for granularity at a region and crop-specific level. This would require a significant amount of effort at the beginning of the process. However, once the utilities have created a framework and completed the first round of data collection efforts, regular updates would allow utilities and other market actors to gain a clearer understanding of equipment baselines and practices in the market.

1 MASI Description

This Agriculture Measure, Application, Segment, and Industry (MASI) study details findings from Navigant Consulting, Inc.'s (Navigant) research into the current equipment installation, usage, and maintenance practices in the California agricultural industry. Navigant's research focused on current practices in the California agricultural market, with the goal of understanding equipment and systems installation and usage patterns. Navigant also explored agricultural market trends, drivers, and barriers to energy-efficiency adoption, as well as growers' decision-making processes in respect to energy usage and equipment installation. Navigant has provided recommendations to help program planners in future program design efforts.

The California agriculture market consists of a variety of market segments, which Navigant's *2010-2012 Agriculture Market Characterization* (hereafter the "Market Characterization") study explored in detail. For the 2014-2015 Agriculture MASI study, the California investor-owned utilities (IOUs) were primarily interested in greenhouses and irrigated agriculture. Therefore, the Navigant team excluded from this study agriculture segments such as refrigerated warehouses, post-harvest processing, and dairies, except in the context where dairymen grow crops for cattle feed. The team instead focused their research efforts on the following agriculture market segments:

- Greenhouses & Nurseries, Including Floriculture
- Irrigated Agriculture Segments:
    - Field Crops
    - Fruit and Tree Nut
    - Vine Crops (Including Vineyards & Wineries)

Based on project scoping discussions with the California IOUs, Navigant focused its research on the following two distinct market segments:

- Greenhouse equipment and installation practices (greenhouses)
- Agricultural irrigation design and usage (irrigated agriculture)

The following subsections further describe the research approach that Navigant took to address each of these research areas.

1.1.1.1 Greenhouse Equipment and Installation Practices

The purpose of the greenhouse portion of this MASI study was to identify current and emerging installation practices in California greenhouses. Navigant conducted primary and secondary research to identify current and emerging installation practices in California greenhouses. With input from the California IOUs, Navigant identified the following measures listed in Table 1 as key areas of focus.

Table 1. High-Level Greenhouse Technology List for Review

End Use	Technology Type
Greenhouse [process-related] building shell measures	Shade cloths
	Infrared film
	Shell insulation and glazing
	Thermal or heat curtains
Greenhouse [process-related] HVAC measures	Boilers
	Condenser fans
	Unit heaters
	Geothermal heat pumps
	Bench (radiant) heating
	Pumps and motors
	VFDs
Irrigation measures	Domestic water heaters
	Water recycling

Source: Agriculture MASI Scope of Work

In addition to determining the installation practices for these particular measures, Navigant also addressed a number of other research questions related to growers' decision-making processes and equipment usage. Table 2 lists these research questions.

Table 2. Greenhouse Equipment Research Questions

Research Question
What are the standard equipment installation practices for greenhouse growers? - What equipment are greenhouse growers installing without program incentives? - How does this differ between replacement vs. new construction? - What factors influence growers' equipment choices? - What factors influence growers' decisions to retrofit vs. replace equipment? - How do growers determine whether to replace on burnout vs. replace early? - What are the thresholds for payback and ROI that must be met for early replacement? - Who are the decision-makers and influencers?*
How do these replacement practices differ between large and small operations? - What is the best way to define 'large' vs. 'small' operations for program planning purposes?
What will be standard equipment practices in the future? - What equipment is becoming common and what is state-of-the-art? - What are the trends for emerging or mature energy-efficient equipment in markets such as Europe, and can the California market apply these developments?
What equipment do the IOUs currently rebate? - Is any of this equipment currently 'standard practice' and should it be removed from the list of common equipment practices? - Which equipment would be the most reliable source of savings for IOU programs? - How does this differ between existing buildings and new construction?
To what extent do utilities' programs influence growers' replacement practices?

*In the 2010-2012 Market Characterization, Navigant identified decision-makers and elements of the decision-making process for equipment replacement. The Navigant team will use this study to build on this information and determine whether this has changed.

Source: Agriculture MASI Scope of Work

1.1.1.2 *Agricultural Irrigation Design and Usage*

The irrigated agriculture portion of this study defines prevalent irrigation system designs within California's irrigated agriculture segment. Per the IOUs' request, Navigant focused the 2014-2015 MASI study on farmers' current installation practices rather than on future trends. For the irrigated agriculture portion of the study, Navigant and the California IOUs also developed the following list of key areas of focus shown in Table 3.

Table 3. High-Level Irrigation Technologies

End Use	Technology Type
Irrigation System Components	Irrigation delivery systems
	Water purification systems
	Moisture level sensors
	Pumps and motors
	VFDs
Pump System Maintenance	Pump efficiency testing

Source: Agriculture MASI Scope of Work

In addition to identifying measures of interest, Navigant addressed the following research questions to better understand system design practices and decision-making methods. These research questions include the following listed in Table 4.

Table 4. Irrigation Research Questions

Research Question
What do current irrigation systems look like in terms of design, maintenance, and usage practices? - What operating pressures do growers typically use? - What are the current irrigation scheduling practices?
How are growers designing and using their current irrigation systems? - How does this vary by crop type (e.g. tree vs. field crops) - How does this vary by irrigation system? - What do equipment replacement practices look like, and how does this vary by ROB vs. Early Replacement?
How do these design and usage practices differ between large and small operations? - What is the best way to define 'large' vs. 'small' operations for program planning purposes?
What actions are growers taking to reduce water usage? - To what extent do growers rely on water distribution systems/practices to reduce water usage? - To what extent are growers water-stressing their crops to reduce water usage? - To what extent would growers be conserving water if they were not in drought conditions?

Source: Agriculture MASI Scope of Work Methodology

The Navigant team consulted a number of sources for this study, ranging from secondary research to in-person interviews. The following subsections describe the Navigant team's methodology for this MASI study.

1.1.2 Literature Review

The MASI team built upon the existing research that Navigant conducted through an extensive industry analysis for the *2010-2012 Agriculture Market Characterization.* The team began by reviewing the 2010-2012 Market Characterization and Navigant's 2013 Potentials, Goals, and Targets Study results. This information included the final reports, program data, previous literature review, interview transcripts with IOU program staff, and interview transcripts with subject matter experts (SMEs) as well as market actors. The MASI team also conducted a high-level search for literature published since the previous studies took place, and searched for other agricultural documents that had not been included in the previous studies.[1] Navigant has incorporated findings from this review of existing literature into the findings of this study.

[1] The full Literature Review from the 2010-2012 Market Characterization can be found here: http://www.calmac.org/publications/Ag_Study__Literature_Review_Final.pdf

In addition to reviewing existing literature, the MASI team also conducted a high-level analysis of the 2010 California Irrigation Methods Survey Results by Crop Category, the 2012 United States Department of Agriculture (USDA) Census of Agriculture, and the 2014 USDA Farm and Ranch Irrigation Survey. This analysis offered further insights into the status and direction of the agricultural market, and an understanding of the common irrigation equipment types in the irrigated agriculture market. Findings from these analyses are also included in the findings analysis where relevant.

1.1.3 In-Depth Interviews

To build on Navigant's secondary research, the MASI team conducted in-depth interviews with a number of market actors. The team began by interviewing seven IOU agricultural program managers and key account managers to understand the IOUs' current agricultural offerings, views on the state of the agricultural industry, and common participation practices for IOU agriculture programs. The Navigant team referenced the findings from these interviews when drafting the subsequent interview guides for SMEs and growers. Additionally, the team used suggestions from program managers when identifying SMEs and growers to interview.

The MASI team also interviewed five SMEs in each market segment. For the purposes of this study, SMEs included individuals such as three researchers from local universities and the UC Extension Service, one utility agricultural account manager, two members of trade associations, and four contractors/designers who work closely with growers to design energy-using systems and select equipment. These ten interviews provided an overview of equipment installation practices in both the greenhouse and irrigated agriculture market segments. As shown in Table 5, the MASI team met its target number of completed interviews for the greenhouse study. However, for the irrigated agriculture study, one market actor needed to cut an interview short due to time restraints. Therefore, the MASI team fell slightly short of its target number of completed interviews for the irrigated agriculture portion of its study.

Table 5. Completed SME Interviews by Market Segment

Segment	Target Completes	Completed Interviews
Greenhouses	5	5
Irrigated Agriculture	5	4.5

Source: Navigant analysis

In addition to program manager and SME interviews, the Navigant team spoke directly with 28 growers across both market segments. Initially, the team intended to use IOU customer contact data to identify growers to participate in these interviews. However, Navigant only received data from one IOU throughout the course of the study. This data did not include contact names, which made it difficult for the Navigant team to identify the correct contact within the organization.

Ultimately, the team was able to complete 18 of the target 18 interviews for the irrigated agriculture segment, but only 11 of the target 18 interviews with greenhouse growers. **Error! Reference source not ound.** shows the final disposition report for the grower interview calls.

Table 6. Disposition Report for Grower Calls

Disposition Category	Irrigated Ag	Greenhouses
Number of Completes	18	11
Number of Refusals	23	3
Number of Bad Numbers	28	3
Number of Attempted Calls/Emails	**261**	**53**

Source: Navigant analysis

Due to the lack of grower contact data, the lack of responses to cold calls from growers, and the need to delay phone calls given the lack of contact information, Navigant explored various alternatives to recruiting agricultural customers. In particular, the Navigant team asked trade associations, SMEs, program managers, and other growers to suggest growers who would be willing to participate in the interviews. This 'snowball sample' method proved to be the most successful means of reaching growers. Navigant also asked a number of trade associations to help recruit growers for the interviews. These associations could only offer paid advertising in their newsletters, and typically would not offer suggested contacts as it would be a breach of their customers' privacy. Per request of the IOU account managers, a member of the Navigant team also traveled to California to meet in person with four irrigated agriculture growers. Although Navigant was able to speak to growers of various sizes and crop types, the "snowball sample" method of recruiting led to a concentration of growers in certain geographic areas. This was particularly true for greenhouses, for which Navigant was only able to reach coastal growers. Utilities should focus future research efforts on inland greenhouses, in particular, to better understand this market segment. Table 7 and Table 8 show the geographic location of greenhouse and irrigated agriculture grower respondents, respectively.

Table 7. Geographic Location of Greenhouse Grower Respondents

Geographic Location	Number of Respondents
Northern Coastal	5
Southern Coastal	5
Multiple Sites*	1

*Note: This greenhouse operation was one of the largest in California and has sites in northern coastal, southern coastal, and southern inland areas.

Source: Navigant grower interviews

Table 8. Geographic Location of Irrigated Agriculture Grower Respondents

Geographic Location	Number of Respondents
Northern California	4
Southern California	3
Central Valley	4
Central Coast	7

Source: Navigant grower interviews

To better understand differences between large and small operations, Navigant interviewed growers of various-sized operations. Navigant retroactively categorized growers respective to other respondents, based on square footage for greenhouses and acreage for irrigated agriculture growers. One of the irrigated agriculture farms may have been a hobby farm, or a residence with a small orchard on the same property. However, as this customer was included in IOU agricultural customer data, Navigant included this respondent in the sample. Table 9 shows the number of completed interviews in each size category, and the range of sizes within each size category.

Table 9. Number of Respondents per Size Category

Size Category	Greenhouses	Irrigated Agriculture
Small (Greenhouses: <500,000 sq. ft.) (Irrigated Ag: <200 acres)	4	8
Medium (Greenhouses: 50,000-1,000,000 sq. ft.) (Irrigated Ag: 200-2,000 acres)	4	5
Large (Greenhouses: >1,000,000 sq. ft.) (Irrigated Ag: >2,000 acres)	3	5

Source: Navigant analysis

The interview guides for all interviews are included in Appendix B through Appendix D.

2 Market and Industry Analysis

2.1 Industry Characterization

The agriculture sector is difficult to define by a single metric. For research and program purposes, organizations typically categorize agricultural operations by NAICS code,[2] which delineates segments by crop type. In practice, however, this distinction is often less clear. For example, some operations grow multiple crops, which may fall under different NAICS codes. Certain operations grow a portion of their crops under greenhouse cover, while simultaneously growing outdoor field or orchard crops. Dairy operations across California often grow alfalfa on the same plot of land in order to feed their cattle. Growers may sometimes live on the same property as their farm, and their residential and commercial energy use can be on the same meter. These nuances make it more difficult to succinctly categorize agricultural operations than it would be to categorize industrial facilities or commercial operations. Therefore, while this study focuses on greenhouses and nursery operations and irrigated agriculture operations, utilities should note that these operations are complex and may include energy end uses beyond standard agricultural operations.

To better understand the agricultural market, scholars and organizations often characterize the size of agricultural operations by their area in square footage or acreage. Utilities, however, approach their agricultural customers based on energy consumption, categorizing energy-intensive operations as 'large' accounts and low-consumption customers as 'small' accounts. While area and energy consumption can help utilities to focus their energy-efficiency efforts, findings from this study show that the most meaningful ways to categorize farms and greenhouses are by crop type(s) and water source(s). These two factors are the primary determinants of an operation's overall area, the type of systems and equipment that a grower installs, and the amount of water and energy that the operation uses. For example, one irrigation system designer explained that a farmer who grows strawberries would have a much smaller plot of land than one who grows alfalfa, but strawberries have higher input costs per acre than alfalfa in terms of energy, water, labor, and other factors. Furthermore, the market value of the crop will play a large role in the amount of money a farmer will spend upfront to prepare for a harvest. Because the inputs required to grow these two crop types differ greatly, it is problematic to compare farms growing different commodities on the same scale.

Discussions with growers supported this finding. The Navigant team asked growers whether they would categorize themselves as small, medium, or large operations. For the purposes of this study, Navigant categorized growers by their size relative to each other and to other operations in utility data. However, when growers self-reported the size their operations, they often did so by comparing themselves to other operations that grew the same crop. For example, one medium-sized greenhouse grower identified his operation as "the largest [rose grower]; most everyone else is out of business." Another grower said that their operation was large for organic herbs, but small- to medium-sized on the

[2] The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy.

Central Coast. Therefore, the most common method growers use to self-identify is not by comparison with other producers in the overall market, but rather with other operators in the same crop category.

The geographic location of a farm or greenhouse and its source of water can also play a significant role in a grower's energy consumption. For instance, the differences in weather between coastal and inland operations, and the differences in climate between northern and southern California can have significant impacts on heating, ventilation, and air-conditioning (HVAC) uses in greenhouses or irrigation on farmland. Geography also determines an operation's water source, which plays a key role in growers' irrigation pumping. The Navigant 2010-2012 Market Characterization found that irrigation pumping is the most energy-intensive process for irrigated agriculture. With decreasing water availability, growers must drill deeper or additional wells to account for declining water tables.[3] Pumping water is less of a concern for those who have a municipal source or easy access to groundwater or river water. Therefore, the source of water for a farm or greenhouse should be a consideration for utilities looking to minimize on-farm energy use.

2.1.1 Greenhouses

As previously mentioned, agricultural operations are typically categorized by NAICS code. Greenhouses, nurseries, and floriculture fall under the NAICS code 1114. This industry group refers primarily to operations growing nursery stock and flowers, or crops grown under covers such as greenhouses, cold frames, cloth houses, or lath houses.[4] Nursery stock includes short-rotation woody crops with growth cycles of ten years or fewer. Covered crops can be removed from their coverings at any point in their maturity, and typically have perennial life cycles. As shown in Table 10, most of the growers that Navigant interviewed for this MASI study were in the floriculture industry.

Table 10. Greenhouse Respondent Crop Types

Self-Reported Size	Number of Respondents*	Cut Flowers	Indoor Plants	Outdoor Plants	Herbs
Small	4	-	1	0	-
Medium	4	2	4	1	1
Large	3	3	1	1	-
Total	**11**	**5**	**5**	**2**	**1**

*Multiple responses allowed

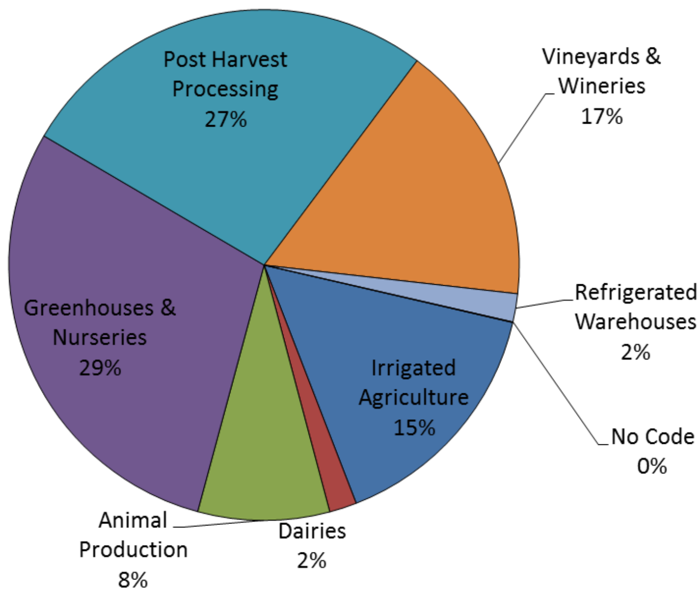
Source: Navigant grower interviews

[3] NASA Jet Propulsion Laboratory, 2009. http://www.jpl.nasa.gov/news/news.php?release=2009-194.

[4] North American Industry Classification System, 2007. http://naics-code-lookup.findthedata.org/l/124/Greenhouse-Nursery-and-Floriculture-Production.

The greenhouse and nursery segment is an important component in California's agricultural market, and is the largest natural gas consumer within the state's agricultural market (see Figure 1). California leads the nation in sales of greenhouse and nursery products, and is a dominant producer of cut flowers and greens (59 percent of national sales), greenhouse grown fruits and berries (66 percent of national sales), and nursery transplants (60 percent of national sales). The greenhouses and nurseries segment plays a prominent role in California's production of food crops, landscaping plants, flowers, plugs, garden and household plants, and vegetable transplants. Sales of nursery, greenhouse, and floriculture products accounted for 7.4 percent of California's total agricultural revenue in 2012.[5]

Figure 1. Proportion of Natural Gas Sales by Segment



Source: Navigant 2010-2012 Agriculture Market Characterization

Overall, the number of California greenhouse producers is small compared with the total value of production of floriculture and nursery products, ranging from a high of $2.4 million average sales per producer in 2010 to a low of $2.0 million in 2006.[6] Most of the greenhouse industry is concentrated among a small number of very large greenhouse operations. According to Navigant's findings from the 2010-2012 Market Characterization, the greenhouses and nurseries market segment consists of a handful of companies that can be broken into three tiers based on the acreage of production. As of the Market Characterization, two companies, Monrovia and Hines Horticulture, represented approximately one-third of the greenhouses and nurseries market segment.[7] This may have shifted since the Market

[5] Navigant Consulting, Inc. (2013). *Market Characterization Report for 2010-2012 Statewide Agricultural Energy Efficiency Potential and Market Characterization Study*. Boulder, CO. Retrieved from http://www.calmac.org/publications/CA_Ag_Mrkt_Characterization_Final_5-13-13.pdf.

