Energy Research and Development Division

**FINAL REPORT**

# Wexus Energy and Water Management Mobile Software for the Agricultural Industry

PON-14-304

**California Energy Commission**

Edmund G. Brown Jr., Governor

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# PREFACE

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

In 2012, the Electric Program Investment Charge (EPIC) was established by the California Public Utilities Commission to fund public investments in research to create and advance new energy solution, foster regional innovation and bring ideas from the lab to the marketplace. The California Energy Commission and the state's three largest investor-owned utilities – Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company – were selected to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to their electric ratepayers.

The Energy Commission is committed to ensuring public participation in its research and development programs that promote greater reliability, lower costs, and increase safety for the California electric ratepayer and include:

- Providing societal benefits.
- Reducing greenhouse gas emission in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, next with renewable energy (distributed generation and utility scale), and finally with clean, conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

*Final Report* is the final report for the *Wexus Energy Management Mobile Software for the Agricultural Industry* project (Contract Number EPC-14-070) conducted by Wexus Technologies, Inc. The information from this project contributes to Energy Research and Development Division's EPIC Program.

All figures and tables are the work of the author(s) for this project unless otherwise cited or credited.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

California's agricultural industry is one of the state's largest users of energy and water and has been historically underserved by a lack of effective efficiency technologies. The agriculture industry is also rapidly transitioning to the next generation of technology: mobile, cloud-based software, big data, and connected devices in the field. The combination of rising energy rates, increasing regulation and reporting, drought and changing weather patterns is driving demand for new agricultural energy efficiency solutions. Farmers currently cannot manage what they do not measure, leading to higher operational costs.

This project deployed the Wexus (Water-Energy Nexus) mobile, cloud-based Internet of Things software platform into California's agricultural industry. The Wexus platform leverages existing utility meter infrastructure and additional sensors for real-time monitoring and control. Wexus helps agribusinesses quickly assess usage and cost information for electricity and water from virtually anywhere, on any mobile device. Through customized alerts and reporting, the platform allows farms to quickly respond to changes in energy usage, adjust and optimize equipment in the field, and reduce operational expenses due to energy costs.

Through collaboration with project partners University of California Davis and Polaris Energy Services Inc, this project further extended existing water-energy data analysis, visualization and remote controlling capabilities to the Wexus Internet of Things platform to further optimize water-energy resource management in the agribusiness sector.

Keywords: California Energy Commission, Agriculture, Agribusiness, Energy, Water, Sustainability, Water-Energy Nexus, Drought, California, Utilities

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# EXECUTIVE SUMMARY

## Introduction

California's agricultural industry is one of the state's largest users of energy and water and has been historically underserved with a lack of effective efficiency technologies and utility programs to meet the industry's unique needs. Eight million agricultural acres in California consume 80% of the total water pumped in the state and nearly eight percent (8%) of the state's total energy (CAWSI). **A combination of rising energy rates, increasing regulation and reporting of water consumption, unpredictable and prolonged droughts with changing weather patterns, and severe labor shortages are driving demand for new agricultural energy and water efficiency solutions.**

Wexus Technologies was founded in 2014 in response to a lack of energy management technologies for the agri-food industry (inclusive of agriculture, food processing, and irrigation districts) and in response to the severe California drought, which began in 2011. This drought was so severe that it was driving farms out of business due to a lack of surface water and high utility costs associated with pumping more groundwater. For most agricultural energy users, water pumping and irrigation are the most energy-intensive activities on-site, and they occur during the summer growing season when electricity rates are the highest. Thirty-three percent (33%) of on-farm water usage coincides with peak energy usage and peak energy pricing, resulting in farmers paying high prices on their energy bills in excess of $100,000 per month in many cases (CAWSI).

The multiyear Californian drought also led to an increase in policy activity related to the water-energy nexus. By May 2012, the California Public Utilities Commission filed Decision 12-05-015 which included guidance to expand water-energy nexus efficiency portfolios, programs, and cost-effectiveness calculations (CPUC 2016). During this time, investor-owned utilities (IOU's), the water sector, agricultural industry partners, and the public began collaborating in a series of workshops to progress the development of solutions (CPUC 2016). Prior to the drought and these policy drivers, utility-scale technologies and a policy framework did not exist for approaching the unique intersection of water and energy in California, even though movement of water in the state accounts for up to 20% of peak energy loads (CPUC 2019). It was abundantly clear to the Wexus team that **these policy changes in combination with new, highly scalable Internet of Things (IoT) technologies could solve many of water-energy nexus problems for the agricultural industry and utility ratepayers in California.**

In addition to high energy usage and costs, the agri-food industry faces several unique challenges. Farms in California often manage dozens or even hundreds of electric meters tied to irrigation pumps, processing facilities, buildings, and solar arrays across multiple ranch locations, spanning thousands to tens of thousands of geographical acres. They manage hundreds of different crop types with chronic shortages of qualified workers. Depending on the type of crop grown, a farm can be a low-margin business with cash flow affected by fluctuations in crop prices, labor, and weather patterns. This in turn leads to a lack of business operating funds to invest in new, critically needed efficiency technologies.

The agri-food industry lacks tools to manage energy consumption and costs at scale. The status quo is summarized, high-level day-old data or month-old paper utility bills. Irrigation pump efficiency ratings are also reported on paper. Monitoring energy consumption and costs down to each meter is near-impossible with manual, paper-driven methods and without field-deployable, connected data technologies. In addition, utility-scale water metering is essentially non-existent. Farms must use their own operating funds to pay for water monitoring, resulting in piecemeal deployments and prolific use of estimations. Prior to this project, the Wexus team also found that farmers saw energy bills as a "sunk cost" or "cost of doing business" and were spending up to 50% more on energy bills than necessary. In essence, farmers cannot manage what they cannot measure, and they need scalable, field-proven technologies.

**All of these problems are extremely important to note and to understand from a farmer's perspective, because they ultimately lead to higher operational costs for farms, as well as difficulties for the state of California to reach energy efficiency and greenhouse gas reduction goals.**

## Project Purpose

This project further developed the Wexus (water-energy nexus) mobile, cloud-based software platform for commercialization in California's agri-food industry. The Wexus mobile software platform helps agri-food businesses quickly access energy usage and spending data through an online web application. The platform connects to utility advanced metering infrastructure (AMI) via standardized Green Button Connect utility platforms, and additional hardware can be installed on-site and integrated into the platform for real-time, granular monitoring and alerting. The Wexus platform alerts farms via email reports, in-app notifications, and SMS text alerts to quickly adjust equipment in the field to drive energy efficiency and avoid peak time of use (TOU) hours, to reduce labor hours associated with reporting, and to save on utility bills.

The Wexus mobile software project benefits California ratepayers in investor-owned utility (IOU) territories by promoting greater electric grid reliability and lowered energy costs for farms. Wexus delivered a user-driven, feature-rich platform, specifically built for the agri-food industry. **There were three key overall goals for this project:**

- to <u>engage agricultural partner sites in California Investor Owned Utility (IOU) territories</u> to participate in the Wexus mobile software project and to identify energy efficiency measures at these sites;
- to <u>provide wider proof of concept and use cases</u> for scaling the Wexus mobile software platform throughout PG&E and SCE IOU regions in California; and
- to <u>fully assist and train partner sites in the effective use of the Wexus mobile software platform</u> and to <u>quantify actual energy savings after measures have been implemented</u>.

Working with agricultural business owners to reduce energy usage has historically been a large barrier to achieving the state's energy goals, because agricultural business owners do not traditionally relate their operational activities to actual energy usage. **This project had several key objectives:**

- To aid agricultural deployment sites in reducing their overall energy usage by providing actionable energy and cost data, including at peak times of day.
- Target potential energy reductions by up to ten percent from baseline usage.
- To continue to develop and refine the Wexus cloud-based software platform through deep analysis of utility electric meter data, utility tariff and rate data, utility bills, water usage data, greenhouse gas emissions data and continued agricultural customer feedback at the site level.
- To engage agricultural deployment sites in continuing education and training on the effective and efficient use of the technology to reduce their energy usage by up to ten percent, to identify potential energy savings measures in the field, and to quantify actual energy savings after savings measures had been implemented.

## Project Approach

Wexus conducted a real-world demonstration for this project, working with a select group of highly engaged, diverse farms: three farms in Pacific Gas & Electric (PG&E) territory and one in Southern California Edison (SCE) territory. Prior to this project, Wexus had developed a minimally viable product based upon market research. In order to continue refining the platform for this project, Wexus selected **four partner farms with representation from four different verticals: berry, row crop, dairy, and vineyard.** A variety of verticals was important, because different crop types have different growing schedules and irrigation needs and, thus, varying energy and water consumption patterns.

Each partner farm needed to commit to a multi-year project with frequent check-ins for site visits and feedback. Each partner farm was also required to have multiple ranch locations and several irrigation pumps/meters. In total, **the project included a total of 47 irrigation pumps connected to 36 electric utility meters across 11 ranches, covering a total of 3,700 acres.**

For each partner farm, the Wexus team conducted an initial site visit to audit existing equipment specifications and to understand on-site operations through one-on-one interviews with employees. The Wexus team used this information in conjunction with historical electricity data to determine potential energy savings measures. The team then trained the partner site how to effectively use the software via webinars and additional on-site visits. On a bi-weekly to monthly basis, Wexus team members conducted partner site follow-up meetings to gather continuous feedback about the software.

For product development, the Wexus team uses the **Build-Measure-Learn framework** along with Agile processes. These industry standard approaches will be explained in more detail in Chapter 2. Conceptually, this product development approach **emphasizes continual engagement with customers to understand their needs and market trends. Iterative software releases are required to launch new product features, quickly and with minimal waste.**

During the Build Phase, Wexus developed a product roadmap by translating user needs from interviews into user personas, user stories, and wireframes of key product features. Then in the Measure Phase, Wexus validated product features with usability tests, partner farm interviews, and split or alpha/beta testing. Wexus also built user metrics to track engagement with various software product features. During the Learn Phase, Wexus continued to gather insights from regular customer interviews, day-to-day operations, and key user metrics. This feedback was iteratively fed back into the Build-Measure-Learn development loop to deliver increasing value.

Wexus also partnered with the University of California Davis' Center for Water-Energy Efficiency (CWEE) for measurement and verification (M&V) for the project. The teams developed **a new energy and water M&V methodology for the agricultural sector, which did not previously exist in the industry.** The teams compiled a robust dataset from multiple sources.

**Hourly electricity usage data from the 37 electric utility meters was the primary source** of data for collection and analysis, particularly for accessing several years of historical data. The Remotely accessing on-site IOU electric meters through the advanced metering infrastructure (AMI) and IOU Green Button Connect platforms was the most cost-effective approach to gathering partner farm electricity data, since it does not require constant on-site data gathering.

However, an advanced utility metering infrastructure for water does not exist and installing water monitoring equipment on all pumps across an entire farm was outside of the project budget. The Wexus team worked with CWEE to **develop a water estimation methodology based upon electric utility meter consumption, well depth, and pump efficiency performance**.

The Wexus also team worked with project subcontractor Polaris Energy Services to **install additional IoT monitoring equipment at two irrigation pumps/wells per each partner farm to measure electricity and water usage in real-time, fifteen-minute intervals.** Real-time monitoring allowed Wexus to send actionable alerts to partner farms based on current operations. Partner farms assisted Wexus with pump selection in order to maximize the usefulness of the technology for their specific farm. This project approach of having a mix of data sources aligns with Wexus' business model to allow farms to select a customized mix-and-match of software-as-a-service (SaaS) levels per meter, with and without additional monitoring equipment, depending on the irrigation pumps' usage and the return on investment.

## Project Results

This project achieved its overall goal to engage agricultural partner sites in California to use the Wexus mobile software and to identify and implement energy and cost savings. The success of engaging partner farms in the Build-Measure-Learn product development process can be seen in the evolution of the Wexus mobile software over the course of the project. Listening to the real needs of farmers in the field is critical to helping California reach energy and water efficiency goals. During this project, Wexus' rich feature-set solved key problems for agribusinesses:

- Labor: field-level remote equipment status tracking and real-time irrigation pump efficiency alerting with SMS text messages and in-app alerts allows farms to reduce manual labor and to manage their labor force more effectively.
- Regulation and Reporting: reduce overhead labor and enable compliance with regulation through energy and water bill and consumption reporting (in automated email formats); data export tools (in csv formats); and an energy usage and cost savings dashboard.

- Costs: the platform provides growers a digital, comprehensive cost management tool to evaluate rates, including time-of-use; to compare billing trends year-over-year; to respond in real time to changes in energy costs; to reduce operational expenses by identifying equipment in the field that may be experiencing efficiency or water aquifer problems; and to reduce operational expenses.

This project successfully provided wider proof of concept and use cases for scaling the Wexus mobile software platform throughout PG&E and SCE IOU regions in California. The Wexus technology platform will continue to evolve in response to customer and market needs. This project proves that these types of real-time, data-driven platforms provide agricultural customers with critical, missing information to help track and reduce energy usage and costs and that the agri-food industry is a very receptive customer base when given the right tools that meet their business needs.

In terms of savings results, three of the four farms had substantially lower average electricity usage during the project period**, thus achieving the targeted ten percent (10%) reduction from pre-project baseline values.** In total, **partner farms reduced electricity usage by 1.14 GWh/year or 17.2% on average unadjusted** and by 38 MWh/year and one percent on average, when modeled as adjusted. The unadjusted values are the observed changes, directly calculated between the baseline and project time periods, while the adjusted results are based upon several statistical models, which attempt to estimate the impact of factors outside the scope of the project (e.g. major farm operation/crop changes, weather, drought conditions, and EE equipment or renewable energy installations). Values should be adjusted to control for energy usage changes that did not occur due to the project with Wexus, however the CWEE models did not result in statistically significant adjusted results. For example, the dairy partner farm's savings could not be accurately adjusted due to significant variability in irrigation pump usage over time, long periods of non-use due to crop irrigation cycles, and unavailable utility data for some months in 2018 (due to technical software changes in Southern California Edison's Green Button Connect platform). The row crop partner farm provides another example due to a large solar array installed on-site during the project. Solar metering for farms is very complicated due to aggregated net metering structures, and the CWEE models were not able to fully separate the effects of the solar array install as compared to the Wexus project. **Due to these considerations, neither the adjusted nor the unadjusted results provide a complete picture of the savings results, and they should be viewed in conjunction with each other.**

An important takeaway of this project is that additional work is necessary to refine CWEE's M&V models used for the adjusted results, because they did not consider all of the external variables in the agricultural industry with complete confidence. **The Wexus team looks forward to continuing to pioneer and refine this M&V/savings model for the agricultural industry and to implement it in new California third party energy efficiency programs.**

The Wexus team also developed time-of-use peak period alerts sent via SMS text messages to encourage partner farms to reduce demand during peak times and/or shift usage to off-peak times. SMS text alerts help farmers make an informed cost-driven decision about irrigating during costly peak hours, and they also help farms remotely verify whether their employees are following planned irrigation schedules (i.e. whether pumps are actually on or off). Wexus expected partner farms to receive alerts frequently, daily in many cases, and to only be able to change irrigation schedules a limited number of times. Yet, **almost 10% of the time, three partner farms *did* respond to the peak period alerts and collectively saved 8.9MW of demand and over $7,000 in peak demand surcharges across the life of the project**. (The dairy farm opted out of the alerting due to operational considerations.) This validated the Wexus team's hypothesis that farmers wanted the ***option* to make a real-time data-driven energy-cost decision** (as opposed to paying the paper utility bill thirty days later).

Ultimately, the final decision is in the farmer's hands to curtail energy usage and depends on many factors. **It is critical for energy policy makers to understand that farmers are running a business and energy consumption is a cost of doing business for them, not a primary revenue driver.** Technology platforms like Wexus that automate laborious tasks, such as tracking energy and water consumption and utility bills and costs, and that relate them to the actual farming operation with historical dashboard and real-time alerts can help drive overall energy markets awareness, behavioral change, and improved net operating income for farms.

## Technology Transfer or Market Adoption (Advancing the Research to the Marketplace)

Wexus' objective is to continue to commercialize and scale the Wexus product in the California IOU market through 2020. According to the 2012 United States Department of Agriculture Census, there are **over eighty thousand (80,000) farms and ranches in California that collectively spend over two billion dollars per year on energy,** which includes electricity and fuel. Assuming a seven percent (%) share of market estimate per industry standard for software companies, the potential for Wexus is to address an agricultural customer base with over $140 million annual energy spend in California. Wexus' strategy for further commercialization in California is a four-step approach:

- Continue to drive growth in the PG&E service territory through the on-going Ag-Energy program.
- Expand into additional electric service territories in California.
- Serve as a Third-Party Energy Efficiency (EE) Program Implementer (or subcontractor) under the new California Public Utilities Commission (CPUC) mandated portfolios.
- Expand partnerships with local channel partners.

The Wexus team will focus on transferring knowledge of this project in order to educate key stakeholders about the significant and historically underserved agricultural user base. The more quickly that the Wexus team disseminates these project results, the more quickly that agricultural markets can adopt new technologies like the Wexus IoT software product and ag-energy IoT products in general. In turn, increased adoption of the Wexus product will increase energy efficiency (EE) savings, promote greater electric reliability, and lower energy costs for agribusinesses by driving behavioral change and unlocking access to utility-sponsored and third party-financed equipment retrofits. Wexus will focus on disseminating project results to three key user types through online blog posts, social media, attendance at conferences, and continued one-on-one business meetings through the outside sales team:

- Agribusinesses i.e. current and potential Wexus customers;
- Electric service providers including investor owned utilities (IOUs), municipal utilities, and community choice aggregators (CCAs); and
- Hardware vendors including channel partners and renewable energy providers.

The Wexus team will also look to inform regulatory bodies like the Clean Energy Commission and the California Public Utilities Commission about the project results to feed back into the water-energy nexus policy conversations, which are ongoing. One desired outcome is additional policy in support of water-energy nexus programs specifically for agricultural customers with the use of scalable Internet of Things (IoT) technology platforms similar to Wexus.

As an outcome of this project, Wexus has identified several new challenges are on the horizon for the agri-food industry. Wexus is eager to address these in future projects. The Wexus team **highly encourages the California Energy Commission, the California Public Utilities Commission, and investor-owned utilities to research, provide funding, and create efficiency programs to help solve these ongoing issues for the agricultural industry, which will ultimately help California achieve its energy goals of 100% renewables by 2045:**

- Solar photovoltaic (PV) system net metering is a pain point for farmers who converted available farmland, bought large (+1MW), expensive ground-mounted solar PV systems, and often do not have the tools to validate their systems energy generation/ performance and return on investment (ROI). Even reading and interpreting their monthly utility solar bills is a significant challenge.
- Financing options for IoT hardware and sensors (both public and private) will be increasingly important as more AgTech and IoT solutions become available to agricultural customers. Farmers will need different mechanisms to help pay for these solutions, since agriculture is typically a low-margin business driven by fluctuations in crop prices and weather patterns, and available cash from farm operating funds to invest in new technologies is scarce.
- Community Choice Aggregation (CCA) in California has become more widespread in 2018, particularly in the Salinas Valley where there is a significant concentration of agricultural businesses. CCAs provide customers with another option to purchase energy generation outside of their existing investor-owned utility (IOU), along with access to different energy generation mixes (like 100% renewables) and rebate programs. However, once a customer is enrolled in a CCA it can be very difficult to track actual costs and bills to ensure their enrollment, because data is disaggregated on their bills and not available via IOU Green Button Connect platforms. **Until IOUs release CCA energy generation usage/billing data, it will be extremely complicated for customers to determine whether enrolling in a CCA versus staying with an IOU actually saves them money on their energy bills.**
- Inputs for advanced Cost Calculator features, such as energy intensity analysis, will provide the next level of real time, predictive energy and cost management tools and

will incorporate more granular agronomic data, particularly ranking energy intensities by crop type and localized weather data.

- Utility time of use (TOU) rate changes are expected to launch in 2019 and 2020 in both PG&E and SCE territories. Farms will need tools to understand and manage these new rates, to help compare and contrast the best options for them, and to manage irrigation pumping operations around new TOU hours and place less stress on the utility grid.
- Measurement and Verification (M&V) methodologies for agriculture need to continue to be developed through ongoing research. This project pioneered new M&V models that had to be developed from basic mechanical engineering models typically used in the commercial and industrial building industries. Energy and water consumption data sets from thousands of farms and hundreds of different crop types are needed to build a reliable, robust M&V model for the agricultural industry that will ultimately drive more energy efficiency and help California meet its climate change goals.

## Benefits to California

Engaging farm partner sites to reduce energy usage has historically been a large barrier to achieving the state's energy goals. In Wexus' experience, this barrier exists largely because agri-business owners do not relate their operational activities to actual energy usage. The Wexus software platform overcomes this barrier by relating actual farming business operations to actual energy usage and impact to the bottom line, which encourages cost savings and ultimately reduces energy usage.

The Wexus software platform has leveraged existing AMI infrastructure and utility Green Button data platforms extensively to offer initial savings to partner farms without the need for additional hardware installations on site. The Wexus platform has also integrated this electricity data into tariff engines to compare rates and to estimate water usage for reporting. This platform could be extended to other business verticals, for example oil wells, food processing sites, irrigation districts, or cannabis growers, to deliver even more value to additional ratepayers.

The Wexus mobile software project benefits California ratepayers in investor-owned utility territories by promoting greater electric reliability and lowered energy costs for farms. **The Wexus IoT software platform and other IoT-driven technologies have the potential to save these agribusinesses upwards of ten percent per year on their energy usage and costs and to ease the process of incorporating renewable energy into business operations.** The potential impact of a ten percent (10%) reduction in energy costs/usage for California's agricultural industry is $200 million per year and 2,200 GWh per year (based upon recent statewide spend and usage). This in turn would result in potential greenhouse gas reductions of 1.3 billion pounds of carbon dioxide per year.

**This level of reductions would make a very significant impact toward helping California achieve its long-term energy goals of reducing energy consumption per capita and integration of 100% renewables by 2045.** Every dollar saved by an agribusiness is a dollar that can be re-invested into the agribusiness to improve conditions/wages for labor, into additional energy efficient technology, or into the local community.

# CHAPTER 1: Overview of the Project

## Introduction

The Wexus team identified the current state of the agricultural industry in California and focused on solving three key problem areas:

- **Labor** has always been a challenge for agribusinesses due to the seasonality, large geographic footprints, and physical demands of the business. This issue continues to become more challenging with changes in labor and immigration laws in recent years. Agribusinesses have historically not had easy access to innovative efficiency technologies, which could help them manage their operations remotely, automate the turning on/off of equipment, and increase cost efficiency to decrease labor needs and make labor demands more predictable.
- **Regulation and reporting** requirements for energy and water consumption for farms has increased dramatically in the last two years, particularly due to the recently passed law called the Sustainable Groundwater Management Act (SGMA). But farms do not have the tools or necessary financial mechanisms for installing water sensors, monitoring usage, collecting data, and quickly reporting it without deferring existing labor which is already in short supply.
- **Costs** of energy and water are difficult to manage due to: disconnected and geographically spread energy usage points on a farm which can cover thousands of acres and miles of territory; non-digitized, paper copies of bills to monitor energy costs and consumption; and a lack of digital tools for estimating and forecasting energy and water-related costs in real time. Yet, California's agricultural industry is one of the states' largest users of energy and water and collectively spends over two billion dollars per year on energy (per USDA Agriculture Census, 2012).

The combination of pressing labor challenges, increased regulation and reporting, rising energy costs, and the threat of drought and changing weather patterns is driving demand for new agricultural energy efficiency solutions. The future of the agricultural industry depends on innovation in AgTech (defined as technology entrepreneurship focused on solving agribusiness problems) and IoT "Internet of Things" (defined as networks of devices connected over the internet to deliver real time insights and make data-based actions and decisions). For this project, Wexus focused on providing product solutions to these key problem areas.

## Goals and Objectives

### Project Goals

The project goals were as follows:

- To engage agricultural deployment sites in California Investor Owned Utility (IOU) territories to participate in the Wexus mobile software project and to identify energy (and water) efficiency measures at these sites.

- To provide wider proof-of-concept and use cases for scaling the Wexus mobile software platform throughout IOU regions in California.
- To fully assist and train deployment sites in the effective use of the Wexus mobile software platform to quantify actual energy (and water) savings after measures have been implemented.

### Project Objectives

The project objectives were as follows:

- To aid agricultural deployment sites in reducing their overall energy usage by providing actionable energy and cost data, including at peak times of day.
- Target potential energy reductions by up to ten percent from baseline usage.
- To continue to develop and refine the Wexus cloud-based software platform through deep analysis of utility electric meter data, utility tariff and rate data, utility bills, water usage data, greenhouse gas emissions data and continued agricultural customer feedback at the site level.
- To engage agricultural deployment sites in continuing education and training on the effective and efficient use of the proposed technology to reduce their energy usage by up to ten percent, to identify potential energy savings measures in the field, and to quantify actual energy savings after savings measures have been implemented.

## Technical Approach

### Scope of Work

The key tasks for the project included the following:

- **Confirm partner farms, visits sites to audit equipment and operations, and conduct baseline energy usage analysis.** The selection of the partner farms will be discussed in more detail below.
- **Provide energy savings analysis and recommendations to partner farms.** The goals of this task were to (1) provide training on the Wexus Software solution, (2) compile and analyze customer site information and energy (and water) data, (3) determine several potential energy (and water) savings measures and recommendations (4) continue to engage the customer/site to incorporate the energy savings measures into its operations.
- **Implement the hardware and software deployments and continuously engage customers.** The goals of this task were to (1) continue to engage deployment sites and track which specific energy and water savings (where water data is available) measures have been implemented, (2) install irrigation pump energy monitoring and controls equipment at the three deployment sites and (3) determine which specific measures still need to be implemented to reach energy efficiency targets of up to ten percent reduction from baseline use.
- **Develop the energy software product.** The goal of this task is to further develop the technical aspects of the Wexus software through the use of industry standard product

management techniques and practices for cloud based, mobile software, including the Build-Measure-Learn Process and Agile methodologies.

- **Evaluate the project benefits.** Collaborate with a third party, University of California Davis' Center for Water-Energy Efficiency (CWEE), on the measurement and verification for the project.
- **Transfer technology/knowledge** to key stakeholders, the public and policy decision makers.
- **Prepare for production readiness to** ensure the commercialization of the project results.

## Partner Farm Sites

Wexus selected four partner farms with a variety of crop types, thus different planting and harvesting schedules and different irrigation requirements: berry, row, dairy, and vineyard. These four partner farm spread across 3,700 acres and eleven ranches with **forty-seven irrigation pumps connected to thirty-six electric utility.** Each partner farm was a highly engaged, early adopter with a commitment to participate in the project for multiple years. They made time for the project for regular check-ins, equipment installations, and periodic surveys/interviews.

For each partner farm, the Wexus team conducted an initial site visit at each partner site to audit existing equipment specifications and determine on-site operations through one-on-one interviews with employees. Then the team uploaded and analyzed partner site information and energy data into the Wexus software database and determined potential energy savings measures. The team then trained the partner site how to effectively use the software via webinars and additional on-site visits. On a bi-weekly to monthly basis, Wexus team members conducted partner site follow-up meetings to gather continuous feedback about the software and fed this information into product development.

## Build-Measure-Learn Product Development

Build-Measure-Learn is a process to achieve continuous software product development.

- **Chapter 2 details the Build phase**, during which Wexus developed hypotheses about the key problems facing agribusinesses and potentially useful product solutions. Wexus then validated these hypotheses with market research and interviews and testing with partner farms in the field.
- **Chapter 3 documents the Measure Phase**, in which Wexus tested prototypes of the product features with partner farm users, deployed IoT hardware devices and sensors in the field, released the software into production, and built user metrics.
- **Chapter 4 summarizes the key project takeaways from the Learn** Phase, during which Wexus continued to gather insights from regular customer interviews, operational feedback from the field, and monitoring of ongoing user metric reports and key performance indicators (KPIs).

## Goals and Objectives Achieved

**Chapter 5 summarizes and reviews in detail the savings results for** each partner farm. Overall, the Wexus team succeeded and achieved the goals of the project in aiding agricultural deployment sites in reducing their overall energy usage by providing actionable energy and cost data, including at peak times of day. Ultimately, agribusinesses will make decisions based upon their operational needs, but this project demonstrated that access to actionable, data-driven insights provided partner farms the visibility and the option to reduce energy usage and costs by ten percent from baseline usage.

As already detailed in Chapter 2-4 about the Build-Measure-Learn phases, the Wexus team continued to successfully develop and refine the Wexus cloud-based IoT software platform through deep analysis of utility electric meter data, utility tariff and rate data, utility bills, water usage data, geolocation data, greenhouse gas emissions data and continued agricultural customer feedback at the site level. The cornerstone of this product development framework is customer feedback and iterative learning, so the Wexus team continuously engaged partner farms in education and training over the course of the project.

# CHAPTER 2: Build Phase

The Wexus team used industry standard product management techniques and practices for cloud-based, mobile software: build-measure-learn methodology. During the "Build Phase", Wexus built a product roadmap under three distinct phases (pre-launch, pre-market fit, post-market fit). They utilized the industry-standard Agile software development framework in the software development process and translated user needs into product features via the user development model, testing and validating product features through usability tests, split and Alpha/Beta (A/B) testing. They tracked user metrics and KPIs and developed user experience (UX) design through user personas and empathy maps, features and user stories, wireframing and storyboarding.

## Build-Measure-Learn Methodology

The Wexus team utilizes the Build-Measure-Learn framework pioneered by Silicon Valley entrepreneurs and product development veterans Eric Ries and Steve Blank and thoroughly documented in the New York Times bestseller The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Business (2011). The "Lean Startup" movement is transforming how new products are built, launched and scaled into the market with minimal waste. This movement brings principles from lean manufacturing and Agile product development to the process of innovation which helps companies succeed in a business landscape riddled with risk. The Lean Startup is about learning what a company's customers really want. It is about testing a company's vision continuously, adapting and adjusting quickly to customer needs to scale a product into the market as fast as possible.

### Waterfall: An old and ineffective product development methodology

Prior to the "Lean Startup" model, the predominant software development methodology was the Waterfall methodology. This is a very structured, linear, "point A to point B" approach, which has several shortcomings, particularly very few points of feedback with users. The typical phases of a Waterfall based product development cycle can be understood as five sequential steps (Figure 1):

1. Requirements
2. Design
3. Implementation
4. Validation
5. Maintenance

**Figure 1: Waterfall methodology of product development (source: eSparkBiz).**


Waterfall development typically begins with a list of “Requirements” needed to accomplish the goals of the project. A “backward planning” process is used to state the key success metrics of the finished project and then “work backward” to determine the specific tasks and deliverables that must be carried out to meet the end goal. A long list of technical specifications is also typically created during this phase, which is then handed to the design and engineering teams to implement. Typically, once the requirements have been set during this phase, they cannot be re-visited for major changes.

After this large list of requirements is created, prototype “Design” begins, and project participants plan how they intend to complete all of the necessary scope of work tasks. The design process includes a list of time/schedule expectations, a list of which project groups conduct a specific type of work or task, and a list of the sequence or order of the tasks. Any tasks that are not included in the early planning stages of the project typically will be excluded as the project is already underway. This often results in wasted time and effort because the initial estimated time to complete tasks conducted during the “requirements” phase can be vastly incorrect or groups and skill sets of project team members can change during longer project durations.

The “Implementation” phase of a software Waterfall project consists of carrying out the specific project tasks to complete the defined scope of work and ensure the previously created design prototypes work and are linked to live data. If complications arise during this phase that are in conflict with the original design, they tend to be resolved as minimally as possible in order to keep the project tracking on-time and on-budget. This often leads to conflicts between the design and engineering teams, which can lead to longer task timelines and create unproductive animosity between team members.

The “Validation” phase of a software Waterfall project seeks to include feedback from the potential end user/customer. By this phase of the project, a considerable amount of design and engineering time and cost has already been sunk into the project. This in turns means that it is very difficult to change course and make vast improvements to the product if feedback from potential users is less than optimal. In the waterfall methodology, product managers place a great amount of emphasis on “shipping” the product to potential customers to see if they will actually purchase it.

The final “Maintenance” phase of a software Waterfall project consists of a smaller group of engineering team members who are tasked with fixing bugs or correcting issues that potential or actual customers identify in the product. Very little feedback loops exist in this phase, and the voice of the customer is often lost as the other project team members move on to another project and few, if any, resources remain to make needed key changes or to make overhauls of key features.

The key weakness in the Waterfall method of software product development is the fact that customer feedback is not a priority during the “Requirements, Design and Implementation” phases. By the time the “Validation” phase occurs, it is too late to incorporate significant feedback. Waterfall projects also take significant amounts of time to complete from start to finish, typically on the order of years. This means that customer feedback and user needs at the start of the project may be very different than those at the time when the product is shipped. During Waterfall projects, the voice of the customer is almost completely lost in the actual product, which ends up creating a huge amount of wasted resources in personnel, time and money if the customer does not actual use or need the product.

## Build-Measure-Learn: a vastly improved methodology

The Build-Measure-Learn methodology is a vast improvement over the traditional “Waterfall” product development method for creating software products. It provides a framework to truly join lean manufacturing and Agile product development principles, focusing on quality, speed, elimination of waste, and customer satisfaction. The typical phases of a Build-Measure-Learn product development cycle are broken down into three areas as shown in Figure 2:

1. Ideas and Hypotheses - Build
2. Code and Tests - Measure
3. Data and Key Performance Indicators - Learn

**Figure 2: The Build-Measure-Learn Feedback Loop (source Eric Ries).**


Build-Measure-Learn is a feedback loop process. Companies begin with hypotheses to be tested and experimented and are searching for repeatable and scalable business models. This method uses tools like a Business Model Canvas to frame hypotheses, Customer Development processes to get out of the building to test hypotheses in the field, and Agile Engineering to build the product iteratively and incrementally with minimal wasted time, cost and labor.

Agile is a product and project management methodology that emphasizes “individuals and interactions rather than processes and tools; working software over comprehensive documentation; customer collaboration over contract negotiation; and responding to change over following a plan” (Manifesto for Agile Software Development). In Agile, product development teams break the product roadmap and vision into manageable amounts of work to be released as Sprints, on a frequent (often 6-8 week) basis.

During the “Build” phase, a list of “Hypotheses” is created to determine the goals of the customer, not necessarily the project. Emphasizing building as the first step misses the key insight about a Lean Startup. The ideas and hypotheses are critical. The hypotheses are created via a series of working sessions and exercises that seek to define the project team’s best guess as to what customers might want in terms of a product that solves specific needs in the market. Once the hypotheses are logged and categorized (typically referred to as “epics” in Agile terminology), the project team then plans and specifies a smaller subset of “sprints” to do various tasks like user experience (UX) research and interviews with potential end user customers, user experience design to create static prototypes, or to create near-fully working and engineered prototypes, often referred to as minimum viable products or “MVPs.”

The “Measure” consists of creating a series of design prototypes or MVP’s and testing them directly with potential end users to gain immediate and ongoing feedback in the field. This greatly accelerates the product development process and either validates or refutes the team’s initial hypotheses. This phase is often referred to as “getting out of the building” and the product team is expected to interview multiple end users to gain a consistent percentage of feedback about the potential product, and immediately catalogue and relay this information to the overall team to minimize wasted time and resources.

The “Learn” phase of a software Agile development project consists of analyzing the catalogued feedback obtained during the “Measure” phase and determining if the initial hypotheses created during the “Build” phase are valid or not. If a hypothesis is completely invalidated by potential end user customers, the team goes back to the “Build” phase to refine the hypothesis or create another one entirely.

The goal of designing these prototypes and minimum viable products is not to get data but to get insight. The entire point of getting out of the building and into the field with end users is to inform the company’s product vision. The insight may come from analyzing customer responses, but it also may come from ignoring the data or realizing that a company may be creating a new, disruptive market that doesn’t exist, or that experiments may need to be changed from measuring specifics to creating entirely new features or products.

As part of the Build phase, Wexus developed hypotheses about the key problems facing agribusinesses and potentially useful product solutions.

# Wexus Product Roadmap

The Wexus product team created a “Build Phase” plan for refining the technical aspects of the software and organized it into three stages: pre-launch, pre-market fit and post-market fit. The details of this approach are laid out in the product road map (Figure 3).

## Phase I: Pre-launch

In this first phase of the product road map, research was conducted with project farm sites via surveys and interviews. Data was collected and analyzed. From this analysis, Wexus created user personas, wrote user stories, and created storyboards. Using this information, an information architecture was created that helped inform ways to improve upon the existing software platform.

## Phase II: Pre-market fit

During the pre-market fit phase, prototypes of new features were designed. The prototypes were built using feedback from research during the pre-launch stage and customized to meet the needs of the personas the product team created. After the prototypes were built, they were tested with project farm sites and then further revised in preparation for integration into the software platform.

### Phase III: Post-market fit

The third phase of product development, post-market fit, involved presenting the UX designs to the product team engineers, building the features into the existing software platform, testing the product for quality assurance and releasing the newest features for partner farm users.

**Figure 3: Product Roadmap**


## User Experience (UX) Design

In line with Task 5 "Continuous Energy Software Product Development," the Wexus team accomplished the goal of refining technical aspects of the Wexus software through industry standard product management techniques and practices for cloud based, mobile software. The first step in the process was to put all new features from the product roadmap through a rigorous UX design process. This process involved initial research via partner farm interviews to understand pain points and industry needs. With this data in mind, Wexus' UX designer created user personas, wrote stories detailing problems those personas needed to have solved, and created new features to solve those problems. Once those features were scheduled for development on the product roadmap, wireframe prototypes of features were designed, built, tested and refined.

## Wireframe Prototypes

For each product feature, the UX designer created digital blueprints (called wireframe prototypes) detailing what the look, feel and flow of what a feature would look like once they were built by the front end and back end software developers. These designs were used initially to test the validity of a feature and ease of use for a partner farm user. The designs were refined as the UX designer received more feedback from partner farm users during research and testing. The final wireframes were presented to the software engineers and then built into the software platform through computer code.

The wireframes showed a detailed view of the new feature, how it would be used, and where the user could find the feature within the software interface. After testing multiple versions of the Wexus platform with partner farm users (Figure 4), the product team decided to update the user interface with four main pages, each with a specific purpose:

- An overall dashboard with graphs for tracking and visualizing energy, water and cost metrics over time (Figure 5)
- A map to show the current location and status of all meters, sub-meters, and pumps (Figure 6)
- A page to download energy and water data in CSV format (Figure 7)
- A “Savings Plan” page to track a user farm’s cost, energy (kWh) and demand savings, and tips with links to IOU utility programs to help them save further (Figure 8).

**Figure 4: Dashboard Page Wireframe**

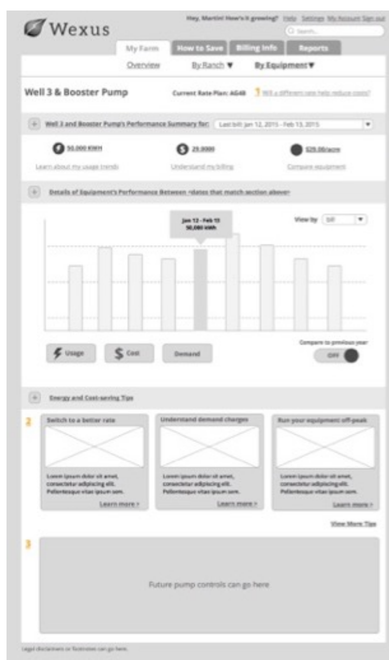


**Figure 5: Updated Dashboard Page Wireframe**

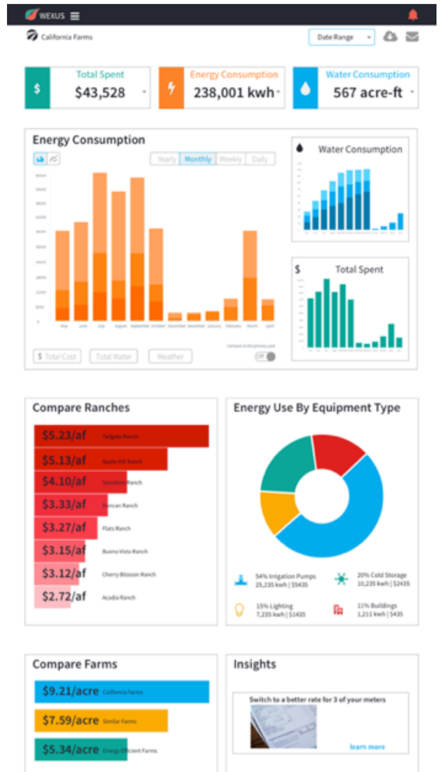



**Figure 6: Map Page Wireframe**

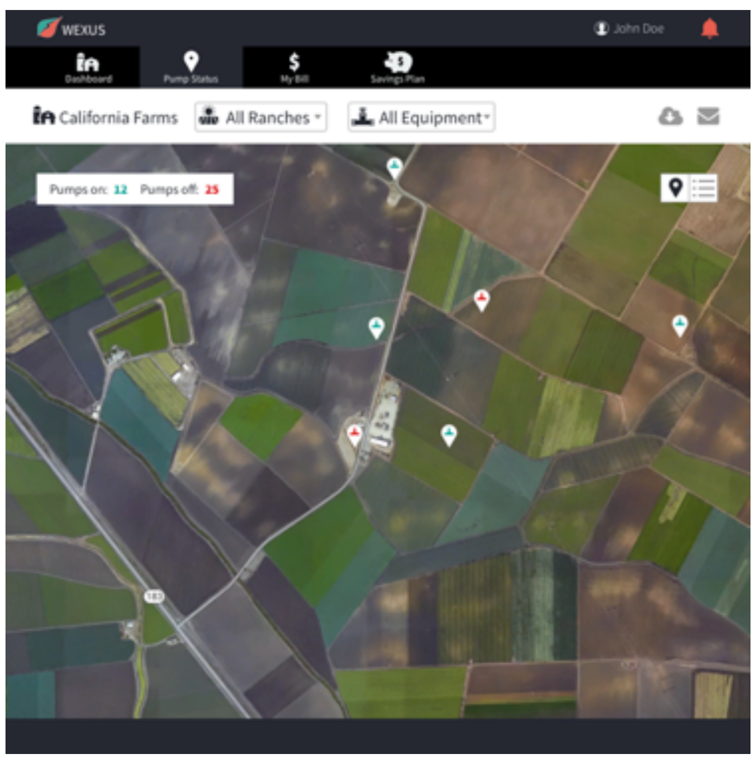


**Figure 7: Download Data Page Wireframe**

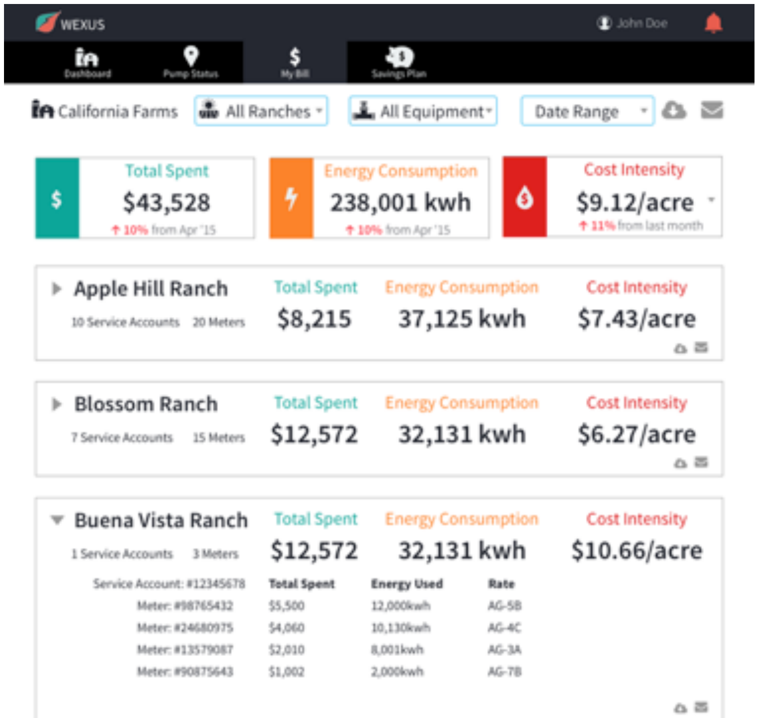
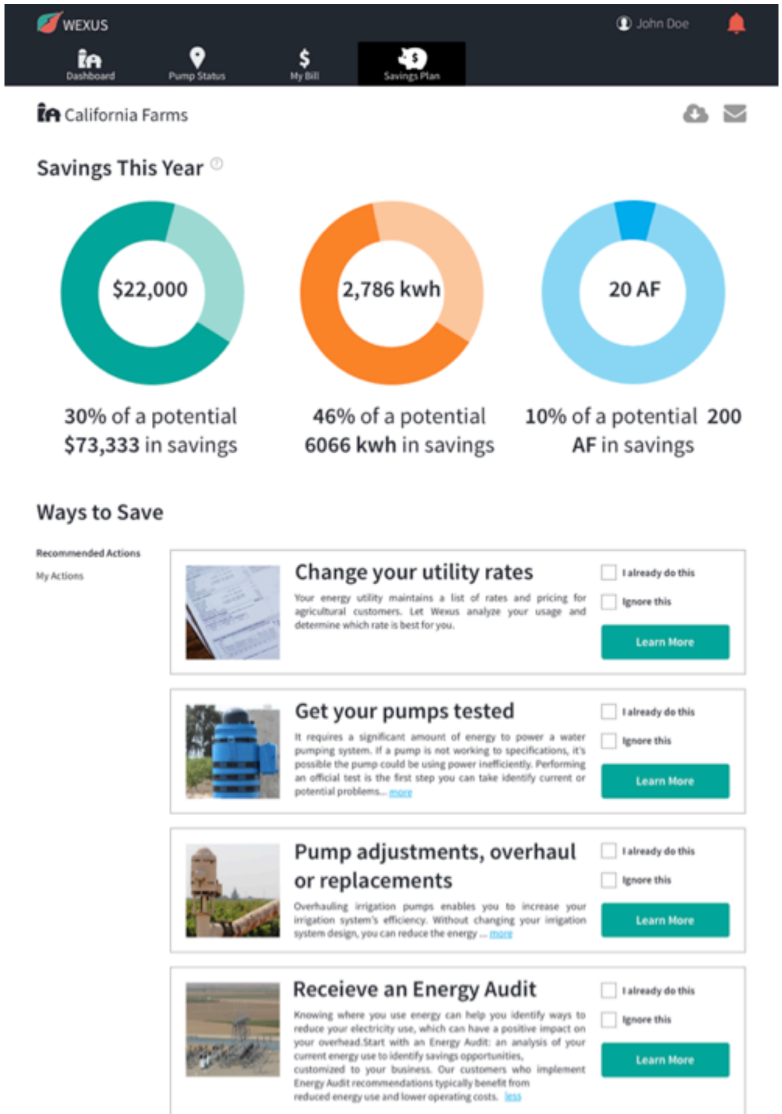


**Figure 8: Savings Plan Page Wireframe**




## User Stories & Storyboarding

In addition to updated pages in the Wexus software platform, UX research and design also led to the creation of monthly and mid-monthly automated email reports and SMS text alerts.

Before the wireframes were built, the UX designer wrote user stories that detailed three aspects of a given feature:

- For whom the feature is designed
- What problem the feature solves
- Why the problem needs to be solved
- How the feature solves the problem

These stories were then illustrated into storyboards (Figure 9). The storyboards made the needs of a feature very clear and help show what features are necessary to build to solve the user's specific problem.

**Figure 9: Storyboard for the "Reporting Rachel" user persona**


## User Personas

A user persona is a fictional archetype created by a product team to embody the type of person who should use their product. When created, the characteristics of that persona, as they relate to the product, are outlined to help the product team understand the persona's problems, wants and needs. Under this project, the Wexus product team created four user personas (Figure 10). These personas were made after the product team interviewed partner farm users and analyzed their responses. The responses showed certain trends based on the user's role on the farm and the types of daily tasks that role required a person to do.

- **General Manager George** is responsible for the business of managing and leading the farm. Wexus hypothesized that General Manager George was most concerned with overall historical usage across an entire portfolio of several ranches as well as cost data.
- **Ranch Manager Ralph** oversees the operations of a farm, ranch, or subset of crops. This user persona is operationally focused and would be most interested in real-time pump and equipment-level information.
- **Reporting/ Accountant Rachel** provides administrative support and cares about tracking energy and water costs and creating historical reports.
- **Sustainability Manager Emily** is focused on measures that will save energy and water, in addition to costs while meeting corporate sustainability goals.

**Figure 10: User Personas**


### Empathy Maps/Features

An empathy map is a collaborative tool the product team used to gain a deeper insight into the partner farm users. The Wexus team built an empathy map to represent each user persona, including the daily tasks each user persona needs to accomplish and detailed information about the steps each user persona needs to take to complete those tasks.

Once the product team understood these tasks as described in the empathy maps, the tasks were mapped to specific new features to help users accomplish tasks more easily. The UX designer then processed the features from the four empathy maps, built an overall framework within the software interface, and mapped the features into several sections to interact with each other in the most efficient way possible.

## Front End (FE) Features

Wexus tested and developed the top ten features of the platform, using feedback from pilot farm interviews and user testing to gain insight on the most useful features for the platform. The top features were:

- A main **"Dashboard" page** showing current and historical utility costs as well as energy and water usage on a yearly, monthly, daily and hourly basis.
- A **"Pump Status" page** to see the location and real-time status of all utility meters across an entire farm, separated by their energy/water end-use i.e. irrigation pumps, buildings or solar arrays.
- A **"Pump Efficiency & Health" subpage** which shows the efficiency rating, energy-water usage, and cost intensity in acre-feet of water of any pump on the farm in real time.
- An **"Irrigation Cost Calculator" feature** to forecast actual energy costs for the week and for the month depending on the farm's irrigation schedule, current weather conditions (Evapotranspiration ET), energy rate plans, and irrigation pump specifications.
- **"Monthly Email Reports"** that summarize monthly energy-water costs and usage with an analysis of year-over-year percentage change as well as irrigation pump efficiency breakdown.
- **"Mid-month Email Reports"** that show a deeper analysis of the "Monthly Email Reports" with current energy spend, energy usage, water usage and resulting year-over-year

percentage change for all three metrics, as well as specific recommendations to improve the efficiency of each irrigation pump, and the current savings to date in terms of cost ($), energy (kWh) and power demand (kW).

- A **"Savings Plan" page** to track annual cost, energy (kWh) and peak power demand (kW) annual savings with links to access IOU rebate and efficiency incentive programs to boost savings.
- A "Utility Rate Analysis" section on the "Savings Plan" page for pilot farms to see their current utility rates and annual spend by meter as well as a recommendation for the best, most cost-effective rate plan with annual cost savings and percentage change based on the actual energy usage and time of use for each meter.
- Real time SMS text alerts that automatically notify the user in the field on their phone when actionable issues occur, particularly notifications up to ninety (90) minutes in advance about peak energy usage and potential demand charges per irrigation pump and dropping pump efficiency that could indicate an equipment failure or aquifer problem.

## Platform Pages

### Dashboard

One of the primary features of the Wexus software platform is a Dashboard page. Its purpose is to quickly and easily give the user a snapshot of overall energy, water and cost trends on their farm. By default, the dashboard displays three charts: energy consumption, water consumption, and energy cost by month (Figure 11). In the energy and water consumption charts, the bars are stacked to show energy or water consumed during peak, partial peak and off-peak times of day based on utility time of use (TOU) rate plans. An additional button allows the user to simultaneously toggle between year-over-year time periods to make comparisons in line with changes to farming operations or other factors (Figure 12).

Within the dashboard, the user can also change the time range of the charts between yearly, monthly, daily (Figure 13) and hourly views. The user can then filter the view of their farm's energy from the entire farm down to a specific piece of equipment such as a building or pump.

**Figure 11: Dashboard Page**

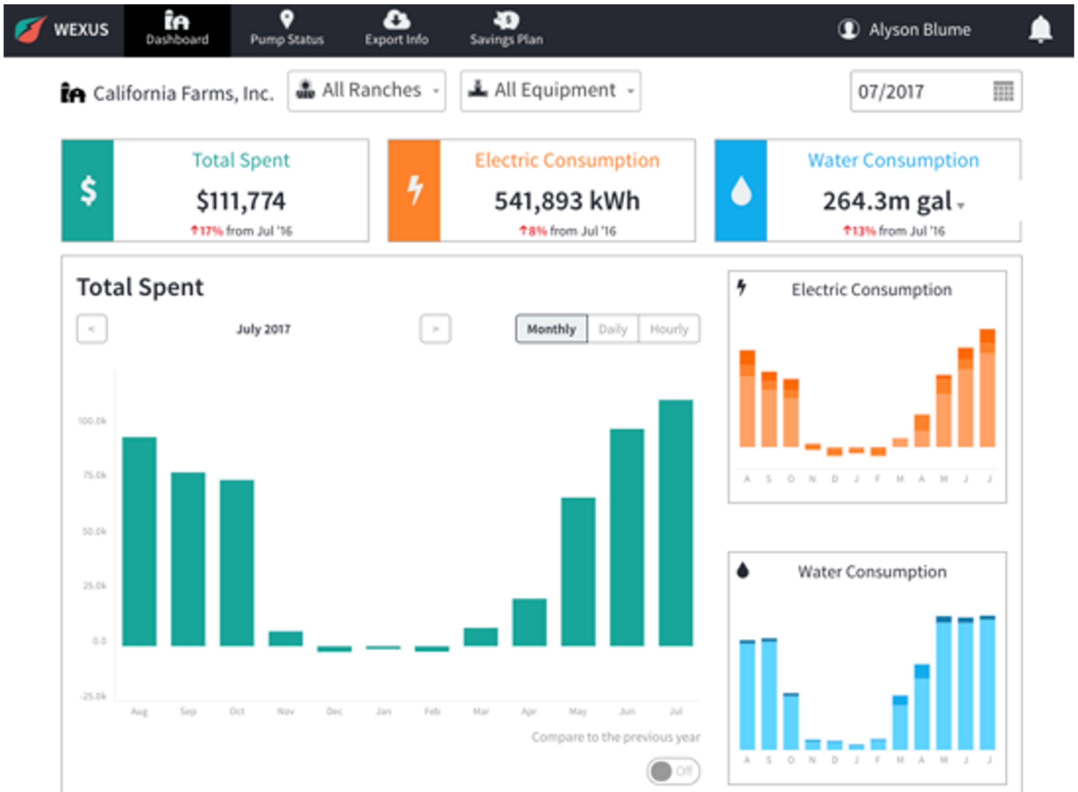



**Figure 12: Dashboard Page: Comparing Year Over Year**

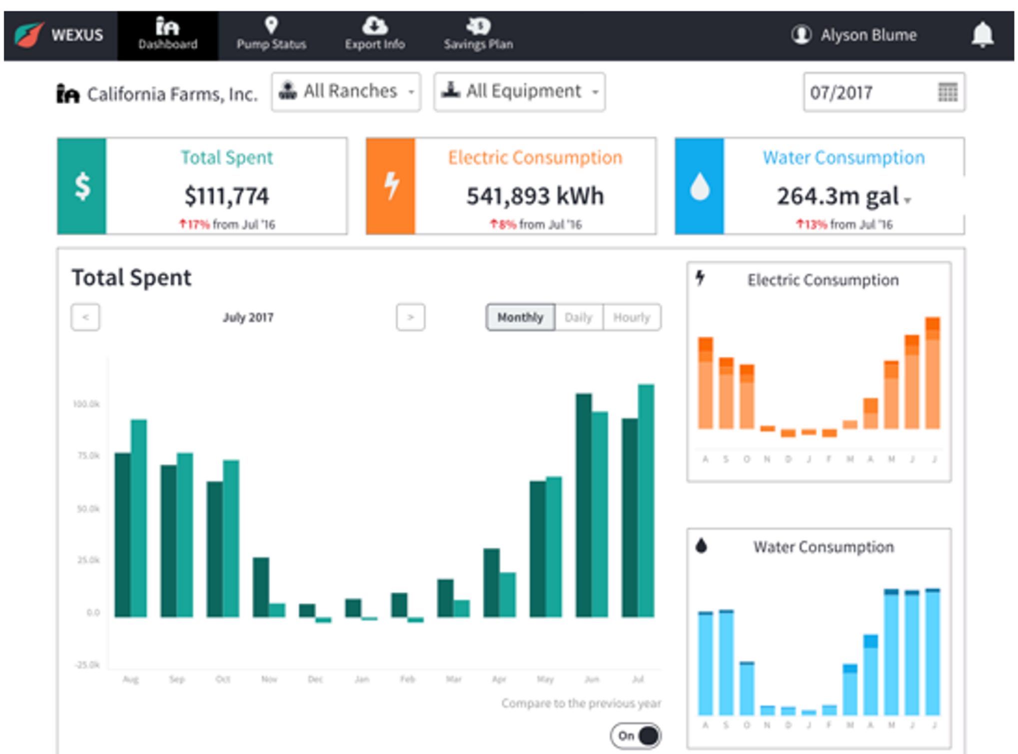
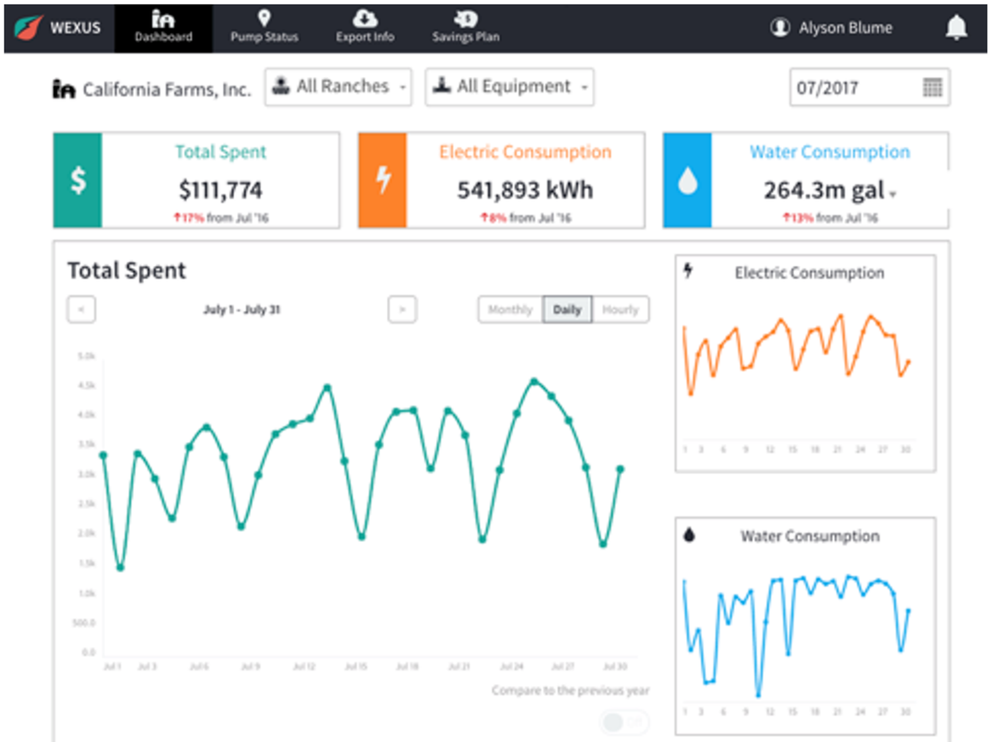


**Figure 13: Dashboard Page: Daily View**




*Pump Efficiency & Health*

When a user filters Dashboard data down to show a single piece of equipment and that equipment is a pump, additional data is displayed on the dashboard. This second section deals specifically with information to show the user the health and efficiency of that pump. As shown in Figure 14, there are three charts displayed in this section: pump efficiency, water energy trend, and cost intensity.

The first chart tracks the pump's efficiency month to month. Efficiency is calculated using an industry standard mechanical engineering equation with several variables: total dynamic lift, water flow rate, discharge pressure, and energy usage. In addition to tracking the efficiency value, the chart also shows the user if the efficiency level is within recommended industry guidelines. When the number appears in the green field, it indicates good efficiency. When the number lands in yellow it indicates the pump's efficiency is dropping, and the pump may need some maintenance to get back up to a healthy level. A number appearing in the red field indicates that pump efficiency is very low, and the pump could soon experience mechanical failure.

The second chart (Figure 15) shows the trend of water use at any given interval against energy use for the same interval. When a pump is healthy, blue points (water) and orange points (energy) fall across the chart in a relatively flat line. However, if one of the fields of points decreases while the other remains flat, it can indicate problems such as a decrease in efficiency due to pump motor maintenance, cracked well casing, a sensor failure, etc.

The final chart (Figure 16) shows cost intensity. This chart measures the cost per acre-foot of water pumped. This chart illustrates the cost/benefit of maintaining good pump efficiency; when efficiency increases, the cost per acre-foot of water (and resulting work needed to be done by the pump) decreases.

**Figure 14: Pump Efficiency Chart**

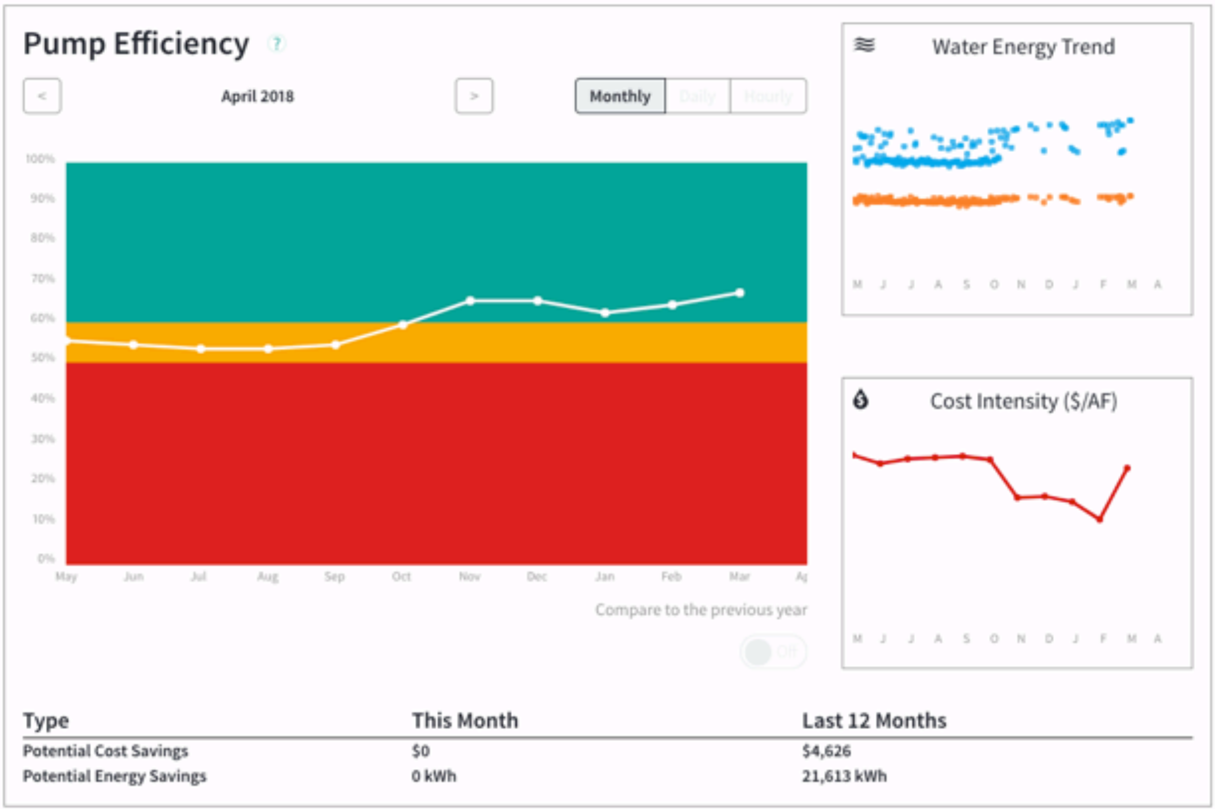


**Figure 15: Water Energy Trend Chart**

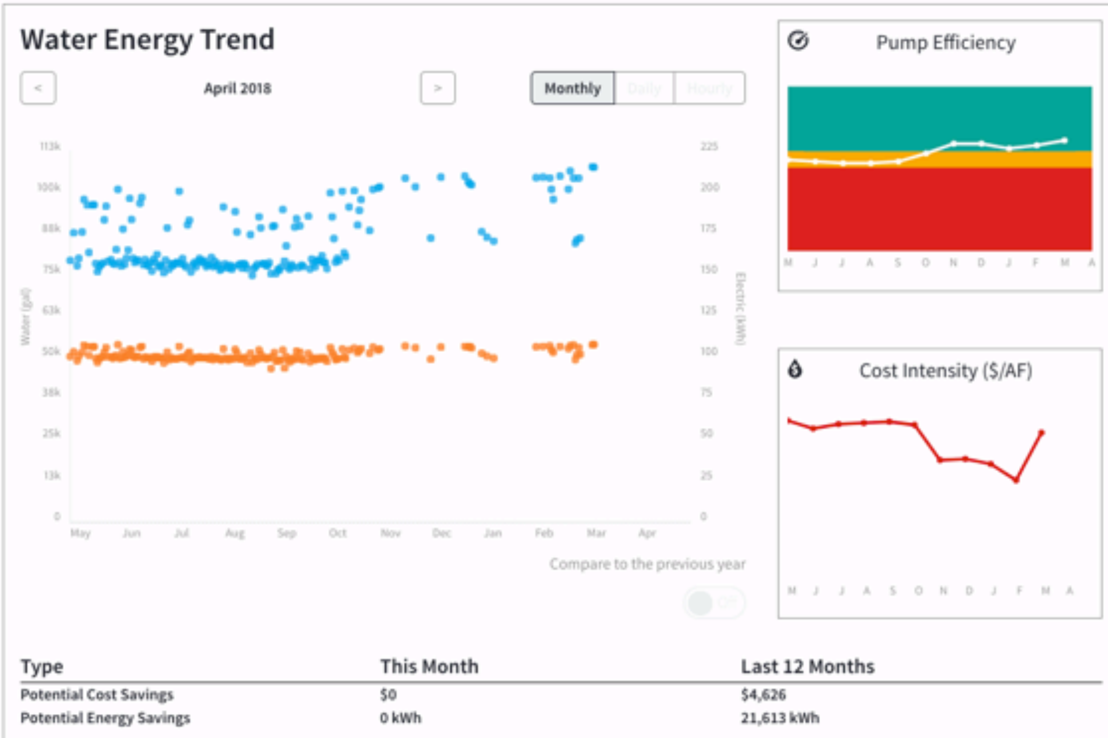
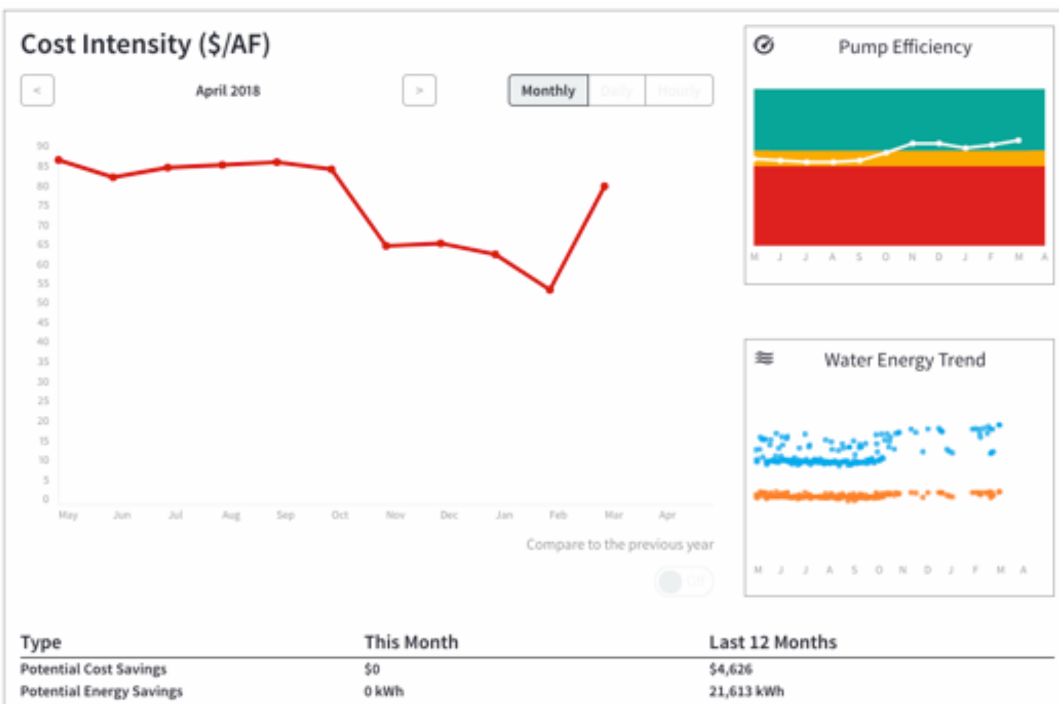



**Figure 16: Cost Intensity Chart**



*Cost Calculator*

The Cost Calculator feature on the Dashboard allows users to forecast the actual energy costs related to a given irrigation schedule in advance. This tool was built to help growers make more informed decisions about their watering habits in line with energy (kWh) and demand (kW) charges per irrigation pump, based on their actual feedback. Per Figure 17, this feature has a chart which shows the cost per acre-foot of water during off-peak, partial peak, and peak times of day and overlays this information with the user's local weather data (specifically, Evapotranspiration or "ET"). The user can enter up to four irrigation sets per day and dynamically shift what time those irrigation sets occur based on the actual energy charges and TOU demand charges they would incur on that specific day. As the user changes the irrigation set information, the cost associated with that schedule is also dynamically updated. The user can see both a daily view and a weekly view of their irrigation schedule and associated energy costs for that day or projected for that month (Figure 18).