[6] USDA, *Floriculture and Nursery Crops Yearbook. FLO-2007*, Economic Research Service, September 2007. http://www.ers.usda.gov/Publications/Flo/2007/09Sep/FLO2007.pdf.

[7] This information came from SME interviews in Navigant's 2010-2012 Agriculture Market Characterization.

Characterization, as a 2014 list of top greenhouse growers lists California's Color Spot Nurseries and Altman Plants as the top two greenhouse growers in the US.[8] Interviews from the 2010-2012 Market Characterization also indicated that the following five companies list constituted approximately 15 percent of the overall market share. , and the final tier was composed of approximately ten companies that constitute about half of the overall market share. However, interviews for this MASI suggest that there may be many more greenhouse operations than previously indicated, particularly when including hobby farms. The USDA Census of Agriculture states that there are over 1,000 greenhouses in California devoted to floriculture, alone. This likely indicates that there are numerous individual greenhouse sites, although large greenhouse growers may operate many of these sites. One SME for this MASI indicated that there may be hundreds of greenhouses across California, and it is likely that the market is significantly larger than indicated in the Market Characterization. A comprehensive, industry-wide baseline study would allow for a better understanding of the number and types of growers within the California greenhouse market.

The values of these market shares and the number of operations in California may have shifted since the Market Characterization. According to SME interviews for this MASI, the majority of greenhouse production is still concentrated among very few growers. Both Navigant's 2010-2012 Market Characterization and the 2014 USDA Census of Agriculture (Table 11) indicate that both the greenhouse and nursery segments saw a contraction in acreage from 2002 to 2007. One SME explained that this contraction of the market was a result of an economic recession at the time, during which many greenhouses went out of business. Since then, the market segment has rebounded in terms of acreage, although it has not yet reached 2002 levels. Two SMEs stated that they expect the industry to continue to grow as money becomes easier to borrow, technology advances, and demand for organic produce increases.

Table 11. USDA Census Data for California Greenhouses and Nurseries

Year	Greenhouse (Acres)	Nursery (Acres)	Crop Value ($ per Acre)
2002	4,701	82,506	N/A
2007	3,478	74,688	$46,808.44
2012	4,529	76,295	$31,941.16

Source: USDA 2014 Census of Agriculture

[8] Gallagher, A., Drotleff, L. and Wright, J., 2014, "2014 Top 100 List Shows Growers Are Expanding." *Greenhouse Grower*. Accessed from http://www.greenhousegrower.com/business-management/top-100/2014-top-100-list-shows-growers-are-expanding/

2.1.2 Irrigated Agriculture

For the purposes of this MASI study, irrigated agriculture refers to agricultural operations requiring irrigation that are located outside of a covered area (e.g., greenhouse). These include commercial growing operations producing field crops; row crops; fruit, tree nut, and vine crops; and vineyards and wineries. When separated by NAICS code, these market segments fall under the 111 NAICS category, which includes "crops [grown] mainly for food and fiber.[9]" This NAICS code also includes greenhouses and nurseries; however, as Navigant explored greenhouses and nurseries separately, the team is excluding this subsegment from the irrigated agriculture portion of the report. The farmers whom Navigant interviewed typically grew more than one crop. Table 12 includes the list of crops that respondents reportedly grew.

Table 12. Irrigated Agriculture Respondent Crop Types

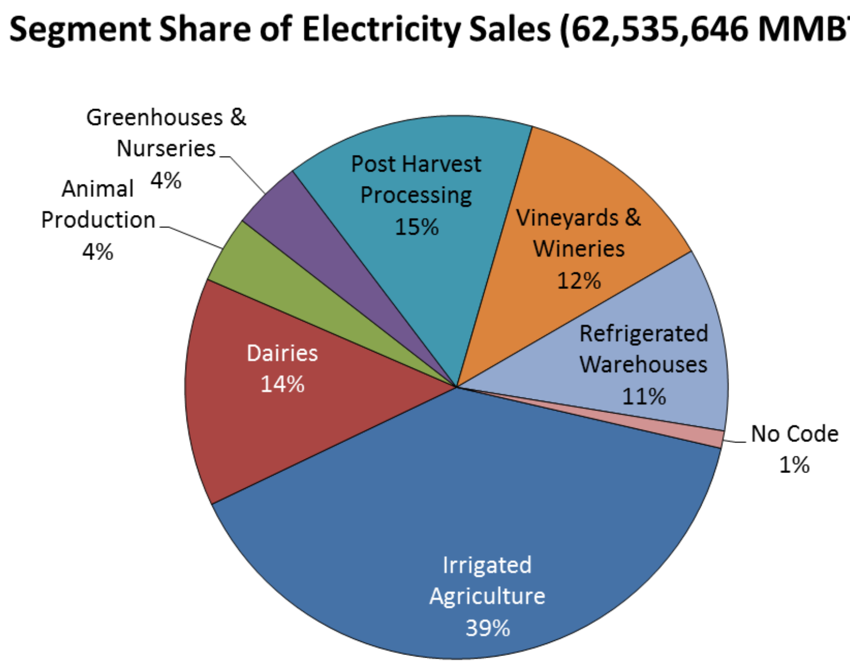
Farm Size	Number of Respondents*	Tree Nuts**	Vegetables	Vine Crops	Rice, Grains, or Corn	Citrus	Other
Small	8	3	-	-	1	3	2
Medium	5	3	-	1	1	1	3
Large	5	4	4	2	3	-	1

*Multiple sources allowed
**Also includes olives
Source: Navigant grower interviews

[9] North American Industry Classification System, 2007. http://www.census.gov/econ/industry/def/d111.htm.

The irrigated agriculture segment is the largest consumer electricity within California's agriculture market, as shown in Figure 2. California farms irrigate just less than 8 million acres of arable land,[10] using primarily electric power to extract, move, and pressurize water for crops. In 2012, California's 80,500 farms and ranches generated a record $44.7 billion in revenue.[11] Although these operations occupied over 25 million acres, growers only irrigate 30 percent the land area. Less than 6 percent of California's farms and ranches controlled 60 percent of these irrigated acres,[12] 82 percent of which they cultivated for orchards, forage crops, vegetables, grapes, and rice, as shown in Table 13.

Figure 2. Proportion of Electricity Sales by Segment



Source: Navigant 2010-2012 Agriculture Market Characterization

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[10] National Agricultural Statistics Service (NASS), 2014, *2012 Census of Agriculture: United States*. U.S. Department of Agriculture. Report No. AC-12-A-551. http://www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/Reports/2012cas-all.pdf.

[11] California Agricultural Statistics, 2012 Crop Year, USDA National Agricultural Statistics Service. http://www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/Reports/2010cas-all.pdf.

[12] NASS, 2014.

The fruit, tree nut, and vine segment is also a key area of California agriculture. According to the 2010-2012 Market Characterization, California produces more fruit, tree nut, and vine crops than any other state.[13] In 2010, fruit, tree nut, and vine crops accounted for 16.3 percent of California IOUs' agricultural energy sales, with electric water pumping as the main energy end use. California's vineyard and winery market segment is similarly robust: as of 2010, California produced 90 percent of American wine and held the fourth spot in global wine production. With regard to energy use, vineyard and winery Crops consumed 12.9 percent of 2010 agricultural energy sales, with gas sales larger than electricity sales in terms of total MMBTU. Table 13 shows California's major irrigated acreage by type of crop.

Table 13. USDA Census Data for California Irrigated Acreage by Crop, 2012

Type of Crop	Irrigated Acreage		
	2002	2007	2012
Orchards	2,828,788	2,728,176	3,072,245
Forage (includes hay and haylage, grass silage, and greenchop)	1,676,935	1,554,197	1,346,666
Vegetables	1,025,056	968,965	985,731
Rice	531,314	531,075	561,968
Corn (for silage or greenchop)	391,300	460,514	461,898
Total	**6,453,393**	**6,242,927**	**6,428,508**

Source: 2012 Census of Agriculture

As previously discussed, the term 'irrigated agriculture' refers to multiple agricultural subsegments, and the category therefore is incredibly diverse in terms of crop type, geographic location, size, and seasonality. Because of this, it is difficult to draw comparisons between, for instance, field crops and vineyards, as the growing season, crop rotation, irrigation methods, geographic concentration, and operation size vary immensely. Given this variability, the findings presented in this study draw on trends and practices highlighted by the experts and growers who were available for interviews. Where appropriate, the Navigant team has emphasized responses that are unique to a particular market segment, rather than applicable to irrigated agriculture as a whole.

2.2 *Initiatives to Date*

The California IOUs offer a number of incentives for agricultural purposes. Until recently, these included non-residential equipment rebates such as boilers, lighting, and HVAC measures, as well as agriculture-specific rebates such as sprinkler-to-drip irrigation conversions and greenhouse shell measures. California utilities are in the process of altering their incentives list based on changing Industry Standard

[13] Navigant Consulting, Inc., Market Characterization Report for 2010-2012 Statewide Agricultural Energy Efficiency Potential and Market Characterization Study, 2013.

Practices (ISP). In particular, The Pacific Gas and Electric Company (PG&E) has recently removed incentives for microsprinklers for tree crops and vineyards due to ISP concerns, although the incentive for this measure is still available for field crops. Utilities have also added measures to their incentive list, such as an agriculture-specific deemed incentive for pump motor VFDs.

2.2.1 Federal Initiatives

In 2014, the U.S. Congress passed the *Agricultural Act of 2014*, also known as the Farm Bill. This legislation authorized agricultural subsidy programs across the country through 2018 and allocated $956 billion to food stamps, crop insurance, conservation, and commodity programs, among other end uses.[14]

With funding from the 2014 Farm Bill, the USDA's Natural Resources Conservation Service (NRCS) offers the Environmental Quality Incentives Program (EQIP). The EQIP program is available to all producers, regardless of operation size or type of crop produced, in all 50 states, the District of Columbia, and the Caribbean and Pacific Island territories. General eligibility criteria requires participants to receive an on-farm energy audit from a list of certified Technical Service Providers (TSP), and to secure documentation of a full 12 month's history of the farm's energy use. The program allows eligible participants to receive financial and technical assistance to implement conservation practices. In essence, this program allocates funds for farmers to receive assistance in land and energy conservation, including providing incentives for on-farm energy audits (Energy Management Plans). The program also offers rebates of up to 75 percent of the equipment cost to install any energy-efficient measure with a simple payback of 10 years or less, or measures itemized on the states list of eligible technologies. Eligible measures for the state of California include lighting, dairy plate coolers, ventilation and fan upgrades, irrigation pumps, grain dryers, greenhouse improvements, heating and refrigeration units, insulation and building envelope sealing, and motor controls and variable speed drives.

Additionally, the Farm Bill funds the Rural Energy for America Program (REAP), offered by USDA Rural Development. This grant program provides financial assistance for farmers and rural small businesses to purchase renewable energy systems and make energy-efficiency improvements to reduce energy consumption. It also allows farmers to participate in technical assessments, energy audits, and feasibility studies. The NRCS also offers several smaller agricultural programs such as the Conservation Stewardship Program, Conservation Innovation Grants, and Conservation Activity Plans. These programs provide incentives for on-farm energy audits and other conservation practices.

With regard to accessing these initiatives, farmers typically have a contract with their local USDA NRCS office through the Conservation Stewardship Program (CSP), where farmers are eligible to receive payments through land management and conservation efforts. Through this contract, NRCS sometimes funnels farmers to the EQIP program. However, Navigant was unable to find quantitative data on the number of farmers who apply for and proceed with Agricultural Energy Management Plans through EQIP. Navigant could not identify a federal tracking system or evaluation that tracks the impact of the EQIP or REAP programs.

[14] The Hill, House passes $956B farm bill. http://thehill.com/blogs/floor-action/house/196819-house-passes-956b-farm-bill.

2.2.2 California Initiatives

Most of the state initiatives that apply to agricultural producers are general initiatives applicable to all non-residential entities. The exception is an agriculture-specific, partial sales-and-use tax exemption for facilities that use solar photovoltaic (PV) systems for their farm equipment or machinery.[15] The California State Board of Equalization runs this initiative, and it is only applicable to taxes levied by the state, and not by local governments.

The California Department of Food and Agriculture (CDFA) also provides competitive grant funding through the State Water Efficiency and Enhancement Program (SWEEP) for financial assistance to agricultural operations to implement water and energy conservation measures. The program's mission is to increase water efficiency and reduce greenhouse gas emissions. The program is funded through emergency drought legislation as an intention to target agricultural irrigation systems and to incentivize the investment in water irrigation treatment and distribution systems that reduce water and energy use.

Other statewide initiatives that could apply to agricultural producers typically relate to small-scale renewable energy generation, particularly solar. These initiatives include the California Solar Initiative, which offers rebates for solar PV installations; the Renewable Market Adjusting Tariff (ReMAT), which "allows eligible customer-generators to…sell the electricity produced by small renewable energy systems (up to 3 megawatts);"[16] the CPUC's Renewable Feed-In Tariff (FIT) program, which offers FITs to small-scale generation projects; and the CPUC's Self-Generation Incentive Program, which "provides incentives to support existing, new, and emerging distributed energy resources."[17] Although these programs could apply to agricultural customers in theory, Navigant was not able to identify agricultural customers who had participated in these programs. These programs could provide an opportunity that agricultural customers could leverage for future projects.

2.3 *Codes and Standards*

A number of international and federal standards apply to equipment used in agricultural operations. In particular, the International Organization for Standardization (ISO) sets standards on design, operation, and test method requirements for irrigation equipment.[18] Furthermore, the U.S. Department of Energy sets standards for commercial equipment used in greenhouse applications, such as commercial water heaters, refrigerators, boilers, motors, fans, and pumps, among others.[19] Enforcement of these standards typically takes place at the manufacturer level, so any equipment that a grower installs presumably will meet the minimum standard.

Building codes typically do not apply to the growing portion of an irrigated agriculture operation, as these operations do not grow their crops under permanent cover. Similarly, greenhouses are not

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[15] Database of State Incentives for Renewables & Efficiency (DSIRE). http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA257F&re=0&ee=0.

[16] DSIRE. http://dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA167F&re=0&ee=0.

[17] CPUC Self-Generation Incentive Program. http://www.cpuc.ca.gov/PUC/energy/DistGen/sgip/.

[18] International Commission on Irrigation and Drainage. http://www.icid.org/res_irri_.isie.html.

[19] US Department of Energy. http://energy.gov/eere/buildings/standards-and-test-procedures.

permanent structures, and therefore building codes do not apply to the growing portions of these operations either. Building codes could apply to on-site, post-harvest facilities; however, because post-harvest practices are outside of the scope of this study, building codes do not apply here.

2.4 Common Equipment Practices

The agricultural market is continuously shifting due to technological advancements, decreasing water availability, and the succession of younger generations in farm ownership. Because of this, utilities and regulators are increasingly concerned with understanding what equipment growers are currently installing and how they are using this equipment. This report, and in particular this section, will provide a high-level, qualitative review of common equipment installation and usage practices on farms and in greenhouses. While this study does not determine specific, quantitative baselines for individual measures, it offers insight into on-farm equipment practices, which can help to direct utilities' future programming efforts.

2.4.1 Greenhouses and Nurseries

According to the 2010-2012 Market Characterization, in 2010, greenhouses and nurseries represented approximately 8.3 percent of total energy sales within the agriculture sector. Within the greenhouses and nurseries market segment, gas sales tend to be larger than electricity sales, and the Southern California Gas Company is the largest gas supplier. Typically, greenhouses will use more energy than nurseries due to greenhouses' space-conditioning and refrigeration requirements, which often do not apply to outdoor nurseries. The Market Characterization study identified key energy end uses as lighting, space-conditioning (cooling, heating, and humidification), sorting, packing, cold storage, and irrigation-related (pumping, sprinklers). MASI grower interviews supported these findings, as growers cited process-related lighting, irrigation pumping, refrigeration, and space heating as their key energy end uses. The following subsections describe these end uses and their associated equipment in further detail.

2.4.1.1 Greenhouse Building Shell

The shell of a greenhouse is a significant determinant of a greenhouse's overall energy use, as the quality of the shell and the presence of additional insulation measures can greatly affect the greenhouse's space heating and cooling needs. Shell materials range from polyethylene plastic, which is the least efficient material and has a measure life of 3-5 years, to acrylic, which is the highest energy-efficient material and has a measure life of over 20 years. Most shell materials are available in multiple layers, with additional layers indicating higher efficiency. When selecting a building shell material type, growers must consider the cost of the material, the efficiency, and the needs of the crop, among other factors. For example, the sensitivity of the plant to light may factor into the installation decisions for high-end crops, such as orchids. Geographic location will also factor into a grower's decision regarding greenhouse shell materials. One greenhouse builder stated that polyethylene plastic is more common in the Central Valley, as wind is less of an issue in this area than at coastal greenhouses. Coastal greenhouses, on the other hand, tend to install harder coverings such as polycarbonate because wind can blow plastic coverings off relatively easily. It is important to note that most of the greenhouse growers whom Navigant interviewed for this MASI were located on the coast. Therefore, utilities should keep in mind that inland greenhouses may have different equipment installations and practices than those described in this study.

Existing Greenhouses

Navigant asked greenhouse growers about their building shell on both existing and new construction (<5 years old) greenhouses. All of the growers had existing greenhouse areas over five years old, with the exception of one medium-sized orchid grower. When asked what shell materials they used on their existing greenhouses, four growers stated they had single-layer polyethylene film, five had double-layer polyethylene film, and one had four-layer polyethylene film. One medium-sized grower also claimed to have single-layer polycarbonate sheets and glass houses in some of the greenhouses. This grower stated that the operation sometimes replaces the glass panels with double-layer polyethylene, which is more efficient than glass in terms of heat loss.

Navigant also asked growers whether they had added additional insulation or upgraded their building shell in the last five years, and whether they had received an incentive for this installation. Six growers claimed that they had upgraded or installed some form of additional insulation on existing greenhouses. These respondents had installed double-layer polyethylene, added a second layer to existing polyethylene-covered greenhouses, or in one instance, added infrared (IR) film and heat curtains to their existing double-layer polyethylene. Four of these growers claimed that they received a rebate, although only one of these rebates was for a building shell upgrade to double-layer polyethylene film. When asked whether his organization would have installed the double-layer polyethylene in the absence of a rebate, the individual stated that they would have but not at the time that they installed it.