**Figure 17: Cost Calculator**

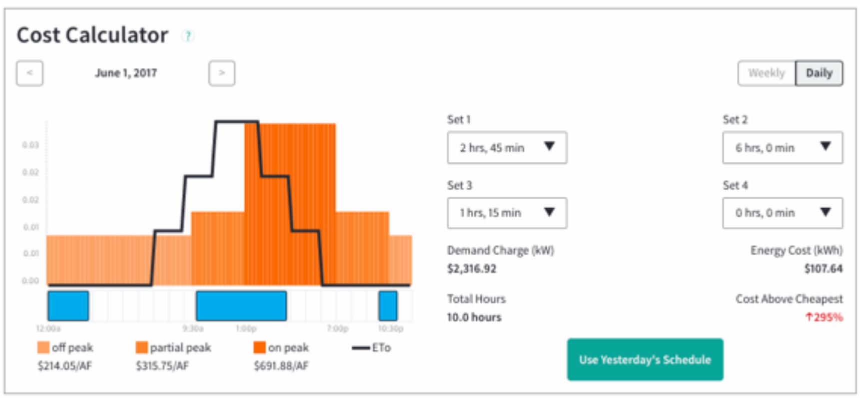
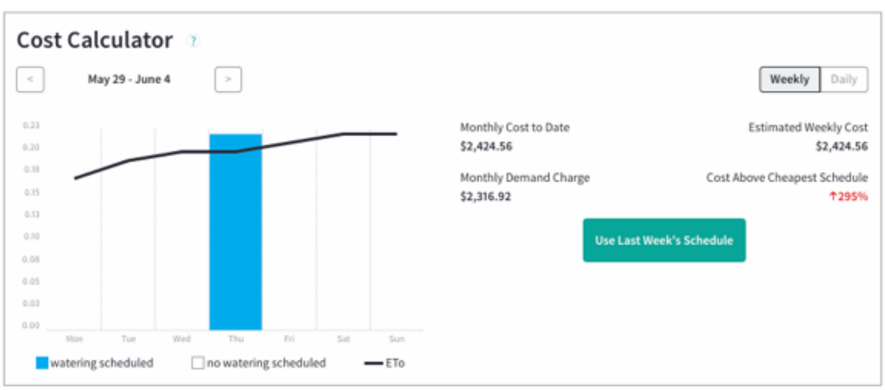



**Figure 18: Cost Calculator Weekly View**



**Pump Status**

The Pump Status page of the software interface shows the user exactly what is happening at their various pumps and buildings in real time. Farmers can see where their pumping equipment or buildings are located with geo-tagged data, whether their pumping equipment is currently running (on or off status), their actual cost of water in per acre-foot measurements per pump, and the current efficiency status of an irrigation pump. All of this information allows farmers to see their energy and water consumption in real time, and to make cost-driven decisions with their energy data.

Figure 19 shows a map of a partner user's farm with icons placed over the location of the various irrigation pumps, buildings, cold storage units and more. Figure 20 shows that when an icon is clicked on, a small panel displays more detailed information about what is happening with that piece of equipment at that moment.

**Figure 19: Equipment Status Page Map**

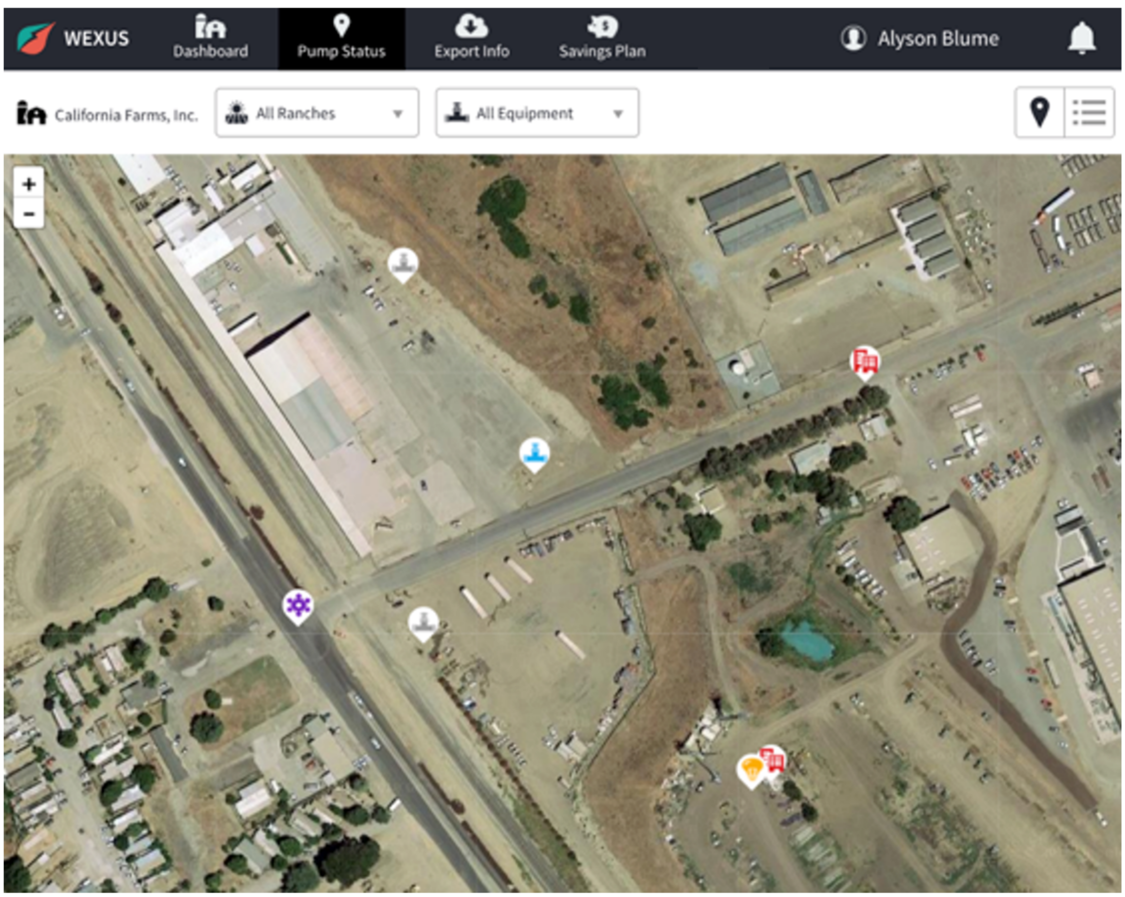
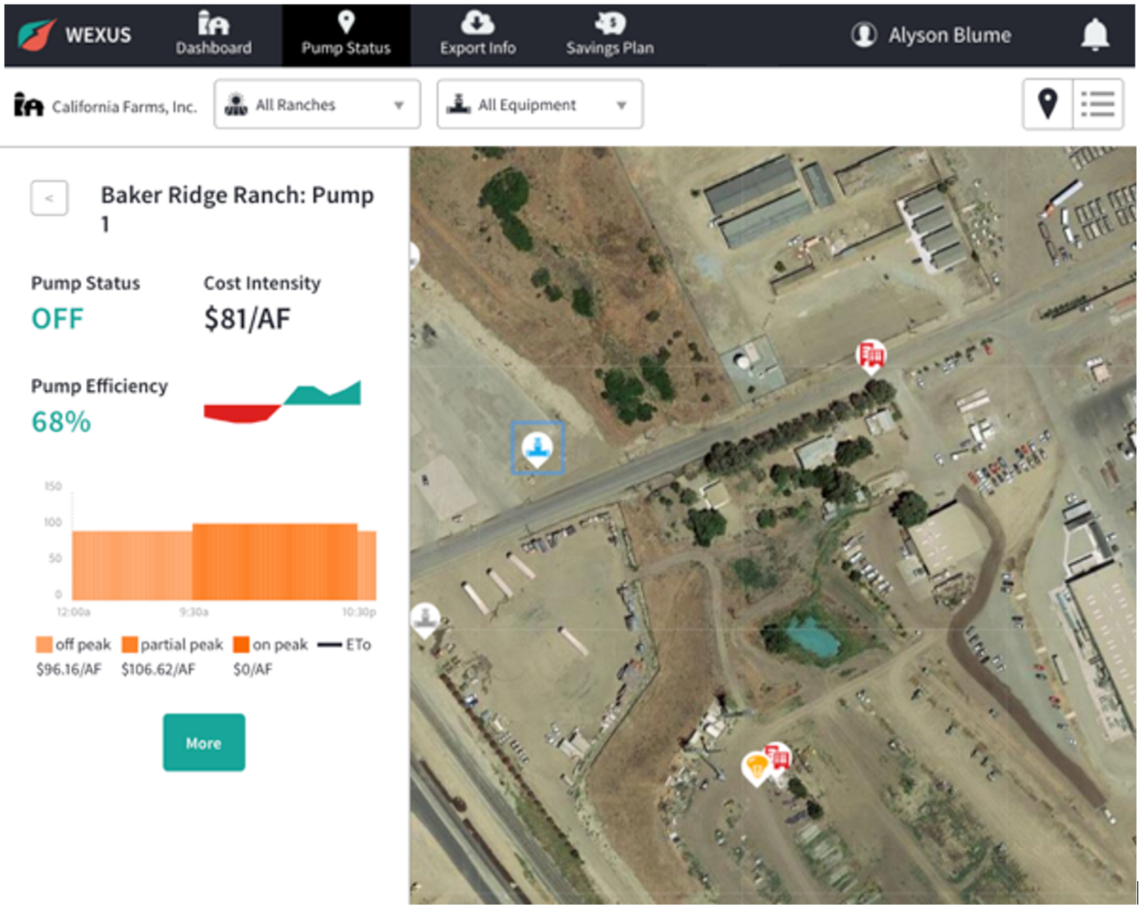


**Figure 20: Equipment Status Map Overlay**

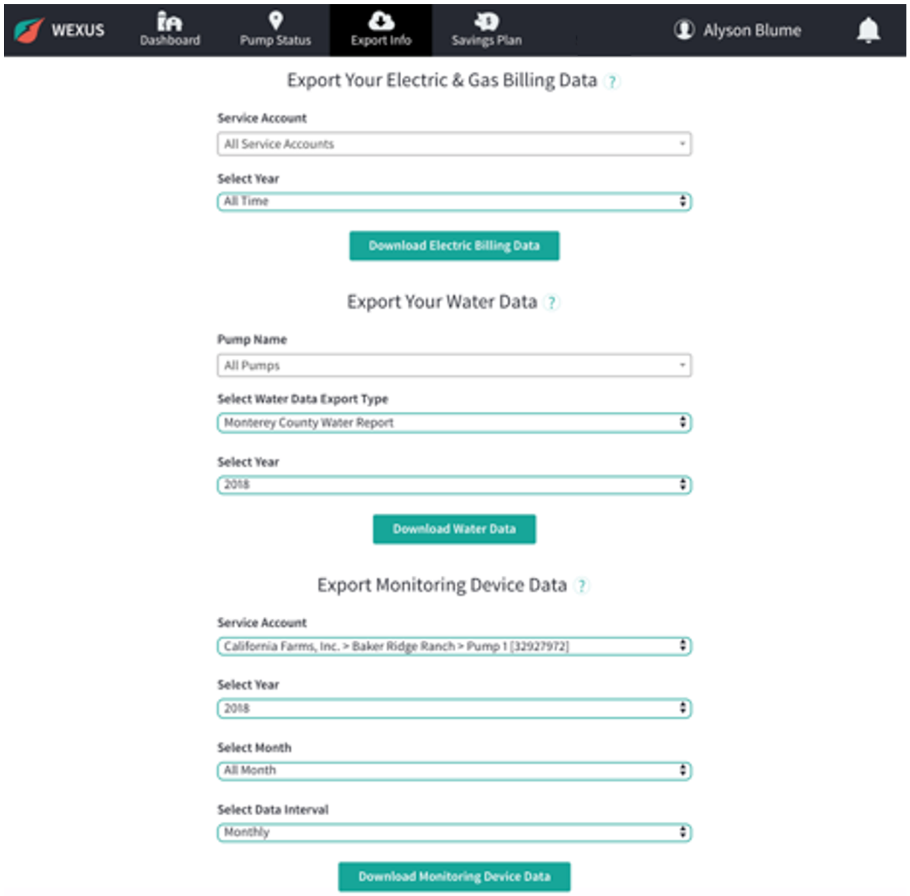



**Export Info**

The Export Info feature allows users to use the Wexus software platform to download billing, energy and water consumption information into exportable CSV files. Once downloaded the user can use the data for deeper analysis or upload the CSV into accounting and software for further monitoring. As shown in

Figure 21, on this page in the Wexus platform, the user can select to export electric or gas related billing data, water data as well as other monitoring device data for their farm by billing period, year, month or day.

**Figure 21: Export Info Page**




### Savings Plan

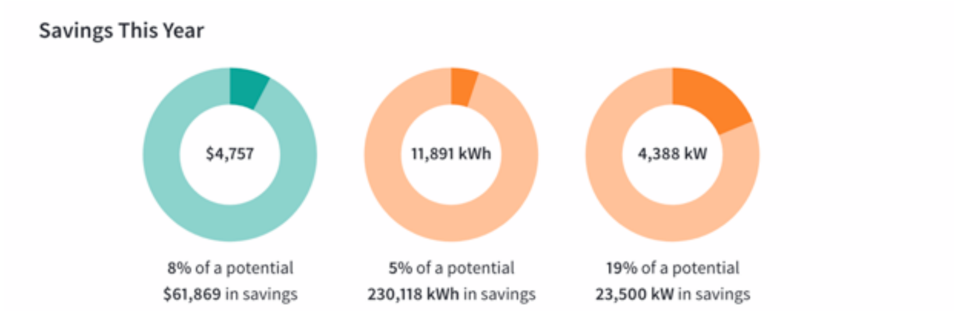
The Savings Plan feature was built into the Wexus software platform. In line with Task 3, Energy Analysis and Recommendations, this section was built with the intent to track annual savings progress and to make actionable recommendations to the user on how to save more money, water and energy.

*Savings This Year*

As shown in

Figure 22 the section begins with several pie charts with track the total potential savings and actual savings in dollars, kilowatts, and kilowatt-hours across the company.

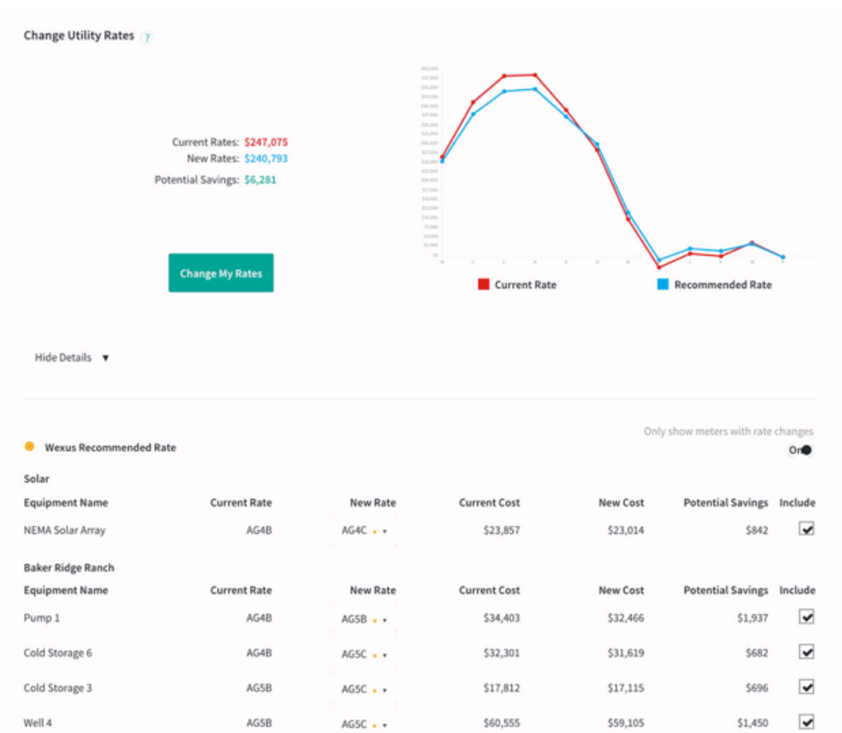
**Figure 22: Savings This Year Charts**




*Change Utility Rates*

The purpose of this section is to help the user choose the best IOU energy rates for their farming operation on a meter-by-meter basis and then notify their utility company to change to the best rate for optimum cost savings. Using the last 12 months of energy usage data for each meter and the latest agricultural rate plans from PG&E or SCE, Wexus calculates various scenarios and recommends new rates for each meter. As shows in Figure 23, this section displays what energy costs the user under their current rates and what energy would cost under the new rates. The user can also examine other scenarios besides the Wexus recommended rates to see how their costs could change. Once they have chosen their new rate plans, the user can click the button in this section to send a notification to Wexus to contact the utility company and have the rates changed on the user's behalf.

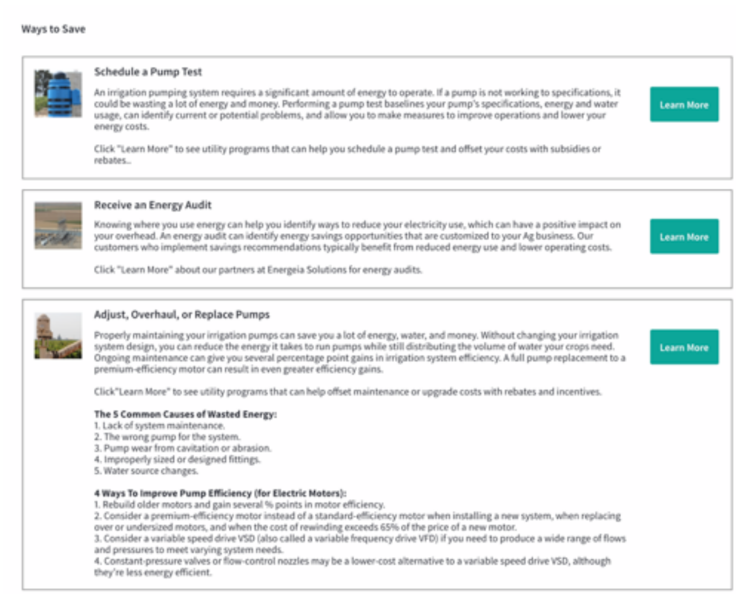
**Figure 23: Rate Analysis**



*Ways to Save*

The third section of the Savings Plan feature provides recommendations on actionable ways to save more cost, energy and water through IOU programs. The recommendations are customized to the user's utility company and provide links to places where they can get more information or take action (Figure 24).

**Figure 24: Ways to Save Recommendations**




*Important Contacts*

The final section of the Savings Plan feature displays important contacts (Figure 25). These contacts are all energy and water related, including their IOU account manager, and provides a place for the grower to quickly find the vendors they need for all their energy and water related needs.

**Figure 25: Important Contacts**


## Email Reports

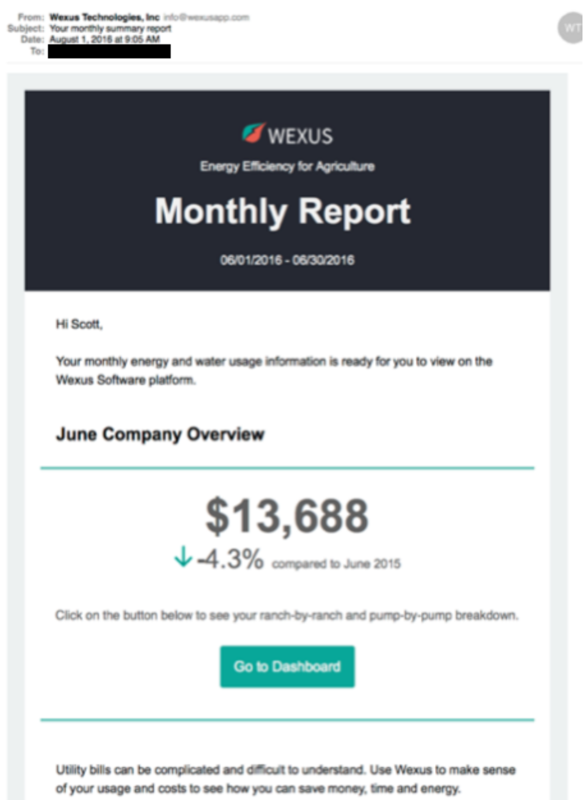
### Monthly Email Reports

At the end of each month, users are sent a report via email. The purpose of this email (Figure 26), in line with Task 4: Implementation and Continuous User Engagement, is to provide a monthly summary of the user's energy use. The following information is displayed in the body of the email:

- Total amount spent on energy that month and a comparison to how much was spent at the same time the previous year
- The average pump efficiency of each pump monitored that month
- The change in each pump's efficiency level since the last moth
- The trend in pump efficiency for each pump over the last 12 months
- A button to click and log into the Wexus dashboard for more detailed information.

This email is sent automatically by the Wexus software platform to each user at the end of each month.

**Figure 26: Monthly Email Report**



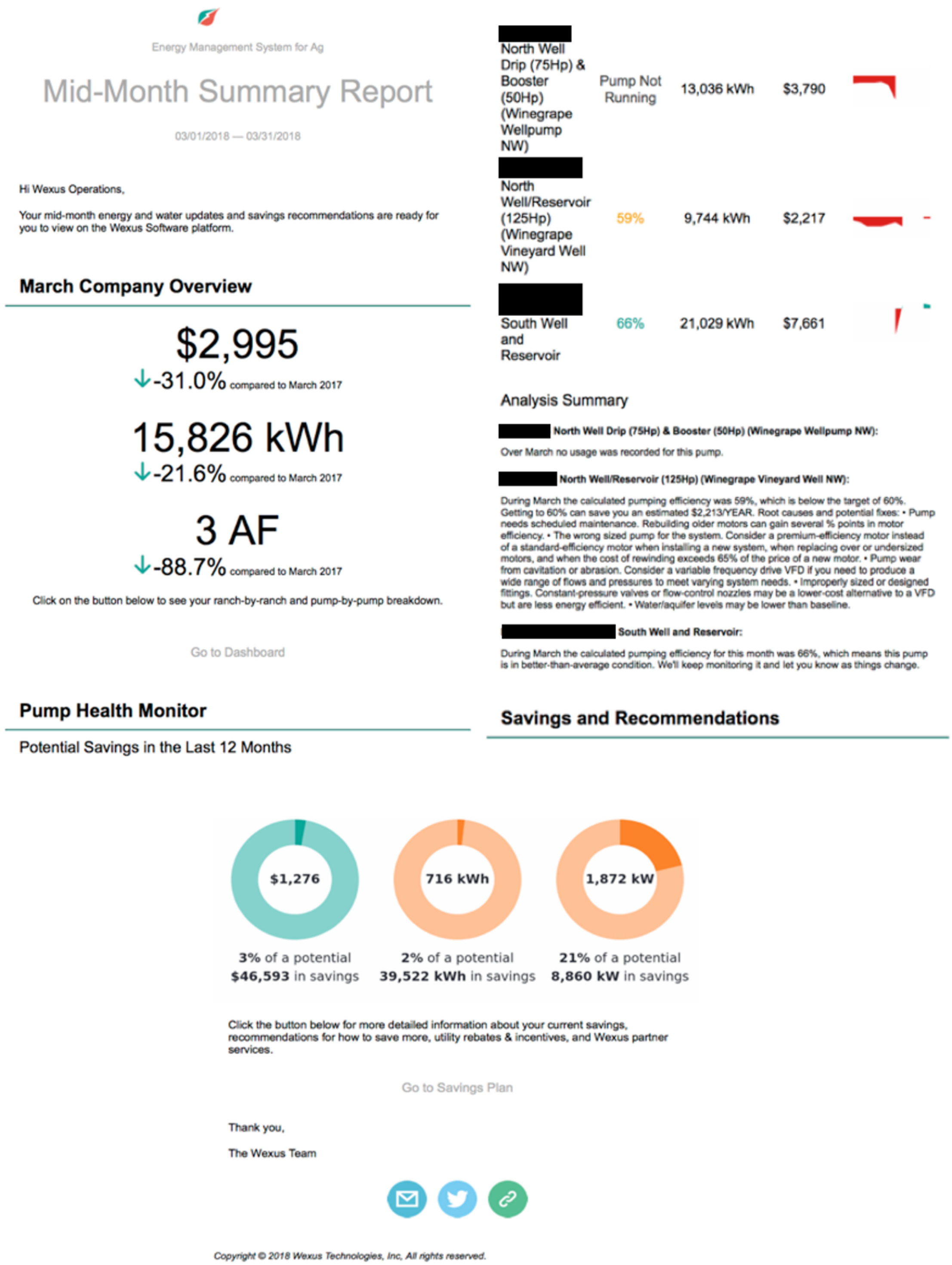

### Mid-Monthly Email Reports

In line with Task 4: Implementation and Continuous User Engagement, a bi-weekly site energy report email (Figure 27) is sent to users. It was created in a way that it can be sent automatically by the Wexus software platform mid-month and it can also be customized by the Wexus operation team if desired. The following information is displayed in the body of the email:

- Total amount spent on energy that month and a comparison to how much was spent at the same time the previous year
- The total energy consumed that month and a comparison to how much was consumed at the same time the previous year

- The total water consumed that month and a comparison to how much was consumed at the same time the previous year
- The average pump efficiency of each pump monitored that month
- The change in each pump's efficiency level since the last moth
- The trend in pump efficiency for each pump over the last 12 months
- An analysis of each pump's efficiency and recommendations on how to improve the efficiency level, if needed
- The total number of alerts sent for each pump and the potential energy and dollar savings resulting from responding to those alerts
- An analysis of the alerts the user responded to and the resulting actual savings from that response
- Pie charts tracking potential and actual dollar, kilowatt and kilowatt hour savings
- A button to click and log into the Wexus dashboard for more detailed information.

**Figure 27: Mid-Monthly Email Report**


Energy Management System for Ag

## Mid-Month Summary Report

03/01/2018 — 03/31/2018

Hi Wexus Operations,

Your mid-month energy and water updates and savings recommendations are ready for you to view on the Wexus Software platform.

### March Company Overview

$2,995
-31.0% compared to March 2017

15,826 kWh
-21.6% compared to March 2017

3 AF
-88.7% compared to March 2017

Click on the button below to see your ranch-by-ranch and pump-by-pump breakdown.

Go to Dashboard

### Pump Health Monitor

Potential Savings in the Last 12 Months

| | | | |
|---|---|---|---|
| [redacted] North Well Drip (75Hp) & Booster (50Hp) (Winegrape Wellpump NW) | Pump Not Running | 13,036 kWh | $3,790 |
| [redacted] North Well/Reservoir (125Hp) (Winegrape Vineyard Well NW) | 59% | 9,744 kWh | $2,217 |
| [redacted] South Well and Reservoir | 66% | 21,029 kWh | $7,661 |

Analysis Summary

[redacted] **North Well Drip (75Hp) & Booster (50Hp) (Winegrape Wellpump NW):**

Over March no usage was recorded for this pump.

[redacted] **North Well/Reservoir (125Hp) (Winegrape Vineyard Well NW):**

During March the calculated pumping efficiency was 59%, which is below the target of 60%. Getting to 60% can save you an estimated $2,213/YEAR. Root causes and potential fixes: • Pump needs scheduled maintenance. Rebuilding older motors can gain several % points in motor efficiency. • The wrong sized pump for the system. Consider a premium-efficiency motor instead of a standard-efficiency motor when installing a new system, when replacing over or undersized motors, and when the cost of rewinding exceeds 65% of the price of a new motor. • Pump wear from cavitation or abrasion. Consider a variable frequency drive VFD if you need to produce a wide range of flows and pressures to meet varying system needs. • Improperly sized or designed fittings. Constant-pressure valves or flow-control nozzles may be a lower-cost alternative to a VFD but are less energy efficient. • Water/aquifer levels may be lower than baseline.

[redacted] **South Well and Reservoir:**

During March the calculated pumping efficiency for this month was 66%, which means this pump is in better-than-average condition. We'll keep monitoring it and let you know as things change.

### Savings and Recommendations

| $1,276 | 716 kWh | 1,872 kW |
|---|---|---|
| **3%** of a potential **$46,593** in savings | **2%** of a potential **39,522 kWh** in savings | **21%** of a potential **8,860 kW** in savings |

Click the button below for more detailed information about your current savings, recommendations for how to save more, utility rebates & incentives, and Wexus partner services.

Go to Savings Plan

Thank you,

The Wexus Team

## Alerts

As part of Task 3 Energy Analysis and Recommendations, the Wexus software platform automatically detects energy or water issues that need to be addressed by the user and alerts them via in-app notifications and SMS text notifications.

### In App Alerts

The Wexus software platform has been designed to automatically process real-time customer energy and water usage data and then alert users directly within the software platform to actionable issues. As shown in Figure 28**,** a user logs into the platform and sees a bell icon with a number indicating unread alerts pertaining to their farm. When the user clicks the bell icon, a list of specific alerts appears (Figure 29) and can be clicked on for more specific information and a diagnosis of the problem including peak energy usage, missing bills, energy surges, missing energy or water data due to meter problems. Each alert is paired with a specifically designed icon to quickly inform the user to the type of alert and the level of urgency associated with it.

**Figure 28: Alert Icon in Wexus Platform**

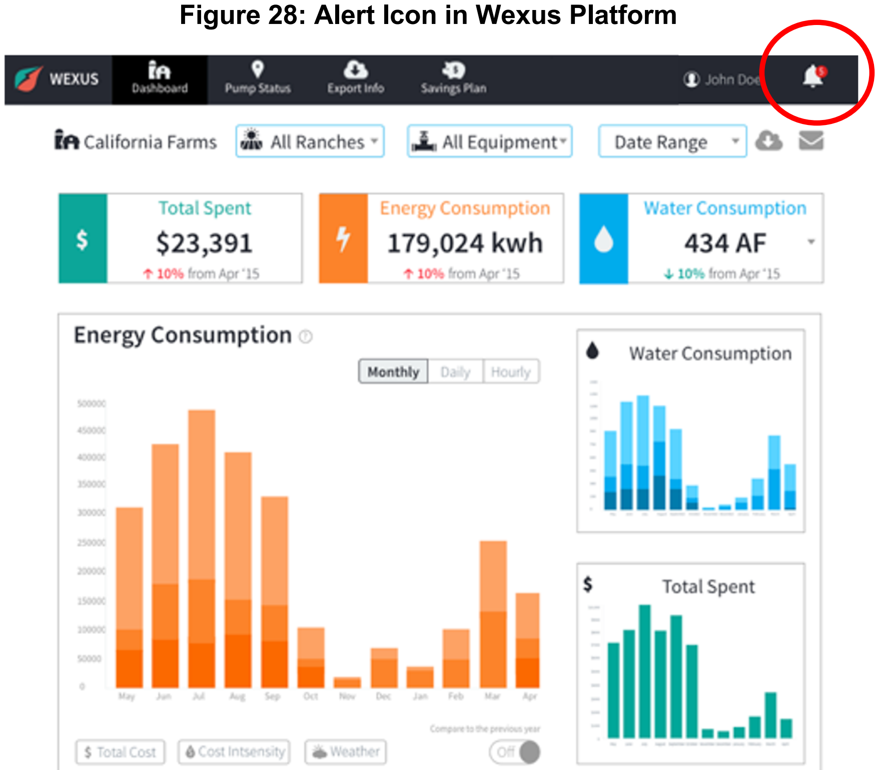
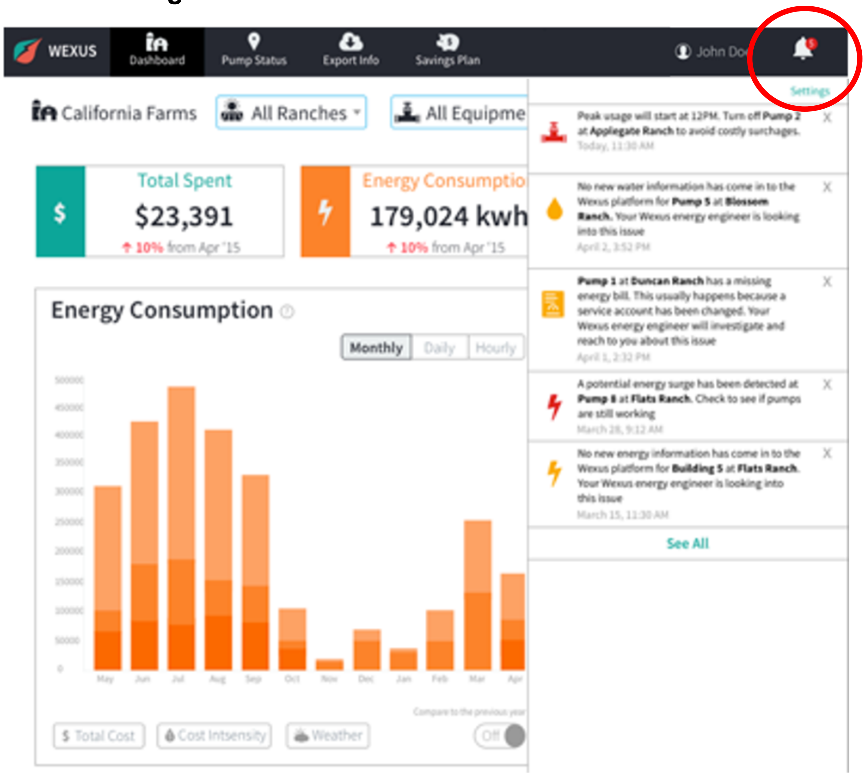


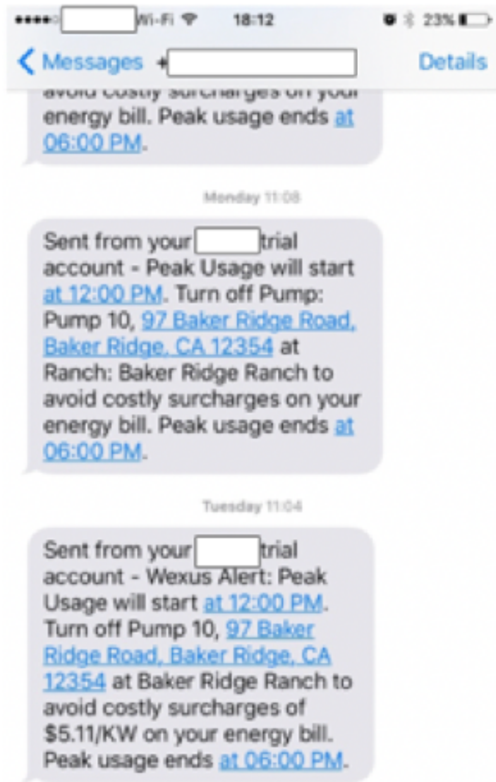
**Figure 29: Alerts Overlaid on Platform Screen**




### SMS Text Message Alerts

When ongoing analysis by the Wexus software platform uncovers an issue that needs to be addressed by the user immediately, such as high peak energy usage or dropping pump efficiency, an alert is automatically sent to the user via SMS text message to their cell phone. This type of alert allows the user to see it in the field and act quickly to remedy the problem before incurring high costs or having an irrigation pump fail during critical watering times (Figure 30).