The split between single- and double-layer polyethylene film in existing greenhouses suggests that the segment may be moving toward a slightly higher-efficiency building shell. However, some growers indicated that they still used single-layer polyethylene on some greenhouses, and that the process for upgrading is slow due to the cost of the material. One grower stated that his operation had been working on changing their roofs over eight years; currently, they are halfway through the process but cannot replace their materials faster because they are too expensive. This was consistent with findings from the SME interviews.

Similarly, one greenhouse builder explained that it is difficult to convince growers to install higher-efficiency materials because growers are unsure of the payback. This builder stated that most of his customers would not install higher-efficiency materials if a rebate were unavailable, and that even though his customers are often impressed with the savings, they would still revert back to single-layer polyethylene if there were no rebate available the next time. According to this builder, greenhouse growers are so cost-conscious that they will occasionally buy used materials from a neighboring greenhouse if the other greenhouse is retrofitting their buildings. One large grower confirmed this, stating that if there is no rebate available for upgrading his greenhouse material, he will "scavenge" walls from another area in his greenhouse that require less heat. Navigant's interviews revealed that five greenhouse growers used double-layer polyethylene, which suggests that there may be some greenhouse growers who are moving toward slightly higher-efficiency shell materials without the aid of incentives. However, the cost of materials may inhibit other growers from installing higher-efficiency insulation. Navigant therefore recommends that utilities continue to offer incentives for higher-efficiency shell insulation retrofits.

New Construction Greenhouses

Six of the eleven greenhouse growers interviewed had installed new greenhouse space in the last five years. These included all three of the large growers, one medium-sized grower, and two small growers. When asked the type of shell insulation that they installed on new greenhouse space, only one, large grower claimed to have installed single-layer polyethylene on his greenhouse. The remaining growers installed either polyethylene or polycarbonate, and responses varied as to whether they had single or double layers. This suggests that double-layer polyethylene film may be common practice among coastal greenhouse growers in California.

Table 14 shows the shell material on both new construction and existing greenhouses, as well as the number of layers.

Table 14. Building Shell Materials on Respondents' Greenhouses

Greenhouse	Size	Existing/ New Construction	Existing Shell Material	New Construction Shell Material
Greenhouse #1	Small	New Construction	Not Applicable	Single-layer polycarbonate
Greenhouse #2	Small	Both	Single-layer polyethylene	Double-layer polyethylene
Greenhouse #3	Small	New Construction	Not Applicable	4-layer polyethylene, 2-layer inflatable polyethylene on roof
Greenhouse #4	Small	Existing	Double-layer polyethylene	Not Applicable
Greenhouse #5	Medium	Existing	Single-layer polyethylene, double-layer polyethylene, single-layer polycarbonate	Not Applicable
Greenhouse #6	Medium	Existing	Double-layer polyethylene	Not Applicable
Greenhouse #7	Medium	Existing	Double-layer polyethylene	Not Applicable
Greenhouse #8	Medium	Both	Double-layer polyethylene	Double-layer polyethylene
Greenhouse #9	Large	Both	Single-layer polycarbonate, double-layer polycarbonate	Double-layer polycarbonate
Greenhouse #10	Large	Both	Double-layer polyethylene	Double-layer polyethylene
Greenhouse #11	Large	Both	Single-layer polyethylene	Single-layer polyethylene

Note: Not Applicable indicates that growers did not have existing greenhouses (5+ years old) or new construction greenhouses (<5 years old), respectively.
Source: Navigant grower interviews

All of the greenhouses that had installed double-layer, new construction materials - whether polycarbonate or polyethylene - indicated that they received incentives for their installations. When asked whether they would have installed the same type and amount of material had a rebate not been available, the small and medium-sized growers with polyethylene film stated that they would have installed the same material. The large growers who installed polycarbonate and double-layered polyethylene material, however, claimed they would have had to put it off and potentially purchased it later. Both of these growers said that the rebate was very important – 7 and 8 out of 10, respectively – in their decision to install their new materials.

These responses and the growers' responses for existing building shell upgrades suggest that building shell costs may actually be more restraining for large growers than for small or medium-sized growers. Some smaller growers tended to have higher-efficiency materials than the large growers, and were reportedly less dependent on incentives than small or medium-sized growers were. This may not be representative of the market as a whole. However, the dependence of the large growers on incentives, and the slow, iterative approach that growers are taking to upgrade their building shells, suggests that there are still energy saving opportunities in the greenhouse market.

Other Shell Measures

Added insulation measures were relatively common among the greenhouse growers whom Navigant interviewed. These measures included IR film, heat curtains, and shade cloths. Over half of the growers stated that they did have at least one of these measures, and most of these respondents had a combination of these measures, as shown in Table 15.

Table 15. Building Shell Materials on Respondents' Greenhouses

Size	Number of Respondents	IR Film	Heat Curtains	Shade Cloths
Small	4	3	3	3
Medium	4	3	3	3
Large	3	1	1	2

Source: Navigant grower interviews

Findings from the SME interviews indicated that these measures might be less common across the industry as a whole. One utility staff member estimated that only a quarter of small greenhouses and approximately 40 percent of large greenhouses have IR film, heat curtains, or shade cloths. One SME stated that the use of these installations depended heavily on the geographic location of the greenhouse. In particular, this SME stated that IR film is not common on the coast, but is much more common on inland polyethylene greenhouses. Another SME, a greenhouse expert from the UC Cooperative Extension, explained that commodity is another key driver in the use of these measures, more so than the greenhouse's size or sophistication. For example, this SME stated that some greenhouses in southern California require shade cloths in the summer because the crop will burn in the sun. Similarly, some crops thrive under infrared light or high levels of heat, while others need protection from these elements.

While some growers' heat curtains and shade cloths were reportedly very old, others tended to replace them every three to five years. The 2005 PG&E Greenhouse Baseline study found that neither shade cloths nor thermal curtains were standard baseline practices. Navigant did not find any recent secondary literature to suggest that these measures had become standard practice since the Baseline Study took place. Grower interviews, however, did show that they were common among the respondents interviewed, which could be a factor of the greenhouses' locations (mostly coastal) and crop types.

Regarding IR film, grower interviews did show that most of the respondents had this measure in at least some of their greenhouses. The 2005 Greenhouse Baseline Study indicated that IR film likely was the baseline for roofs, but not for greenhouse walls. The study also stated that some growers were skeptical about the energy savings from IR film. An SME whom Navigant interviewed for this MASI – a major vendor for greenhouses across California – expressed similar concerns. This vendor claimed that the utility incentive for this measure was particularly high relative to the potential savings and the measure life. A statement from one of the growers supported this suggestion; this grower stated that he had been using IR film since the 1980s or 1990s, yet when he reviewed the savings he achieved from it, he found that if anything, he was using slightly more energy with IR film. Although the grower realized this lack of savings ten years ago, he continues to install IR film every time he replaces his greenhouse shell. When asked why he continues to install the measure, he stated that the incentive is high enough that it is worth installing, as it diffuses light and does not burn his plants. The vendor SME who expressed this concern stated that utilities could reduce the incentive for IR film by half, and growers would still install the measure. Comparatively, the builder emphasized that polycarbonate panels achieve higher savings and last longer than polyethylene plastic with IR film. Therefore, he recommended that utilities prioritize incentives for higher-efficiency shell material over incentives for IR film.

Another SME suggested that the use of these measures will depend primarily on the needs of the crops, themselves. The SME, a greenhouse expert from the UC Cooperative Extension, stated that the effects of IR film on plant growth is an area in need of further research. This SME predicted that once the industry had a better understanding of the effects of IR light on specific crops, the installation of this measure would become commodity-driven.

Building Shell Recommendations

Grower and SME interviews showed that there are still a number of greenhouse growers using single-layer polyethylene film for both existing greenhouses and new construction. According to explanations from both growers and SMEs, it is possible that in the absence of rebates, growers would revert to installing single-layer polyethylene film, particularly as a replacement measure. However, utilities should consider adjusting incentives for higher-efficiency materials so that they are more attractive as compared to double-layer polyethylene. Polycarbonate is more efficient than polyethylene and has a longer measure life, which would mean that growers do not need to replace it as frequently.

One greenhouse builder also expressed safety concerns with the installation of polyethylene film. In particular, this builder explained that due to cost concerns, greenhouse growers are increasingly installing their own polyethylene film instead of paying contractors to install it. According to the builder, there have been an increasing number of accidents related to growers installing their own building shell. The builder explained that this could potentially cause insurance companies to refuse coverage of installations not done by a contractor, which could in turn increase the labor costs associated with polyethylene film. If this were to occur, growers likely would be more limited by financial concerns associated with building shell measures, and may therefore rely even more heavily on incentives to pursue energy-efficiency opportunities.

Regarding added shell measures, SMEs suggested that the applicability of these measures to greenhouses depends on the geographic location of the greenhouse and the temperature and light requirements of specific crops. Most of the growers whom Navigant interviewed had at least one of these measures in place. However, growers may have installed the measures to improve the yield and quality of their crops and to mitigate environmental factors associated with coastal weather conditions.

2.4.1.2 Pumps and Motors

According to grower interviews, greenhouse operations primarily used motors for irrigation pumping, air movement, refrigeration, and, in some operations, conveyors. All growers stated that their motors were AC, and the age and size of these motors varied greatly for each grower. Virtually all respondents stated that they had numerous small motors, ranging from 0.25 to 3 hp, for air movement, evaporative cooling, booster pumps, and for operating automatic vents. In addition to small motors, growers also had various mid-sized pumps, ranging from 5 to 15 hp, for on-site refrigeration, boiler pumps, and irrigation pumping.

Only three respondents claimed to have motors larger than 20 hp. Two of these were large growers; one had multiple 20-75 hp well pumps, while the other had multiple, 100 hp pumps for the same purpose. The third grower was a technologically sophisticated, medium-sized orchid grower. This grower had mostly 12 hp motors for conveyance and for operating ventilation panels, as well as a smaller number of 35 hp motors for cranes that they used to move plant beds.

When asked about their replacement practices, growers stated that they will repair the equipment for as long as possible and will only replace equipment on failure. This was true for all the growers who had undergone equipment replacements during their time with the company. The larger growers stated that they might be inclined to replace equipment early if the repair would only be short term and the equipment would break down shortly after. If the equipment is particularly old and unreliable, large growers emphasized that the labor required for repairing a motor might not be worth the effort and money. Furthermore, growers indicated that motor rewinds are becoming as expensive as repairing or replacing motors when they stop working. This indicates that there may be opportunity in large greenhouses to target early replacement of large motors.

Variable Frequency Drives (VFDs)

VFDs were in place in at least half of the respondents' greenhouses. As shown in Table 16, VFDs were more common in larger operations than in smaller greenhouses. Most of the VFD installations were located on main pumps from wells and water sources to pressurize the irrigation systems. In one operation, they had installed VFDs on water recycling pumps, and in another, on water tanks for cooling pads. Growers reportedly installed VFDs both as retrofits and on new pumps, with no apparent trend toward one or the other. Notably, only the large growers received an incentive for their VFDs at the time of the interviews. Navigant did not ask respondents explicitly why they did not receive a rebate; however, one respondent explained that the utility must approve the measure before he could install it, and he may waste more energy in that time than the rebate was worth. While this may not represent the mentality of all small growers, it illustrates that farmers' top priority is to keep their operations running, and that uncertainty around rebate amounts and processing time could negatively influence participation in efficiency programs.

Table 16. VFD Installations in Greenhouses

Greenhouse Size	Number of Respondents	Installed VFDs	Received Incentive
Small	4	2	0
Medium	4	3	0*
Large	3	2	2

*One grower was in the process of applying for a rebate, but had not yet received it.
Source: Navigant grower interviews

Greenhouse growers indicated that they valued VFDs for their efficiency savings and their application to large motors. A quarter of the respondents worried that the quick start and stop of large pumps would wear on their irrigation systems. They characterized VFDs as "gentler," and they attributed lower, long-term maintenance costs with VFD installations. Larger growers tended to emphasize cost savings associated with VFDs, while smaller growers tended to emphasize efficiency. One large grower did not give a specific reason for installing VFDs, but rather explained, "Based on our usage and irrigation methodology, VFDs made the only sense."

These interviews suggested that VFDs might be present on most farms, typically on larger well pumps. However, growers typically did not install VFDs on all of their pumps and motors. One grower in particular stated that if he had received rebates for VFDs, he would have installed more of them. This indicates that while growers are willing to invest in VFDs for their larger motors, there still may be energy saving opportunities in incentivizing motors for medium-sized applications.

2.4.1.3 Irrigation Systems Equipment

Navigant asked growers a series of questions about their irrigation systems. All but one respondent reported that they had drip systems in place, and over half of these systems were more than 20 years old. This suggests that greenhouse growers have been using low-flow, pressurized irrigation systems for a number of years, and there likely are limited savings opportunities in conversion to low-flow systems.

Growers reported that their water came from either municipal supplies or wells. Six of the eleven growers had water recycling systems, and eight growers had some form of filtering or purifying their water. One grower indicated that he had no runoff, and therefore had no need for a water recycling or purification system. Of those who did have a system in place, there was no apparent relationship between the size of the greenhouse and the presence of these systems. Although most of the growers did not know the capacity of their systems, the three who did know claimed that the systems ran between 15,000-50,000 gallons per day. Interestingly, nearly all of the small to medium-sized growers had their systems in place for over 10 years, while the two large growers with water recycling systems had only installed them within the last year. This suggests that these systems may be a growing trend but are not yet in place in all greenhouses.

When asked what they used recycled water for, most growers cited irrigation purposes. One grower claimed that the water was too saline to use for irrigation, so they would run the water through cooling pads to cool the greenhouses. Another grower claimed that they used the recycled water to sanitize harvest equipment. Overall, greenhouse growers appeared to be conscious of water conservation in their operations, regardless of how they ultimately used this water.

2.4.1.1 Other Equipment

According to SME interviews, the equipment found within a greenhouse is largely dependent on its geographic location and the type of crop grown in the greenhouse. The greenhouse grower interviews supported this to an extent, as the type and age of equipment in the greenhouses varied from grower to grower. However, given the relatively small number of interviews included in this study, there is not enough representation to draw conclusions for individual crop types across the market.

Navigant did note some consistencies among growers' equipment. For instance, as shown in Table 17, most growers used a combination of boilers and floor or under-bench radiant heating to heat the greenhouses. This finding was consistent with the 2005 Greenhouse Baseline Study, which indicated that under-bench heating was the most common form of heating among those respondents. Respondents from this MASI indicated that their boiler systems tended to be very old – some up to 80 years old. For those growers who knew their system's efficiency, they estimated that their boilers ranged between 50 to 80 percent efficient. The radiant heating systems were typically installed at the time of the boilers, indicating that these systems are likely very old, as well. Because these systems are aging and may be relatively inefficient, utilities may find savings opportunities in replacing these heating measures, either as they fail or as early replacement measures. Two growers, in particular, stated that they were interested in learning more about the efficiency of boilers compared to water heaters. This may be an area in which utilities can pursue further energy efficiency.

Table 17. HVAC and Process Measures in Greenhouses

Greenhouse Size	Number of Respondents	Boilers	Water Heater	Fans*	Unit Heaters	Radiant Heating
Small	4	4	0	2	1	4
Medium	4	4	1	4	2	3
Large	3	2	1	0	1	1

*Navigant asked respondents about condenser fans, but based on respondents' descriptions, it is likely that these fans were actually circulation fans rather than condenser fans.
Source: Navigant grower interviews

Approximately half of respondents claimed to use condenser fans; however, growers' descriptions of these fans suggested that these were more likely circulation fans for air movement than condenser fans. Overall, the use of fans varied with the geographic location of the greenhouse and varied in age. Respondents indicated that they either had not replaced them since installation, or that they replaced them as they burn out.

Four respondents also claimed to have unit heaters. Of these respondents, only two knew the last time they had replaced these heaters, both of which were in the last year. The large grower with unit heaters stated that he buys new heaters every year, which tended to be very efficient. However, this is most likely not representative of the market overall. Given the limited HVAC information offered by respondents, Navigant was not able to establish industry standard practices for these systems. However, the information that growers did offer suggest that growers do not typically have standard replacement protocols for HVAC equipment. Therefore, there may be further efficiency opportunities in the replacement of fan systems and space heating.

Although the Navigant team did not ask about lighting measures, two growers expressed interest in light-emitting diode (LED) lighting. One claimed that he had already installed approximately 50 LED lights on a trial basis, and had done so without assistance of a rebate. The other grower stated that she had approached her utility representative about installing LEDs, and was waiting to hear from them regarding possible incentives. Utilities may already offer rebate for LEDs through their non-residential program offerings; however, utilities may consider targeting the agricultural industry specifically with LED incentives.

2.4.2 Irrigated Agriculture

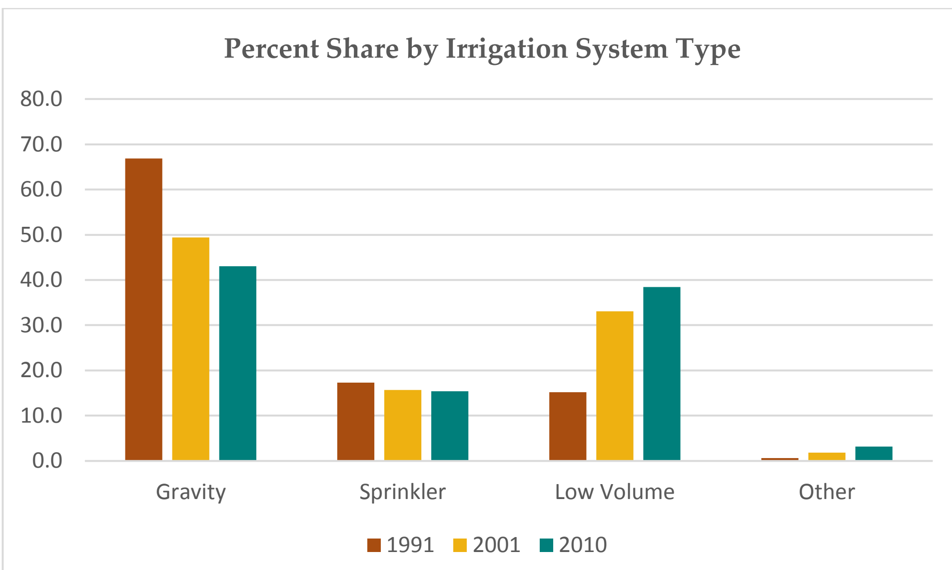
As found in the 2010-2012 Market Characterization, irrigated agriculture consumes the most electricity of any agricultural market segment in the California IOU service territory, equaling 39 percent of the market's overall electricity consumption in 2010. The balance of the electrical use depends on the crop grown, the hydrological conditions, climate, and the extent to which the business engages in post-harvest activities. Similarly, embedded energy associated with groundwater resources varies by source and location.