**Figure 30: Text Message Alert**




## Back End (BE) Database Features & Data Integrations

A back end database integrates multiple data sources and supports what the Wexus user sees on the front end user interface to make data actionable. The back end database is essentially the backbone of the Wexus platform. With a customized administration user interface, Wexus operations and support staff can pull data from multiple sources, enable security, and manage user accounts and content including:

- Company Details – handle all non-energy related company information such as ranch names, addresses, user accounts, etc.
- Water Data Input – pump information, water flow meters, water consumption
- Utility Data – usage points, account IDs, meter and sub-meter locations
- Software Configuration – meter locations, text message alerts, pump efficiency improvements and utility rate schedules
- Third Parties – Utility and energy partner data
- Solar – Solar array and NEMA account information
- Alerts – Energy and water alert configuration and messaging

Various cloud-based sources of data have been integrated into the Wexus back end database through multiple APIs:

- Utility bills and energy consumption
- Sub-meter and water consumption data
- Weather information
- Maps
- SMS alerts

- Email report integration
- Dashboard metrics and analytics
- Error logging
- User contracts
- File storage

# CHAPTER 3: Measure Phase

During the Measure Phase, the Wexus team accomplished the goal of validating product features with usability tests, partner farm interviews, and split, or alpha/beta, testing. This process involved initial research via partner farms to understand pain points and specific industry needs around energy and water management. The Wexus team accomplished this goal by visiting and conducting multiple user experience interviews with the four partner farms in this project to gain an understanding of the features that users prefer as well as recommendations for improving the software experience. The results were compiled, documented and analyzed to validate software features and improve the Wexus platform.

## Product Feature Development and Validation

### Pilot Farm Surveys

During the initial stages of this project in July-October 2015, the four pilot farms (Row Crop, Vineyard, Dairy, and Berry) were interviewed. Their pain points around energy, water and labor task management were recorded, their historical energy and water data (where available) was baselined, and their specific energy-water crop needs were discussed.

The Wexus team established baseline energy usage across each partner site through an analysis of one year's energy and cost data, available from the local utility (PG&E and SCE). The data was accessed from the utility on behalf of the partner site via standard utility data privacy forms and processes, and continuously uploaded into the Wexus software database. The Wexus team then conducted an initial site visit at each partner site to audit existing equipment specifications and determine on-site operations through one on one interviews with employees. Then the team uploaded and analyzed partner site information and energy data into the Wexus software database and determined potential energy savings measures. The team then trained the partner site how to effectively use the software via webinars and additional on-site visits. On a bi-weekly-to-monthly basis, Wexus team members conducted partner site follow-up meetings to gather continuous feedback about the software and fed this information into product development.

The Wexus team discovered an overall theme across all four partner farms that energy and water management were a laborious task for each farm, regardless of crop type. Each farm had little insight into energy costs, particularly during time of use periods. Utility bills were sent in paper format each month, and energy spend on irrigation was seen more or less as a "sunk cost" of doing business due to a complete lack of actionable, real time data or any software applications to help manage the energy data or water data process in the field.

## Usability Testing

To conduct usability testing in order to improve the software platform experience, the Wexus team gathered feedback from its four pilot farm sites through a series of moderated testing sessions. The team presented users with various software prototypes to gauge their effectiveness. The goals of these sessions were to:

- Discover basic usability problems.
- Gauge user understanding of core software feature concepts.
- Understand how the data being presented is used and acted upon.
- Gauge the value of data and users' understanding of data visualizations.
- Gauge user understanding of the software interface and graphics.

The results of these sessions were recorded and analyzed by the Wexus team. Many of the comments from the users revolved around the data and its applicability in various farming-related decisions. The overall feedback from the pilot farm users was positive and mapped into a "word cloud" to determine the most impactful areas (Figure 31). The most common software recommendations from users were mapped into another "word cloud" (Figure 32). Those recommendations were centered around data specifically: to have more than one unit of measurement for water usage; to include and compare more data sets; to have robust data controls; and to include more data for irrigation pump efficiency. Users also wanted notifications for peak energy usage/time of use, additional guidance and recommendations for utility rate analysis based on historical time of use and forecasted energy costs and usage in future months depending on the seasonality of the crop and growing cycle.

Many of these recommendations were integrated into the Wexus platform including more data sets, robust data controls, rate analysis, more specific irrigation pump data, notifications for peak energy usage and higher energy costs/demand charges, and guidance on utility rate analysis and rate plans.

**Figure 31: Word Cloud of Positive Partner Farm User Feedback**

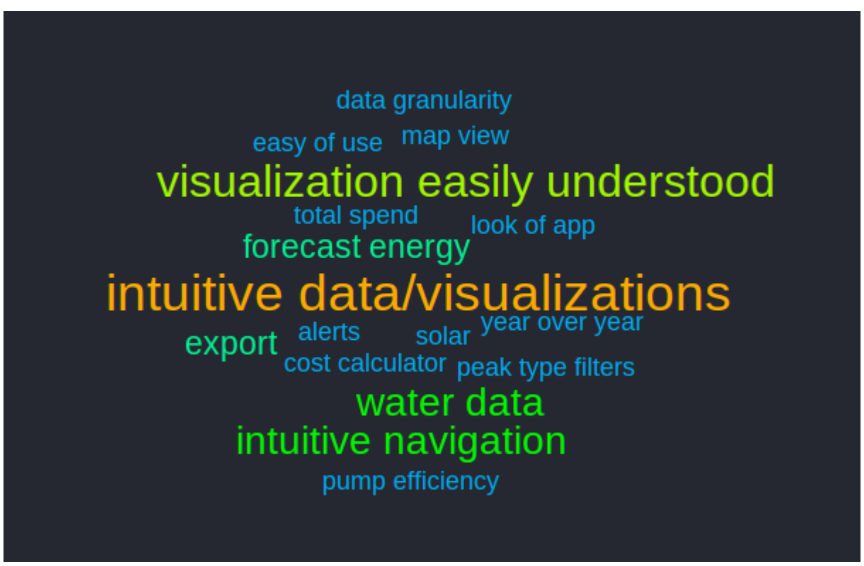
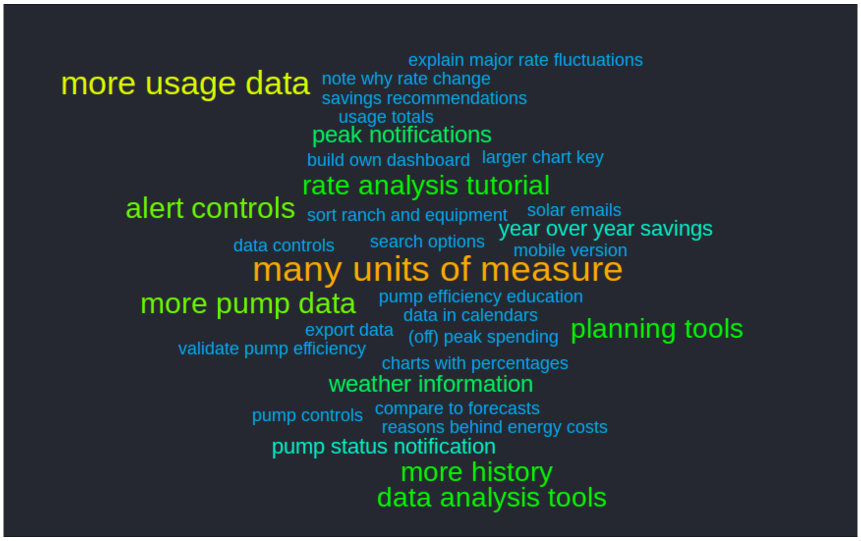


**Figure 32: Word Cloud of Partner Farm User Recommendations**




## Split, or Alpha/Beta, Testing

Split, or Alpha/Beta, testing is a software industry standard method of determining user preferences for layouts, data visualization formats, and other user experiences by evaluating an Alpha version as compared to a Beta version. Wexus provided pilot farm users with multiple prototypes and data visualization options to evaluate which version of a feature was the most effective. Throughout the course of the project there were several tests performed with the pilot sites.

The first example of a split test sought to determine the most effective method for naming an energy usage endpoint from a list of equipment (i.e. irrigation pumps, cold storage buildings, and others). The Wexus team presented two options to the pilot farm sites to label their utility meter data and associated equipment: (1) "Meter List" and (2) "Equipment List." The Berry Grower, the Vineyard/Wine Grower and the Dairy Farm all preferred the name "Equipment List" over the name "Meter List" because the naming convention more easily fit within their farming operations.

In the second example of a split test, users from the Vineyard/Wine Grower pilot farm were presented three different graph types with historical and current energy data and asked to evaluate which graph was most effective for their needs. The first graph was presented in the form of a bar chart with current and year-over-year energy consumption data that allowed for quick comparisons and analysis. The second graph was presented in the form of a donut/pie chart with the same data. And the third graph was presented in the form of an area chart. The users all preferred the bar chart graph view for displaying energy data and the Wexus team incorporated these findings into the dashboard.

In the third example of a split test, pilot farm users were presented two different options for viewing water usage data: measurement in gallons or measurement in acre-feet. Acre-feet is a commonly used unit of measurement in the agricultural industry (one acre-foot equals 325,851 gallons). All users preferred to have the option to toggle between both gallons and acre-feet. The Wexus team incorporated this feedback into the dashboard feature.

# Metrics & Reporting

To supplement the product feature development and validation in the Measure Phase, Wexus also developed metrics to evaluate and track user persona engagement and activity. The Wexus team measured partner farm engagement using analytics software such as Keen.io, launched email reports with various software tools like Mailchimp, and logged all automated SMS text alerts within the Wexus platform. Wexus team members also conducted regular in-person and remote check-ins within the pilot farm sites. This section details how Wexus defined and built user metric reports and provides initial results.

## User Metrics for the Platform

Analytics tracking software like Keen.io was integrated into the Wexus platform to track specific user actions. The Wexus team tracked key actions to evaluate user engagement, such as monthly user logins, monthly page visits, page visits by pilot farm user type.

### Monthly User Logins

Monthly user logins are defined as a cumulative count of the number of times a specific user logs into the platform. Then the Wexus team analyzed the types of users logging into the platform and categorized them according to user persona type (i.e. General Manager, Ranch Manager, Reporting/Accounting, and Sustainability Manager).

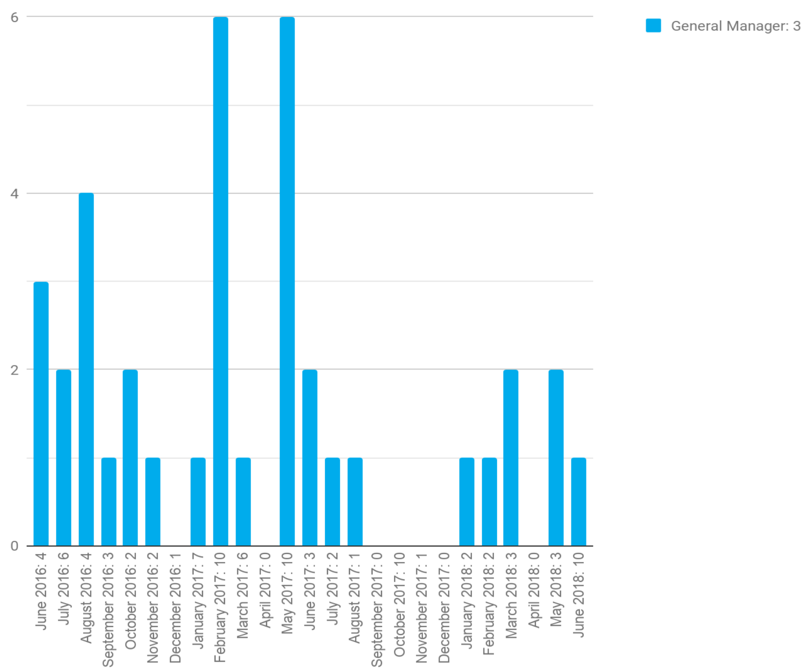
Per Figure 33, the General Manager user personas at the four pilot farm sites consistently logged into the platform on a monthly basis throughout the year, with the most logins during the peak summer season when energy and water usage is at its highest intensity. The team also noticed a drop off in logins during the less energy-water intensive winter months due to the seasonality of the agriculture industry.

Per Figure 34, the Reporting/Accounting user personas at the four pilot farm sites consistently logged into the platform during the winter season when compliance and reporting is typically due for year-end accounting closeout/reconciliation.

Per Figure 35, the Sustainability Manager users logged into the platform the most in October 2017 consistently logged into the platform on a monthly basis throughout the year, with the most logins during the peak summer season when energy and water usage is at its highest intensity. The team also noticed a drop off in logins during the less energy-water intensive winter months due to the seasonality of the agriculture industry.

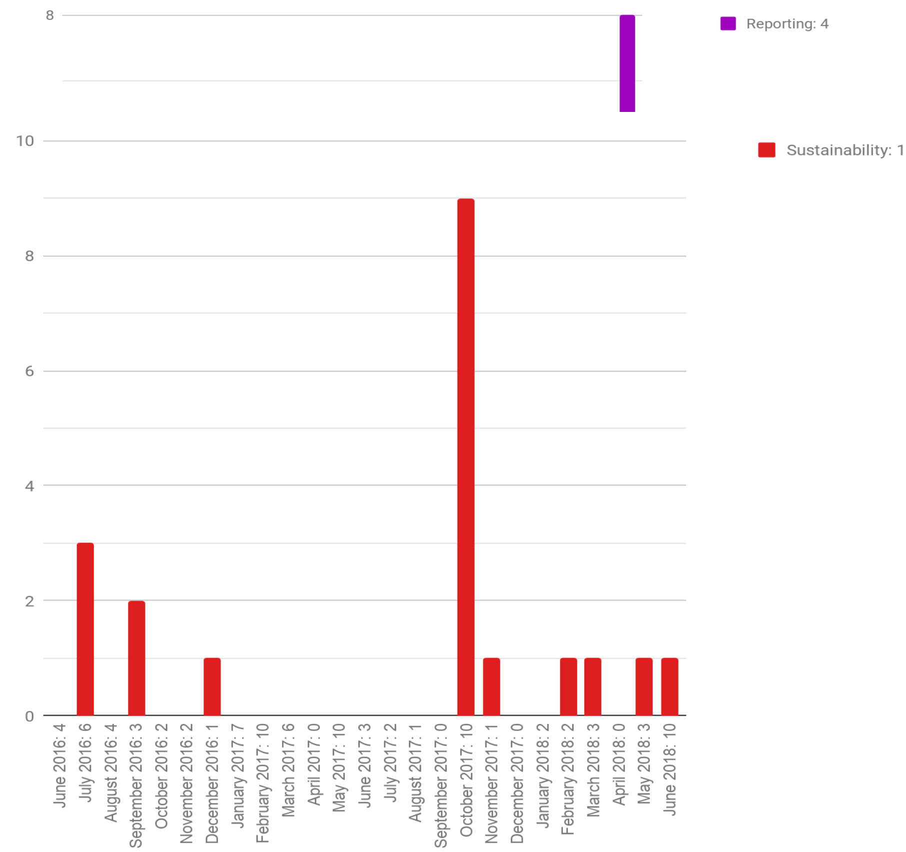
Per Figure 36, the Ranch Manager user logged into the platform in July 2017 after the SMS text alert features were launched. Ranch Managers tend to spend most of their time directly in the field and communicate via direct cell phone calls or text messages. The team noted that Ranch Managers derived the most value from the software via the in-app or SMS text alert messages with actionable information.

**Figure 33: General Managers Monthly Number of Logins (June 2016-June 2018)**




**The bar chart above shows the number of logins per month for the three general managers from the partner farm sites between June 2016 and June 2018.**

**Figure 34: Reporting/Accounting Users Monthly Number of Logins (June 2016-June 2018)**

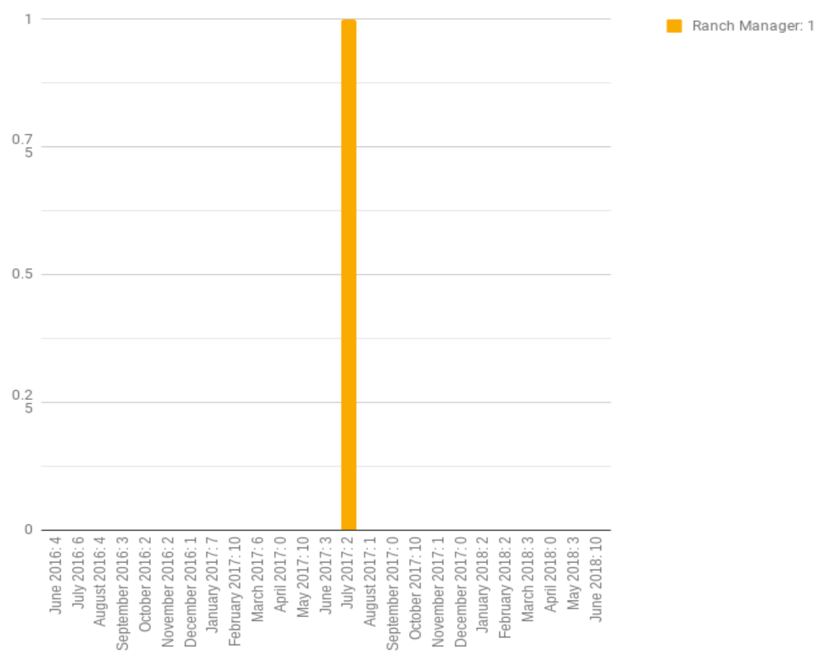



**The bar chart above shows the number of logins per month for the four reporting users from the partner farm sites between June 2016 and June 2018.**

**Figure 35: Sustainability Manager Monthly Number of Logins (June 2016-June 2018)**

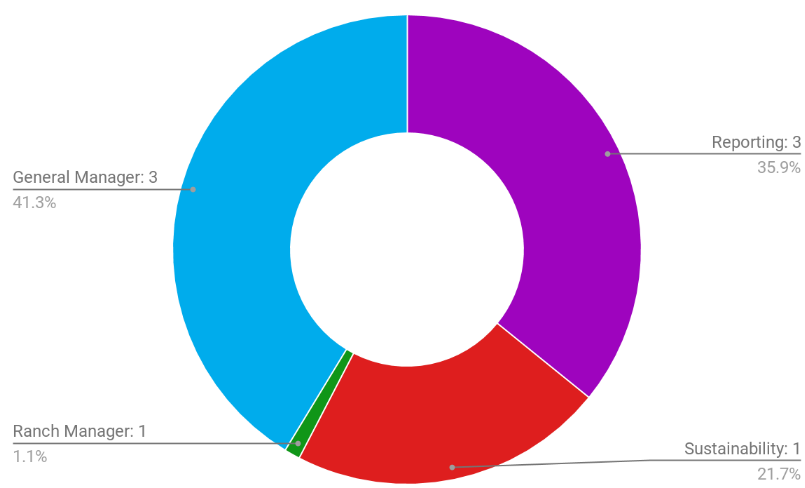
**The bar chart above shows the number of logins per month for the one sustainability manager user from the partner farm sites between June 2016 and June 2018.**

**Figure 36: Ranch Managers Monthly Logins (June 2016-June 2018)**




**The bar chart above shows the number of logins per month for the one ranch manager user from the partner farm sites between June 2016 and June 2018.**

**Figure 37: Login Percentage by User Persona Type (June 2016- June 2018)**




**Donut chart showing the overall percentage logins from June 2016 to June 2018 by each partner farm user persona.**

## Total Page Visits per Month

Total page visits per month are defined as a count of the number of times a specific user logs into the platform under a specific page type. Throughout the project, the Wexus team analyzed the types of pilot farms logging into the platform and tracked which specific pages in the platform they logged into in order to determine the effectiveness of each page and its features. These pages were: Company/Dashboard Page, Pump Status Page, Export Info Page, and Savings Plan Page.

In the early stages of the project from June 2015 to June 2016, the Wexus team manually tracked the number of user logins per month. After June 2016, the Wexus team implemented an automated tracking system with an industry standard software tool called Keen.io, which allowed more granular user tracking and analytics (this explains the two different graphs below).

Per Table 1, the Company/Dashboard landing page is by default the first page a user sees after logging into the platform. For the twelve-month period from July 2017 to June 2018, six unique partner farm users logged into the platform on a consistent basis.

**Table 1: Total Page Views by Page Type (July 2017-June 2018)**

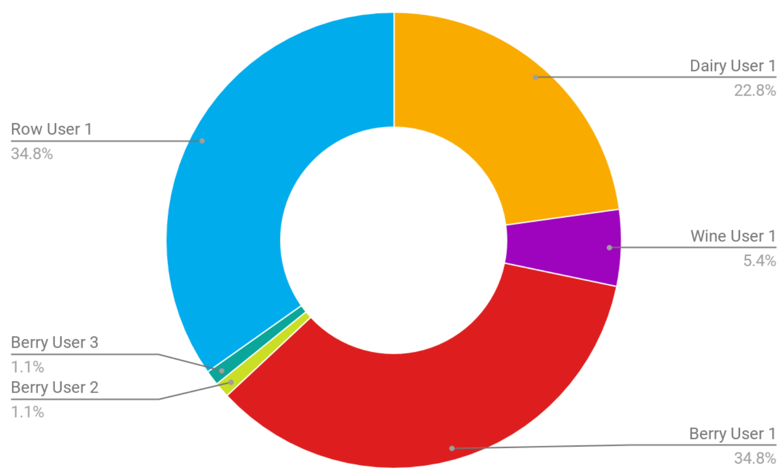
| **Company Page: 6 Unique Visitors** | **Pump Status Page: 3 Unique Visitors** | **Export Info Page: 2 Unique Visitors** | **Ranch Page: 4 Unique Visitors** |
|---|---|---|---|
| July 2017: 2 views | July 2017: 0 views | July 2017: 0 views | July 2017: 0 views |
| August 2017: 2 views | August 2017: 0 views | August 2017: 0 views | August 2017: 1 views |
| September 2017: 0 views | September 2017: 0 views | September 2017: 0 views | September 2017: 0 views |
| October 2017: 10 views | October 2017: 12 views | October 2017: 1 views | October 2017: 7 views |
| November 2017: 1 views | November 2017: 0 views | November 2017: 0 views | November 2017: 0 views |
| December 2017: 0 views | December 2017: 0 views | December 2017: 0 views | December 2017: 0 views |
| January 2018: 2 views | January 2018: 0 views | January 2018: 0 views | January 2018: 0 views |
| February 2018: 2 views | February 2018: 0 views | February 2018: 0 views | February 2018: 3 views |
| March 2018: 3 views | March 2018: 4 views | March 2018: 0 views | March 2018: 3 views |
| April 2018: 0 views | April 2018: 0 views | April 2018: 0 views | April 2018: 0 views |
| May 2018: 3 views | May 2018: 3 views | May 2018: 0 views | May 2018: 5 views |
| June 2018: 8 views | June 2018: 6 views | June 2018: 1 views | June 2018: 14 views |
| **Total Usage: 32 views** | **Total Usage: 25 views** | **Total Usage: 2 views** | **Total Usage: 33 views** |

**The table above shows the number of views under each page within the software during the 12-month period from July 2017 to June 2018. The Company page and the Ranch page had the most views.**

### Total Visits per Page by Grower Type

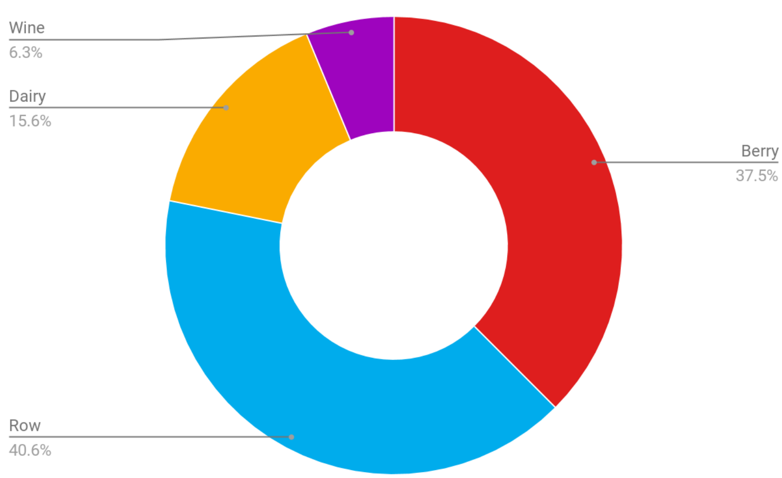
Total page visits by grower type is an informative metric as it provides more granular analysis into which specific pages and data within the Wexus software platform provide the most value to each farm type or user type. Figure 38 shows the total number of page visits by partner farm user for a one-year period between July 2017 to June 2018. The remaining Figure 39, Figure 40, Figure 41, and Figure 42 show a further breakdown of page visits by partner farm user for the Wexus Company page, Pump Status page, Data Export page and Ranch page respectively. The results of logins per page differ by farm type and user type due to the specific information these users seek based on their job roles/personas, which can vary by crop, by month and by seasons in agriculture (i.e. planting, harvesting, off season etc.).

**Figure 38: Total Page Visits by Partner Farm User (July 2017-June 2018)**



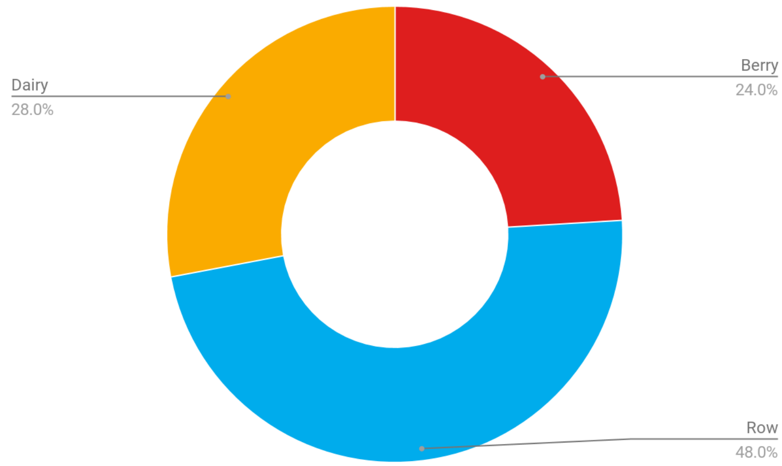

**Donut chart showing which partner farm types and users accounted for the most overall page visits during the 12-month period from July 2017-June 2018. The berry farm users had the most page visits during this time period.**

**Figure 39: Percentage of Company Page Visits by Partner Farm Type (July 2017-June 2018)**



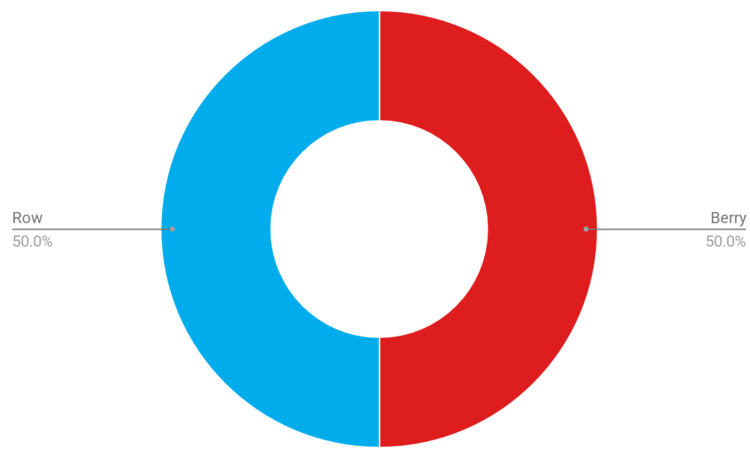
**Donut chart showing which partner farm types accounted for the most Company page visits during the 12-month period from July 2017-June 2018. The berry and row crop farm users had the most Company page visits during this time period.**

**Figure 40: Status Page Visits by Partner Farm Type (July 2017-June 2018)**



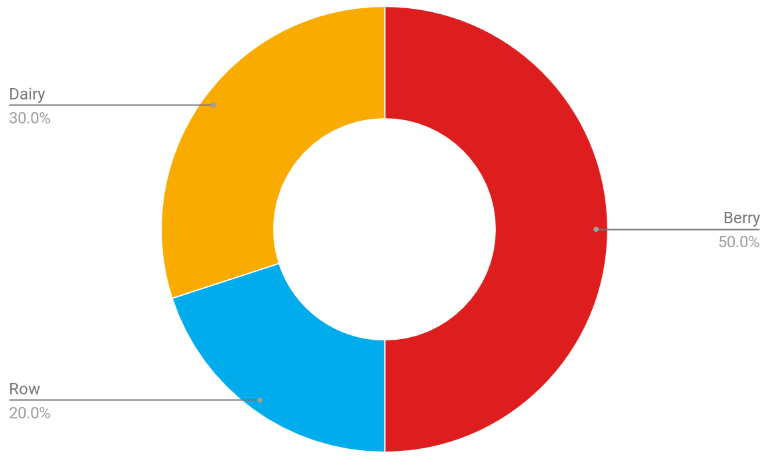

**Donut chart showing which partner farm types accounted for the most Pump Status page visits during the 12-month period from July 2017-June 2018. The row crop farm users had the most Company page visits during this time period.**

**Figure 41: Percentage of Export Data Page Visits by Partner Farm Type (July 2017-June 2018)**




**Donut chart showing which partner farm types accounted for the most Export Data page visits during the 12-month period from July 2017-June 2018. The row crop and berry farm users had an equivalent percentage of page visits.**

**Figure 42: Percentage of Ranch Page Visits by Partner Farm Type (July 2017-June 2018)**




**Donut chart showing which partner farm types accounted for the most Ranch page visits during the 12-month period from July 2017-June 2018. The berry farm users had the highest percentage of page visits.**

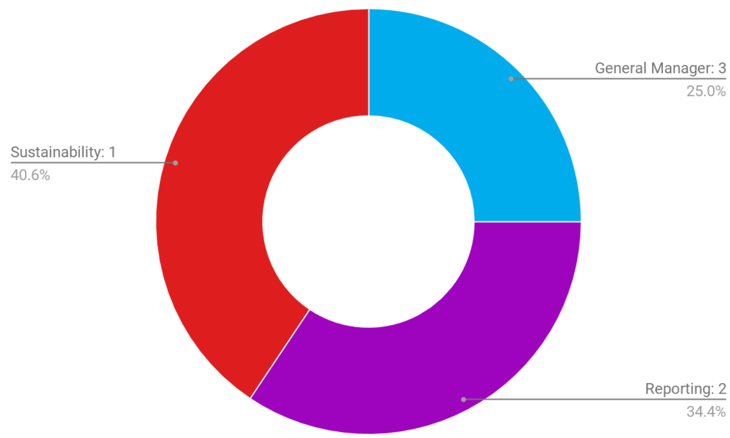
### Total Page Visits by User Persona

The total page visits by user persona allows a deeper understanding of which specific users are gaining relevant information and actionable insights from the software to make cost, energy and water reporting decisions (Figure 43 and Figure 44). Wexus found that sustainability managers and reporting/accounting users were highly engaged in the platform because the technology made it much easier for them to find and export relevant energy and water data with Wexus' automated tracking, particularly during certain periods of the year like quarterly accounting closeouts or annual corporate sustainability reporting or compliance reporting (Figure 47 and Figure 48).

The Pump Status page was predominantly used by the Sustainability Manager persona with some usage by the General Manager personas. As detailed in Figure 45 and Figure 46, the sustainability manager accounts for nearly half the visits on this page. Those visits were typically concentrated during October, which suggests preparation for annual corporate sustainability reporting and compliance closeout, or for scheduling annual maintenance of pumping systems.

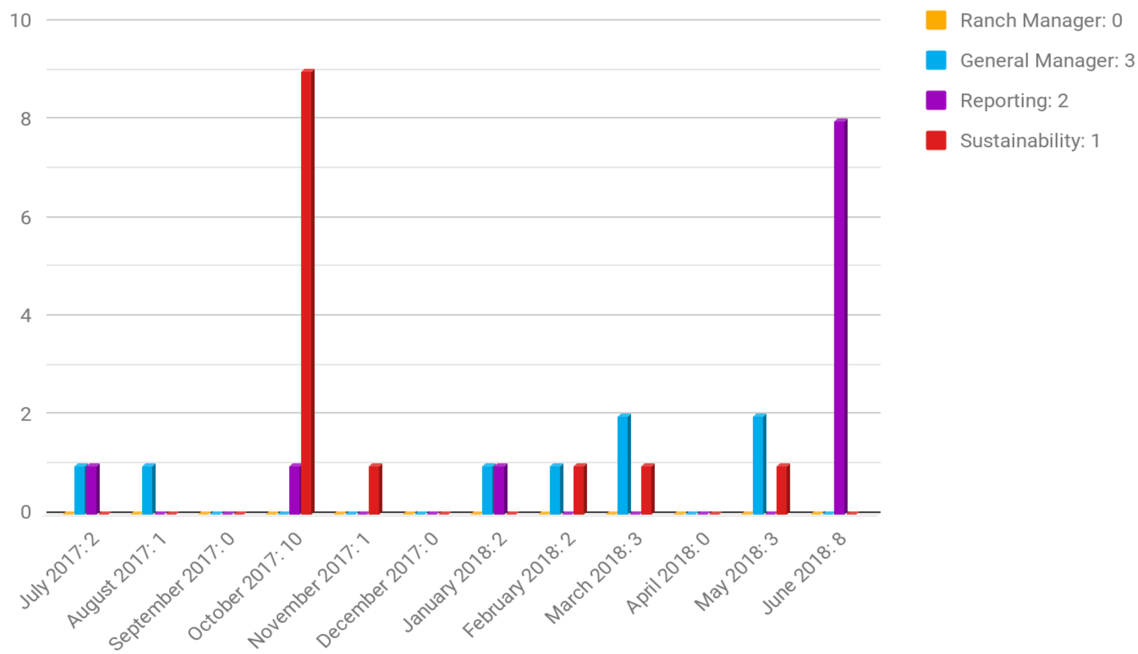
Figure 49 and Figure 50 detail user data about engagement with the Ranch page. This engagement during the project for the Ranch page was most relevant and consistent for General Manager personas, whereas the Reporting/Accounting and Sustainability Manager personas used the Ranch page only a couple of times a year or less.

**Figure 43: Percentage of Company Page Visits by User Persona Type (July 2017-June 2018)**



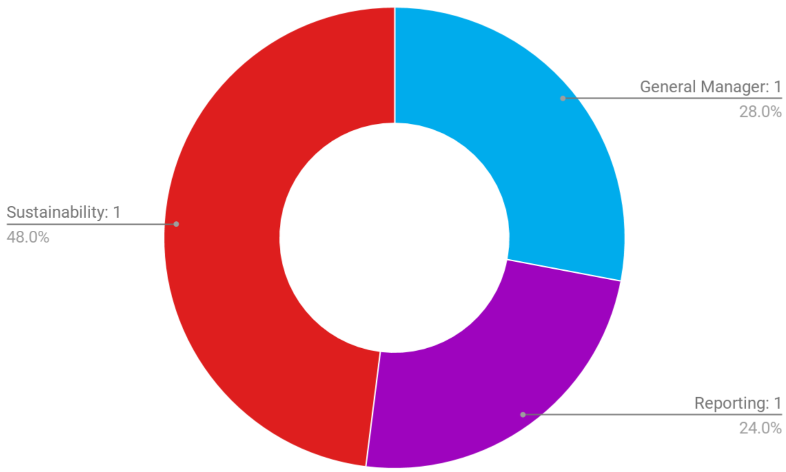

**Donut chart showing which partner farm type users accounted for the most Company page visits during the 12-month period from July 2017-June 2018. The sustainability and reporting users had the highest percentage of page visits.**

**Figure 44: Company Page Visits by User Persona Type (July 2017-June 2018)**



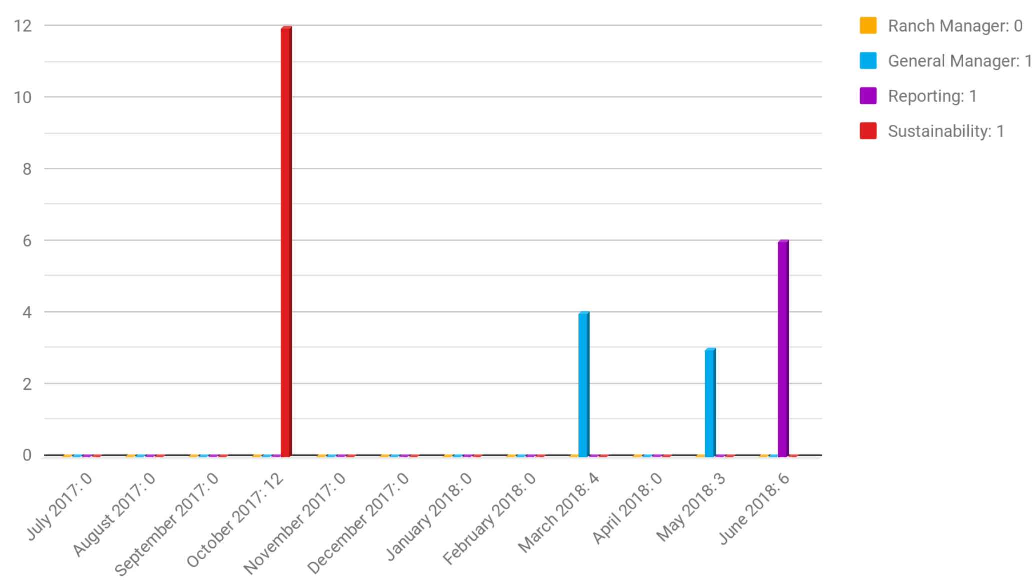

**Bar graph showing the number of monthly Company page visits by user persona type.**

**Figure 45: Percentage of Pump Status Page Visits by User Persona Type (July 2017-2018)**



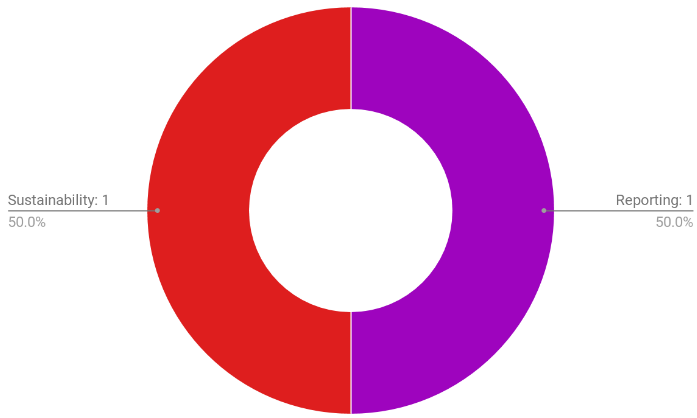

**Donut chart showing which partner farm type users accounted for the most Pump Status page visits during the 12-month period from July 2017-June 2018. The sustainability and GM users had the highest percentage of page visits.**

**Figure 46: Pump Status Page Visits by User Persona Type (July 2017-June 2018)**



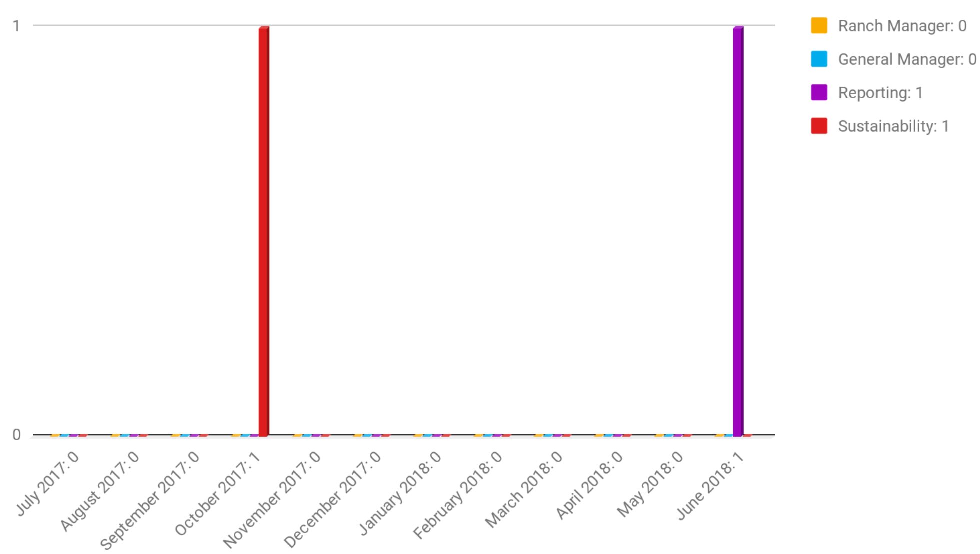

**Bar graph showing the number of monthly Pump Status page visits by user persona type.**

**Figure 47: Percentage of Data Export Page Visits by User Persona Type (July 2017-2018)**



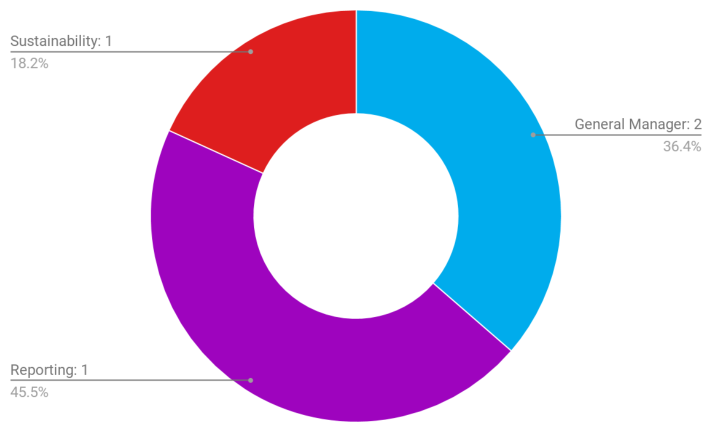

**Donut chart showing which partner farm type users accounted for the most Data Export page visits during the 12-month period from July 2017-June 2018. The sustainability and reporting users had the highest percentage of page visits.**

**Figure 48: Data Export Page Visits by User Persona Type (July 2017-June 2018)**



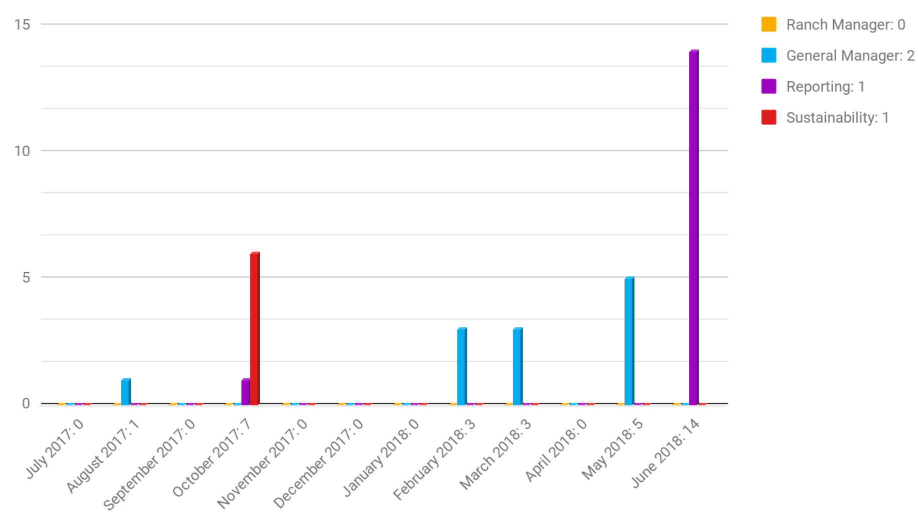

**Bar graph showing the number of monthly Data Export page visits by user persona type.**

**Figure 49: Percentage of Ranch Page Visits by User Persona Type (July 2017-2018)**




**Donut chart showing which partner farm type users accounted for the most Ranch page visits during the 12-month period from July 2017-June 2018. The reporting and general manager users had the highest percentage of page visits.**

**Figure 50: Ranch Page Visits by User Persona Type (July 2017-June 2018)**




**Bar graph showing the number of monthly Ranch page visits by user persona type.**

## User Metrics for Alerts

### In-App Alerts

One of the most requested features from the historical partner farm surveys was the need for real-time alerts. The Wexus team then implemented automated alerts into the software (defined as “in-app alerts”) to notify farmers when a specific, actionable issue relating to energy and water usage or costs occurs on their farm. The types of alerts that were built into the “in-app” (within the platform application) component of the software included the following:

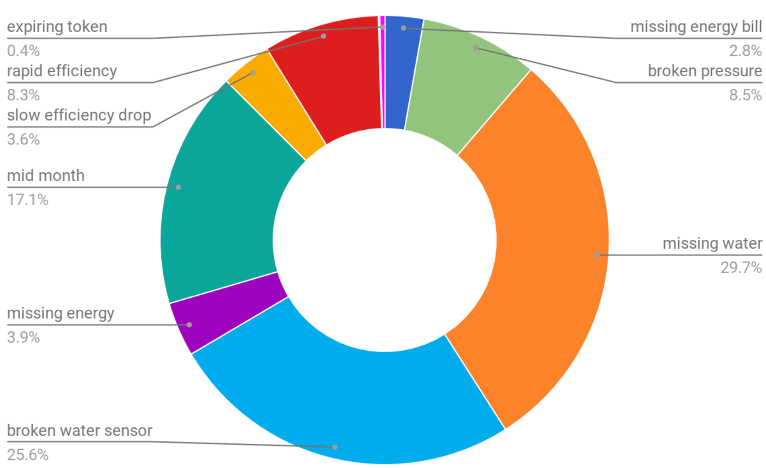
- Missing water data intervals
- Missing energy data intervals

- Broken pump pressure sensor
- Broken water sensor/flow meter
- Missing energy bill
- Mid-month equipment comments
- Slow efficiency reduction (indicating aquifer level decline over time, typically several months)
- Rapid efficiency reduction (indicating an equipment problem, typically over several days)
- Utility rate change request
- Energy usage point changed

Figure 51 shows which in-app alerts were most commonly sent to Wexus users. More than half of the alerts sent to pilot partner farms were for two most common issues: a broken water sensor/flow meter and missing water interval data. When a flow meter fails, the Wexus software sends the "broken water sensor" in-app alert to the user, along with the location and name of the pump so that the user can take action. A broken flow meter also means that Wexus is no longer receiving water data, which results in a second in-app alert, informing the user of missing water interval data.

Most of the time, missing water interval data was due to broken water sensor/flow meters. However, it is important to have this type of alert, because there may be other root causes. Missing water interval data can also be caused by an irrigation pump being shut off for an extended period of time due to scheduled maintenance or simply no need to irrigate crops in that particular field or ranch. An irrigation pump may be removed altogether. Another common cause of missing water data is when the electric utility issues a new service agreement number (this applies to pumps using electrical usage to estimate water usage). In this case, the new service agreement number needs to be assigned in the Wexus software in order to continue receiving electricity data from the utility and estimating water data.

**Figure 51: In-app Alert Percentages by Type**



**The pie chart above shows the percentage of in-app alerts sent to partner farm users by type. Missing water interval data and broken water sensor alerts were the most common in-app alerts, followed by mid-month comments/recommendations and broken pressure sensor alerts.**

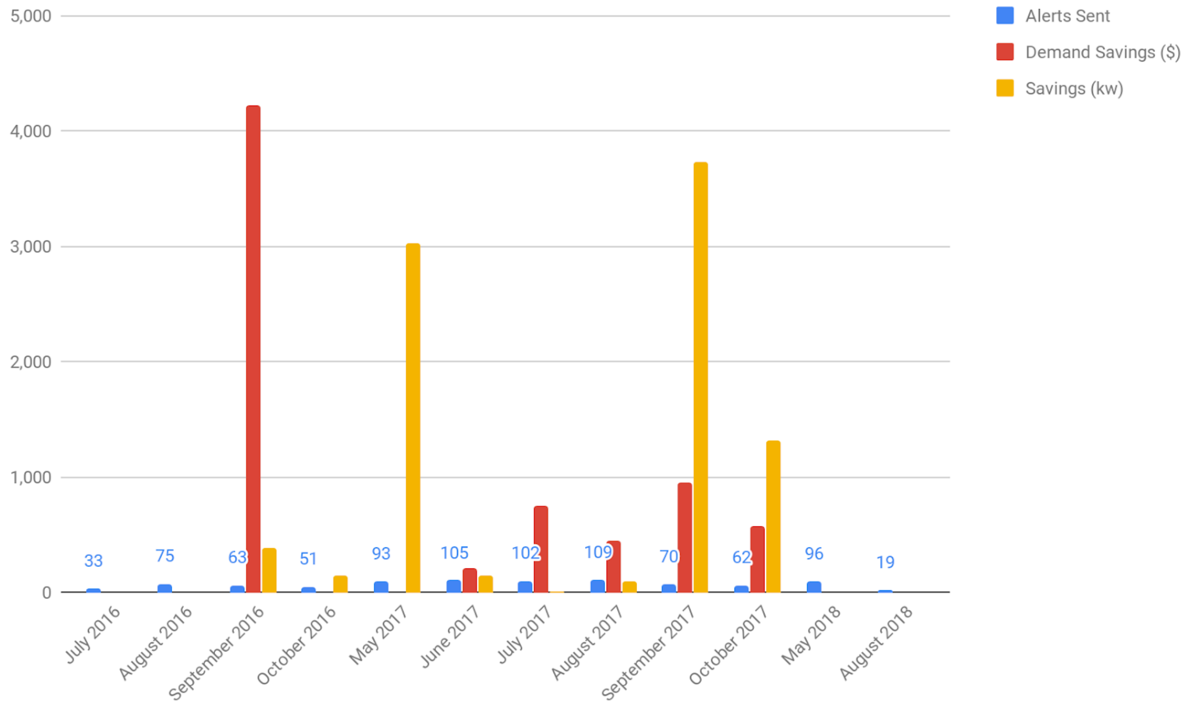
### SMS Text Alerts

During the initial survey/kickoff stage of the project, all of the partner farms requested a specific feature: SMS text alerts as a vehicle to get specific, actionable energy-water related information to employees in the field on their mobile devices. This feature was implemented into the Wexus software and notifies farmers in advance of peak usage hours while an irrigation pump is running. The alert pulls specific field-level data about an irrigation pump: its name and location; the cost per kW in peak demand charges tied to its current utility rate; and whether the pump is on or off. The SMS alert settings can also be adjusted by users directly in the software to alert them at specific times: 30 minutes, 60 minutes or 90 minutes in advance of peak hours.

SMS text alerts helps farmers make an informed cost-driven decision as to whether they should continue to irrigate during costly peak hours to meet the water needs of their crop because of plant stress or weather issues, or potentially shut off a pump to avoid peak hours and the resulting surcharges on their energy bill. The partner farm sites also confirmed that it was very useful to simply know if an irrigation pump in the field was on or off so that managers could confirm whether their employees were following their prescribed crop irrigation schedule for that particular day or week, and if not, hold their employees accountable.

Since this feature was released, a total of 860 SMS alerts were sent during the project for 8 total irrigation pumps at the 4 partner farm sites (2 pumps per farm). See Figure 52. Approximately 10 percent of the time, partner farms were able to shut off their irrigation pumps to avoid peak hours and save costs as well as to avoid potential stress on the utility grid during peak times of day during warmer summer months when energy usage for crop irrigation is typically in full swing.  Wexus had hypothesized that partner farms would receive very frequent alerts, possibly on every peak day, and that they would only be able to respond occasionally due to operational needs. Based on the 10% response rate to peak period alerts, this hypothesis Wexus seems to be true, and partner farms reduce peak period 10% more frequently than they would have in the absence of these alerts. The Wexus team will continue to evaluate the effectiveness of the SMS text alerts and how to further improve this feature during the Learn phase and beyond this project.

**Figure 52: Total SMS Alerts Sent and Demand Savings by Month (July 2016 - July 2018)**



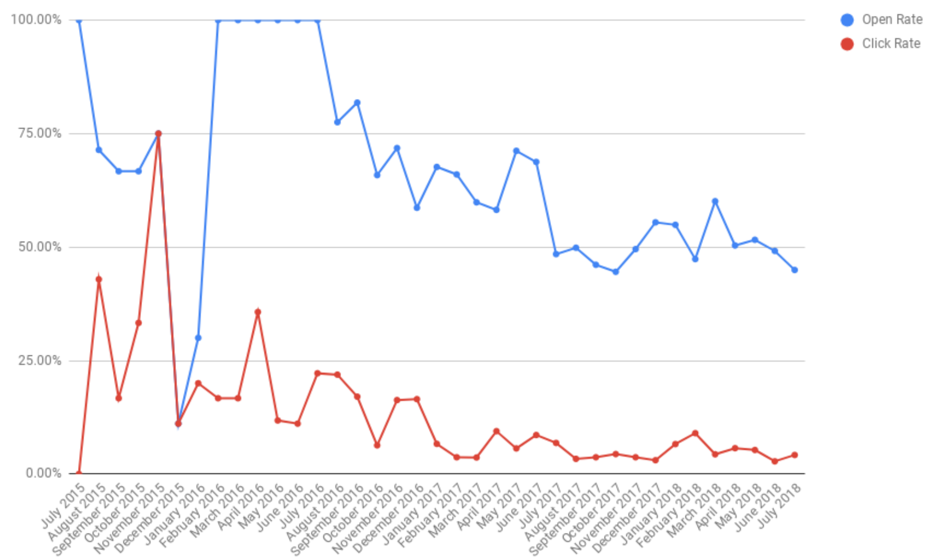

**The bar graph shows the total number of SMS alerts sent to all partner farm sites during each summer peak period and resulting demand surcharge cost savings and power demand avoided across all partner farm sites.**

## User Metrics for Email Reports

Wexus team provided monthly and mid monthly email reports to all four partner farms across the life cycle of the project. The reports were automatically generated using data from the Wexus software and sent via an email report integration software. To measure user engagement, Wexus tracked specific email statistics, such as how many user accounts each email was sent to, how many users opened the email, and how many users clicked on a link in the email. These statistics allowed the Wexus team to see how effective the email reports were and to modify the data within them to reach maximum impact for farmers.

Figure 53 displays the percentage of emails opened and links clicked within each email by month across the project life cycle. Both monthly email reports and mid-month email reports are included in these figures. The Wexus team also noted that the level of engagement correlated with seasonal changes in the agricultural industry. For example, when the off-season began (typically December through March), there was typically a decrease in the percentage of emails opened. When the harvest season ended (typically October and November) and when planting/preparation ramped up in spring (typically April and May), there was an increase in the email open rates. This was explained by farmers being more focused on annual end of year reporting and closeout and a need to report costs, energy usage, and water usage.

**Figure 53: Total Email Opens and Clicks (July 2015-July 2018)**




**The line graph above shows the percentage of all emails opened and the link click rate across the project life cycle from July 2015 to July 2018.**

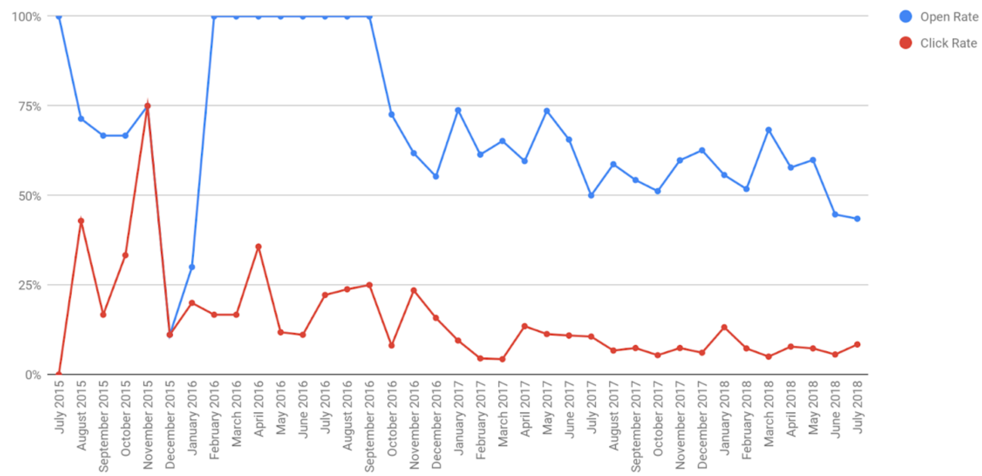
### Monthly Email Report Statistics

The Wexus software platform automatically sends monthly email reports at the end of each month summarizing a farms' total energy spend and energy usage for the previous month. This data is then compared to the previous year's data for the same month, so the user can see how their spending and usage has changed versus the previous year. Farmers specifically requested year-over-year comparisons instead of month-over-month comparisons due to the unique seasonality of their growing operations. The monthly email also includes a breakdown of average irrigation pump efficiency, the previous year's pump efficiency for the same month, and the trend in pump efficiency over the last 12 months. This data allows the user to analyze the overall health of their irrigation pumping system and if any action is needed to improve efficiency and cost savings without having to log into the platform if they are pressed for time.

The Wexus team noted across the project life cycle that the email open rate was high for most months. This shows that the partner farmers were deriving value and using the Wexus software platform regularly, obtaining useful and relevant data that most farms would struggle to track, and finding ways to potentially conserve energy and water and reduce associated costs.

Figure 54 shows the email open rate and click rate across the project life cycle for all email report types. The Wexus team noted a drop off in the open rate typically during the months of February and March with an uptick after the month of March due to the start of the planting season and a need to understand the impact of associated energy and water usage and costs from irrigation operations.

**Figure 54: Percent of Monthly Email Opens and Clicks (July 2015 – July 2018)**



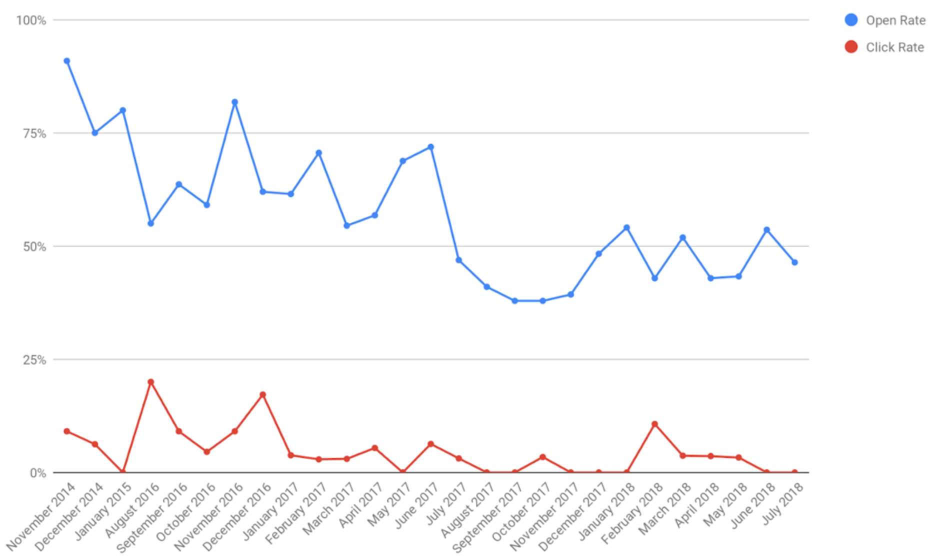

**The line graph above shows the percentage of all monthly emails opened and the link click rate across the project life cycle from July 2015 to July 2018.**

### Mid Monthly Email Report Statistics

Halfway through each month, the Wexus software platform also sends an automated "mid-month" email with more specific, granular information to notify farm users of their current total spend, energy usage, water usage, and year-over-year changes for all three metrics. This email also includes more specific irrigation pump data and tailored recommendations to boost efficiency, number of SMS alerts sent for an irrigation pump for that month, and it tracks the total savings in costs ($), energy (kWh) and power demand (kW) for the year which is also contained on the Savings Plan page within the software.

Figure 55 the monthly email open rate and click rate across the project life cycle. The Wexus team again noted a drop off in the open rate typically during the months of February and March with an uptick after the month of March due to the start of the planting season and a need to understand the impact of associated energy and water usage and costs from irrigation operations.

**Figure 55: Mid Monthly Email Statistics**



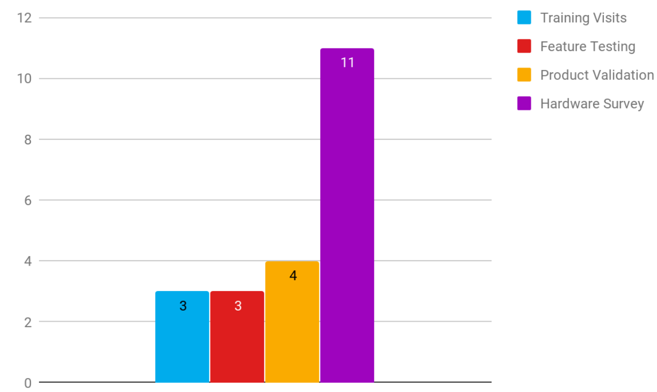

The line graph above shows the percentage of all mid-monthly emails opened and the link click rate across the project life cycle from July 2015 to July 2018. Wexus expected the open rate to decrease over time, as users became familiar with their farms' patterns. Many individuals wait to review the results until their regular, typically monthly, meetings with Wexus energy engineers. The Wexus team is continuing to target a software industry standard minimum 30% email open rate and 10% email click rate.

## Site Visit Statistics

The Wexus team performed site visits with the four pilot farms starting in July 2015. There were four reasons for the site visits: training, feature testing, product validation, and hardware surveys (Figure 56).

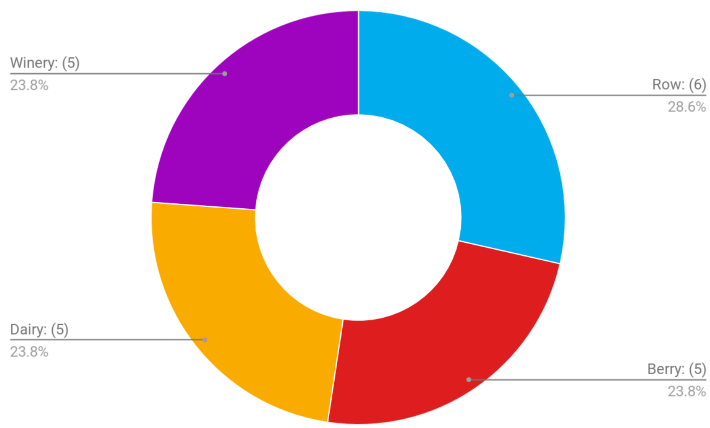
The Wexus team visited the pilot farm sites a total of twenty-one times (Figure 57): the vineyard five times, the row crop grower six times, the dairy/almond farmer five times, and the berry grower five times. Eleven of twenty-one site visits were needed to conduct hardware surveys; four visits were needed for product validation and interviews; and three visits were needed for training and feature testing.

**Figure 56: Types and Number of Partner Farm Site Visits (July 2015- July 2018)**




**The bar graph shows the number of types of site visits at all partner farms.**

**Figure 57: Total Partner Farm Site Visits by Type (July 2015- July 2018)**




**The bar graph shows the number of types of site visits at all partner farms with near-equal distribution of visits for each farm type.**

# CHAPTER 4: Learn Phase

The Build-Measure-Learn framework has provided Wexus an effective and efficient way to deliver product features that meet customers' needs and to respond to feedback and recommendations. During this project, Wexus continually learned and iterated upon the software to continuously improve.

In the Learn Phase, Wexus continued to gather insights from regular customer interviews, operational feedback from the field, and monitoring of ongoing user metric reports and key performance indicators (KPIs). This feedback was iteratively fed back into the Build-Measure-Learn development loop to deliver increasing value to partner farms and solve key energy and water related operational issues. The results of the Learn Phase can be seen in the evolution of the Wexus mobile software over the course of the project and in the identification of validated roadmap items to be developed in future projects.

## Learnings from Site Selection and Equipment Deployment

Four partner farms participated in this project, each with a different primary crop type. At each site, the Wexus team tracked existing utility meter infrastructure for the entire farm and then deployed a set of real-time energy and water monitoring equipment at two irrigation pumps on each farm to test and compare the effectiveness of historical utility data with real time, actionable data. This section describes the process behind site and farm type selection, equipment deployment, and summarizes the key points learned over the course of the project.

### Site Selection Process

During the Build phase, Wexus hypothesized that the key problems in terms of energy and water management in agriculture were potentially the same for various types of farms regardless of crop type. However, the Wexus team still wanted to ensure that participating partner farm sites represented a mix of various crops and farm types to control for different variables. For example, different crop types have different planting and harvesting schedules, which in turn causes a need of varying operational requirements and schedules. The four partner sites included the following types of crops:

- **Dairy** farms grow various crops for feed, including alfalfa, silage, and almonds (hulls).
- **Row** crops planted in neat rows (such as onions) to be farmed with use of machines.
- **Berry** crops also planted in near rows which require large amounts of manual labor to hand pick and pack them into nearby coolers.
- **Wine** grape growers are permanent crops planted in trellis rows, which are capital intensive and have a longer-term growing cycle of several years to achieve actual wine grape production ready for harvest.

The Wexus team also recruited partner farms in its extensive agricultural network who were committed to a long-term project with frequent check-ins for equipment installation and ongoing feedback for product development. Ideally each partner farm would also have a variety of engaged user personas.

The Wexus team discovered that each partner farm had a similar organizational structure (despite the different crop type) and various types of roles depending on the size of the organization. Some of the partner farms were family owned and locally operated, while others were large, corporately run farms with national reach and remote offices. However, the Wexus team was able to identify common traits and similar types of roles at all of the partner farms and created several user personas that fit these common roles during the Build phase of the project. (These personas are fictional archetypes, which help the product team understand a particular user's problems and needs.) An individual's job title does not have to correspond to the persona role.

## Equipment Deployment Learnings

The Wexus team deployed its full suite of products, including software, hardware and support at the partner farm sites under this project. The Wexus software product contains an initial layer that remotely accesses the electric utilities' advanced metering infrastructure (i.e. "smart meters"), but this data is limited to a lag of twenty-four (24) hours and does not include any water usage information. In order to test and compare the effectiveness of historical utility data with real time, actionable data, Wexus also deployed a set of real-time energy and water monitoring equipment at two irrigation pumps on each farm. This section describes learnings about the equipment selection, the importance of an experienced, trusted contractor network, and importance of site visits.

### Selection of Equipment

It was important to bring advanced IoT technology of interconnected devices to the partner farm sites in order to tests the team's hypotheses around delivering real-time energy and water insights, enabling data-based decision-making, and providing more granular reporting. This equipment provides partner farms with more granular electricity usage data than the utility meter could provide as well as matching granular water usage data in fifteen-minute intervals. An important requirement of the equipment selected was for the data to be transmitted in real-time and available in the Wexus software for immediate operational information and action. A standard set of equipment was installed at the eight irrigation pumps receiving real-time monitoring:

- **Pump automation controller** with remote on/off controls and with Open Automated Demand Response capability
- **Veris current transformer** (CT) meter for electricity demand and usage measurements
- **Magnetic flow meter** (AG8, 10, or 12) for water usage measurements
- **Pressure transmitter** (PTX) for water pressure data

During the selection of this monitoring equipment, Wexus learned that some partner sites were eager to engage with the hardware directly on-site in order to incorporate the technology into their daily operations. For example, when determining the flow meter equipment to be deployed at irrigation pumps, partner farms noted that a digital screen readout on the flow meter was valuable because it allowed them to take readings on their own while working in the field. Many water flow meters have analog dials, which log the historical and current water usage of a well but tend to be less accurate for monitoring current flow due to wide swings in the analog dial/pointer. Wexus was able to incorporate this feedback and choose hardware that met this recommendation.

**Importance of an Experienced, Trusted Contractor Network**

As the Wexus team planned IoT equipment deployments, they discovered that many partner farms preferred to have the option of using their own on-site contractors to install the equipment or the option of having access to an experienced and trusted network of contractors through Wexus' team. The Wexus team subcontracted with an experienced team at Polaris Energy Services, as well as local subcontractors to install the IoT equipment at partner farm sites. The technical deployments for this project went very smoothly due to the overall team's years of experience with IoT deployments.

**Importance of Site Visits**

It is very uncommon for farm sites to be uniform in size, layout, or configuration. Each farm has dozens or hundreds of irrigation pumps and wells, often each with a dedicated electric utility meter, spread out over acres of land. Pump and other equipment are repaired and replaced on an as-needed basis, and each pump can have slightly different specifications. Fields can be purchased, sold, and/or leased year-over-year. Due to the variety and large geographic footprint of each site, thorough planning and physical site visits were critical for successful deployments.

Each deployment required multiple site visits in order to plan, survey, install, and audit. From October through November 2015, Wexus engineers conducted site visits to survey existing hardware and project subcontractors installed the equipment. The Wexus team then conducted additional site visits to audit the equipment installations and identify necessary re-configurations or re-calibrations. Summary reports of each site visit, along with photos, are available in Appendix B of this report.