Gas sales to the irrigated agriculture sector constitute a much smaller portion of the market share, representing approximately 15 percent of the IOUs' total sales in 2010. Gas usage in this market segment contributes primarily to gas-fired irrigation pumping, although secondary processes such as small-scale dairy farming or greenhouse cultivation could also be contributing factors. When designing programs, utilities should consider the heavy use of electricity in the market segment, as well as the supporting practices that can take place on irrigated agriculture farms. The following subsections describe energy end uses for irrigation agriculture and their associated equipment in further detail.

2.4.2.1 Irrigation Systems and Design

According to SMEs and utility staff, the market has been gradually moving away from gravity-based irrigation systems toward drip and microsprinkler system. This is primarily due to decreased water availability and because farmers are increasingly tearing out field and row crops to replace them with fruit and nut trees, which require different irrigation systems. The 2013 USDA Farm and Ranch Irrigation Survey (FRIS) supports this assumption to an extent, as does the 2010 California Irrigation Methods Survey Results by Crop Category. According to the latter source, use of all irrigation types have increased in terms of acreage, although the share of low-volume systems has increased the most steadily, as shown in Figure 3.

Figure 3. Irrigation Methods Survey Share of System Type (All Crop Types)



Source: 2010 California Irrigation Methods Survey Results

Similarly, the FRIS, shows that gravity and sprinkler systems have decreased in terms of acreage from 2008 to 2013, although they have actually increased in terms of total farms using these systems. The use of drip, trickle, or low-flow micro systems have increased by around 20 percent, as shown in **Error! Not a valid bookmark self-reference.**.

Table 18. FRIS Data for California Land Irrigated by Water Distribution Type

System Type	Total	Gravity Systems		Sprinkler Systems		Drip, Trickle, or Low-Flow Microsprinklers	
Metric	**Acres Irrigated**	**Farms**	**Acres Irrigated**	**Farms**	**Acres Irrigated**	**Farms**	**Acres Irrigated**
2008	7,329,245	15,530	4,189,852	18,369	1,367,179	21,253	2,336,130
2013	7,543,928	15,231	4,539,426	13,479	1,662,125	25,408	2,783,022
Percentage Change	3%	-2%	8%	-27%	22%	20%	19%

Source: 2014 USDA Farm and Ranch Irrigation Survey (FRIS)

In looking solely at low-flow systems, FRIS data shows that the use of drip systems has increased in California, both in terms of irrigated acreage and number of farms using these systems. However, usage of microsprinklers has actually declined both in acreage and in number of farms, as shown in Table 19. The FRIS data does not indicate whether growers are converting their systems from microsprinklers to a different irrigation type, or whether they are simply removing their microsprinklers. However, while there is an apparent trend toward low-flow systems, this data shows that there in fact has not been a trend toward microsprinklers, in particular. The California Irrigation Methods Survey groups low-volume systems together, therefore Navigant was unable to cross-reference this study with the findings from FRIS in this context.

Table 19. California Land Irrigated by Low-Flow Water Distribution Type

System Type	Total Low-Flow Systems		Surface Drip		Subsurface Drip		Low-Flow Microsprinklers	
Metric	**Farms**	**Acres Irrigated**	**Farms**	**Acres Irrigated**	**Farms**	**Acres Irrigated**	**Farms**	**Acres Irrigated**
2008	21,253	2,336,130	12,781	1,246,243	648	242,235	9,344	847,652
2013	25,408	2,783,022	16,106	1,588,184	1,463	369,828	9,152	746,104
% Change	20%	19%	26%	27%	126%	53%	-2%	-12%

Source: 2014 USDA Farm and Ranch Irrigation Survey

Eight of the interview respondents claimed to have changed their irrigation systems in the last five years. These growers changed from various system types – including flood, furrow, hand-move sprinkler, drag lines, drip and microsprinkler – to primarily drip or microsprinkler systems. When asked the reason for changing their irrigation system types, farmers mentioned the unavailability of water, improved distribution uniformity, labor efficiency, and improved yield and quality of the crop when using drip and microsprinkler systems. Three of these respondents claimed that drip and microsprinkler systems save water when compared to their old systems (flood, furrow, and drag line, respectively). In reality, on-farm water savings can depend heavily on a farmer's irrigation practices, although these systems tend to provide increased control over the application of water when compared to flood, furrow, and other irrigation types.

The shift from gravity to low-flow systems could potentially increase energy sales, as these systems require added pressurization. Findings from the 2010-2012 Market Characterization support this, indicating that the use of surface water is declining within this segment as farms convert their land use to higher value crops. Because irrigation district water is not always available when farmers need it, the segment is trending toward the widespread adoption of pressurized groundwater systems. To accommodate this vast adoption of new irrigation technology, many irrigation districts are investing in modern water delivery systems. However, market experts agree that the trend toward pressurized irrigation systems will continue, and will have a significant impact on the segment’s electricity consumption. Utilities such as PG&E have recently introduced an agriculture-specific deemed incentive for pump motor VFD retrofits, and intend to offer a similar incentive for new pump motors. If the trend toward pressurized irrigation systems continues, VFD program such as these could be an important feature in utilities’ agriculture programs.

To further understand irrigation equipment installations and usage, Navigant asked farmers about their on-farm irrigation systems. Sixteen of eighteen farmers reportedly used microsprinklers or drip systems on at least part of their farm. Most of the growers with large farms indicated that they have had these systems in place for long periods – typically between 10-25 years. Of the six small respondents who used either microsprinkler or drip irrigation, three had older systems while two had systems less than five years old. Two small farmers also still used flood irrigation for their field crops. Table 20 shows the types of irrigation systems mentioned by small, medium, and large farmers.[20]

Table 20. Irrigation System Types on Respondents' Farms

Farm Size	Crop Types	Number of Respondents	Drip	Micro-sprinkler	Other Sprinkler	Flood
Small	Tree nuts, citrus, tree fruit (avocados, persimmons), wine grapes, feed for cows (wheat and corn)	8	2	4	-	2
Medium	Tree nuts, olives, grapes, field crops, citrus, rice	5	5	2	2	1

[20] For this table, the sizes of the farms are based on respondent self-reports rather than Navigant’s classification of farm size.

Farm Size	Crop Types	Number of Respondents	Drip	Micro-sprinkler	Other Sprinkler	Flood
Large	Tree nuts, olives, rice, vineyards, vegetables, melons, cut flowers (outdoor), prunes	5	5	1	4	-
Total	**-**	**18**	**12**	**7**	**6**	**3**

Source: Navigant grower interviews

When asked why they chose to install the type of irrigation system that they chose, growers mentioned water efficiency, distribution uniformity, the needs of certain crop types, and increased yield and quality of the crop that results from drip irrigation. While most farmers reportedly used one system type per each crop type, two medium-to-large operations used a combination of drip and microsprinkler systems on a single crop type for different purposes. In particular, one farmer who used these systems on wheat and vegetables claimed he would use hand-move sprinklers for germination or setting vegetable transplants, while he would use a buried drip system to irrigate throughout the growing season. Another farmer claimed he would irrigate his almonds using a drip system and would use microsprinklers only for frost protection. The latter farmer owned a medium-sized operation that also grew rice using a flood irrigation system. When asked about his drip system, this farmer claimed that he had previously installed a similar system in an orchard north of Chico, and he found that the system was so efficient and grew such good trees that he wanted to convert his current orchard to drip irrigation. However, because he also used microsprinklers for frost control, his utility did not consider his system to be exclusively drip and therefore would not rebate his installation.

These grower interviews supported the assumption that drip and microsprinkler irrigation are becoming prevalent within the industry. However, most of the growers whom Navigant interviewed grew orchards or vegetables; there may be more efficiency opportunities to promote low-flow systems among field crop farmers throughout California. Utilities should note that low-flow systems might not be appropriate for all crops. For example, crops such as rice require high amounts of water, and growers often will prioritize the health of their crops over water or energy efficiency. Addressing the market by crop type could help utilities to distinguish between late adopters and farmers who use water-intensive systems because their crops require it. Utilities can then address these late adopters directly to identify barriers to technological adoption.

Operating Pressures

All medium-to-large farmers were able to explain the operating pressures at which they ran their systems. Of the small farmers interviewed, only half of the farmers knew the operating pressures that they used for their irrigation systems. All but one respondent claimed to be using the operating pressure from the original system design; the one respondent who had changed the operating pressure had set it to a lower pressure due to the drought. Of the 12 respondents who reportedly monitored their operating pressure, 11 used the standard pressure gauges on the original system to do so. Two farmers used hand-held sensors in addition to the standard pressure gauges, while one used an Aquavar variable speed pump controller. The range of operating pressures reported by farmers is included in

Table 21.

Table 21. Respondents' Operating Pressures by System Type

Grower	Size	Crop Type(s)	System Type	Operating Pressure (psi)
Grower #1	Small	Avocados	Microsprinkler	150
Grower #2	Small	Citrus	Microsprinkler	35-90
Grower #3	Small	Olives	Drip	30
Grower #4	Small	Citrus	Microsprinkler	Don't Know
Grower #5	Small	Wheat and corn	Flood	Don't Know
Grower #6	Small	Tree nuts, persimmons	Surface drip	Don't Know
Grower #7	Small	Tree nuts	Flood	Don't Know
Grower #8	Small	Citrus	Microsprinklers	30
Grower #9	Medium	Citrus, avocado, wine grapes	Microsprinkler, drip (for grapes)	Microsprinkler: 20 Drip: 15
Grower #10	Medium	Rice and tree nuts	Flood (rice), drip, microsprinkler	Sprinkler: 40-50 Drip: 18
Grower #11	Medium	Tree nuts, prunes, olives	Sprinkler, drip	Sprinkler: 40 Drip: 20
Grower #12	Medium	Tree nuts, olives	Drip and microsprinkler	Microsprinkler: 25-40 Drip: 40-60
Grower #13	Medium	Cut flowers	Drip	70
Grower #14	Large	Tree nuts, raisin grapes, field crops, alfalfa	Pivot, sprinkler, drip	Pivot: 20 Sprinkler: 25-30 Drip posts: 25 Drip tape: 10-12
Grower #15	Large	Vegetables	Drip and sprinkler	Sprinkler: 70-80 Drip: 10-12
Grower #16	Large	Tree nuts, vegetables, cotton, melons, wheat	Drip	35-50
Grower #17	Large	Vegetables, tree nuts, grapes	Drip and sprinkler	Sprinkler: 35-38 Drip: 12
Grower #18	Large	Tree nuts, rice, olives	Microsprinkler, some drip	40-45

Note: See Table 9 for size delineations.

Source: Navigant grower interviews

Although nearly all growers stated that they use the original operating pressures from the original design, utility staff expressed concern over the lack of third-party standards for pressure requirements. According to one utility staff member, market-leading companies require less pressure for their systems in order to achieve the same output. However, industry manuals typically do not state this, and because there are no third-party standards for operating pressures, installers often over-design the systems to ensure that systems produce sufficient water regardless of the manufacturer.

One SME expressed additional concerns regarding operating pressures, explaining that even though growers would not change operating pressures without a reason, sometimes system wear can lead to changes in operating pressures. This SME stated that a number of evaluations were conducted in 2014 for a pilot program, which reviewed operating pressures in addition to conducting pump efficiency tests. Although the results from this study were not available at the time of the interview, the SME claimed that those systems that were evaluated were 11 percent more efficient than those that were not evaluated regularly. Given this, Navigant recommends that utilities perform tests on operating pressures at the time of pump efficiency tests to ensure that the system is running according to its original design.

Distribution Uniformity

Grower interviews suggested that most farmers do not formally track distribution uniformity on a regular basis. Navigant asked 14 of the growers whether they tracked distribution uniformity in their operations. All but two small growers reported that they did track it in some form, however, they seemed to track this manually by looking at gauges, and did not track this regularly.

Of the seven farmers who claimed to track distribution uniformity in-house, only two indicated that they use a formal method of tracking this information. These two farmers both monitored on a daily basis. One of these farmers had a large operation and grew a variety of crops on 9,600 irrigated acres of land, using flood, furrow, and hand-move sprinklers. The other farmer had 41 irrigated acres of citrus fruits and used microsprinklers. This suggests that while most farmers do not formally track distribution uniformity, those who do may not fall exclusively into a size or crop category.

Five growers stated that they have received information on distribution uniformity from third-party evaluations in the past, such as PG&E pump tests, UC Extension studies, and NRCS evaluations. Only one respondent who used a third party claimed that they receive this information regularly (annually). Utilities should consider offering farmers regular system optimization tests in addition to pump efficiency tests. By providing information on operating pressures and distribution uniformity, utilities can ensure farmers' overall systems are running efficiently, which could save both water and energy.

Moisture Sensors

The use of soil moisture monitoring systems was prevalent among the larger growers, but uncommon among small growers. All respondents with a large or medium-sized farm used some form of soil moisture monitoring system. Most indicated that they used basic moisture sensors, but some growers either had or were considering buying systems that are more sophisticated. These systems included combinations of features such as flow meters, gypsum probes, infrared guns, and on-farm weather stations. Three of these growers indicated that in the past, they had used PureSense, a third-party environmental management firm. However, these growers claimed that the company went out of business, although Navigant could not find evidence that the company had gone out of business. Two of these three farmers continued to use moisture sensors in-house, while the third began using the ClimateMinder application by Rain Bird.

Two growers were also in the early stages of acquiring pressure bombs, a device that measures the moisture content of the crop's leaves. The larger of these two growers had recently purchased one of these devices, while the medium-sized grower was planning to split the cost of a pressure bomb that he would share with a neighboring farm. This suggests that while growers are using irrigation technology that is more advanced, cost is still a barrier to widespread adoption of these devices.

The cost barrier is relevant even for existing technologies such as basic moisture sensors. While medium-to-large growers all used moisture monitoring systems, this does not mean that they are employing these technologies on a broad scale. For example, one large farmer operated 6,000 irrigated acres, but could not afford to use moisture sensors on all of his plots. Instead, he used only three moisture sensors and placed those in plots that were representative of his other fields – one with heavy clay soil, one with medium soil, and one with sandy soil. This farmer would then apply the moisture readings to the rest of his land and irrigate his other fields accordingly. This illustrates that large farms are willing to pursue energy and water conservation, but remain constrained by the initial costs of these technologies. Utilities should consider providing incentives for these monitoring technologies, as farmers can currently only use them on a minimal scale.

With regard to the eight small farmers interviewed, only one claimed to use moisture sensors or irrigation controls. The rest relied on visual inspection of the plants or had a set irrigation schedule that they might alter based on the weather. Two of the farmers said they used to have moisture sensors, but either the devices had broken or the farmer removed them because he could not tell if they were making a difference. These responses suggest that the use of moisture sensors or irrigation controls are not standard practice on small farms, and utilities may want to consider incentivizing moisture monitoring systems on small farms to encourage water conservation.

2.4.2.2 *Pumps and Motors*

Navigant asked farmers about their irrigation water source and their pumps and motors. Twelve of the eighteen farmers used wells for their irrigation water, although some farmers had multiple water sources on their land. The depths of these wells varied, from 150 feet to 2,400 feet, with the average well depth coming to around 515 feet. Pumps were either electric or diesel; no respondents used natural gas pumps in their operations. Table 22 shows the average number of electric pumps on the farm, as well as the size ranges and pump and motor types.

Table 22. Pumps and Motors on Respondents' Farms

Farm Size	Avg. No. of Electric Pumps	Avg. No. of Elec. Booster Pumps	Pump/Motor Size Range (hp)	Pump Types	Motor Types
Small (8)	3*	1	1-100	Turbine, submersible, centrifugal	AC**
Medium (5)	9	1	2-175	Turbine, submersible, induction	AC, induction motors
Large (5)	38*	9*	30-450	Turbine, centrifugal	AC

*Each of these values may be skewed slightly due to a single outlier. With regard to small farms, one respondent had eight pumps on his farm. If one were to exclude this respondent from the calculation, the average number of electric pumps on small farms would be two. Similarly, one large respondent only had three electric pumps on deep wells. If one were to exclude this respondent from the calculation, the average number of electric pumps on large farms would be 46. Regarding booster pumps on large farms, three of the five respondents did not use booster pumps. The other two had 10 and 40 booster pumps, respectively.
**Only three of the eight small respondents were able to identify the types of motors that they used in their operations. A third respondent answered "AC/DC," however given this farmer's size and other responses, the evaluation team has determined that his motors are likely AC.
Source: Navigant grower interviews

Most of the pumps on respondents' land were over five years old, and two small farmers had pumps over 35 years old on their land. Eight respondents claimed to have at least one new pumps (installed within the last five years), yet only three of these new pumps were installed on new wells. Navigant did not ask farmers about their pump efficiency due to time constraints. However, when speaking with a SME from the Cal Poly Irrigation Training and Research Center (ITRC), he stated that it is difficult to find a new motor that is inefficient due to the standards placed on motors at the manufacturer level. This SME also stated that if farmers install a VFD on a new motor, they likely will install a premium motor, as well.

Two large farmers claimed to have received incentives for their new pump installations, while a third, large grower claimed he might have received an incentive for his motor replacement but not the pump.

One small grower claimed he applied for an incentive but had not yet received it. When asked how influential the incentive was on their choice of pump and motor equipment, all but one respondent indicated that they would most likely have installed the same equipment at the same time if an incentive had not been available. However, two respondents claimed that they would not have installed VFDs on their systems if there had not been an incentive.

Pump and Motor Maintenance

Nearly all farmers claimed that they replace pump and motor equipment only upon failure. Navigant asked 14 of the respondents whether there was anything that would motivate them to replace equipment before it failed. Of these respondents, only one explicitly stated that there was nothing that would convince him to replace his equipment early. This individual was a large grower with 60 pumps who conducts complete well tests every other year. The remaining respondents offered a variety of answers; however, the overarching message was that farmers might replace their equipment early if the efficiency of the new equipment was significantly higher than that of their existing equipment, and if they knew the cost savings would make it worth the investment. Four respondents indicated that financial incentives or utility assistance would help to convince them, and three also mentioned that the reliability of their existing equipment would factor into their decision. Notably, two respondents (one medium, one small) stated that if incentives were available for VFDs, they would be willing to install VFDs on their systems. This suggests that growers are willing to pursue efficiency measures, but are constrained by costs. Increased awareness of available incentives may encourage growers to take further efficiency actions.

When asked about equipment maintenance, three of the five large farmers indicated that they have somewhat regular maintenance schedules. None of the small or medium-sized farmers conducted maintenance or repairs on a regular basis. When asked whether they conduct regular pump efficiency tests, all large farmers reportedly conduct annual or semi-annual pump tests through utilities' pump efficiency test programs. Four of the five medium-sized farmers had also conducted pump tests in the past, although they were typically not a regular practice and only one grower had done them through a utility program. Of the eight small growers interviewed, only five of them had ever conducted a pump efficiency test, and these were typically one-time tests. One small grower claimed that they conducted in-house pump efficiency tests every week by reading his smart meter and referencing that against their pumping pressure and the amount of water delivered. However, this grower was the exception, as most of the small farmers claimed that they were not interested in conducting them because they felt they were unnecessary. This may indicate that small- and medium-sized growers are unaware of utilities' subsidized pump efficiency tests, or that they do not see the value in them. Navigant recommends that utilities target small- and medium-sized growers for their pump efficiency test program.