During the site surveys, Wexus learned that several key items were important to document and verify:

- **Latitude and longitude location** of equipment in order to locate easily for install/maintenance and map accurately in the software. Both farms and utility data often had inaccurate coordinates.
- **Electrical service and pump specifications** needed to be captured in detail. Notes and photos were extremely useful when the team was back in the office and planning the scope of work for the equipment installation. It was critically important to have a knowledgeable team like Wexus' that was already familiar with farm equipment and configurations and to verify that a site passed certain technical acceptance criteria. For example, the berry partner had a pump that

they wanted included in the project, but the site survey revealed that the pump operated on diesel and there was no electrical service data available.

- **Connectivity (cellular coverage)** is critical for IoT real-time data flow. Wexus did not encounter any connectivity issues that affected equipment deployment or ongoing data transmission. This is due to the Wexus team's experience in selecting cellular data providers in rural areas, which are prone to wide gaps in connectivity.
- **Scope of work** with detailed information to be reviewed and confirmed with partner sites prior to installation. This helps ensure no miscommunications or missed expectations about the work to be completed. Wexus also found that some partner farms needed to have equipment moved or re-configured at a later date when they made changes to their farming operations. For example, the Dairy partner site decided to discontinue use of a well after the project had already kicked off, and the installed equipment was moved to another well in October 2016. This equipment movement was unavoidable due to the partner farm's business needs; however, the clear scope of work ensured that the partner farm understood their financial responsibility for the change.

# Interviews with Partner Farms

The Wexus team conducted regular interviews with partner farms throughout the project to gather insights to inform product validation and feature testing. The first phase of the product road map was Pre-launch, during which Wexus conducted product validation interviews. During the second phase, Pre-market, Wexus designed feature prototypes and tested these with partner farm sites. Wexus incorporated feedback into revisions of the features prior to full integration into the software platform. As Wexus evolved the product and developed more features, ongoing interviews for product validation and feature testing continued with customers during regular (typically monthly) check-in meetings.

When possible, Wexus team members visited the partner farm sites to conduct face-to-face interviews. Summary reports documenting each site visit with descriptions and photos is available in Appendix B.

## Product Validation (Build Phase)

Initial interviews for product validation took place from July through October 2015. The primary purpose of these interviews was to better understand the partner farms' pain points around energy, water, and labor task management. One of the key insights was that all four partner farms found energy and water management to be a laborious task, regardless of crop type. The interviews also validated Wexus' hypothesis that farms did not have insight into electric energy spend, particularly during time of use periods. Partner farms indicated that this was due to the fact that utility bills were sent in paper format each month. In addition, energy spend on irrigation was seen more or less as a "sunk cost" of doing business due to a complete lack of actionable, real time data or any software applications.

## Usability Testing (Measure Phase)

The primary form of feature testing with partner farms was usability testing. During these moderated interviews, Wexus presented users with various software prototypes to gauge the effectiveness of features. From these interviews, Wexus created two word clouds to visualize the key insights.

The first word cloud (shown in the Measure Phase section - Figure 31) encapsulates the positive feedback from partner farms about the prototype features. This graphic provided Wexus with an understanding of its product strengths: effective visualizations of data and ease of use of visualizations and navigation. Wexus has always been focused on clearly and effectively showing the data to users, and the partner farms found that Wexus had succeeded in this area from the beginning. Another priority of Wexus' is a user experience in which users can access the information they need quickly and efficiently. Initial usability testing confirmed that Wexus had succeeded in providing this function through the use of various clickable icons, and Wexus has continued to improve ease of use of the application in every iteration of the software since. Identifying the product strengths early in the project allowed the Wexus team to ensure these areas remained an ongoing priority.

The second word clouds (shown in the Measure Phase section - Figure 32) summarizes the most common software feature requests or recommendations from partner farm users. While Wexus was not able to integrate all of these recommendations immediately during the initial product development, it has worked on them over time.

Many of these recommendations centered around data and units of measure. For example, partner farms wanted the option of selecting water consumption in either gallons (gal) of water or acre-feet (AF) of water. The Wexus team ultimately decided that the best course of action was to offer users the ability to view water consumption in either type of unit through a toggle view. The Wexus team also iterated on in-app and SMS text alert features based on partner farm feedback. When the alert features were initially rolled out to the partner farms, users did not have the ability to disable or alter them within their view of the software settings. After several feedback interviews noting that users wanted the ability to change alert settings, the Wexus team made changes to the software while also providing the ability to set the amount of warning time before a TOU peak period (30, 60 or 90 minutes).

The initial round of usability testing and the word clouds generated from it provided Wexus with an excellent framework for what functionality to continue to prioritize: visualization and ease of use. It also provided the Wexus team with a robust list of recommendations for continued software feature improvements.

## Ongoing Interviews (Learn Phase)

Since software product development is iterative and ongoing, the Wexus team continued to conduct interviews with partner farms for product validation and feature testing. The team collected data and feedback during the equipment deployment process through structured check-in meetings (typically monthly). During check-in meetings, partner farms shared positive feedback, any issues encountered, recommendations for feature improvements and helped develop new features by reviewing the latest prototypes with the Wexus team.

### Day-to-Day Operational Feedback

The Wexus team was in close contact with partner farms throughout the project during both monthly scheduled check-ins and day-to-day operational activity. Partner farms often provided feedback through additional channels like direct phone calls and emails, outside of the regularly scheduled monthly interviews. The Wexus team also catalogued this additional feedback to further validate and improve features for ongoing product development. The Wexus team has an internal communication channel dedicated to sharing immediate customer feedback in real time so that information and improvements are immediately available to the product team members.

From this ongoing feedback, Wexus learned more about the pain points of not having access to real-time energy and water data and how partner farms would utilize alerts from the installed IoT equipment at irrigation pumps. Many farms spend **over $100,000 per month in energy bills** during the prime summer irrigation months, when electricity rates are higher, especially during the peak time-of-use period. Peak demand charges can comprise 50% or more of total monthly utility bills. Yet, partner farms could not manage these energy costs for the following reasons:

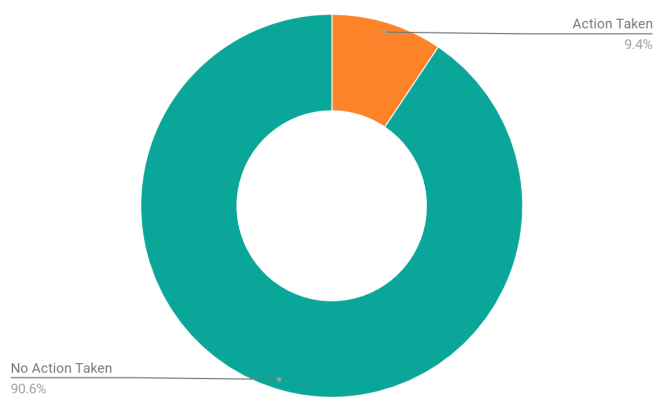
- (1) they did not have the ability to track and alert their teams in the field about when pumps were actually in operation (i.e. whether they were on or off and meeting the farm's planned irrigation schedule);
- (2) it was difficult/impossible to track which meters (and associated pumps) were on which utility rate schedules (which have varying peak windows), and thus when the peak periods occurred for different pumps;
- (3) they did not have the ability to verify and alert in advance whether pumps were operating during peak energy hours so that corrective action could be taken by farm employees (i.e. irrigation teams) to potentially avoid the very high peak hour surcharges and quickly curtail usage.

Farmers wanted the ability to track their historical energy consumption, costs and peak power demand on a pump-by-pump basis to quickly identify peak usage trends. They also wanted the ability to be alerted in advance and make cost- and crop-driven decisions about whether to take action to reduce their peak power demand (kW) and resulting surcharges. Over the course of the project, the Wexus team built these capabilities into the platform and then tracked what type of action the partner farms took in response to the alerts, as shown in Figure 58. The team found from the data and follow-on interviews that most of the time farms could not take immediate action to curtail their energy usage after receiving SMS text alerts in advance due to the ongoing variables of crop types, irrigation schedules, available surface water and groundwater amounts, operational and labor demands, and changes in weather. Additional user feedback, research, and funding is needed to continue to improve the participation rate and how best to allow farmers to manage demand and pump scheduling. Wexus hypothesizes that remote control capability (i.e. removing the manual labor) could improve participation, as well as improved algorithms to better target pump alerts based on crop type or weather. These ideas need to be tested and vetted in the future.

However, almost 10% of the time (when receiving almost daily alerts), farmers DID take corrective action to curtail their peak energy consumption to avoid much higher demand charges when crop cycles, labor and weather allowed, **resulting in nearly 9MW of power demand shed and over $7,000 in peak surcharge savings by the four farms** during the life of the project.

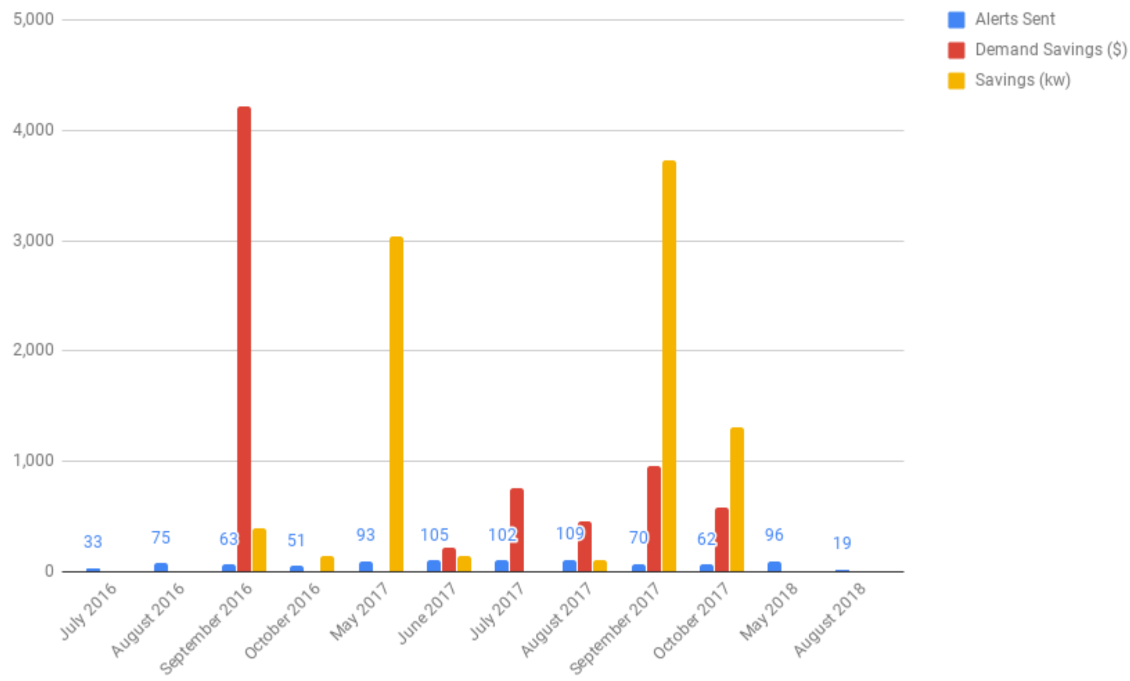
This validated the Wexus team's initial hypothesis that farmers wanted the **option to make a data-driven energy-cost decision** to manage both their historical and real time energy and water usage via predictive SMS text alerts in the field and a historical usage dashboard. In the end, the Wexus team found it was best to place the final decision in the farmers' hands as to whether they could curtail energy usage in their farming operation in line with costs, crop yields, weather and labor requirements.

**Figure 58: Total Actions Taken in Response to SMS Text Alerts (July 2016 - August 2018)**




Per Figure 59 below, throughout the life cycle of the project, when partner farms responded to a predictive peak hour SMS text alert (either thirty, sixty or ninety minutes in advance) they saved an average of $50 per day, a total of 8,855 kW (8.9MW) and $7,170 in avoided peak demand surcharges. This proves that having access to real-time consumption data and alerts (as opposed to thirty-day-old paper or PDF utility bills) can be very valuable to farms and help California meet its energy efficiency goals.

**Figure 59: SMS Text Alert Savings in Dollars and Kilowatts (July 2016 - August 2018)**

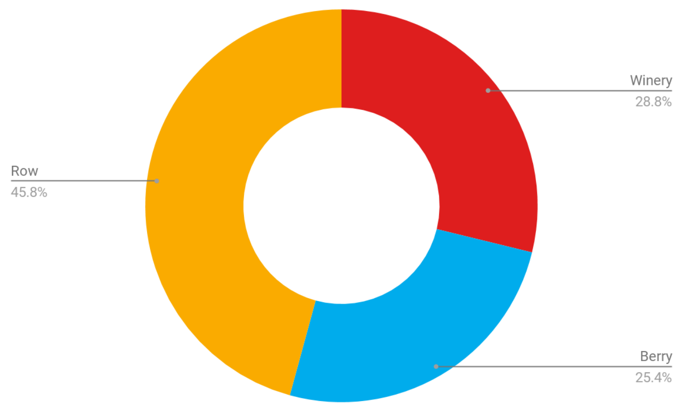



Per Figure 60 below, from July 2016 through August 2018 partner farms took action and curtailed peak energy usage a total of fifty-nine (59) times after receiving SMS text alerts from the Wexus IoT platform. The Row crop partner farm had the highest response rate to SMS text alerts during the project at a total of 46%, as compared to the Vineyard and Berry partner farms. Through follow-on interviews, the Wexus team discovered that the Row crop farm tended to respond more frequently to SMS text alerts because they had had higher levels of water consumption for irrigation and a more frequent and shorter-term crop cycle, which tended to result in higher energy costs and higher potential savings if they could avoid peak TOU hours. But as noted above, the potential energy cost savings were always a lower priority than the potential crop yield and resulting top line farm revenue from the actual harvested crop.

This is a key area to note for future energy policy in California: **it is critical for energy policy makers to understand that farmers are running a business and energy consumption is a cost of doing business for them, not a primary revenue driver. Technology platforms like Wexus that automate laborious tasks,** such as tracking energy and water consumption and utility bill costs, **and that relate them to the actual farming operation** with historical dashboard and real-time alerts **can help drive overall energy markets awareness, behavioral change, and improved net operating income for farms.**

**Figure 60: Total Actions Taken in Response to SMS Text Alert by Farm Type (July 2016 - August**

**2018)**




**Takeaways from Ongoing Interviews**

During check-in meetings, the Wexus team engaged partner farms for ongoing feedback and feature recommendations. Much of the ongoing feedback was similar to the initial interviews as seen in the word clouds. Users liked many of the Wexus features including the ability to export both energy and water data, the predictive irrigation cost calculator, real time SMS text alerts, ongoing tracking and scoring of irrigation pump efficiency, and the map with geo-tagged equipment locations and status of irrigation pumps, buildings, and solar arrays. Users also liked the “look and feel” of the app and commented on the ease of use of graphs and particularly found year-over-year comparison data to be useful when determining energy and water intensity of various crop types or irrigation schedules.

Some features received less positive feedback which the Wexus team logged and made changes as appropriate. Two users did not find greenhouse gas (GHG) emissions data to be a useful metric for farming operations, and the Wexus team chose not to include this data in the current dashboard. Three partner farms requested the ability to see all utility rate options and compare the potential savings if they switched rates. In response, the Wexus team continued to iterate on the rate analysis tool to improve usability and posted a written and video tutorial on the company blog page about how to use this tool.

## Key Performance Indicators

During the Learn Phase, Wexus tracked the following Key Performance Indicators (KPIs) in order to evaluate user engagement with the software platform:

- User Accounts with Active Logins
- Page Visits per Login
- Engagement: Seasonal Variability
- Login Activity After Visits with Partner Farms

## User Accounts with Active Logins

The KPI for User Accounts with Active Logins (previously "Connecting Accounts" in the Measure Phase Report) tracked the engagement of user accounts by partner farm company type, user persona, and login activity. The Wexus platform allows farms to sign up as many users as desired to access the platform and the farm's data.

"User Accounts with Active Logins" is an insightful metric to understand how different user personas engage with the software and how different partner farm company types choose to connect users. Tracking this KPI allowed the Wexus team to better understand how engaged a particular partner farm was with the software and how widespread the actual usage of the product was across the entire farm. This in turn allowed Wexus to provide better customer service to partner farms by understanding who was engaged, which user personas valued the software, and which user personas needed more training and support to increase engagement.

Table 2 shows the total number of user accounts for each partner farm and how many users were active at any point from January to July 2018. All partner farm types had multiple user accounts. The Berry farm had the most users with five total accounts. However, all partner farms had only partial user engagement with one or two active users. This provided the Wexus team with data to engage inactive users and to determine the best way to increase it.

Table 3 provides further detail by each user persona in the project. The "Other" label indicates a user was created but was not associated with one of the four user personas determined by the team. As expected, a majority of the inactive user accounts (five out of eight) are "Other". While there is not enough data to draw significant conclusions, there is a general trend that General Managers are more likely to be an active user of the Wexus platform across all farm types, with the exception of the row crop partner farm (Sustainability Manager was the most active).

**Table 2: Number of Connecting Accounts for Each Partner Farm in 2018**

| Company | Total Accounts | Active Accounts |
|---|---|---|
| **Wine** | 2 | 1 |
| **Berry** | 5 | 2 |
| **Row** | 3 | 1 |
| **Dairy** | 3 | 1 |

**Table 3: Number of Connecting Accounts by User Persona in 2018**

| Company | General Manager | | Ranch Manager | | Reporting/ Accounting | | Sustainability Manager | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Active?** | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** | **Yes** | **No** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Wine** | 1 | - | - | - | - | - | - | - | - | 1 |
| **Berry** | 1 | - | - | 1 | 1 | 1 | - | - | - | 1 |
| **Row** | - | 1 | - | - | - | - | 1 | - | - | 1 |
| **Dairy** | 1 | - | - | - | - | - | - | - | - | 2 |

The Wexus team will continue to track these KPIs and gather data from more farms on the platform in order to predict and refine which user personas will be most active with the technology. This knowledge will allow Wexus' business development and marketing team to improve outreach and engagement with more farms in the ag market.

## Page Visits per Login

The "Page Visits per Login" KPI provided insight into user activity after they logged into the software. The Wexus team tracked logins by each user as well as how many pages the user visited during each session. When a user logged in, they were shown the default page of the "Company Dashboard." Therefore, multiple page visits per login indicated that the user visited other pages in addition to the "Company Dashboard."

Table 4 shows the number of page visits per login by each partner farm type and user persona over the course of the project. General Manager personas typically visited many pages within the platform each time they logged in. This suggested that the General Managers were clicking the Pump Status page to get additional detail on their ranches and equipment. The detailed page visit study by persona type in the Measure Phase Report also supports this finding. The team also found that Sustainability Managers page visits were similar in number to General Managers, which suggests that this persona valued the energy and water data for corporate sustainability reporting (CSR).

**Table 4: Page Visits Per Login by Partner Farm Type and User Persona**

| | General Manager | Ranch Manager | Reporting/ Accountant | Sustainability Manager |
|---|---|---|---|---|
| **Wine** | 2.3 | | | |
| **Berry** | 2 | 1 | 2.2 | |
| **Row** | 6 | 2 | | 2.7 |
| **Dairy** | 3.7 | | | |

The Wexus team also found that Reporting/Accounting user personas typically visited the "Data Export" page in addition to the main "Company Dashboard" landing page. This suggested and was confirmed in later interviews that Reporting/Accounting users could quickly find the relevant energy, water and cost information they needed with just one click. The team also found that Ranch manager personas had fewer numbers of logins to the software platform and predominantly used the SMS text alert feature.

## Engagement: Seasonal Variability

Running an agricultural business is obviously seasonal by nature. The Wexus team initially hypothesized that user engagement with the software would be subject to highs and lows throughout the year depending on planting and harvesting schedules. The "Engagement: Seasonal Variability" KPI (also named "Engagement Drop Off" in the Measure Phase Report) allowed the Wexus team to track how farm seasonality and crop variability correlates to engagement and use of the product.

Figure 61 shows typical farming cycles for different crop types over the course of the year. Vineyard (wine grapes) and Berry (strawberries) crop types tend to have a harvest that ends in September through October, which lines up with the overall increase in engagement trends. Row (crops) have a season that ends earlier in August. Dairy farms typically grow a variety of crops, such as silage and alfalfa for cow feed, which have shorter and more consistent crop cycles and resulted in more consistent use of the Wexus software throughout the year.

**Figure 61: Partner Farm Annual Crop Cycles**

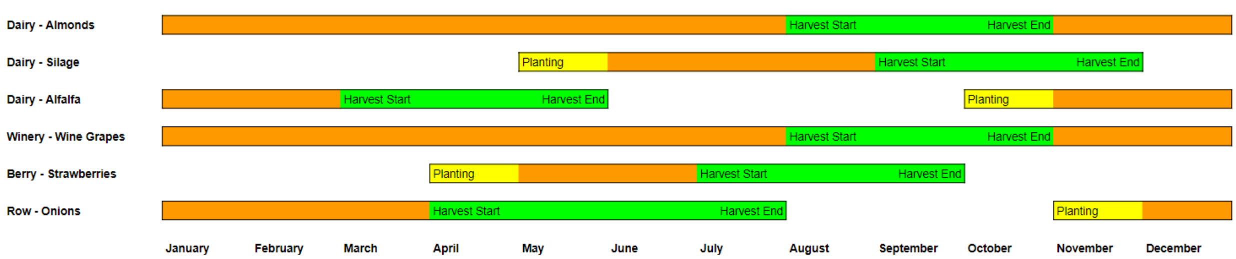
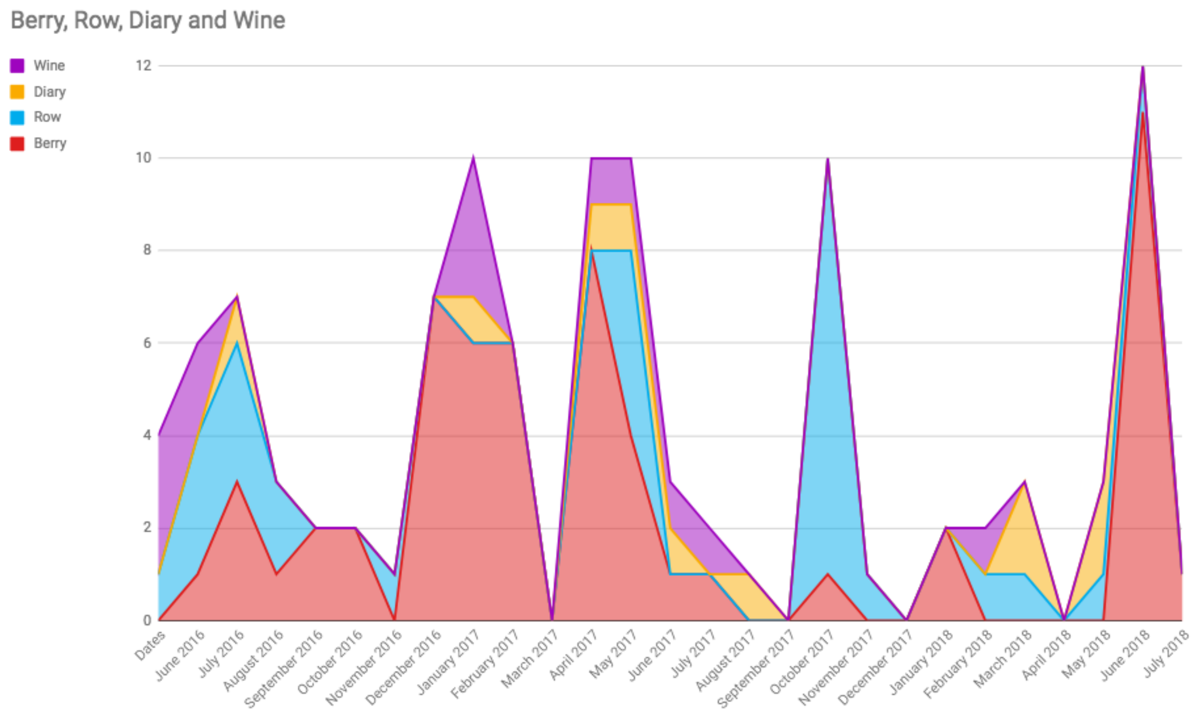



Figure 62 shows the monthly logins by partner farm from June 2016 through July 2018. The team noted **two key seasonal trends** as to when farmers engage with the technology:

- There was generally **less user activity** during the busiest times in agriculture in the late fall immediately after harvest (September through October) and in early spring (March) during planting season. These seasons are critical to a farm's revenue and profitability, and labor is at its peak for the year.
- There was generally **more user activity** during winter months (December through February) as farms review operations for the year, conduct maintenance on equipment, and reconcile accounting records, as well as during late spring through summer months (April through August) when farms are in post-planting and operations season.

**Figure 62: Monthly Logins by Partner Farm**




Understanding the seasonal variability in engagement allowed the Wexus team to respond to customers and anticipate their needs. The Wexus team modeled its product development cycle on agricultural seasons to ensure that key features were released in advance of an uptick in engagement and the Wexus operations team could be prepared to support customers.

## Login Activity After Visits with Partner Farms

During this project, the Wexus team hypothesized and validated that personalized support and in-person site visits at partner farms would be a critical component to generating awareness about energy and water efficiency in farming operations. Following the project kickoff in July 2015 and the IoT hardware installations in October-November 2015, the team conducted an additional ten (10) site visits from May 2016 to June 2018 at all four partner farm sites. These additional site visits served multiple educational functions for the partner farms including software onboarding and training, energy markets education, software feature "refreshers" for existing or new farm employees, and training about new product features when they were released. These site visits also allowed the team to conduct surveys of the installed IoT hardware and sensors to ensure they were continuing to perform properly, to better understand changes to farming operations and irrigation schedules, and to review additional on-site equipment in need of maintenance or efficiency upgrades. Insufficient data was available to correlate user login activity with the in-person site visits to evaluate this KPI. However, Wexus continues to track this metric across its entire customer base, outside of this project.

## Outcomes of the Learn Phase

The "Learn" phase of a software Agile development project consists of analyzing the catalogued feedback obtained during the "Measure" phase and determining if the initial hypotheses created during the "Build" phase are valid or not. The goal of designing these experiments and minimal viable products (MVP's) is not to get data but to get insight. The purpose of getting out of the building and into the field with end users is to inform the company's product vision. The insight may come from analyzing customer responses, but it also may come from ignoring the data or realizing that a company may be creating a new, disruptive market that doesn't exist, or that experiments may need to be changed from measuring specifics to creating entirely new features or products.

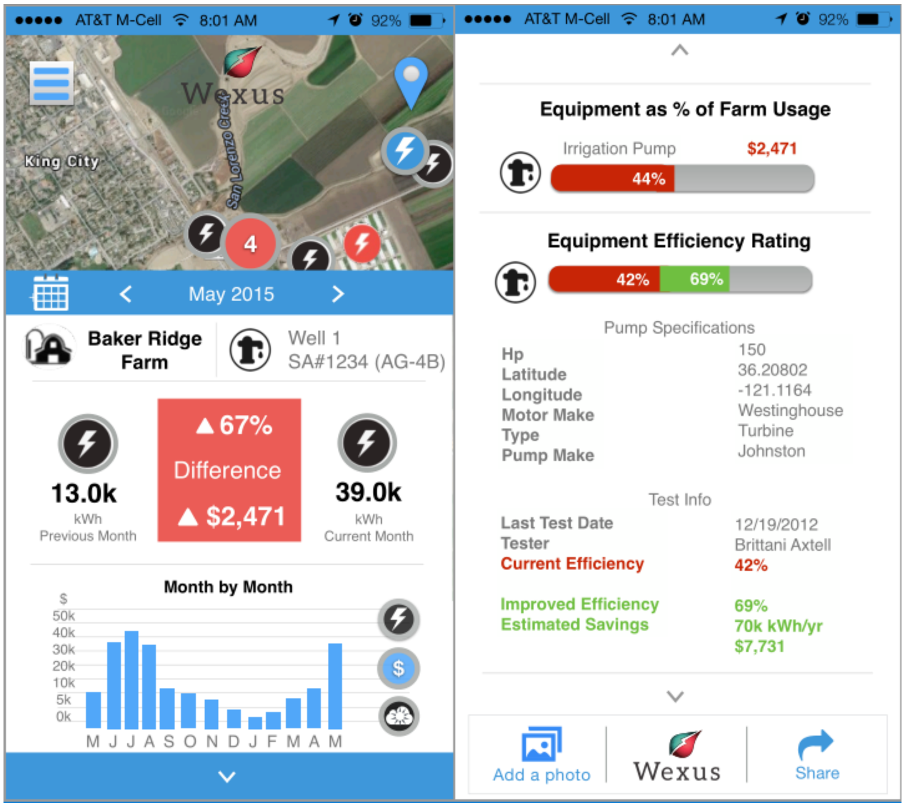
Wexus used the insights gathered during the Learn phase to continue to iterate upon the software to better meet users' needs and deliver increasing value. This section describes some of the key changes made over the course of the project.

### Software Version 1.0 released March 2015

Version 1.0 of the software shown in Figure 63 was created before the scope of this project in March 2015. The image on the left side of the figure is the first version of the Ranch Page, and the image on the right side of the figure is the first version of the Equipment Page. These initial versions were based upon the Wexus team's initial hypotheses about which features agribusiness users would need in terms of energy and water management. During testing *with other farmers outside of this project,* the team learned that farmers found the map of pump locations to be very useful and found the interface simple and easy to use with understandable charts and graphics. The version was data-rich and provided actionable information in a small amount of space.

However, users found that several areas could be improved in this early version. The energy billing information provided was found to be not granular enough since farmers wanted to track peak energy consumption down to the hour. Farmers also wanted granular water data, side by side with the energy data in the same intervals in order to find potential irrigation anomalies. Farms found the pump efficiency metric to be useful but wanted to see historical trends over time.

Figure 63: Screenshot of the Wexus Software Application v1.0, March 2015.




## Software Version 2.0 released May 2016

By May 2016, the Wexus team had conducted several more rounds of user testing interviews *with farmers inside and outside of the scope of this project*, and Wexus released a second version of the software. Screenshots from this release are shown in Figure 64 (Ranch Page) and Figure 65 (Pump Status Page). Billing, cost and energy usage information was now available as a month-over-month and year-over year comparison. Additional detail of time-of-use billing periods was also now provided, particularly on the equipment page. User experience was improved by making it easier for users to view information down to different irrigation pumps, types of buildings and lighting equipment.

As expected, users found that several areas could be improved in this second version of the software. Billing information was made more granular down to hourly intervals, utility tariff engines were built, real-time IoT hardware and sensors were deployed and connected to the platform, water data was incorporated, and company and ranch level aggregation views were added.

**Figure 64: Screenshot of the Wexus Software Application v2.0, Ranch Page, May 2016.**

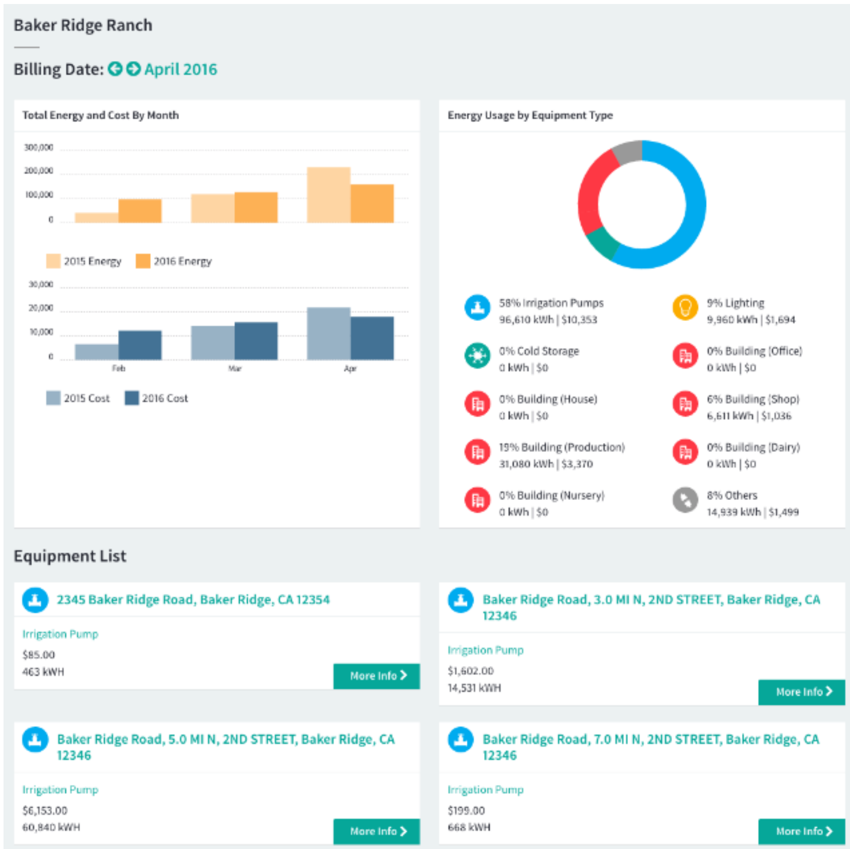
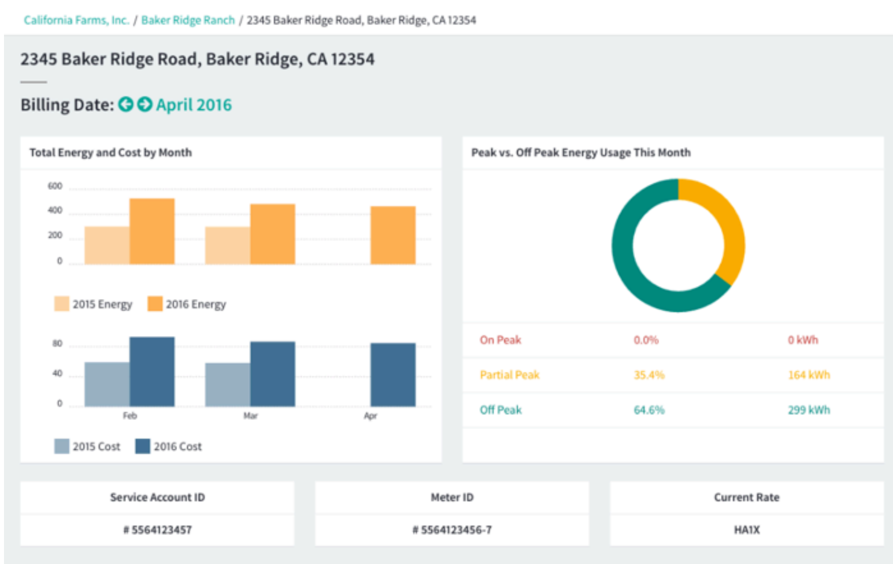



**Figure 65: Screenshots of the Wexus Software Application v2.0, Pump Status page, May 2016.**

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## Software Version 3.0 as of July 2018

By July 2018, the Wexus team had conducted several more rounds of user testing interviews *with partner farms from this project*. Wexus released a third version of the software with an even simpler and more intuitive user interface (UI).

Screenshots of the Company/Dashboard page are shown in Figure 66 and the Current Savings Plan page in Figure 67. Navigation was further improved through the introduction of a menu bar for the main pages: Dashboard, Pump Status, Export Info, Savings Plan. Within these pages, users can view data at the aggregate level or use drop-down menus to see different ranches and/or pieces of equipment. Water information was integrated in two units of measure, acre-feet (AF) and gallons (gal). Billing, energy, and water data was improved with annual, monthly, daily, and hourly intervals. Breakdowns of time-of-use energy usage and costs were made available in a year-over-year comparison. The map feature was also re-introduced. An "Export Info" page was introduced per user feedback which allows them to export energy, water and cost data into usable csv formats for accounting and compliance. Real time alerts were refined in the form of SMS text alerts and in-app alerts to improve automation and address potential equipment or labor issues on the farm.

**Figure 66: Screenshots of the Company Page (July 2018).**

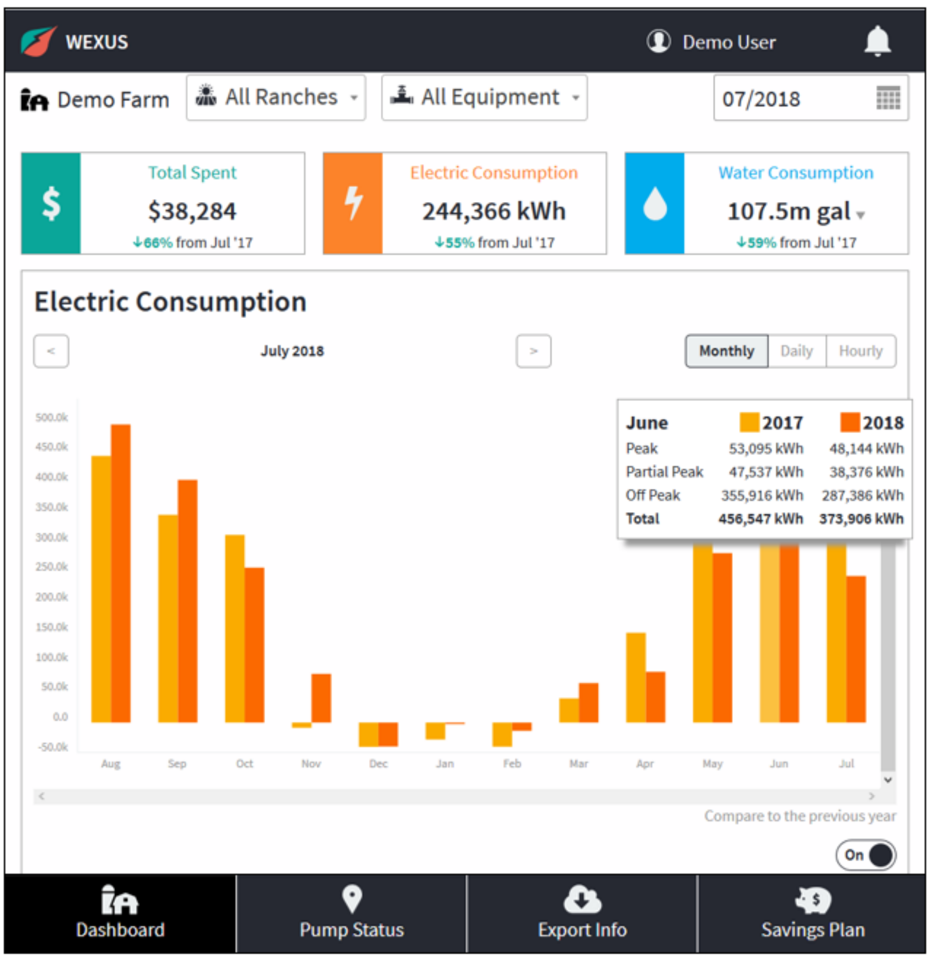
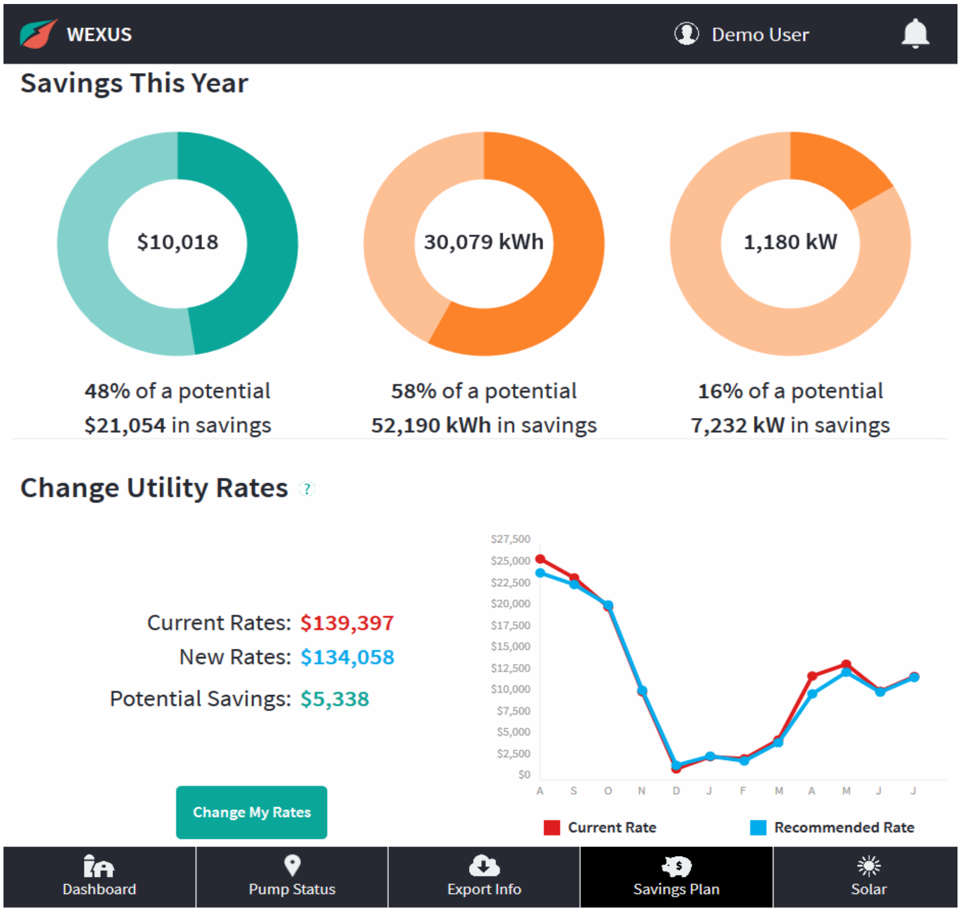


Figure 67: Screenshots of the Current Savings Plan Page (July 2018).




## Future Roadmap Items Identified

The future of the agricultural industry will be driven by AgTech (technology entrepreneurship focused on solving agribusiness problems) and IoT "Internet of Things" (networks of devices connected over the Internet to deliver real time insights and make data-based actions and decisions).

During this project, Wexus developed and improved upon a rich feature-set to help agribusinesses solve key problems including:

- **Labor**: remote equipment status tracking and real time irrigation pump efficiency alerting with SMS text messages and in-app alerts.
- **Regulation and Reporting**: energy and water bill and consumption reporting and data export tools; an energy usage and cost savings dashboard which includes Time of Use (TOU) rates, costs, and consumption from the month down to the hour.
- **Costs**: The platform allows growers to quickly respond in real time to changes in energy usage, adjust and optimize irrigation equipment in the field which may be experiencing efficiency or water aquifer problems, and reduce operational expenses due to energy costs by increasing efficiency with real time TOU SMS text alerts before hitting peak hours.

The takeaways from this project have also enabled Wexus to construct a long-term roadmap to continue to provide farms with solutions to their problems around labor, regulation and reporting, and rising energy and water costs. Wexus also continues to stay up to date with changing needs and trends within the agricultural industry. By mid-2018, several new challenges are on the horizon that Wexus is eager to address in future projects. The Wexus team **highly encourages the California Energy Commission, the California Public Utilities Commission (CPUC) and Investor Owned Utilities (IOU's) to research, provide funding, and create efficiency programs to help solve these ongoing issues for the agricultural industry** which will ultimately help California achieve its long-term energy goals of 100% renewables by 2045:

- **Solar photovoltaic (PV) system net metering** is a pain point for farmers who converted available farmland, bought large (+1MW), expensive ground-mounted solar PV systems, and often do not have the tools to validate their systems energy generation/ performance and return on investment (ROI). Even interpreting their monthly utility solar bills is a significant challenge.
- **Financing options for IoT hardware and sensors** (both public and private) will be increasingly important as more AgTech and IoT solutions become available to agricultural customers. Farmers will need different mechanisms to help pay for these solutions, since agriculture is typically a low-margin business driven by fluctuations in crop prices and weather patterns, and available cash to invest in new technologies is scarce.
- **Community Choice Aggregation (CCA) in California** has become more widespread in 2018, particularly in the Salinas Valley where there is a significant concentration of agricultural businesses. CCAs provide customers with another option to purchase electric generation versus their existing investor-owned utility (IOU) along with access to different energy generation mixes (like 100% renewables), cost savings, and rebate programs. However, it can be extremely complicated to determine whether enrolling in a CCA versus staying with an IOU will actually save money off energy bills, and once a customer is enrolled in a CCA it can be very difficult to track actual costs and bills to ensure their enrollment was worth the effort.
- **Cost Calculator feature** will provide the next level of real time, predictive energy and cost management tools and will incorporate more granular agronomic data, particularly ranking energy intensities by crop type and more specific weather data.
- **Utility time of use (TOU) rate changes** which are expected to launch in 2019 and 2020. Farms will need tools to manage these new rates, to help compare and contrast the best options, and to manage irrigation pumping operations around new TOU hours to optimize their costs and place less stress on the utility grid.

Wexus remains committed to the Build-Measure-Learn process with Agile project management in order to continually improve its product for farmers. Listening to the real needs of farmers in the field is critical to helping California reach energy and water efficiency goals and adapt to climate change, and the Wexus technology platform will continue to evolve in response to these needs.

# CHAPTER 5: Savings Results

This chapter details the savings results and the measurement and verification (M&V) methodology for the *Wexus Energy and Water Management Mobile Software for the Agricultural Industry* project. University of California Davis' Center for Water-Energy Efficiency (CWEE) collaborated with Wexus Technologies on the M&V scope of the project.

The objectives of the project included the use of the Wexus software platform in conjunction with services:

- To aid partner farms in reducing their overall energy usage by providing actionable energy and cost data, including at peak times of day.
- Target potential energy reductions by up to ten percent from baseline usage.
- To engage partner farms in continuing education and training on the effective and efficient use of the proposed technology to reduce their energy usage by up to ten percent, to identify potential energy savings measures in the field, and to quantify actual energy savings after savings measures have been implemented.

## Summary of Key Project Activities and Savings Results

### Data Sources and Methodology

The project study group included four partner farms with a total of forty-seven irrigation pumps and eleven "ranch" locations, covering 3,700 acres. A summary of site visits/surveys to the partner farms with descriptions and photos is available in Appendix B. A major advantage of developing a data-driven approach to jointly managing water and energy resources is that a robust dataset for monitoring and verification is hardwired into the project deployment.

Hourly electricity usage data from thirty-seven electric utility meters was the primary source of data for collection and analysis, especially for historical data**. Use of data from electric utility advanced metering infrastructure is the most cost-effective approach for partner farms to access their data, because the necessary metering infrastructure and hardware is already installed. Data is available to approved and authorized third parties through standard Green Button utility data platforms.**

**An advanced utility metering infrastructure for water does not exist in California,** so farms must utilize estimates, manually read flow meters in the field, or install equipment with data connectivity at their own expense. For this project, the **Wexus team worked with CWEE to develop a water estimation methodology based upon electric utility meter consumption, well depth, and pump efficiency performance.** This water estimation methodology was used for baseline time periods prior to this project and for wells without additional water monitoring equipment installed.

The Wexus team worked with project subcontractors to install additional monitoring equipment on two irrigation pumps/wells at each partner farm to measure electricity and water usage in real-time and on more granular, fifteen-minute intervals. Real-time monitoring allows the capability to send actionable alerts to partner farms based upon current operations. **Partner farms assisted Wexus with pump selection for additional monitoring equipment (on two pumps per farm) in order to maximize the cost-effectiveness of these installations.** This approach aligns with Wexus' business model to allow farms to select a customized mix-and-match of SaaS plans, with or without additional monitoring equipment, depending on the irrigation pumps' usage and the return on investment from energy cost savings.

Wexus also conducted a comparison between estimated water data (using pump specifications and electricity usage) and data from installed flow meters. The team found on average that the estimated water data was on average 20% higher than data from flow meters. While the sample size was small**, this finding indicates that farmers may actually be over-reporting their water consumption when using estimates. Additional research is needed to refine the water estimation methodology and/or to justify funding to support funding to support famers to install flow meters** (for example, through California On-Bill Financing program).

CWEE compiled a robust set of data on historical electricity consumption to develop baseline values. Additional data was collected directly from local IOUs, as well as other publicly available sources. Even with a robust data collection plan there were gaps in available utility data or periods of variable operations that impacted some of the savings results. In some cases, energy or water consumption data was not available due to operational changes on a farm. For example, a temporary shut-off of an irrigation pump for maintenance, a purchase of a new ranch, or changing farm crop types (e.g. switching from growing low-margin row crops like alfalfa to growing high-margin, permanent tree crops like almonds) would impact energy and water baseline consumption data. Whenever possible, the Wexus and UC Davis CWEE teams looked for alternative data sources to fill these gaps.

CWEE then developed several models to evaluate energy usage before and after the project began, incorporating data over a period of several years. The changes in electricity usage presented in this report include:

1. the <u>unadjusted</u> (i.e., directly calculated) average change in the average electricity use levels between the baseline and project time periods, and
2. the <u>adjusted</u> results from several statistical models, which estimate the impact of factors outside the scope of the project (e.g. major farm operation/crop changes, weather, drought conditions, and EE equipment or renewable energy installations).

CWEE also calculated the resulting effect on associated greenhouse gas (GHG) emissions and energy costs.

## Energy Usage and Cost Savings

Overall, results show that three of the four farms had substantially lower average electricity usage during the project period relative to baseline values. See Table 5 for results at each partner farm for the unadjusted results and those calculated using a model to control for external factors. In total**, partner farms reduced electricity usage by 1.14 GWh/year or 17.2% on average unadjusted and by 38 MWh/year and 1% on average, when modeled as adjusted.** Neither the adjusted nor the unadjusted results provide a complete picture of the savings results, and they should be viewed in conjunction with each other. The Dairy partner farm is an excellent example of the limitation in CWEE's model, because there was significant variability in pump usage over time, long periods of non-use due to crop irrigation cycles, and unavailable utility data for 2018. The Vineyard and Berry partner farms had fewer variables to control for and exceeded the targeted 10% reductions in energy from unadjusted baseline values. **One important outcome of the project is that additional work is necessary to refine the models used for the adjusted results, because they did not take into account all of the external variables in the agricultural industry with complete confidence.** Wexus looks forward to continuing to refine this savings model, especially during consideration of new California third party implemented energy efficiency programs.

Overall, results show that **Berry and Vineyard partner farms reduced water usage by 8.3% and 8.9%, respectively.** Water savings calculations were not available for two partner farms (Dairy and Row) for these reasons. Water usage estimations (based upon electric usage) may not be possible due to availability of data or site conditions, such as behind-the-meter renewable energy. Future projects would benefit from a larger budget (or financing programs) for installation of real-time energy and water monitoring equipment at more irrigation pump locations.

**Table 5: Overall Savings Results by Partner Farm**

| Partner Farm | Average change in electricity/ costs - unadjusted | Average change in electricity/ costs - adjusted | Average change in water usage | Notes |
|---|---|---|---|---|
| **Berry** | -11.3%<br>-118,990 kWh/year<br>-$16,800/year | -5.6%<br>-60,225 kWh/year<br>-$8,400/year | -8.3% | |
| **Row** | -29%<br>-998,411 kWh/year<br>-$141,600/year | -1.8%<br>-61,970 kWh/year<br>-$8,800/year | - | Solar array was installed on-site mid-project for additional energy and cost savings, impacting model and water estimates. |

| Partner Farm | Average change in electricity/ costs - unadjusted | Average change in electricity/ costs - adjusted | Average change in water usage | Notes |
| --- | --- | --- | --- | --- |
| **Dairy** | +1.8%<br>+31,725 kWh/year<br>+$1200/year | +7.3%<br>+128,663 kWh/year<br>+$4,000/year | - | Increases are due to uncontrolled variables. Dairy farm had extreme variability in pump usage over time and long periods of non-use due to operational needs. Electric usage data was also unavailable in 2018 due to a utility data access issue, so the full project duration was not evaluated. Water monitoring equipment was relocated mid-project due to customer needs. |
| **Vineyard** | -15.3%<br>-53,783 kWh/year<br>-$7,600/year | -12.7%<br>-44,643 kWh/year<br>-$6,400/year | -8.9% | |
| **TOTAL** | **-17.2%**<br>**-1,139,459 kWh/year**<br>**-$164,800/year** | **-1%**<br>**-38,175 kWh/year**<br>**-$19,600/year** | - | The statistical models CWEE used to calculate the adjusted results were limited and not able to take into account all of the external variables in the agricultural industry with complete confidence. Neither the adjusted nor the unadjusted results provide a complete picture of the savings results. |

This project was designed for a small group of partner farms with representation from different sectors (berry, row, dairy, and vineyard), each with multiple ranch locations and many pumps/meters. The project was also designed for a high level of engagement and collaboration with a small number of sites. **A small group of highly engaged partner farms was critical to achieve the project objective of developing and refining the Wexus cloud-based software platform through collaborative product design and testing.** The small group size for this project worked well as a proof-of-concept and for development of use cases for the current Wexus technology platform. **In addition to improving the adjusted models for higher certainty of site-specific analysis, a program-level evaluation could be conducted with a larger study group of farms, using a control group.** Note that evaluating customer savings based upon a control group is problematic for agriculture since there are so many site-specific variables. It is difficult to provide a fair result for individual agribusiness customers when using a control group approach for rebates and energy saving calculations (especially given the state of the current adjusted models). However, a control group analysis is a good recommendation for program-level evaluation of complex behaviorally based conservation programs in the agricultural sector.

## Response to Alerts

The Wexus team developed several types of alerts to notify partner farms when a specific, actionable issue relating to energy and water usage or costs occurs on their farm. One method of alerting is through "in-app" (within the platform application) notifications. The other type of alert was SMS text messages for time-of-use peak periods.

In-app alerts monitored a variety of issues, including missing energy/water data, broken sensors, pump efficiency changes, and automated recommendations to change utility rates. T**he in-app alerts related to pump efficiency changes were particularly important to partner farms in order to avoid major operational issues.** A slow efficiency drop indicates dropping well water levels over time, which partner farms need to know in order to plan alternative water sources and/or change irrigation or crop plans. A rapid efficiency drop indicates an equipment problem, and an alert can help farmers know when to maintain a pump in order to avoid a failure (which could subsequently damage crops).

More than half of the in-app alerts sent to pilot partner farms were for two issues: a broken water sensor/flow meter and missing water interval data. These alerts can have many root causes, including broken equipment, major changes in irrigation (such as a pump turned off for a long period of time), removed/re-located pump, and changes in the electric utility service agreement number (which breaks the data transfer of electric usage used for estimated water usage). **Learnings from the water-related alerts highlight the complexity of monitoring or estimating water usage on agricultural sites and the potential benefits/challenges of on-site monitoring.**

Wexus also developed time-of-use peak period alerts sent via SMS text messages. Partner farms receive alerts either thirty, sixty, or ninety minutes (depending on their customized setting) in advance of peak hours with the pump name and location, the cost per kW in peak demand charges tied to its current utility rate, and whether the pump is on or off. SMS text alerts helps farmers make an informed cost-driven decision as to whether they should continue to irrigate during costly peak hours, and they also help farms remotely verify whether their prescribed irrigation schedule is being followed. Wexus expected partner farms to receive alerts frequently, daily in many cases, and to only be able to change irrigation schedules a limited number of times. Yet, **almost 10% of the time, three partner farms *did* respond to the peak period alerts and collectively saved 8.9MW of demand and over $7,000 in peak surcharges**. This validated the Wexus team's initial hypothesis that farmers wanted the ***option*** **to make a real-time data-driven energy-cost decision** (as opposed to thirty-day-old paper or PDF utility bills). Ultimately, the final decision is in the farm's hands and depends on many changing factors. **It is critical for energy policy makers to understand that farmers are running a business and energy consumption is a cost of doing business for them, not a primary revenue driver.** Technology platforms like Wexus that automate laborious tasks, such as tracking energy and water consumption and utility bill costs, and that relate them to the actual farming operation with historical dashboard and real-time alerts can help drive overall energy markets awareness, behavioral change, and improved net operating income for farms. Wexus will continue to incorporate farmers feedback and these results to improve the effectiveness of peak period alerts.

# Overview of Measurement and Verification Methodology

The four partners are a Berry Farm, a Row Crop Farm, a Dairy Farm, and a Vineyard. Each of the four participating partner farms is comprised of multiple, geographically distinct ranches. In some cases, the ranches are physically separated by miles, and, in other cases, they are directly adjacent. Each of the ranches is served by irrigation pumps, which are metered by one or more separate utility electricity meters.

Four time periods were defined to establish a comparative baseline as well as project implementation phases:

1. Extended Baseline (January 2008 - June 2013)
2. Baseline (July 2013 - June 2015)
3. Uptake (July 2015 - December 2015)
4. Treatment (January 2016 - June 2018)

The Extended Baseline period provides supplemental baseline data covering a longer, more varied period of time of approximately five and a half years. Data covering the entire Extended Baseline period was not available for all meters (some ranches had been purchased more recently, for example), so this period was only used in selected analyses. The Baseline period covers the two years immediately preceding the start of the project. Energy use data is essentially complete for all of the analyzed meters during this period. These two periods are referred to collectively as the “baseline” period.

The Uptake period covers the first six months following the start of the project. Changes in energy use relative to the baseline are reported for this period, but it is considered to be a distinct period during which some aspects of the project were still being implemented and full impact would not necessarily be expected. The Treatment period covers the subsequent two and a half years, when the project was underway. These two periods are referred to collectively as the “project” period.

## Data Collection

Electricity usage data was obtained for each of the wells and irrigation/booster pumps on the participating farms. The data was originally measured and collected by the regional power utility (PG&E or SCE) and made available to CWEE at the level of monthly billing records for all of the metered irrigation pumps on the farms. (Most meters are connected to a single pump, but some meters are connected to more than one.) The monthly billing data typically included measurements on several variables in addition to total electricity usage, including cost, peak-period electricity usage, and maximum electricity demand. Hourly interval data for electric usage was also available for many of the meters, however often only for a limited time span that did not cover the full baseline period.

Peak-period usage is the amount of electricity used during designated peak use time periods. Electricity accounts that have a service agreement with a time-of-use (TUO) rate plan pay higher rates for electricity used during those hours. The precise peak period times are specified in the rate schedule, but typically weekday afternoons during the summer months. There are a variety of agricultural rate options with different durations (e.g. four or six hours) and different days of the week (e.g. Monday/Wednesday/Friday only)

Maximum demand is another measure of electricity usage, which is a component of many service agreements. It measures the maximum rate of electricity consumption recorded during a billing period.

The amount of baseline data provided by Wexus (from utility Green Button Connect platforms) varied by meter, and the earliest available was from March 2012, comprising at most three complete years of usage data in the overall baseline timeframe. Notably, these years were during the recent period of severe drought in California. To increase the amount of overall baseline energy data available for analysis, CWEE obtained additional electricity meter data from the energy utility providers.[1] The goal was to develop a better profile of operating conditions over more varied conditions and to obtain a sample of the energy usage trends on other farms in the region not participating in the project. This data comprises the Extended Baseline period for both project and control groups.

### Electricity Meter Data

Figure 68 shows total electricity usage from meters on the participating partner farms over a 10-year period, broken into the four time periods established above. (The Uptake period is located between the Baseline and Treatment periods but remains unlabeled here and in following figures due to space limitations.)

[1] UC Davis was able to access this data as a result of a California Public Utilities Commission (CPUC) ruling mandating that energy investor owned utilities (IOUs) release consumer data to specific third parties (CPUC Decision 14-05-016, May 2014).

**Figure 68: Electricity Usage for Partner Farms over a 10-year Period**

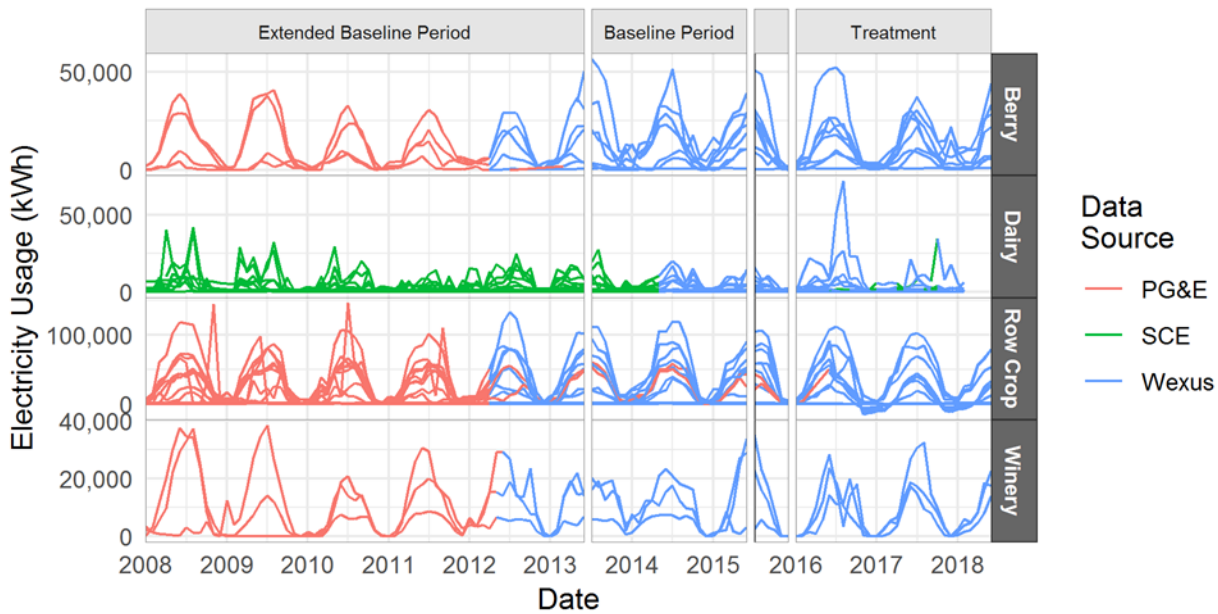
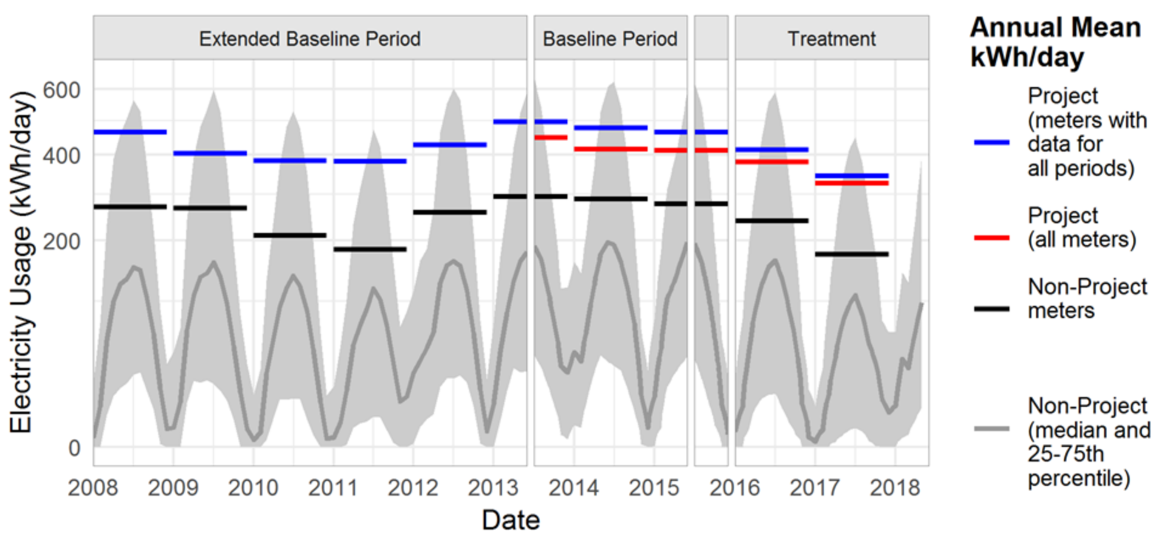



Figure 69 compares partner farm total electricity usage with that of potential control group agricultural accounts in the region[1]. The continuous gray line shows the median daily electricity use for the regional pumps. The horizontal black lines show annual average values for the regional control group meters, and the gray shading represents the median including the 25th to 75th percentiles for these same meters. The blue and red horizontal lines show annual average values for partner farms.

**Figure 69: Electricity Usage for Project and Regional Agricultural Pumps over a 10-year Period**




In addition to the expected seasonal variation, a long-term, year-over-year pattern in average annual electricity usage is apparent in Figure 3. The long-term trend for the partner farms generally tracks with the trend for the other regional farms. Part of the site selection criteria was higher electricity usage than other farms on average, i.e. those with a high opportunity for energy savings. Also, note that the more recent Baseline period (non-extended) is a period of relatively high electricity usage for both project and regional farms, roughly corresponding to the recent California drought.

### Other Data

An advanced utility metering infrastructure for water does not exist, so farms utilize estimates, manually read flow meters in the field, or install equipment with data connectivity at their own cost. Additional monitoring equipment was installed on two wells at each partner farm to measure electricity and water usage in real-time and on more granular, fifteen-minute intervals. Partner farms assisted Wexus with pump selection to maximize the cost-effectiveness of these installs.

For this project, Wexus worked with CWEE to develop a water estimation methodology based upon electric utility meter consumption, well depth, and pump efficiency performance. This water estimation methodology was used for baseline time periods prior to this project and for wells without additional water monitoring equipment installed.

To determine both cost and GHG emissions, state level averages and coefficients were used (see "Measuring Changes in Cost" & "Measuring Changes in GHG Emissions" in the Methodology section).

Weather data specific to each farm was obtained from the California Irrigation Management System (CIMIS) with weather stations distributed throughout the agricultural regions of the state. The stations measure common environmental characteristics such as air temperature and precipitation, and key variables related to irrigation demand, such as vapor pressure and solar radiation, which are used to calculate reference evapotranspiration.

## Methodology

This analysis evaluates changes in electricity and water usage between baseline and project periods in an effort to assess the impact of the Wexus energy and water management system deployment. Electricity usage data was analyzed independently for each of the farms, focusing on the change in electricity use over time between the baseline and project periods. For the individual farm results, the following information was calculated:

- Change in Electricity Use
    - Total Electricity
    - Maximum Demand
    - During Peak Periods
- Change in Water Use
- Change in GHG Emissions
- Change in Cost

This type of pre- and post-comparison is often used for evaluating the impact of technological interventions (e.g., a pump replacement) because changes can be easily isolated and measured under relatively controlled conditions. However, the changes implemented during this project were more complex. As part of this project, CWEE took the first step in developing a single-farm methodology, which can account for multi-variable changes in agricultural operations. This type of methodology is necessary to evaluate a single-farm savings over discrete time periods, independent of other farms. For many reasons, including data access and the very nuanced, location- and crop-driven variables at a particular farm, it is not reasonable to use a large-scale randomized trial with a control group to calculate a specific partner farms savings for rebate and financing purposes. However, a control group approach could be considered for broader program-level evaluation.

In addition, it is best to evaluate the overall impact for a partner farm at the farm- or ranch-level (not meter-level) due to the operational interdependence of meters/pumps across ranches and the farm. To account for bias due to incomplete data and to ensure that operating conditions were as similar as possible between periods, any ranch that did not have complete meter data across all meters for the Baseline and Project periods was excluded. Additional detail is provided in the results for each partner farm.

**External Factors**

For each of the farms, various factors affecting electricity consumption associated with crop irrigation but outside the control of the project were considered. This analysis attempted to isolate and account for these factors so that any electricity savings could reasonably be attributed to the Wexus management system. The most significant factors that might contribute to variations in electricity usage and resulting electricity savings for this project include changes to the following:

- Farm operations (crop type, number of acres planted per crop type, and production levels)
- Pump energy efficiency (resulting in variable electricity consumption)
- Irrigation efficiency technologies (e.g., soil moisture sensors or drip irrigation systems)
- New equipment (e.g., pump replacement with more efficient models, variable-frequency drive (VFD) installations, pump motor repairs, solar PV installations, or new well development)
- Weather (variation in temperature, evapotranspiration rates, and rainfall)
- Drought conditions (changes in weather and a decrease in groundwater aquifer levels which increased pumping energy requirements)

In order to determine if any farm-level changes impacted the results, CWEE considered the responses to the regular surveys (see Appendix A), which Wexus developed and sent. Quarterly questionnaires identified (1) water or pump energy efficiency technologies that were implemented during the project period, (2) changes in farm operations and production levels that would impact electricity and water use, and (3) modifications to wells or pumps. Semiannual questions addressed the impacts of the drought on farm electricity and water use. Any applicable responses to these questions are discussed in the results section for each farm.

### Measuring Changes in Electricity Consumption

In addition to calculating the unadjusted change over time in total electricity consumption for each farm, a regression model was used to estimate the adjusted change, controlling for external factors such as weather. CWEE developed a regression model using available total electricity data for each well and irrigation booster pump on the farms. The model was fit using observed total electricity consumption as the response variable and associated weather data as predictor variables. As mentioned above, daily weather data (including precipitation, temperature, and reference evapotranspiration) was obtained from California Irrigation Management Information System (CIMIS) weather stations in geographic proximity to each farm. Estimated evapotranspiration was also obtained from CIMIS using the precise geographic coordinates of each ranch.

Electricity billing time periods can vary from month to month and year to year, resulting in inconsistent alignment and duration when comparing baseline period data to treatment period data (e.g., data for each billing period can extend between different months and can vary in the number of days recorded per billing cycle). To simplify the comparison of assets and time periods, the billing data was resampled to standard monthly intervals. Since the length of individual months is also variable, the model was fit using average electricity consumption per day (in units of kWh/day) during each month, so that the scale would be consistent.