For the respondents who conduct pump efficiency tests through a utility program, Navigant asked the likelihood that they would perform these tests if their utility had not subsidized them. All respondents who relied on subsidies for their pump tests stated that they either would not conducts these tests at all, or that they would do so less frequently. This suggests that pump efficiency tests are not standard practice, and that if an incentive were not available, farmers would likely not conduct efficiency tests on a regular basis, if at all.

VFDs

As shown in Table 23, large farms were much more likely to have VFDs on their pumps than medium or small farms, and these tended to be on larger pumps. Only one respondent claimed to have VFDs on all his pumps. This respondent was a medium-sized farmer who grew tree nuts, prunes and olives. This particular farmer also had soft-starts on all of his pumps. The remaining respondents with VFDs did not give specific numbers when asked how many VFDs they had. Rather, respondents estimated that they had "a few" VFDs, or stated they had VFDs on their large pumps. This suggests that farmers do not closely track their VFD installations, although two farmers stated they had future VFD installations planned.

Table 23. VFD Installations on Irrigated Farms

Farm Size	Number of Respondents	VFDs	Received an Incentive
Small	8	1*	0
Medium	5	3	0
Large	5	5	4

*A third small farmer also had a VFD, but it was on a milk pump for his dairy operation. Therefore, Navigant excluded that VFD from the irrigation analysis.
Source: Navigant grower interviews

Including the aforementioned medium-sized farmer, five respondents overall claimed they installed VFDs on new pumps. Three of these respondents were large farmers, and two were medium-sized. Two of the three large farmers had VFDs on all new well pumps, as well as some on their older pumps. The other large respondent indicated that he had VFDs on the majority of his pumps, most of which were on new pumps; this suggests that this grower also regularly installed VFDs on new pumps as a standard practice. One of the two medium-sized growers stated that he had VFDs on all of his pumps over 10hp, which included one new pump. The final respondent, as discussed before, had VFDs on all of his pumps.

When asked why they installed VFDs, most respondents claimed that VFDs help the systems to run properly. Two growers mentioned efficiency, and one claimed that their service provider suggested it to reduce noise pollution from their old pump. One large farmer claimed that he installed the VFDs for the incentives, and had also installed soft starts on his equipment. The SME from the ITRC stated that he has been seeing an increase of VFD installations where farmers consolidate a well and a booster pump. Furthermore, this SME argued that VFDs are becoming more common because the prices are slowly falling, and also that they are more common on drip systems than on other system types because of the different block sizes that farmers must irrigate. Given the correlation of drip systems with different crop types, the use of VFDs may have some dependence on the crop types.

Overall, large farmers tended to take advantage of VFD incentives more so than small farmers did. Of the farmers who did not install VFDs, the small- and medium-sized farmers typically claimed that they were too expensive. As previously mentioned, two farmers stated that if incentives were available for VFDs, they would be interested in installing them. This indicates that farmers may not be aware of VFD incentives and therefore are unable to participate in these programs due to lack of awareness. Two farmers also expressed concern about noise interference, and another farmer claimed that his pump company was "anti-VFD" because they did not believe VFDs were efficient. This farmer stated his pump company therefore did not offer him a choice to install them.

These findings suggest that VFDs are not standard practice for small- to medium-sized farmers, and that some farmers may be unaware of the efficiency opportunities available to them. Furthermore, although all large farmers had at least one VFD, they tended to only have VFDs on their large pumps. This suggests that there are still efficiency opportunities within the large farms, as well, indicating that VFDs may not be standard practice for large farms, either.

2.5 Decision Making

Growers' decisions regarding equipment installations, energy and water management, and usage and maintenance practices are subject to a number of factors that do not apply to other industries. These factors can include weather, water availability, and equipment availability, which affect the agricultural sector in a uniquely direct way. The following subsections describe some of the ways in which these factors affect growers' operational decisions.

2.5.1 Greenhouses

When asked about their decision-making process for installing equipment, nearly all greenhouse growers explained that they first considered their need for the equipment. Growers will typically repair any dysfunctional equipment until it fails. If they are unable to repair this equipment, they will consider the cost and payback of the replacement equipment, as well as its efficiency. One grower also stated that he regularly looks to see whether there are any utility incentives available when installing equipment, indicating that incentives do play a role in growers' equipment choices.

When deciding on equipment, five respondents stated that they sometimes work with outside contractors, vendors, or retailers, although it depends on the equipment. Navigant asked growers to what extent these outside contractors influence their equipment selection. Growers stated that these contractors have some influence. However, typically growers' will already have done their own research by speaking with internal maintenance staff, other growers in the industry, and various vendors to make a decision on their equipment installations. One greenhouse contractor whom Navigant interviewed concurred with this finding, stating that growers typically will have an idea of what they want to install, and the contractors help them to identify the correct piece of equipment for their needs.

Growers also explained that they discuss their options with their internal staff, and will often talk with other growers in their area. As the 2010-2012 Market Characterization stated, "California greenhouse and nursery operations tend to be geographically clustered and closely networked." Navigant did not discuss information channels in-depth for this MASI study. However, discussions with growers suggested that grassroots networking – including discussions with other growers, vendors, utility representatives, and trade publications – provides a key information channel among growers.

In terms of tracking their energy and water, growers typically monitored their usage by looking at their bills and occasionally their meters. Only two growers had a computer system that offered this information, one of whom was a medium-sized grower while another was a small grower. Computer monitoring may be an area for potential opportunity savings in the future. Greenhouse growers must account for numerous factors to grow their crops, including temperature, light penetration, humidity, soil moisture, and ventilation, among others. Computer systems allow growers to monitor these factors simultaneously. While these systems typically can monitor factors such as energy and water use, these may not be the highest priority for these growers. Therefore, any monitoring system that utilities might promote to growers would need to incorporate tracking other key factors in addition to energy and water usage.

2.5.2 Irrigated Agriculture

For irrigated agriculture, Navigant asked farmers about the factors that affected their decisions to install or replace equipment. Farmers' responses included the efficiency of equipment, the cost of equipment, and the need for the new equipment. The small farmers, in particular, emphasized first cost and indicated that they will typically choose to repair equipment instead of replacing it. Medium-sized farmers had a slightly more complex means of determining whether to repair or replace equipment. These farmers discussed weighing their options and considering ROI and payback periods, efficiency of the equipment, available incentives, and the amount of water that is available for irrigation. Two of these growers also mentioned working with third-party contractors and utility staff when making these decisions. For the large growers, two stated that efficiency of the equipment was a top priority, and others mentioned equipment cost, reliability, and labor for their staff. Overall, larger firms tended to take a longer-term outlook on costs and savings, and considered a variety of factors in their equipment installations, such as available incentives, maintenance and management costs, and price comparisons from different vendors. Meanwhile, smaller farms expressed urgency in these decisions and sought lower-cost options when possible.

Every grower interviewed relied heavily on the knowledge and advice of their contractors, pump vendors, equipment retailers, electricians, etc. for purchasing, maintenance, and equipment replacement decisions. Throughout the interview, growers were asked a series of questions relating to their decision-making process and as to how it pertained to replacing equipment, installing new equipment, maintenance practices, approaches to pump replacement and/or upgrades, choosing pump or motor efficiency levels, and pursuing energy-efficiency opportunities. Growers consistently replied that they regularly deferred to outside judgment. This is not always beneficial, however. In one instance, a respondent relayed a story about how he expressed interest in a VFD when consulting his contractor, but the irrigation contractor's response was that there are no energy savings associated with VFDs and that the benefits they have on irrigation systems are a myth. The farmer therefore followed the advice of his contractor and did not pursue a VFD any further. This suggests that utilities should focus education efforts not only on farmers, but also on contractors working with these farmers.

One factor that is unique to the irrigated agriculture sector is the impact that seasonality has on equipment-related decisions. In particular, the irrigation season has a crucial impact on farmers' decisions to replace or repair equipment. Growers showed a propensity to keeping their equipment operational under any circumstances in order to maintain their irrigation schedule and their crops properly watered. During the irrigation season, for instance, growers are more likely to conduct repairs than fully replace equipment. This is because the downtime during equipment replacement can significantly interrupt their operation and lead to financial losses. Farmers take a similar approach toward pump efficiency tests, especially if the tests result in a disruption in pump performance. Any major system changes, such as pump and motor replacements, will be done out of season, where downtime in system operation is more ideal.

2.6 *Key Drivers and Market Trends*

California's agricultural market segment has seen significant trends within the last decade in terms of equipment usage, water availability, and crop types grown, among others. However, market trends were not a key focus in the scope of this MASI. The following sub-sections discuss the market trends that arose in discussions with program staff, SMEs, and growers throughout the course of this MASI. It is important to note that this section does not represent all of the trends that are currently taking place in the market, but rather a high-level discussion of those that interview respondents mentioned during their interviews.

Arguably the most significant trend affecting California's agriculture segment is the current drought conditions throughout the state. Approximately 95 percent of California is currently in drought, and scientists predict that California may soon be experiencing a 'megadrought.'[21] As mentioned in the 2010-2012 Market Characterization, "Already, the Southwestern US has seen regular decreases in precipitation, as well as spring snowpack and river flow. Each of these represents a critical supply of water for the region. The Southwest's natural susceptibility to drought further amplifies these water shortages, and the U.S. Environmental Protection Agency (EPA) anticipates that the current water scarcity will be 'compounded by the region's rapid population growth, which is the highest in the nation.'"[22] These trends have already led to the lowering of water tables throughout the state which will mean that California's agricultural producers will need to drill deeper in order to access the water. This likely will further exacerbate water scarcity across the state.

In the last few decades, California and the Southwest also have seen increasing average ambient temperatures and a decline in the number of winter chill hours.[23] This is particularly true in the Bay Delta region and the mid-Sacramento Valley, which have seen greatest rates of change since the 1950s. In general, cold extremes have become less frequent, while heat waves are becoming increasingly prominent in the region. Indeed, studies have shown that in extreme scenarios, heat waves such as the one experienced in July 2006 may occur as frequently as once a year in many parts of California.[24]

These environmental changes will have direct impacts on California's agricultural industry, although certain market segments may feel the effects more acutely. Appendix E provides an excerpt from

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[21] CBS News, "California could be in for century-long megadrought." http://www.cbsnews.com/news/california-could-be-in-for-century-long-megadrought/.

Navigant's 2010-2012 Market Characterization that describes the impacts that these environmental changes could have on California's agricultural subsectors.

2.6.1 Market Trends in California Greenhouses and Nurseries

Market trends were not a key focus of this MASI; however, some SMEs and greenhouse growers mentioned market trends during the course of the interviews. Navigant has included these trends here. It is important to note, however, that this section does not include an exhaustive discussion of the current events occurring within the market. Rather, this section provides a high-level overview of relevant trends that arose during the course of the MASI interviews.

A key market trend, California's greenhouse and nursery segment is increasingly facing competition from other markets, particularly in South America. For example, in the last decade, California's rose industry has shrunk considerably throughout the state. SMEs estimated that the number of rose growers currently in the market were between five and ten. The 2013 California Agriculture Census estimates that there were 26 rose growers as of 2012, as compared to 150 rose growers in 1991.[25] This decline has occurred primarily due to price competition with countries such as Ecuador and Mexico, whose cost of production is significantly lower than that of California roses. While some growers have gone out of business due to this market loss, others have mitigated the impact by shifting focus to other products, such as Gerbera daisies. Because Gerberas are comparatively more delicate than roses, and can be damaged easily in international shipping. Therefore, while the production of roses has largely been outsourced to South America, California floriculturists have created a niche market by producing crops that retain their quality when grown locally. This increasing international competition has created uncertainty in the market, and has caused some growers to be increasingly cost-conscious and risk averse.

As of the 2010-2012 Market Characterization, the container nursery sub-segment had been seeing slightly differing trends, as production is still largely domestic. The primary issue for this sub-segment is regulations, and because much of this market is devoted to landscaping, the downturn of the housing market had created a downturn for this market, as well. In order to cope with this, some major producers were moving out the country to places where they can produce more cost effectively. Additionally, smaller companies were losing traction within the segment, as they were either going out of business or being swallowed by the major producers. Because of this, growers have been increasingly cost-conscious. This could present an opportunity for utilities to encourage energy efficiency by educating growers about the potential savings that they might gain.

One SME explained that the greenhouse segment is also beginning to see the introduction of new crops that farmers had previously grown outdoors. The increased prevalence of pests throughout the state has been a primary driver of this trend, as the pests increasingly harm crops such has oranges and tomatoes. The 2012 USDA Agriculture Census data did not track citrus grown indoors; therefore, Navigant was unable to verify this trend for oranges. However, census data supported this trend for tomatoes, having shown a 12 percent decrease in acres of tomatoes grown in the open from 2007-2012, with a 41 percent

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[25] Santa Cruz Sentinel, "Editorial: Cheap imports winning war of the roses." http://www.santacruzsentinel.com/opinion/20140807/editorial-cheap-imports-winning-war-of-the-roses.

increase in square footage of tomatoes grown in greenhouses during the same period. If this trend continues, California may see an increase in greenhouse space in the near future, and the equipment installation practices may alter based on the crop grown. Given the relatively high value of crops such as oranges and tomatoes, these growers may be to afford higher-efficiency equipment, which could present an opportunity for utilities to promote energy efficiency in new construction.

2.6.2 Market Trends in California Irrigated Agriculture

California's irrigated agriculture segment is also highly dependent on the global market, and is therefore vulnerable to shifts in global demand. For example, China recently has begun to take a strong anti-GMO stance in its agricultural imports. This has had a negative effect on some US industries, including hay. In summer 2014, China began testing their hay imports for the presence of hay made from biotech alfalfa. A recent article in The Australian newspaper explains the effects on the US market:

> *With Chinese dairy producers eager to feed high-protein US alfalfa to cows, US exports of alfalfa hay to China had jumped more than eightfold from 2009 to 2013, reaching nearly 785,000 tons, and accounted for a quarter of such exports in the first 10 months of this year. But as exporters scrambled to ensure their cargoes didn't contain the genetically modified alfalfa, which was developed by Monsanto, shipments tumbled 22 per cent by weight from August to October from a year earlier, according to US Agriculture Department data.*[26]

This decrease in Chinese demand for hay could have a significant impact on the California agriculture market, as California is the second-largest producer of hay in the U.S.[27] Hay is California's 15th highest agricultural export, with California having exported $333 million of hay in 2013.[28] Some California growers have altered their own operations in order to cope with changing international demand. In particular, Navigant's interviews with SMEs and utility staff highlighted a trend in which California farmers are uprooting their field or row crops and replacing them with tree nuts, which are typically more water-intensive than field or row crops. Data from the 2013 USDA Agricultural Census Data supports this finding, showing a 51 percent increase in irrigated pistachio acreage, a 24 percent increase in irrigated walnut acreage, and an 18 percent increase in irrigated almond acreage.[29] According to one IOU staff member, farmers base these decisions on risk and profit, as prices for nuts have increased due to expanded overseas markets for these crops. The increased profit margin for nuts can offset the initial

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[26] The Australian, "US hay exports shrivel as Beijing rejects GM." http://www.theaustralian.com.au/business/wall-street-journal/us-hay-exports-shrivel-as-beijing-rejects-gm/story-fnay3ubk-1227157131674.

[27] National Agricultural Statistics Service (NASS), 2014, *2012 Census of Agriculture: United States*. U.S. Department of Agriculture. Report No. AC-12-A-551. http://www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/Reports/2012cas-all.pdf.

[28] University of California Agricultural Issues Center, 2013, *California Agricultural Exports*, California Department of Food and Agriculture, file:///C:/Users/kmidura/Downloads/2013_ExportsSection.pdf

[29] USDA National Agricultural Statistics Service, Pacific Regional Office-California. (2013). California Agricultural Statistics 2012 Crop Year. http://www.nass.usda.gov/Statistics_by_State/California/Publications/California_Ag_Statistics/Reports/2012cas-all.pdf.

capital cost of converting farmers' fields, and farmers may see a more stable international market for these crops as compared to field crops such as hay.

As a result of environmental pressures and shifts in crop type, growers are changing their irrigation system types to suit the needs of the plant. In particular, with the market trending toward tree nuts, growers are increasingly turning to drip systems. The 2014 FRIS data support this finding; California farms using gravity and sprinkler systems declined at a rate of 2 percent and 27 percent, respectively, between 2008 and 2013, although by acreage these irrigation types increased on both accounts. Meanwhile, drip, trickle, and low-flow systems throughout California increased by 20 percent in terms of farms using these systems, and 19 percent in terms of overall acreage irrigated using these methods. SMEs also highlighted the trend toward drip irrigation, and they expect that this trend will continue into the future as water becomes scarcer and energy prices rise.

The grower interviews supported these findings in the shift toward drip, microsprinkler, and low-flow irrigation systems. Sixteen of the eighteen growers interviewed commented that their current irrigation systems are comprised of drip and/or microsprinklers, either as a portion or as their entire system. Six of the eighteen growers mentioned adopting drip and microsprinkler practices within the last five years, four of which have switched from furrow/flood irrigation systems and two from dragline irrigation systems. In addition, one of the growers who did not utilize drip or microsprinkler irrigation, but rather flood irrigation, commented that he is looking into and planning to make the switch within a year or two.

In addition to adopting pressurized irrigation, many farmers who previously relied on diesel engines are changing to electric motors, according to the 2010-2012 Market Characterization. The combination of these trends will make it critical for utilities to recognize and adapt to the increasing electric consumption that will likely arise in the near future. Pressurized irrigation systems can be extremely energy intensive, thus highlighting the need for farmers to improve pump efficiency on their farms. One SME from the Market Characterization emphasized the need to develop crop rotations using a whole-farm systems approach, with a particular focus on the type of irrigation method that is best suited to the crop. To help mitigate increasing electricity consumption, utilities should help individual field crop customers to develop holistic farm design strategies. Emphasizing pump optimization and crop-specific irrigation technologies will be vital for utilities working with this segment. There is also increasing opportunity for utilities to promote ancillary services such as water recirculation pumps and water storage, which could reduce the use of electricity for groundwater pumping.

2.7 Key Barriers

The primary barrier for agricultural customers across all sectors is first cost of the equipment. In both the MASI interviews and in the Market Characterization, growers consistently cited financial constraints as a reason for not installing higher-efficiency equipment. Even owners of large farms express concerns with staying in business, and must be resourceful in their use of measures such as soil moisture sensors. Utilities can mitigate these concerns to an extent with rebates. However, utilities must be proactive in marketing their programs, as farmers are often too engrossed in their day-to-day operations to seek out efficiency measures.

Growers' tendency to repair equipment until it fails presents another barrier for utilities promoting early replacement programs. Because agricultural operators rely to an extent on third-party contractors, utilities could leverage contractors to promote efficiency equipment. However, contractors could present an additional barrier, as some contractors are reportedly deterring customers from installing measures such as VFDs because they are not convinced of the savings. One greenhouse contractor whom Navigant spoke to for the SME interviews also stated that he rarely promote utilities' energy-efficiency programs to customers because length of time that it takes to receive a rebate makes it difficult for growers' to plan their installations around the rebate. Furthermore, if a grower does not receive the full amount of the rebate that the utility markets, then it reflects poorly on the contractor.

Similarly, one irrigated agriculture SME explained that pump companies are so busy with installations that they will perform the post-installation pump tests at the time of installation, which is typically during the off-season. Because the off-season is winter, the rainiest season, the water tables will be higher during the post-installation tests than they are during pre-installation. This can skew the amount of savings reported – and therefore, the amount of rebate money received – which will disincentivize growers from considering utility programs when installing new equipment. The uncertainty around utility incentives, for both irrigated agriculture and greenhouse customers, can deter agricultural customers from adopting higher-efficiency measures that may be affordable with the support of financial incentives.

In addition to these barriers, there are also a number of barriers that are specific to greenhouses and irrigated agriculture operations, respectively. The following subsections discuss this barrier further.

2.7.1 Greenhouse-Specific Barriers

A key technical barrier for greenhouses is the sensitivity of different crops to various environmental conditions within a greenhouse. Different crop types can be highly dependent on temperature, light, and humidity, among other factors. This can limit growers' options for equipment – for instance, a grower with highly light-sensitive plants may choose not to install highly insulating shell material because it lets through too much light. One SME also pointed out that the color of certain lights, such as LEDs, can be detrimental to growth of certain plants. Therefore, although certain equipment may encourage energy efficiency, a grower's top priority is ensuring the health and quality of the crops.

As a whole, the California greenhouse market is less prone to pursuing cutting-edge efficiency measures than other global markets, due primarily to financial constraints. According to one greenhouse SME, Israel and the Netherlands are the most progressive greenhouse agriculture markets in the world due to their advanced greenhouse technology, but it is difficult for California growers to adopt these same technologies because of the costs associated with implementation. The Netherlands is the center of the European flower market, which enables Dutch growers to operate large, entirely mechanized greenhouses. Israel's advanced technology is attributable to its climate; many crops are impossible to grow outdoors in Israel's heat, so growers there have developed advanced technologies for greenhouse glazing, molded plastics, and insect screening to protect the crops. Given the high level of competition in the California greenhouse industry, along with the high cost of inputs and labor, many greenhouse operations have relocated from California to Central and South America in order to avoid having to install a mechanized system. Those that remain in California tend to operate as simply and economically as possible; staying in business is a higher priority to California growers than investing in state-of-the-art technology. The availability of cost-effective, advanced greenhouse technologies may be inhibiting California growers from being competitive in the broader agricultural market.

2.7.2 Irrigated Agriculture-Specific Barriers

Farmers in irrigated agriculture are primarily concerned with the function of their irrigation systems and their need to maintain the health of their crops. Because of this, farmers will prioritize having their systems running over energy efficiency. One farmer explained that he often has to install his own equipment because his contractors are too busy to install his systems when he needs them. This has happened both for pump installations and for his drip irrigation system on a new orchard. Furthermore, this grower stated that suppliers in his area sometimes run out of certain equipment in stock, and that he is often constrained by what the supplier has in stock. Because he has had to install his own systems due to scheduling conflicts, and because his contractor likely had not presented him with a full range of equipment options, this grower may have missed out on both rebates and on efficiency opportunities in his installations. Other growers also mentioned that both their suppliers and their utility representatives are often too busy to sit down with them and discuss efficiency opportunities. The high demand for these suppliers' and representatives' time may be leading to missed opportunities in energy efficiency within the market.

Furthermore, some growers may not see the financial sense in investing in energy saving technologies. In the minds of some small- to medium-sized growers, their systems are not consuming enough electricity to warrant expensive, energy saving equipment such as VFDs or soil moisture sensors. Small growers often rely on their experience and knowledge to operate their equipment rather than data and analytics the larger growers are trending toward. This is true, to an extent, for medium and large sized growers, as well. When explaining how he makes decisions on irrigation scheduling, one large grower explained that after he has reviewed all of the information from his sensors and computers, he ultimately must use his best judgment to determine when and how much to irrigate. Therefore, while sensors and irrigation data may help growers to make informed decisions about irrigation, it is ultimately the judgment of the grower that is the determinant in how much to irrigate and when. This may be a barrier to the adoption of computerized systems for smaller growers, as they may not see the value in employing these systems.

For those farmers who do rely on computerized systems to schedule their irrigation, the information available to them depends heavily on the offerings from the software company. Three growers stated that the company that had developed their app had gone out of business. One of these growers had found another company to work with, while two began monitoring moisture levels in-house. While growers are moving toward automated systems based on data analytics, uncertainty around the technology may inhibit other growers from relying on these systems in the future. Additionally, the computerized scheduling may not be enough to overcome the significant cost barriers that growers face – one grower claimed to water-stress his orchards during the week and only irrigate his fields over the weekends in order to get time-of-use rates for electric pumping. These computerized systems may offer opportunities for energy and water conservation, but if the technology or the companies offering these systems are unreliable, then growers may not be able to identify these savings.

2.8 Key Findings and Energy Savings Opportunities

2.8.1 General Findings

For both the greenhouse and irrigated agriculture market segments, the commodity and geographic location drive growers' equipment installation and usage practices. While growers consider water and energy efficiency to an extent, their primary concern is the health and yield of their crops. Growers will select equipment based on the needs of the crop that they are growing. This may mean that growers will forgo systems that are more efficient because the crop requires more water to grow. For example, rice requires high amounts of water; therefore, rice growers may continue to use flood irrigation for these crops, as low-flow systems may hurt the crop or decrease a farmers' yield.

The source of an operation's irrigation water can also play a large role in growers' equipment decisions, particularly in irrigated agriculture operations. For example, farms with access to a municipal water source or close proximity to a river will have fewer expenses related to water pumping than farms that require drilling new wells or pumping water long distances. When approaching a grower with programs and information, utilities should consider the operation's crop types and water sources, rather than categorizing an operation by its acreage, square footage, or energy consumption. Addressing the market by crop type could help utilities to distinguish between late adopters and farmers who use water-intensive systems because their crops require it. Utilities can then address these late adopters directly to identify barriers to technological adoption.

Growers remain very cost-constrained in their operations, and continue to rely on rebates for many of their energy-efficiency upgrades. The agricultural industry is moving toward efficiency; however, growers report that this is largely out of necessity. Many growers continue to struggle financially, and a number of greenhouses have gone out of business within the last decade. Rebates for high-efficiency equipment play a critical role in growers' ability to install high-efficiency equipment, and can help them to stay in business. Grower interviews suggest this may apply to both large and small operations. Because of the importance of the agricultural market to California's economy, and because of the tenuous financial situation of many agricultural operations, utility incentives can provide some financial relief to growers who are otherwise unable to install efficient equipment.

2.8.2 Greenhouse Findings

Energy saving opportunities exist within the greenhouse sector, particularly with respect to the building shell. Interviews for this MASI study indicated that in the absence of utility programs, growers likely would revert to installing single-layer polyethylene film. However, there are higher-efficiency materials available for greenhouse shells that may be under-incentivized when compared to the materials that utilities currently incentivize. This is especially true when considering the measure life of the different materials. There may be opportunities to increase efficiency by promoting rebates for higher-efficiency materials, such as polycarbonate or acrylic. Other shell measures such as heat curtains and shade cloths may present additional energy saving opportunities. However, Navigant's interviews suggested that growers may choose to use these materials based on the needs and sensitivity of their crop, and these rebates therefore may be more applicable for certain crop types rather than for the industry as a whole.

Although large growers tend to have more capital to invest in efficiency opportunities than small growers do, the volume of equipment that large must replace can place cost constraints on large growers' efficiency efforts. Large growers arguably have more available funding to pursue energy efficiency than small growers have. However, because of the sheer amount of equipment that they must repair or upgrade regularly, large growers must pace their upgrades due to cost constraints. Grower and subject matter expert (SME) interviews revealed that many large growers will put off equipment upgrades or will revert to lower-efficiency options if there is no incentive available because they cannot afford to install higher-efficiency equipment. If utilities were to discontinue rebates for large greenhouse growers, the industry may revert to low-efficiency equipment or practices.

The use of VFDs is becoming more common in greenhouses. However, growers interviewed typically only use VFDs on large well pumps. There may be efficiency opportunities in offering VFDs on pumps and motors within the greenhouses, themselves. With the increasing penetration of water recycling and purification systems, and with the potential for increased use of conveyance for moving plant beds, VFDs may offer increasing efficiency for these pumps and motors. However, VFDs are not appropriate on all motors, so utilities should consider conducting targeted research into VFDs in greenhouses to pinpoint realistic savings opportunities for this measure.

As growers turn toward automated vent controls and other automated systems, the industry may see a corresponding increase in use of small motors. Many growers also use small fans for air movement. Growers reported that they typically do not repair these fans, as the labor costs are too high to warrant regular repair. Growers stated that they replace these fans regularly, and did not appear to prioritize energy efficiency in small fans.

2.8.3 Irrigated Agriculture Findings

Irrigated Agriculture growers are increasingly aware of energy-efficiency opportunities, but cost concerns drive their equipment decisions. Grower interviews suggest that farmers who pursue efficiency measures do so either because they understand the long-term savings that they will achieve with the installation, or because there was an incentive available to make high-efficiency measures cost-competitive. Farmer's rely heavily on their contractors for information about potential savings and rebates. However, according to growers, contractors and utility staff now have less time to discuss efficiency opportunities with them due to increased interest in efficient measures across the industry. Some growers claimed that they are "at the whim" of contractors, and that contractors' schedules may not always align with those of the farmers. Due to time constraints, some farmers have begun installing their own equipment. If this continues, it may result in missed opportunities in efficiency, as growers' top priority is to get their equipment running rather than focus on system optimization or efficiency. There may be opportunities for utilities to perform system optimization reviews beyond the standard pump efficiency testing to ensure that farmers have properly designed and installed their systems.

Farmers are increasingly aware of the benefits of VFDs, although VFDs are more common in large farms and on larger pumps. According to grower interviews, small and medium-sized growers are less likely to have VFDs on their pumps, and are also less likely to see the benefits of VFDs. Educating and offering incentives to smaller farms may therefore present an opportunity for future potential savings. This opportunity will be particularly relevant if the market continues to move away from gravity-based systems and toward pressurized systems such as drip because pressurized systems may require increased pumping. If they have not already done so, utilities should consider conducting targeted research into VFD applications to estimate energy saving potential from VFD applications on small farms.

The irrigated agriculture market is moving toward the use of computerized systems to determine the timing and quantity of their irrigation and fertilization practices. Although farmers see the benefits of these systems, the upfront cost of the technology often prohibits farmers of all sizes from using these technologies on a broad scale. Farmers are typically only able to afford one or two moisture sensors, although they may have thousands of irrigated acres in operation. There may be energy saving opportunities present in computerized systems, but utilities should ensure that the products they incentivize are reliable, easy to use, and that the company is on-track to remain in business into the future. If utilities do promote these computerized systems, they should also ensure that growers understand how to use the systems; otherwise, they may not achieve the highest amount of savings possible.

3 Recommendations

Based on a review of existing literature and market analyses, as well as in-depth interviews with IOU program managers, SMEs, and growers, Navigant has developed the following recommendations for California IOUs:

Schedule program marketing around the growing season, and conduct field tests, verifications, installations, and rebates according to this schedule. Growers' primary concern is that their equipment is functioning properly during the planting, growing, and harvest seasons. Growers will therefore take any action necessary to ensure their equipment is running, including installing lower-efficiency equipment if it is available at the time they need it. If utilities do not align field tests with growers' schedules, growers will be far less likely to install equipment that requires these field tests. Furthermore, if growers must wait to install equipment until utilities can conduct a pre-inspection, then growers may forgo the incentive and install whatever equipment is available. This may lead to growers installing lower-efficiency equipment. By scheduling inspections and installations around the growing season, utilities are more likely to encourage growers to install higher-efficiency equipment.

Focus on educating contractors on efficiency opportunities, and develop relationships with these contractors. Contractors are an important source of information for agricultural growers. However, not all contractors believe that measures such as VFDs offer energy savings. Furthermore, due to uncertainty surrounding rebate availability, some contractors avoid promoting utility programs, as any variance in the rebate amount or the time that it takes to receive a rebate can reflect poorly on the contractor. Utilities should therefore work with contractors to ensure that they understand the benefits of efficient equipment. In doing so, utilities may gain increased trust from their contractors, and contractors, in turn, may be more inclined to promote high-efficiency measures.

Incorporate system optimization services into program offerings, in addition to pump efficiency testing. Most irrigated agriculture respondents stated that they use the operating pressures from the original system design. However, both utility staff and SMEs expressed concern over the original designs. Respondents suggested that designers might overestimate the operating pressures to compensate for error, which would unnecessarily increase energy use. Furthermore, settings may naturally alter with the operation of the system over time. Utilities should take a systemic approach to ensure that all components of a growers' irrigation system are working synergistically and efficiently. This may be more relevant for larger farms than for smaller farms; however, utilities should explore potential savings in each. Utilities could provide these services to both irrigated agriculture and greenhouse customers as an extension of their pump efficiency program. By offering system optimization services, utilities could achieve increased savings from the system as a whole, as well as gain a better understanding of how growers are designing their systems.

Consider incentivizing moisture sensors and other information-based technologies. Responses from the interviews in this MASI suggest that the market already may be moving toward incorporating computerized controls or information systems into their irrigation planning and systems operation. This is true both of irrigated agriculture and of greenhouse operators. However, because of cost constraints, some farmers who are interested in these technologies are having trouble incorporating moisture sensors and other technologies across their operations, particularly for irrigated agriculture farmers. Incentives from utilities could help farmers invest further in this equipment, which could result in both energy and water conservation. However, while these systems typically can monitor factors such as energy and water use, growers must account for other factors such as fertilization, weather, and other environmental concerns. Therefore, any monitoring system that utilities might promote to growers would need to incorporate tracking other key factors in addition to energy and water usage.

Look at small- and medium-sized pumps as well as large pumps for efficiency opportunities in irrigated agriculture. While there are obvious savings available in targeting efficiency measures for large pumps, both large and small growers often use smaller pumps, as well. In particular, smaller farms with smaller irrigated plots may use small to mediums sized pumps for irrigation. Large farmers also tend to operate plots that can be geographically distant from each other, and may therefore use small- to medium-sized pumps for these plots. By targeting small- to medium-sized pumps as an area for efficiency opportunities, rebates and efficiency information can apply to farmers of all sizes, rather than simply targeting larger farms. This program offering can increase participation, as it is relevant to the entire market segment.

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Appendix B Program Manager Interview Guide

Thank you for taking the time to speak with us today. To give you some background we are conducting a market study on standard and emerging equipment installation practices in California's greenhouses and irrigated agriculture operations. As part of this study, we are interviewing IOU program managers to gain an understanding of the utilities' current programs, market trends, and utility customer characteristics. The information you provide through this interview will provide context for this study and help us to focus our subsequent interviews with subject matter experts, growers, and other market actors.

As we go through these questions, please focus solely on your service area's greenhouse operations and irrigated agriculture operations, including field crops; fruit, tree nut, and vine crops; floriculture operations; and vineyards and wineries.

B.1 Program Manager Introduction Questions

To begin, we would like to understand a little more about your utility's agricultural program offerings.

1. Through email, we spoke briefly about your agricultural program offerings. Do your agricultural programs target a particular type of customer, such as a particular market segment or a particular size?
2. Are there any technical or market barriers that your agricultural programs currently face, particularly as they relate to greenhouses and irrigated agriculture?
    a. If so, what are these barriers (for the Greenhouse and Irrigated Agriculture segments, specifically)?
    b. How are you working to overcome these barriers?
3. Does your utility have specific marketing efforts targeting greenhouses and irrigated agriculture?
    a. In your experience, does your program successfully reach these market segments?
    b. If not, what could be improved?
4. Do your participants typically grow certain types of crops (if so, which)?
5. Do you market your programs differently to agricultural customers than you would to other types of customers?
    a. What do these marketing efforts involve?
6. Do you track your agricultural program participants separately from industrial or other market sectors?
7. Who do you find to be the key decision-makers when working with your agricultural customers (i.e. are you typically working with owners, building managers, etc.)?

a. Does this vary by market segment?

b. Does this vary by crop type?

c. Does this vary by the size of the operation?

B.2 General Future Program Opportunities

8. Do you have any programs you are planning or that you envision launching in the near future?
9. When developing segment-specific program designs and/or marketing strategies for the 2016 program cycle, what information about the market is most important for you to consider?

Appendix C Subject Matter Expert Interview Guides

C.1 Greenhouses

Market Characteristics and Trends

» A major part of our study is understanding how energy use and equipment installation practices differ between small and large greenhouse operations. To do so, we need to understand what should constitute a 'small' vs. 'large' greenhouse operation. In your opinion, what is the best way to characterize the size of a greenhouse operation? [For example, by square footage, production, etc.]

» [IF NOT ENERGY CONSUMPTION] The utilities tend to characterize the size of a greenhouse operation by its energy consumption. In your opinion, does this way of characterizing the market have meaning for the greenhouse sector (i.e. does an energy-intensive operation typically fall into the "large" category, and do low-energy operations typically fall into the "small" category?

  - [IF NO] Why is this an inappropriate way of categorizing the size of a greenhouse operation?
  - [IF YES] Are there exceptions to this (i.e. does the method of characterizing size based on energy work for some crop types/market subsegments but not for others)?

» Around what size operation do you start to see changes in decision-making processes regarding energy usage and equipment replacement practices?

Equipment Replacement Practices

» Our understanding is that <u>owners</u> will typically be the main energy and equipment decision-makers on <u>small</u> greenhouses, while <u>large</u> greenhouses may have dedicated energy managers or facilities managers that make equipment replacement decisions. Would you agree with that? If no, why?

» When making equipment-related decisions, do you find that growers typically have an overall system design in mind, or do they make decisions about individual components independent from a design?

  - Do you find that larger greenhouse operations tend to view their equipment as an overall system, while smaller operations consider each piece of equipment independently?

» For those who view their greenhouse equipment as a system design, what factors influence the way in which growers design their greenhouse equipment?

  - How does this vary for large vs. small operations?

- o How does this vary by crop type (e.g. cut flowers vs. potted plants)?

» Have you seen any trends in greenhouse equipment types, for either small or large greenhouses?

» Would you say that most of today's greenhouse installations in California are retrofits, or are they new installations (either for new greenhouses or new additions to existing greenhouses)?

» To your knowledge, how do growers go about choosing and implementing *new* equipment? [IF NECESSARY] What factors influence their equipment decisions?

» Our understanding is that *existing* greenhouse growers will typically repair their equipment as much as they can rather than replacing it. Would you say this is accurate for both small and large greenhouse operations?

» For equipment replacements, what factors influence growers' decisions to replace on burnout vs. early replacement equipment, for large and small operations?
Small:
Large:

» Are there any instances in which a grower would replace their equipment early rather than repairing it? Please describe.

- o How does this vary based on operation size?

Equipment and Utility Influence

» To your knowledge, is it typical for growers in <u>small</u> operations to track their energy usage?

» To your knowledge, is it typical for growers in <u>large</u> operations to track their energy usage?

- o How do growers use this information?
Small:
Large:

» What processes are the most significant natural gas contributors in California greenhouse operations, for both small and large operations (e.g. heating greenhouses, soil purification, etc.)?
Small:
Large:

- o What equipment is/are involved in this/these process(es)?

» What processes are the most significant electric contributors in California greenhouse operations, for both small and large operations (e.g. lighting, space cooling, etc.)?
Small:
Large:

- o What equipment is/are involved in this/these process(es)?

» For this study, we're trying to understand the specific equipment types that growers will typically install in California greenhouses. Could you please describe the <u>energy-efficient</u> equipment that you might find in the <u>least</u> sophisticated greenhouse and then equipment you might find in the <u>most</u> sophisticated greenhouse for a California operation?

- Could you please describe the typical energy-efficient equipment that you might find in a *small* California greenhouse (e.g. heat curtains, IR film, etc.)?
  - About what percent of small greenhouses in California would you say have these technologies?
  - How does this vary by crop type?
- Could you please describe the typical energy-efficient equipment that you might find in a *large* California greenhouse (e.g. heat curtains, IR film, etc.)?
  - About what percent of large greenhouses in California would you say have these technologies?
  - How does this vary by crop type?

» Are there any crops for which the representative energy-efficient equipment does not apply, for small and/or for large greenhouses?

» How do the equipment usage practices differ between large and small operations (e.g. will large operations run equipment for longer than small operations, etc.)?

» Do you find that there is a trend toward energy efficiency, whether in small operations, large operations, or both?

- How does this vary by crop type?

» For this study, we're particularly interested in a specific set of measures. I'm going to read the list of greenhouse measures to you. Could you please let me know if you would consider these measures to be *standard* installations in California greenhouses, for either small or large greenhouses (i.e. growers typically install them in their greenhouses, regardless of whether or not they are incentivized)? [READ LIST, CHECK THOSE THAT ARE STARNDARD – FOR BOTH SMALL AND LARGE GREENHOUSES]

Equipment Type	Large Greenhouses	Small Greenhouses
Shade cloths		
Infrared film		
Shell insulation and glazing		
Double walls on new construction		
Thermal or heat curtains		
Boilers		
Condenser fans		
Unit heaters		
Geothermal heat pumps		
Bench (radiant) heating		
Domestic water heaters		

  - [*For those that are standard installations*] Are these measures typically installed as retrofit measures or new construction?

- » Who would you say are the most influential groups on growers' equipment purchasing and installation choices (e.g. trade associations, other growers, utilities, etc.)?
  - What are the reasons that these groups are influential for greenhouse operators?
  - How do these groups interact with greenhouse operators?
- » To your knowledge, when growers install energy-efficient technologies (in particular, IR film and heat curtains), do they usually apply for or receive utility incentives?
  - Is this true for both large and small greenhouses?
- » Do growers typically <u>wait</u> for an incentive before installing a new technology?
- » Do you think that growers would still install incentivized technologies if there was not an incentive available to them?
  - Are there any particular, existing technologies that growers currently would NOT install without a utility incentive?
- » When contractors work with growers on equipment replacement, do they typically promote individual components that have rebates associated with them, or do they look at whole system optimization for the greenhouse?
- » On a scale of 1-10, where 1 is not influential and 10 is very influential, how influential are utilities' programs on growers' energy equipment replacement practices?

- How does this vary by:
    - Greenhouse size
    - Replacement vs. new construction installations
    - Crop type

Future Opportunities

» Are there any existing technologies that you think will contribute heavily to operational energy savings in the future?

» Are there any emerging or state-of-the-art technologies that you think will contribute heavily to operational energy savings in the future?

» Do you know of any agricultural markets, either domestic or abroad, that you would consider to be progressive in terms of equipment and energy efficiency (e.g. Europe)?

- If so, what about these markets makes them progressive?

» What technologies do growers in these markets use that are not as widely used within California agriculture?

Close

» Do you have any suggestions for other subject matter experts whom you think we should interview for this study?

» Are there any other market actors (e.g. manufacturers, trade associations) with whom you think we should talk?

» Are there any growers that you would suggest we interview for this study?

» Is there anything else related to California greenhouses or greenhouse equipment that you think we should know?

» Thank you for taking the time to speak with us today. If we have further questions, would it be alright to reach out to you?

Thank you again, have a great day.

C.2 Irrigated Agriculture

Market Characteristics and Trends

- A major part of our study includes understanding how energy use and equipment installation practices differ between small and large farms. To do so, we need to understand what should constitute a 'small' vs. 'large' farm. In your opinion, what is the best way to characterize the size of a farm? [For example, by acreage, production, etc.]
- [IF NOT ENERGY CONSUMPTION] The utilities tend to characterize the size of a farm by its energy consumption. In your opinion, does this way of characterizing the market have meaning for the irrigated agriculture sector (i.e. does an energy-intensive farm typically fall into the "large" category, and do low-energy farms typically fall into the "small" category?
  - [IF NO] Why is this an inappropriate way of categorizing the size of a farm?
  - [IF YES] Are there exceptions to this (i.e. does the method of characterizing size based on energy work for some crop types/market subsegments but not for others)?
- Around what size farm do you start to see changes in decision-making processes regarding energy usage and equipment replacement practices?

Irrigation System Design

- When making equipment-related decisions, do you find that growers typically have an overall system design in mind, or do they make decisions about individual components independent from a design?
  - Do you find that larger farms tend to view their equipment as an overall system, while smaller farms consider each piece of equipment independently?
- For those who view their irrigation systems as a system design, what factors influence the way in which growers design their irrigation systems?
  - How does this vary for large vs. small farms?
  - How does this vary by crop type (e.g. tree vs. field crops)?
  - How does this vary by irrigation system type?
- For this study, we're trying to understand what current irrigation systems look like on California farms, in terms of design, maintenance, and usage practices. Could you please describe the least sophisticated irrigation system and then the most sophisticated irrigation system for a California farm?
  - Could you please describe a representative irrigation system for a small farm?
    - About what percent of small farms in California would you say have this irrigation system type?
    - How does this vary by crop type?

  - Could you please describe a representative irrigation system for a large farm?
    - About what percent of large farms in California would you say have this irrigation system type?
    - How does this vary by crop type?
  - Are there any crops for which the representative irrigation system type does not apply, for small and/or for large farms?

» When California growers install equipment on their farms, is it typically as a replacement/retrofit or are they new installations?

  - [IF NEW INSTALLATIONS], Is this typically on ground that has never been previously used for agriculture, or is this for existing agricultural land where the farmer is planting a new crop?

» Our understanding is that farmers will typically repair their equipment as much as they can rather than replacing it. Would you say this is accurate for both small and large farms?

  - In what instance might a farmer replace their equipment early (rather than repairing it or using it until it burns out)?
  - How does this vary based on farm size?

» To your knowledge, how do growers go about choosing and implementing <u>new</u> equipment? [IF NECESSARY] What factors influence their equipment decisions?

» What are the most common irrigation <u>control</u> types for large and for small farms?

  - How does this vary by crop?

» Have you seen any trends in irrigation equipment types or system design in recent years, for either small or large farms?

  - [IF PRESSURE CONVERSION WAS NOT AN ANSWER] Do you find that there is a trend toward lower-pressure irrigation systems, whether in small farms, large farms, or both?
    - How does this vary by crop type?

Equipment Replacement Practices

» To your knowledge, is it typical for growers on <u>small</u> farms to track their energy usage?

» To your knowledge, is it typical for growers on <u>large</u> farms to track their energy usage?

  - How do growers use this information?
    Small:
    Large:

» Our understanding is that owners will typically be the main energy and equipment decision-makers on small farms, while large farms may have dedicated energy managers or facilities managers that make equipment replacement decisions. Would you agree with that statement?

» Could you please give a brief description of the energy-efficiency and energy-using equipment that you would find on a typical:

   - Row or field crop farm:
   - Fruit, tree nut, or vine-crop orchard:
   - Vineyard:
   - How does this equipment vary by farm size?

» For this study, we're particularly interested in a specific set of technologies. These technologies include:

   - Irrigation controls, particularly on small farms
   - Irrigation delivery systems
   - Pump types
   - Water purification systems
   - Water recycling systems
   - Moisture level sensors
   - Pump efficiency testing

» Could you please tell me, in your experience, what are the most common:

   - Pump types, on small and large farms:
   - Water purification systems, on small and large farms:
   - Water recycling systems, on small and large farms:

» To your knowledge, approximately what percentage of California farms use moisture sensors?

   - How does that vary between large and small farms?
   - What are the most common types of moisture level sensors on small and large farms?

» Are there any technologies in particular that you think utilities should incentivize for the California Ag growers?

» Do you find that farmers typically get regular pump tests?

   - How does this vary by small vs. large farms?
   - Do growers typically receive rebates for their pump tests?
   - [IF YES] Do you think growers would get regular pump tests if there were no incentives available for them?

- To your knowledge, when growers install irrigation technologies (e.g. irrigation distribution systems, pump controls, etc.), do they usually apply for or receive utility incentives?
  - Do growers typically wait for an incentive before installing a new technology?
  - Do you think that growers would still install incentivized technologies if there was not an incentive available to them?
  - Are there any existing technologies that growers currently would NOT install without a utility incentive?
- When contractors work with growers on equipment replacement, do they typically promote individual technologies or components that have rebates associated with them (e.g. VFD on a pump), or do they look at whole system optimization for the farm (e.g. pump optimization for all pumps)?
- Who would you say has the most influence over growers' equipment purchasing and installation choices (e.g. utilities, trade associations, other growers, etc.)?
- On a scale of 1-10, where 1 is not influential and 10 is very influential, how influential are utilities' programs on growers' energy equipment replacement practices?
  - How does this vary by:
    - Farm size
    - Replacement vs. new construction installations
    - Crop type

Water Conservation

- Could you please describe any common practices in irrigation scheduling that you are aware of among irrigated agriculture growers?
  - How does this vary by farm size?
- What actions are growers taking to reduce water usage?
- To what extent are growers water-stressing their crops to reduce water usage?
- In your opinion, to what extent would growers be making concerted efforts to conserve water if they were not in drought conditions?
- In what ways has the drought changed irrigation practices on California farms so far?
  - How does this vary for large vs. small farms?

Future Opportunities

- Are there any existing technologies that you think will contribute heavily to on-farm energy savings in the future?

- Are there any <u>emerging</u> or state-of-the-art technologies that you think will contribute heavily to on-farm energy savings in the future?
- Do you know of any agricultural markets, either domestic or abroad, that you would consider progressive in terms of equipment and energy efficiency (e.g. Europe)?
  - If so, what about these markets makes them progressive?
  - What technologies do growers in these markets use that are not as widely used within California agriculture?

Close

- Do you have any suggestions for other subject matter experts whom you think we should interview for this study?
- Are there any other types of market actor (e.g. manufacturers, trade associations) with whom you think we should talk?
- Are there any growers that you would suggest we interview for this study?
- Is there anything else related to California irrigated agriculture or irrigation equipment that you think we should know?
- Thank you for taking the time to speak with us today. If we have further questions, would it be alright to reach out to you?

Appendix D Grower Interview Guide

D.1 Greenhouses

Thank you for taking the time to speak with us today. To give you some background we are conducting a market study on equipment installation practices in California's greenhouse operations. As part of this study, we are interviewing growers to understand what equipment you are installing in your greenhouses and how you make decisions about your equipment. The information you provide will help utilities to determine the best equipment to incentivize in future programs.

Throughout this interview, I will make references to greenhouse "equipment." To clarify; by equipment, I mean any energy-using technologies within a greenhouse, such as fans, water heaters, irrigation distribution systems, VFDs, etc. In this context, I will also use this term to refer to energy-efficient additions to the greenhouse structure/envelope, such as heat curtains, infrared film, wall glazing, etc. Before we begin, do you have any questions about the study or about how I am using the term "equipment"?

Intro

1. What are the main crops that your greenhouse operation produces?
2. Do you produce this same main product yearly, or do you rotate or change your crop based on the season or other factors?
3. Approximately how many square feet of greenhouse space do you own and/or operate?
4. Approximately what percentage of your greenhouse space has been built in the last 5 years?
5. Do you consider yourself to be a small, medium or large operation? What are the reasons you would classify yourself as this size?
6. Is all your greenhouse space located at once site, or do you have multiple sites operating under one operation?
7. Which processes and equipment use the most electricity in your operation?
8. Which processes or equipment in your operation use the most natural gas?

Decision-making Practices

9. What systems, methods, or equipment do you use to track energy and water usage?
10. Do you track production? If so, how do you track this and what do you do with the information?
11. Could you please describe your decision-making process when deciding to install new equipment or replace existing equipment?

12. Do you typically work with a contractor, vendor, retailer or consultant when installing equipment?
    a. On a scale of 1-10, how influential are contractors, vendors, retailers or consultants on your choice of equipment?
13. Is there anyone else who influences your equipment installation decisions?

New Construction [IF NC GREENHOUSES > 0%]

14. [IF the respondent has built new greenhouses within the last 5 years] Thinking only about the greenhouse space that you've built within the last five years, how many layers of glazing and/or shell insulation did you install when you built these greenhouses?
15. [IF YES] Was any of this glazing or insulation rebated?
    a. If so, approximately what percent of the glazing or insulation was incentivized or rebated?
    b. If a rebate had not been available, would you still have installed the same type and amount of glazing or insulation?
    c. On a scale of 1-10, how influential was the rebate on your decision to install additional glazing or insulation on your greenhouses?

Insulation – Retrofit (IF NC GREENHOUSES < 100%)

16. For your greenhouses that are *over* 5 years old, or for any greenhouses on which you installed *additional* glazing or insulation, how many layers of glazing do your greenhouses currently have?
17. What type of glazing or insulation do you have on your older greenhouses?
18. Do you have any other forms of shell insulation on your older greenhouses?
19. In the last five years, have you added additional glazing or insulation to any of your older greenhouses?
    a. If so, how many layers did you originally have and how many layers did you add?
    b. Did you receive a rebate for your additional glazing or insulation?
        i. If a rebate had not been available, would you still have installed the additional glazing or insulation?
        ii. On a scale of 1-10, how influential was the rebate on your decision to install additional glazing or insulation on your greenhouses?
20. Do you have any plans to add additional layers of glazing or insulation in the near future?
    a. What type of glazing or insulation do you plan to install on your greenhouses?
    b. How many layers or glazing or insulation do you plan to install?

c. On a scale of 1-10, where 1 is not at all likely and 10 is very likely, what is the likelihood that you will add this glazing or insulation if there is NO REBATE/INCENTIVE AVAILABLE?

Other Measures

I am now going to read you a list of equipment types. Again, by "equipment" I mean any energy-using technologies within a greenhouse, such as fans, water heaters, irrigation distribution systems, VFDs, etc. In this context, this term also includes technologies relating to the greenhouse structure/envelope, such as heat curtains, infrared film, wall glazing, etc.

As I read through the list, please tell me whether you currently have any of the technologies in your greenhouses? If you do have them, please also tell me what level of efficiency each technology is, the approximate square footage of greenhouse space it serves, and the last time that you replaced any of this equipment?:

Equipment Type	Have? (Yes/No)	Efficiency Level	Square Footage Served	Last Replaced
Infrared Film				
Heat Curtains				
Shade Cloths				
Boilers				
Condenser Fans				
Unit Heaters				
Geothermal Heat Pumps				
Bench (radiant) Heating				
Domestic Water Heaters				

21. When you installed or replaced this equipment, did you receive a rebate or incentive for any of it?
    a. [For each equipment type] If you had not received a rebate or incentive for the equipment, would you still have installed
        i. The same type of equipment?
        ii. Same level of efficiency?
        iii. Same amount?

iv. Would you have installed it at the same time?

b. On a scale of 1-10, how influential was the rebate on your decision to install this equipment?

22. Do you plan to replace any of this equipment in the near future? If so, which?

    a. [If yes] On a scale of 1-10, where 1 is not at all likely and 10 is very likely, what is the likelihood that you will replace this equipment if there is NO REBATE/INCENTIVE AVAILABLE?

23. Are there any other energy- or water- efficient equipment that you've installed in your greenhouses in the last five years? (Please elaborate)

    a. How many/much (equipment type) did you install?

    b. Was this equipment installed as a retrofit, a replacement, or was it installed in a new greenhouse? [Ask for each equipment type]

    c. Did you receive rebates for any of this equipment? [Identify which equipment was rebated]

        i. Who did you receive the rebate from (i.e. which utility)?

Irrigation Equipment

24. What do you use water for in your operations (e.g. irrigation, cleaning, etc.)?

25. Where does your irrigation water come from (e.g. well, irrigation channel, river, etc.)?

26. What type of water/irrigation distribution system(s) do you have in your greenhouses?

27. How long have you had your current irrigation system in place?

    a. [If <5 years] What type of irrigation system did you have before this one?

    b. [If <5 years] What is the reason that you changed irrigation system types?

28. Could you please describe your irrigation practices (e.g. when do you irrigate and for how long, at what operating pressure, how do you decide when to irrigate, etc.)? How does this vary with the crop?

29. Do you have a water purification system in your greenhouses?

    a. What do you use this for?

    b. How old is this system?

    c. What capacity is this system?

30. Do you have a water recycling systems in your greenhouses?

    a. What do you use this for?

    b. How old is this system?

c. What capacity is this system?

Motors

31. Do you use any motors in your operation? [IF NO, SKIP TO NEXT SECTION]
    a. If so, what are your motors used for?
32. What typical size range of motors does your facility use? What is the predominant size?
33. What is the approximate age of your motor equipment?
34. What types of motors do you use in your operation? (i.e. DC, AC, AC permanent magnet motors etc.,)
35. How do you approach motor replacements and/or upgrades? (e.g. do you have a phased schedule or bulk replacement strategy, replace on failure system, green motor rewind, repair versus replace views, etc.?)
    a. What are the costs and drivers associated with replacing vs. repairing motors?
    b. Are there any motors that you consistently repair or rewind rather than replacing?
    c. What would motivate you to replace those?
36. We would like to understand if there are any motor efficiency or operational practices that are considered "standard" by your organization?
    a. Do you take any energy-efficiency efforts that go beyond regulations (e.g. have you installed VFDs on your motors, do you perform system optimization more frequently than required, etc.)?
37. What specific resources and services do you use to learn about motor efficiency opportunities? (e.g. how do you inform yourself about energy efficiency, O&M activities, new technologies and equipment, etc.?)
    b. Do you consider utility rebate programs for motors? Why or why not?
38. What are the drivers behind your efforts to pursue energy-efficiency opportunities for your motor equipment or process changes? (e.g. energy savings vs. maintenance [cost & time] savings etc.?)
39. Do you use VFDs on your pump(s)? (determine number of pumps, HP, well or booster)
40. (If yes) Why did you decide to install a VFD?
41. (If yes) Did you receive an incentive or grant from your utility or another organization for the VFD?
42. (If yes) Did you install the VFD at the time your pump was new or as a later addition?
43. (If not) Did you consider installing a VFD? (If yes) What factors did you consider?

Emerging Equipment

44. Are there any state-of-the-art water- or energy-efficient technologies that you've heard of that you would be interested in installing in your greenhouses?
    a. If your utility offered a rebate for these technologies, would you be willing to implement them in your greenhouses?

Close

45. Are there any other growers you can suggest we speak with for this study?
    a. If so, could you please provide their name and contact information?
46. Is there anything else about your greenhouse operation that you think we should know?
47. Thank you for taking the time to speak with us today. If we have further questions, would it be alright to reach out to you?

Those are all the questions that I have for you today. Thank you again for your time, have a great day.

D.2 Irrigated Agriculture

Thank you for taking the time to speak with us today. To give you some background, we are conducting a market study on irrigation system design on California's irrigated farmland. As part of this study, we are interviewing growers to understand how you are designing and using your irrigation systems. The information you provide will help utilities to determine the best ways to provide incentives in the future.

Throughout this interview, I will make references to farm "equipment." To clarify; by equipment, I mean any energy-using technologies on your farm, such as pumps, motors, irrigation distribution systems, VFDs, etc. Before we begin, do you have any questions about the study or about how I am using the term "equipment"?

Intro

1. What are the main crops that you grow on your farm?
2. Do you produce this same main product yearly, or do you rotate or change your crop based on the season or other factors?
3. Approximately how many acres of agricultural land do you own and/or operate on this farm?
    a. How many of these acres do you irrigate?
4. Approximately what percentage of your irrigated land have you added last 5 years, if any?
5. Do you consider yourself to be a small, medium, or large operation? What are the reasons that you classify yourself as this size?
6. Which processes and equipment use the most electricity in your operation?
7. Which processes or equipment in your operation use the most natural gas?

Decision-Making Practices

8. What systems, methods, or equipment do you use to track energy and water usage?
    a. Do you track your water distribution uniformity? If so, how do you track this and what do you do with the information?
    b. Do you track production? If so, how do you track this and what do you do with the information?
    c. Do you use moisture sensors or irrigation controls, such as timers, automatic pump controls, SMS, flow meters, on-farm weather stations, etc.? (Probe which they use)
        i. [IF NO?] What might motivate you in the future to install irrigation controls on your irrigation system?
9. Could you please describe your decision-making process when deciding to install new equipment or replace existing equipment? (If necessary, prompt – how did you decide what to

install, when to install it, what alternatives they considered, and did they look at first cost only or lifecycle cost?)

Irrigation System Design

10. What type of irrigation or water delivery system(s) do you have? [DO NOT PROMPT, but if they need clarification, give examples: impact sprinkler, center pivot, hand-move sprinkler, subsurface drip, etc.]
11. How long have you had your current irrigation system in place?
    a. [If <5 years] What type of irrigation system did you have before this one?
    b. [If <5 years] What is the reason that you changed irrigation system types?

Irrigation System Usage

12. At what operating pressure do you typically run your irrigation system at the pump?
    a. Was this the operating pressure that the system was originally designed for, or did you change it after the system was installed? If you changed it, why?
    b. How do you monitor your operating pressure?
13. Have you changed your water scheduling practices in the last 5 years? What are the reasons that you made these changes in your water usage?
14. Could you please describe how you schedule your irrigation?
    a. How do you decide how long of sets to run?
    b. How do these practices change depending on the time of year?
15. Have you changed your water usage practices in the last 5 years? If so, please elaborate.
16. Would you please describe your maintenance practices that you use for your irrigation equipment? For instance, do you have a regular maintenance schedule for your irrigation equipment or do you perform maintenance as necessary?
17. On a scale of 1-10, how likely is it that you would have adopted these changes if California had not been in drought conditions?
18. Do you have a water purification system on your farm?
    a. What do you use this for?
    b. How old is this system?
    c. What capacity is this system?
19. Do you have a water recycling systems on your farm?
    a. What do you use this for?
    b. How old is this system?

c. What capacity is this system?

Pumps and Motors

20. Where does your irrigation water come from (e.g. well, irrigation channel, river, etc.)?
    a. [IF WELL] How deep is your well?
21. How many pumps and motors do you currently have in operation on your irrigated farmland? (Record both # pumps and # motors)
22. Do you use motors for anything other than irrigation pumping on your farm? (If so, please elaborate)
    a. If so, what are your motors used for?
    b. What typical size (horsepower) range of motors does your facility use? What is the predominant size?
    c. What is the approximate age of your motor equipment?
    d. What types of motors do you use in your operation? (i.e. DC, AC, AC permanent magnet motors etc.,)
23. What types of pumps do you have how many of each pump type do you have (e.g. submersible, turbine, end-suction centrifugal, etc.)?
    a. [IF NOT ALREADY ANSWERED] Do you have booster pumps on any of your irrigation lines (how many)?
24. What are the sizes (hp) of your pumps? [ASK FOR EACH PUMP TYPE]
25. How many of these pumps did you install in the last 5 years? Were these replacement pumps or new pumps?
    a. For new pumps, were these installed on new wells and/or land that was not previous used for agricultural purposes?
    b. Did you receive an incentive for any of these pumps?
    c. [IF YES] On a scale of 1-10, if the incentive had not been available to you, what is the likelihood that you would have installed the same pump at the same time?
26. How do you typically approach replacements and/or upgrades for your pumps and motors? (e.g. do you have a phased schedule or bulk replacement strategy, replace on burnout, repair versus replace views, etc.?)
    a. What are the costs and drivers associated with replacing vs. repairing pumps and motors?
    b. When you buy a new pump or motor, how do you decide what efficiency level to purchase and install?

27. Would you please describe your pump and motor maintenance practices? For instance, do you have a regular maintenance schedule for your or do you perform maintenance as necessary?
28. Are there any efficiency practices (e.g. regular motor rewinds or pump efficiency testing) that you would consider a standard practice for your operation?
29. How frequently do you perform pump efficiency tests on your pumps?
    a. Are these pump tests typically subsidized by your utility?
    b. Would you perform regular pump tests if there were no subsidies available? Why or why not?
    c. When you get pump tests, do you typically test all your pumps, or only one pump at a time?
    d. What do you do with the information that you get from pump efficiency tests?
    e. What would motivate you to replace your pumps before they fail?
30. What specific resources and services do you use to learn about motor efficiency opportunities? (e.g. how do you inform yourself about energy efficiency, O&M activities, new technologies and equipment, etc.?)
    a. Do you consider utility rebate programs for efficient motors? Why or why not?
31. What are the drivers behind your efforts to pursue energy-efficiency opportunities for your motor equipment or process changes? (e.g. energy savings vs. maintenance [cost & time] savings etc.?)
32. Do you use VFDs on your pump(s)? (determine number of pumps, HP, well or booster)
33. (If yes) Why did you decide to install a VFD?
34. (If yes) Did you receive an incentive or grant from your utility or another organization for the VFD?
35. (If yes) Did you install the VFD at the time your pump was new or as a later addition?
36. (If not) Did you consider installing a VFD? (If yes) What factors did you consider?

Other Equipment Installations

37. In the last five years, have you installed any other equipment or taken any other actions that we haven't discussed in order to conserve water or energy? Please elaborate.
38. Are there any state-of-the-art water- or energy-efficient technologies that you've heard of that you would be interested in installing on you irrigated farmland?
39. Is there anything that utilities can do to help you more effectively manage your water and energy?

Close

40. Are there any other growers you think we should speak with for this study?
    a. If so, could you please provide their name and contact information?
41. Is there anything else about your operation that you think we should know?
42. Thank you for taking the time to speak with us today. If we have further questions, would it be alright to reach out to you?

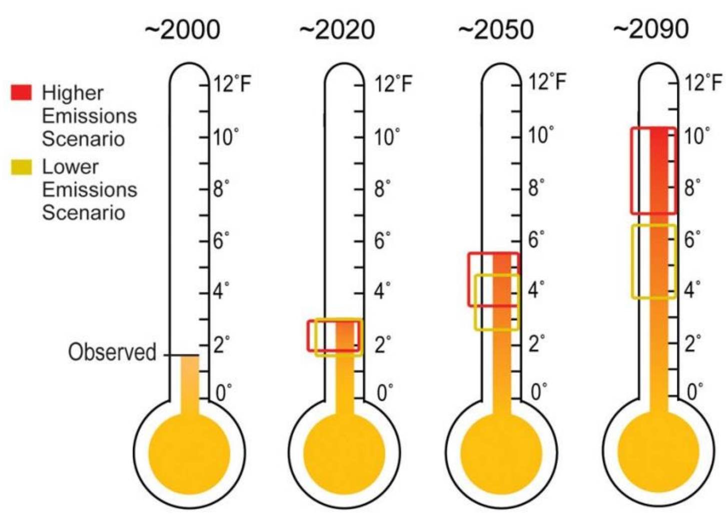
Those are all the questions that I have for you today. Thank you again for your time, have a great day.

Appendix E Environmental Trends

This Appendix includes an excerpt from Navigant's 2010-2012 Agriculture Market Characterization, which describes the effects of changing environmental conditions on California's agricultural subsesegments.

Environmental Impacts on Fruit, Tree Nut & Vine; Greenhouses & Nurseries; Field Crops
Both fluctuations in degree days and the shortage of reliable water will negatively influence the production of many of California's most crucial crops. In particular, increasing temperatures are leading to the decline in winter chill hours, or the number of hours below a certain temperature in which a plant remains dormant before spring growth (see **Error! Reference source not found.**). This trend has the most ignificant impact on fruit and tree nuts, which depend on winter chill hours to properly set fruit. Insufficient chill hours can result in late blooming, which in turn decreases fruit quality and economic yield.[30] A 2008 study commissioned by the California Energy Commission found that declining chill hours has had the greatest negative impact on cherries, while high spring temperatures have brought the most harm to the production of almonds – California's most valuable perennial crop.[31] None of the studies identified benefits to increased temperatures, indicating that the warming climate will only negatively influence crop yield and quality, and in turn, California's agricultural market.

Figure 4. Observed and Projected Temperature Change in the Southwest, Compared to a 1960-1979 Baseline Period

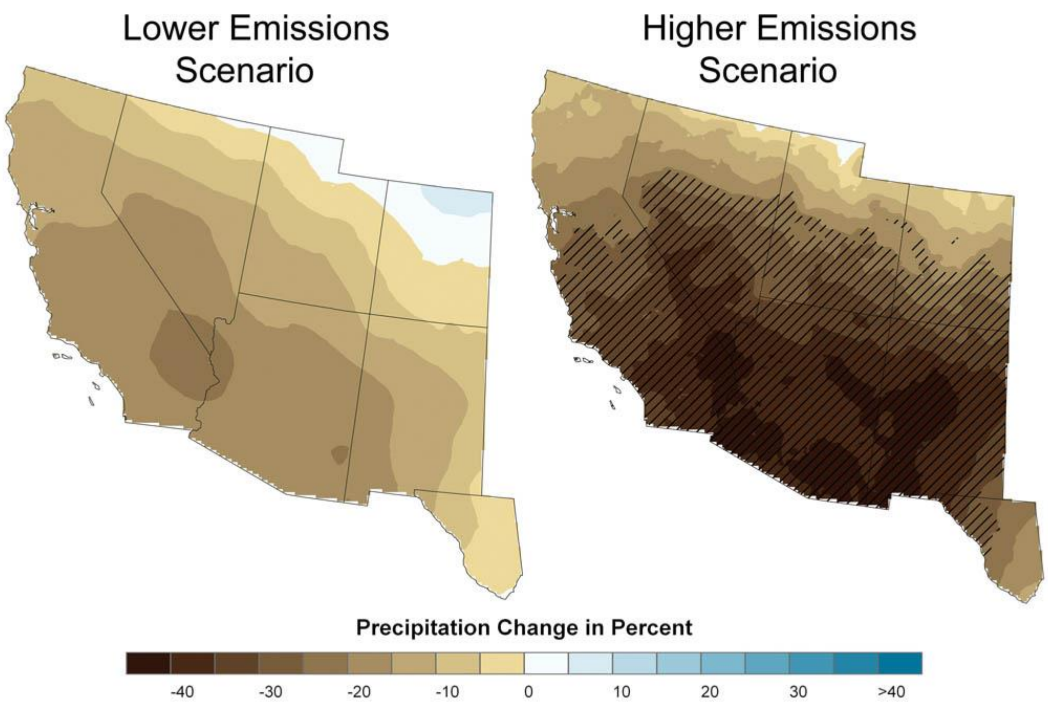


Source: EPA[32]

[30] California Climate Change Center, 2008. http://www.energy.ca.gov/2008publications/CEC-500-2008-077/CEC-500-2008-077.PDF.
[31] California Climate Change Center, 2009, *California Perennial Crops in a Changing Climate*. http://www.energy.ca.gov/2009publications/CEC-500-2009-039/CEC-500-2009-039-F.PDF.

Water scarcity will further harm crop yields in these market segments. Climate change studies across the board identify a drying trend throughout California, as available water from both the Sierra Nevada snow packs and from precipitation has declined (see **Error! Reference source not found.**). These factors an lead to extreme water shortages or drought, effectively limiting the water available for irrigation. Moreover, warming temperatures across the globe are leading to sea level rise. At a localized level, this is resulting in saltwater intrusion in the Delta region and the Salinas and Monterey areas, which could further restrict fresh water resources.[33] The climate-induced trends discussed here may direct crop selection toward row crops, which are less dependent on long-term water supplies and winter temperatures. However, crops of all types will likely suffer from the effects of climate change.

Figure 5. Spring Precipitation Change for 2080-2099 Compared to 1961-1979 under Two Emissions Scenarios



Source: United States Environmental Protection Agency, "Climate Impacts in the Southwest." http://www.epa.gov/climatechange/impacts-adaptation/southwest.html#impactsagriculture.
[1] California Statewide Adaptation Strategy.

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[32] United States Environmental Protection Agency, "Climate Impacts in the Southwest." http://www.epa.gov/climatechange/impacts-adaptation/southwest.html#impactsagriculture.
[33] California Statewide Adaptation Strategy. http://www.climatechange.ca.gov/adaptation/documents/Statewide_Adaptation_Strategy_-_Chapter_8_-_Agriculture.pdf.

Water scarcity will not only harm crop yields, but could also result in financial losses and further trickle-down effects for the California's crop-producing market segments. Population growth in urban areas is notably increasing throughout California, creating further competition for water resources between urban and agricultural customers. Research has found that droughts, competition for resources, and water delivery constraints have "led to losses in excess of $1 billion annually to Central Valley agriculture, translating to tens of thousands of lost jobs, and a reduction in world food supply."[34] Studies estimate that if fresh water availability were more than 20 percent below demand, the agricultural market would incur annual costs of $200 million.[35] Liabilities such as these could inhibit lending from financial institutions in the future, which could further limit growers' abilities to invest in their businesses or in energy-efficient technologies.

Environmental Impacts on Vineyards & Wineries

Due to the nature of the wine grape crop, the Vineyards & Wineries market segment will see slightly different effects on their production as compared to other crop segments. Because grape growth requires less water than other crops, water shortages will have less of an impact on this particular segment. Rather, the change in ambient temperature will have the most significant effect on California wine grape production.

Premium wine grape production requires moderate climate and weather conditions, including adequate heat, low risk of severe frost damage, and a lack of extreme heat.[36] Given the needed conditions, wine grape production will presumably decrease with the higher prevalence of hot days. According to a 2006 study on the effects of extreme heat on premium wine production,[37] certain regions in the US could see as many as 60 extreme hot days per season. The most heat-tolerant wine grapes can only withstand about 14 days of extreme heat, suggesting that much of California's premium wine production will not be able to withstand the rising temperatures.[38] Noah Diffenbaugh, the study's co-author, stated during an interview: "We see production disappearing essentially in what are the prime producing areas, which is Napa Valley, Sonoma Valley, the Santa Barbara area [California] and the Willamette Valley [Oregon]."[39] Future production will likely be limited to coastal and northern areas, predominantly in Oregon and Washington, to the detriment of the California wine market.

Energy Impacts from Environmental Trends

These environmental trends will have the most significant impacts on the California agricultural market through water shortages and higher temperatures. Because of these factors, the industry will likely increase energy usage for irrigation, space cooling and refrigeration. Water shortages and increasing resource competition with urban populations could potentially force agricultural customers to pump water from new sources such as aquifers and potentially desalination efforts. Market segments such as

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[34] Ibid.

[35] Ibid.

[36] White, M., Diffenbaugh, N., Jones, G., Pal, J., and Giorgi, F.,2006, *Extreme heat reduces and shifts United States premium wine production in the 21st century.* http://www.pnas.org/content/103/30/11217.abstract.

[37] Ibid.

[38] Zabarenko, Deborah, 2006,"Climate Change Could Slash U.S. Wine Industry." http://www.enn.com/top_stories/article/4644.

[39] Ibid.

refrigerated warehousing, post-harvest processing, and dairies will increase energy use for refrigeration to ensure the quality of their products. Livestock-related segments such as dairies and feedlots will devote more energy toward the cooling of their livestock to promote high levels of productivity and reproduction. The majority of increased energy usage is likely to be electrical in nature. Potential increases in natural gas usage may come from increased irrigation using natural gas-fired pumps.

Utilities can help manage these increases in energy use by working with agricultural customers to implement high-efficiency technologies in key areas. High-efficiency pumps, advanced refrigeration technologies, improved building shells, and cooling and ventilation technologies should be the focal points for utilities looking to combat the effects of climate change. Moreover, utilities can promote the use of proper irrigation scheduling, particularly for market segments with older equipment and crops that require heavy watering. By properly scheduling irrigation patterns, growers may be able to simultaneously manage water usage while using electricity during off-peak hours.

Other market trends directly affect the Greenhouse and irrigated agriculture segments. The following subsections describe these trends in further detail.