All of the weather variables available from CIMIS were considered in the model fitting process, however many of them are highly correlated with each other, and contain redundant information. In particular, evapotranspiration (ETo) was calculated using some of the other variables, including air temperature and solar radiation as inputs. Evapotranspiration is intended to represent overall irrigation demand and was found to correlate well with the observed electricity usage, so ETo was selected as an important predictor in the model. Precipitation was not used in the ETo calculation, because it can independently affect water and energy use, it was included as a predictor.

In addition to weather variables, which explain most of the seasonal variation, monthly fixed effects were also included to improve the fit of the model to the typical annual usage pattern for each farm.

Time series data, such as monthly energy usage, often have special properties that need to be handled appropriately in statistical models. The main issue is that the values are not completely independent of each other. For example, the total energy usage in any given month is usually very similar to the total energy usage in the previous month, and in the following month, even after controlling for other factors. This property, known as autocorrelation or serial correlation, needs to be modeled correctly in order to accurately estimate error bounds. Several of the quarterly reports used a regression with Autoregressive Moving Average errors (RegARMA) to account for this, but the development of the final models presented here found that this was not necessary. The weather variables and/or month fixed effects were sufficient to remove the residual autocorrelation in the model.

The time periods before and after the implementation of the Wexus technology were differentiated in the regression model using a binary factor. The model structure used in this report to estimate the effect of the project on each of the four individual partner farms is described in Equation 1.

Equation 1: Electricity consumption regression model for an individual farm.

$$\widehat{Y_t} = \beta_0 + \beta_1 X_{t,1} + \beta_2 X_{t,2} + \beta_3 X_{t,3} + \beta_4 X_{t,4} + \beta_5 X_{t,5} + \cdots + \beta_{15} X_{t,15} + \varepsilon_t$$

Where the following are true,

- $\widehat{Y}$ = electricity consumption ($\frac{\text{kWh}}{\text{day}}$)
- $X_1 = \begin{cases} 0 \text{ if Baseline or Project Period} \\ 1 \text{ if Uptake Period} \end{cases}$
- $X_2 = \begin{cases} 0 \text{ if Baseline or Uptake Period} \\ 1 \text{ if Project Period} \end{cases}$
- $X_3$ = average evapotranspiration (in)
- $X_4$ = average precipitation (in)
- $X_5 \ldots X_{15}$ = month fixed effects
- $\beta$ = regression model coefficients
- $\varepsilon$ = independent $\mathcal{N}(0, \sigma^2)$

The model was adjusted for the Row Crop farm to include an indicator for a solar array, which came online early in the project period. A summary of the fitted model and the estimated coefficients is presented in the results section for each farm.

**Measuring Partner Farm Response to Peak Period Alerts**

For irrigation pumps with additional hardware installed for real-time data tracking, Wexus sent peak demand period alerts to customers as SMS text messages to notify them in advance and to help them potentially avoid costly peak demand surcharges during the summer months between May through October. CWEE analyzed the proportion of electricity used during peak hours on these meters, to determine if the customers were responding to the alerts and shifting use to off-peak hours. Wexus developed a rule-based system to identify if a customer had responded to an alert using either of the following two conditions:

- the maximum energy demand of the pump during peak hours is at least 10 kilowatts lower than the maximum energy demand of the pump during off-peak hours (demand reduction), or
- the pump is turned off for at least an hour during the peak period and is turned on for at least an hour after the peak period has ended (usage shift).

**Figure 70: Example Daily Load Profiles for Demand Reduction and Usage Shift Patterns**

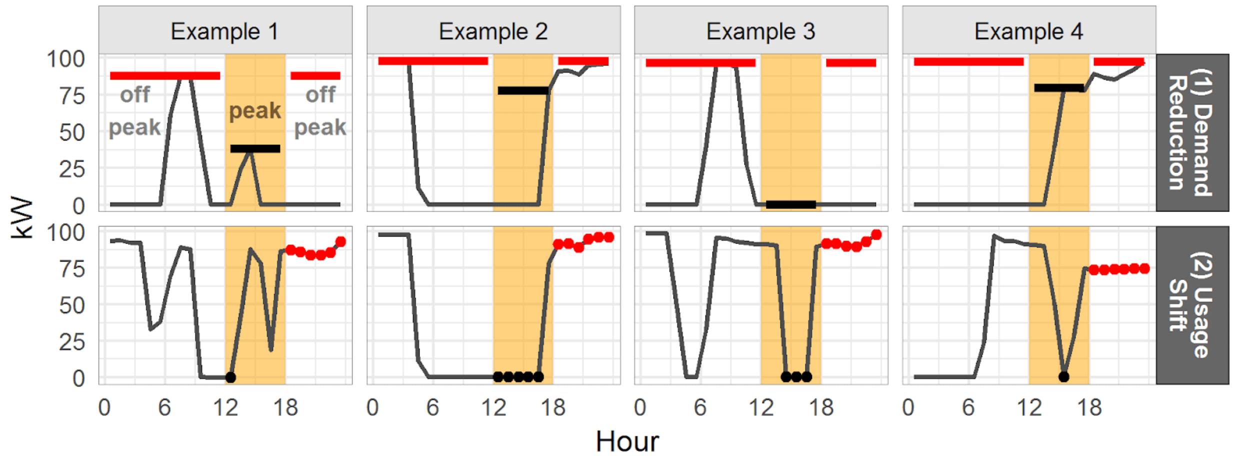



Figure 70 shows several daily use profiles that meet the two specified conditions. Four randomly selected days are illustrated for each pattern. The time interval shown in yellow is the afternoon peak period, while the off-peak period is show with a white background. Row 1 provides examples of “Demand Reduction” during the peak hours (bold black line) of at least 10kW lower than max demand off-peak (red bar). Row 2 provides examples of “Usage Shift” with at least one hour of zero usage during the peak period (black dots) followed by at least one hour of non-zero use later that same day (red points).

CWEE applied this same methodology to identify alert responses, and to look at the trend in apparent responses over time. This was done by applying the same rule-based conditions to the data, including the baseline period before Wexus started sending the alerts. Looking at the trend in frequency of these usage patterns provides a better indication of whether the growers are actually responding to the alerts. It also helps control for the fact that the rule-based conditions are not perfect in identifying actual responses.

### Measuring Changes in Water Use

Since utility metering is not available for water measurement, farms must make a cost-based decision on whether to install their own metering. Historically, monitoring devices with data connectivity have not been cost-effective, so historical measured flow meter data was not available for any of the partner farms at the start of the project. However, 15-minute interval flow data is now available for the wells with Polaris monitoring equipment installed.

To fill in the historical gaps for all farms and the current gaps for pumps without additional monitoring equipment installed, Wexus worked with CWEE to develop a methodology for estimating water usage. Equation 2 uses electricity usage data and data from pump test reports (pump efficiency and depth to groundwater data) to estimate the amount of groundwater pumped from each well over a specific period of time.

Equation 2: Estimated water use equation.

$$\text{Water Use (ac} - \text{ft)} = \frac{\text{Electricity Use (kWh)} \times \text{Pump Efficiency (\%)}}{1.024(\frac{\text{kWh}}{\text{ac} - \text{ft}}) \times \text{Depth (ft)}}$$

Where the following are true,

- “Water Use” represents the volume of groundwater extracted
- “Electricity Use” is the electricity consumption for a specific well
- “Pump efficiency” is the efficiency of the well pump
- “1.024” is a constant representing the electricity required (kWh) by a pump to lift 1 ac-ft of water a distance of 1 foot when operating at 100% efficiency
- “Depth” is the depth of groundwater (the distance a pump has to “lift” groundwater as measured from the ground surface to the groundwater level).

Using the baseline and the current electricity data, baseline and current water use volumes were calculated for each well pump (irrigation or booster pumps were excluded to avoid duplicating water use estimates). Baseline and current water use volumes have only been calculated for pumps with sufficient pump and electrical data available for estimating water data.

To preserve farmer privacy related to water use, this report presents changes in water use as a percent change for each farm. The changes in water use are reported as observed changes over time comparing baseline to current data.

### Measuring Changes in GHG Emissions

Estimated changes in GHG emissions associated with measured changes in electricity usage were calculated using an emission factor of 0.588 lbs CO2e/kWh.[2] Both observed and modeled changes are reported for each farm in terms of pounds of CO2 reduced and the percent reduction from the baseline.

### Measuring Changes in Cost

Estimated changes in cost associated with measured changes in electricity use were calculated using an average statewide electricity rate for the commercial sector of $0.1418/kWh.[3] Changes are reported as observed and modeled change for each farm as the dollar savings value and the percent reduction from baseline.

## Savings Results for Individual Partner Farms

The following sections summarize savings results specific to each of the four participating farms. The results for each farm are presented first as total electricity use, broken down in both baseline and project periods. Next, changes in electricity use are presented and plotted, reflecting the unadjusted difference between the baseline and project time periods. Regression modeling results, which include adjustments for potential external factors, are also

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[2] Using the standardized emission factors outlined in the Program Opportunity Notice for this grant, PON 14-304, *Attachment 14: References for Calculating Energy End-Use, Electricity Demand, and GHG Emissions.*

[3] Using the energy costs outlined in the Program Opportunity Notice for this grant, PON 14-304, *Attachment 14: References for Calculating Energy End-Use, Electricity Demand, and GHG Emissions.*

summarized. Changes in peak energy and maximum energy demand are followed by a section addressing the behavioral response to peak energy alerts. Finally, changes in water, GHG emissions, and costs are presented.

## Berry Farm Savings Results

The Berry farm project deployment site is located near Salinas, California, and includes primarily strawberries and some row crops. The farm includes four ranches that participated in the project, collectively covering approximately 870 acres. There is a total of 12 pumps related to irrigation operations (either well, booster, or drip irrigation system pumps) and a total of 10 electricity meters on the farm. A summary of farm information by ranch is included in Table 6, wherein the number of meters equals the number of pumps unless indicated otherwise.

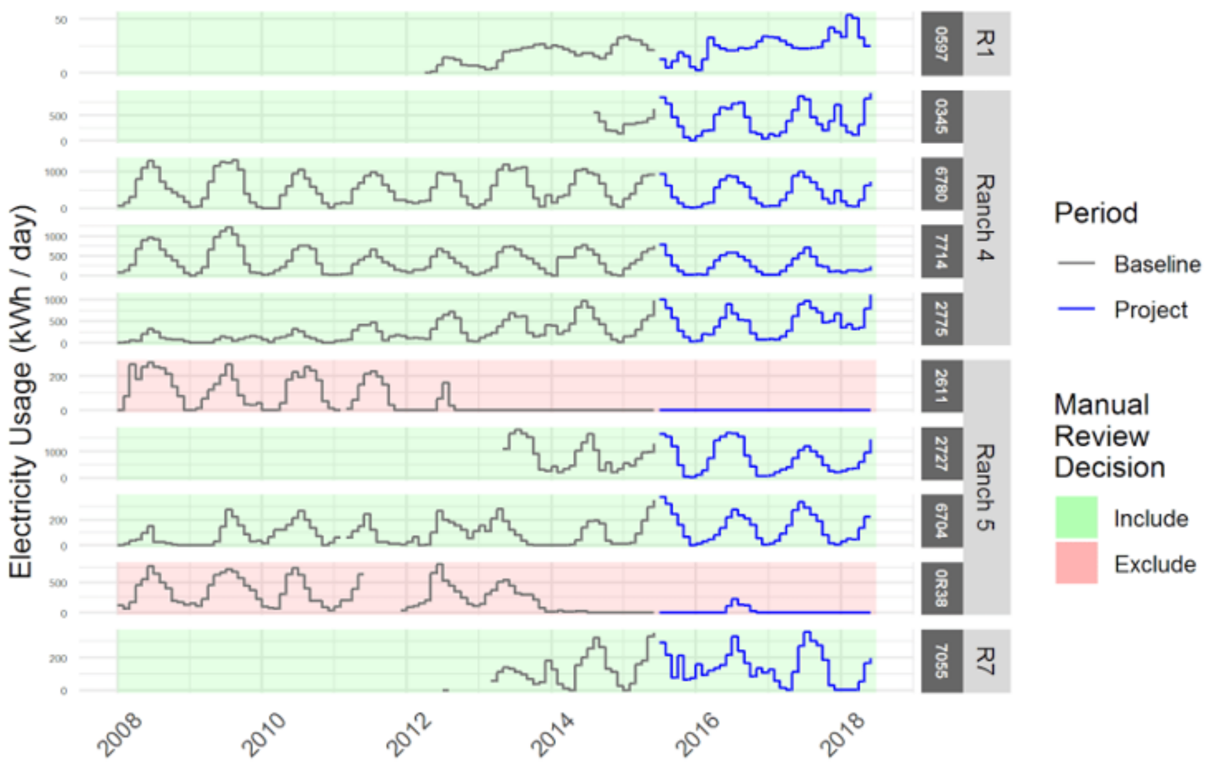
**Table 6: Berry Farm Summary by Ranch**

| Ranch | Acreage | Crop Type | No. Pumps | Comments |
|---|---|---|---|---|
| **Berry Ranch 1** | 72 | Berries | 2 | On 1 meter |
| **Berry Ranch 4** | 516 | Berries/Row Crops | 5 | On 4 meters; 2 meters excluded from analysis |
| **Berry Ranch 5** | 232 | Berries/Row Crops | 4 | |
| **Berry Ranch 7** | 53 | Berries | 1 | |

Strawberries are planted in the spring and harvested in early summer and into the fall. Row crops, such as lettuce, cauliflower, and broccoli, are planted and harvested throughout the year on a rotating basis. Due to these crop requirements, many of these Berry farm irrigation pumps operated twenty-four hours a day, seven days a week from February through November during the project period. For ranches with only one or a few wells, irrigation events were cycled from one crop block to the next over a 24-hour period.

CWEE evaluated data from the ten utility meters individually to determine whether it should be included in the analysis. CWEE chose to exclude two meters from Berry Ranch 5 due to apparent lack of use (it is possible that usage had been shifted to one of the other meters). Figure 71 shows the electricity usage data for each meter for each ranch.

**Figure 71: Berry Farm Meter Data**




Most of the Berry farm crops are irrigated with well water via drip irrigation systems. The drip systems include filtration systems and soil moisture sensors to inform irrigation events. Spray irrigation is used when crops are young, because the period of plant establishment requires increased irrigation. Table 7 provides a summary of pump information for the Berry farm.

**Table 7: Berry Farm Pump Summary**

| Ranch | Meter ID (last 4 digits) | Pump Type | Pump HP | Water Data[4] | Polaris Data[5] |
|---|---|---|---|---|---|
| **Berry Ranch 1** | 0597 | Well/Booster | 30/50 | Yes | No |
| **Berry Ranch 4** | 0345 | Well | 100 | Yes | No |
| | 2775 | Well/Booster | 125 | Yes | Yes |
| | 7714 | Well | N/A | No | No |
| | 6780 | Well | N/A | No | No |
| **Berry Ranch 5** | 6704 | Well | 75 | Yes | No |
| | 2727 | Well | 250 | Yes | No |

[4] Pump specification data available sufficient for <u>estimating</u> water data

[5] Polaris equipment installed for logging real-time water flow and energy use data, and data currently available

| Ranch | Meter ID (last 4 digits) | Pump Type | Pump HP | Water Data[4] | Polaris Data[5] |
|---|---|---|---|---|---|
| **Berry Ranch 7** | 7055 | Well | 75 | Yes | No |

**Electricity Results**

Figure 72 shows the total electricity use time series for each of the Berry farm ranches. Minimal data was available for the Extended Baseline period (due to purchase date of ranches participating in this project), however data was mostly complete for the Baseline, Uptake, and Treatment periods.

**Figure 72: Total Electricity Use Time Series for the Berry Farm**

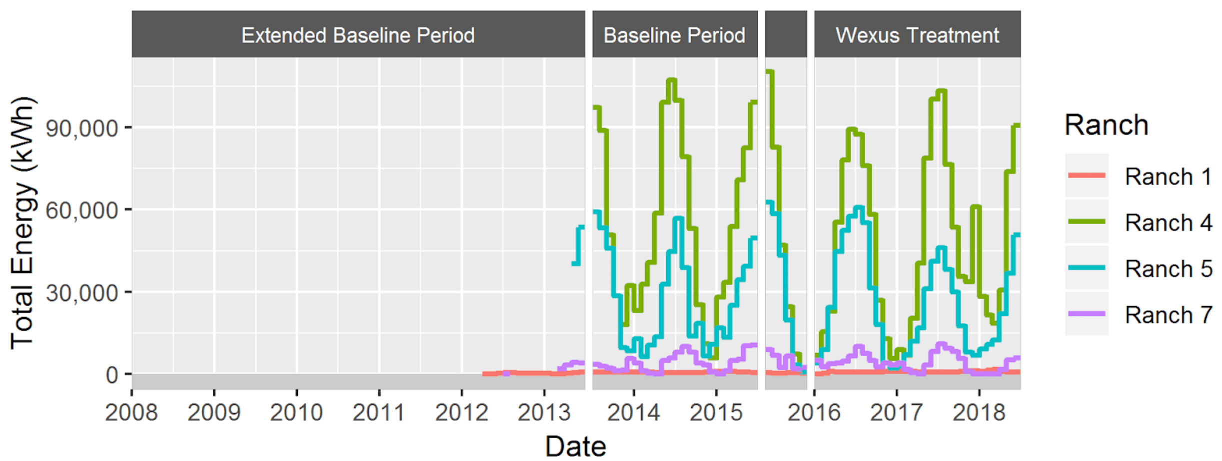



Table 8 shows the average quarterly electricity usage on each ranch during the two-year Baseline period. The majority of electricity use on the farm occurred on ranches 4 and 5.

**Table 8: Berry Farm Average Baseline Electricity Usage (kWh, Jul 2013 - Jun 2015)**

| | Q1 | Q2 | Q3 | Q4 | Total |
|---|---|---|---|---|---|
| **Ranch 1** | 2,485 | 1,843 | 1,760 | 2,325 | **8,414** |
| **Ranch 4** | 106,002 | 258,821 | 234,536 | 60,372 | **659,731** |
| **Ranch 5** | 42,422 | 107,319 | 133,820 | 41,280 | **324,840** |
| **Ranch 7** | 5,733 | 18,508 | 17,161 | 8,283 | **49,684** |

Table 9 shows the total electricity use for each quarter during the project period.

**Table 9: Berry Farm Total Electricity Usage (kWh, Jul 2015 - Jun 2018)**

| | Uptake Period | | Treatment Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| Ranch 1 | 871 | 1,202 | 1,437 | 2,086 | 2,023 | 2,646 | 2,870 | 2,173 | 2,138 | 3,345 | 4,099 | 2,490 |
| Ranch 4 | 240,118 | 33,946 | 45,053 | 222,903 | 221,578 | 45,518 | 36,189 | 219,432 | 233,387 | 130,279 | 68,417 | 195,126 |
| Ranch 5 | 164,260 | 23,443 | 37,209 | 154,624 | 147,315 | 24,056 | 21,905 | 89,279 | 114,235 | 32,224 | 32,106 | 109,373 |
| Ranch 7 | 18,105 | 10,775 | 11,321 | 15,332 | 22,577 | 10,062 | 5,983 | 11,649 | 28,502 | 6,781 | 398 | 12,699 |

*Change in Total Electricity Usage*

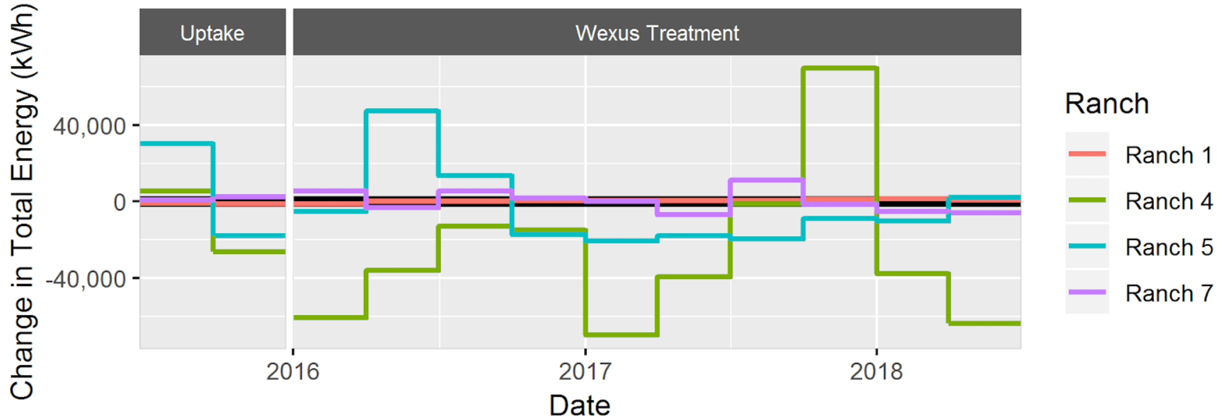
Table 10 shows the unadjusted change in total electricity use for each quarter, relative to the corresponding Baseline quarter. **The average percent change in total electricity use for the Berry farm relative to the Baseline was found to be -11.3%.**

**Table 10: Berry Farm Electricity Usage, Difference Relative to Baseline Period**

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Total |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| Ranch 1 | -889 | -1,124 | -1,049 | +243 | +263 | +320 | +385 | +330 | +378 | +1,020 | +1,613 | +647 | **+4,151** |
| Ranch 4 | +5,582 | -26,426 | -60,949 | -35,918 | -12,957 | -14,854 | -69,813 | -39,390 | -1,148 | +69,907 | -37,585 | -63,695 | **-266,403** |
| Ranch 5 | +30,440 | -17,837 | -5,213 | +47,305 | +13,495 | -17,224 | -20,517 | -18,040 | -19,585 | -9,056 | -10,316 | +2,054 | **-37,097** |
| Ranch 7 | +944 | +2,492 | +5,589 | -3,176 | +5,416 | +1,779 | +250 | -6,859 | +11,341 | -1,502 | -5,335 | -5,810 | **+1,694** |
| Total | **+36,077** | **-42,895** | **-61,622** | **+8,453** | **+6,218** | **-29,979** | **-89,695** | **-63,959** | **-9,014** | **+60,369** | **-51,623** | **-66,803** | **-297,655** |

Figure 73 plots the relative change values from Table 3.

**Figure 73: Change in Total Electricity Use, Relative to Baseline for the Berry Farm**




The Berry grower did not report any major changes in overall farm operations or new water efficiency improvements on the monitored ranches that would impact results. However, the following site-specific farm-level ETo and precipitation data — which could have an impact — were used in the analysis (Figure 74).

**Figure 74: CIMIS Monthly ETo and Precipitation Data for the Berry Farm**

The regression model described in the Methodology section was used to account for the impact of external factors (such as ETo, precipitation, and seasonal variation) on the raw electricity change values, in order to estimate the remaining marginal change in total electricity use during the project treatment period. **Error! Reference source not found.** summarizes the results for t he three variations of the farm-level regression model.

**Table 11: Berry Farm Regression Model Results**

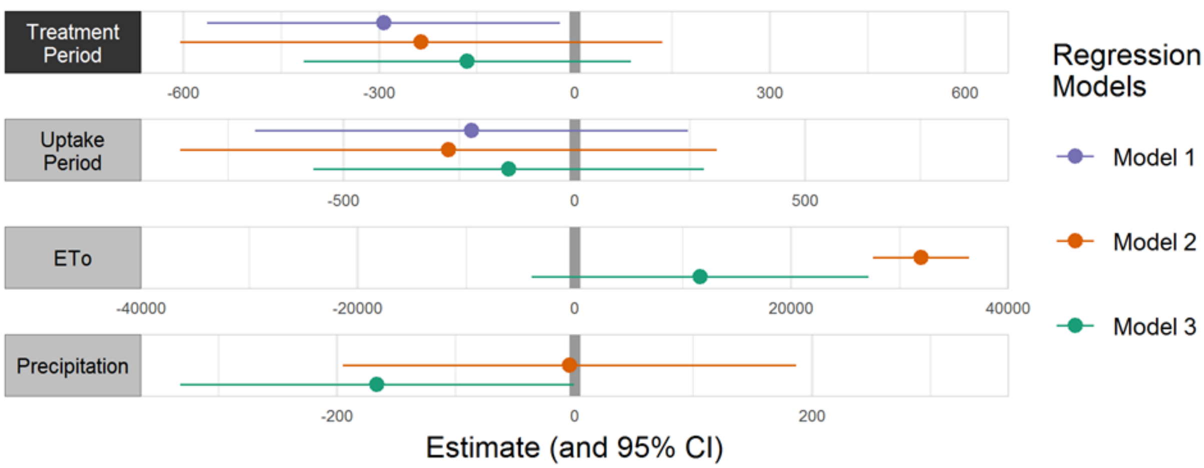
| | (1) | (2) | (3) |
|---|---|---|---|
| **(Intercept)** | 1194.5 *** | 2802.8 *** | 2135.4 *** |
| | (232.8) | (131.3) | (488.6) |
| **Project Uptake** | -222.6 | -273.0 | -142.5 |
| | (232.8) | (289.6) | (209.3) |
| **Project Treatment** | -292.8 * | -235.3 | -164.5 |
| | (134.4) | (184.3) | (124.0) |
| **ETo (in)** | | 31959.7 *** | 11576.1 |
| | | (2209.7) | (7689.9) |
| **Precipitation (in)** | | -4.2 | -166.3 * |
| | | (95.2) | (82.1) |
| **Month Fixed Effect** | Yes | No | Yes |
| **N** | 60 | 56 | 56 |
| **$R^2$** | 0.94 | 0.87 | 0.96 |

| | | | |
|---|---:|---:|---:|
| **logLik** | -448.6 | -437.9 | -407.6 |
| **AIC** | 927.3 | 887.8 | 849.2 |

In addition to the project time periods, both Uptake and Treatment, Model (1) uses a monthly fixed effect to model the seasonal variation; Model (2) uses the CIMIS ETo and precipitation data, which can explain a large amount of the seasonal variation, although the fit is not quite as good; and, Model (3) includes both the monthly fixed effect and the CIMIS weather variables.

**All three models show consistent results, with a reduction in electricity use during the Wexus project period**, however the estimated effect is not significantly different from zero for Model (2) or (3). Model (3) provided the best fit to the data (e.g., R2 = 96%).

**Figure 75: Regression Coefficients for the Berry Farm**




The model coefficients and associated 95% confidence intervals are plotted in Figure 75. The estimated Wexus treatment effect (-165 kWh/day) from model (3) represents about a 5.6% reduction in electricity use relative to baseline.

*Change in Peak Period Electricity Use*

In general, the total amount of peak period electricity use trends similarly with overall electricity use. To account for this, the following results focus on the proportion of electricity used during peak hours as compared to total electricity used. If growers are shifting use away from peak hours, we would expect this proportion to fall over time.

Figure 76 shows the trend in peak period electricity usage for each ranch.

**Figure 76: Change in the Proportion of Peak Period Electricity Usage for the Berry Farm**

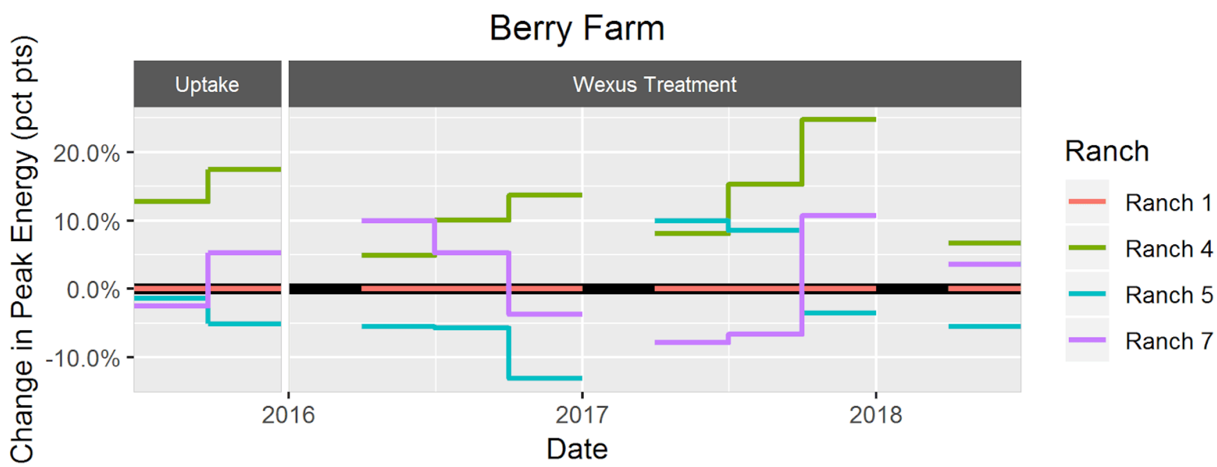



Table 12 shows the observed change in proportion of peak period electricity use (same data that is plotted in Figure 12) for the Berry farm, calculated as the difference relative to baseline. The average proportion of electricity used during peak periods, across the Berry farm ranches, increased by 2.9 percentage points during the Wexus treatment period. **However, this increase was due to additional pump load (e.g. booster pumps) being added to the site during the project, and these site changes were not taken into account in this analysis.**

**Table 12: Berry Farm Peak Electricity Usage, Difference Relative to Baseline (percentage points)**

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Average |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| **Ranch 1** | +0.0 | +0.0 | - | +0.0 | +0.0 | +0.0 | - | +0.0 | +0.0 | +0.0 | - | +0.0 | **+0.0** |
| **Ranch 4** | +12.7 | +17.5 | - | +4.9 | +10.1 | +13.7 | - | +8.1 | +15.3 | +24.8 | - | +6.7 | **+11.9** |
| **Ranch 5** | -1.4 | -5.1 | - | -5.5 | -5.7 | -13.1 | - | +10.0 | +8.5 | -3.5 | - | -5.4 | **-2.1** |
| **Ranch 7** | -2.4 | +5.3 | - | +10.0 | +5.3 | -3.7 | - | -7.8 | -6.6 | +10.7 | - | +3.6 | **+1.6** |
| **Average** | **+2.2** | **+4.4** | **-** | **+2.4** | **+2.4** | **-0.8** | **-** | **+2.6** | **+4.3** | **+8.0** | **-** | **+1.2** | **+2.9** |

*Change in Maximum Electricity Demand*

Table 13 shows the observed change in maximum demand on the Berry farm. The **maximum demand across the Berry Farm ranches decreased by 10.2 kW on average** during the Wexus treatment period.

**Table 13: Berry Farm Max Electric Demand, Difference Relative to Baseline (kW)**

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Average |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| Ranch 1 | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Ranch 4 | +3.2 | +1.3 | -1.7 | +1.2 | +1.9 | -0.4 | +3.2 | +1.3 | +2.9 | +5.5 | +5.0 | +4.5 | **+2.3** |
| Ranch 5 | -16.9 | -48.3 | -5.7 | +10.5 | -12.4 | -51.4 | -29.3 | -20.6 | -20.4 | -51.6 | -26.8 | -8.6 | **-21.6** |
| Ranch 7 | +2.0 | -10.9 | +5.6 | -1.5 | +6.0 | -16.8 | -50.9 | -1.7 | +2.7 | -1.5 | -56.6 | +0.2 | **-11.4** |
| Average | **-3.9** | **-19.3** | **-0.6** | **+3.4** | **-1.5** | **-22.8** | **-25.7** | **-7.0** | **-4.9** | **-15.8** | **-26.1** | **-1.3** | **-10.2** |

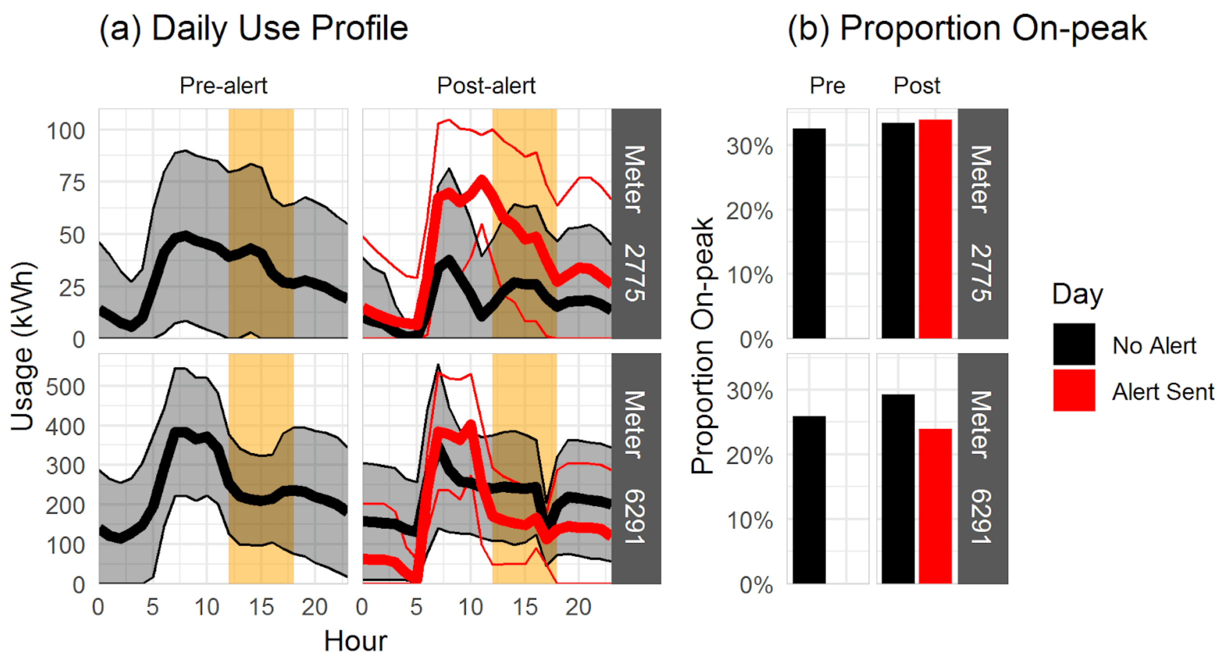
*Peak Energy Alert Response*

Figure 77 shows the daily usage profile for the two meters on the Berry farm that were sent peak period alerts. Meter 2775 (on Ranch 4) has different usage profiles on alert days, however the average proportion of peak period electricity used is essentially identical. Meter 6291 (on Ranch 9[6]) shows a different use pattern on alert and non-alert days, resulting in a smaller relative amount of peak period electricity use on days when an alert was sent, however given that the alerts are sent in response to specific conditions, rather than at random, it is difficult to attribute the difference specifically to the alerts. For example, the alerts were only sent if the meter shows high usage in the hour just before the peak period, so it is expected that the daily use profiles are different.

**Figure 77: For the Berry Farm: (a) Daily Use Profile Pre- and Post-alert, Showing Alert and No Alert**

[6] Ranch 9 was excluded from most of the other analyses, because there is not sufficient pre-Wexus baseline data. Most of the pre-alert data used here for baseline responses is after the Wexus program began, but before peak-usage alerts were being sent.

Days (b) Proportion of Daily Electricity Used During Peak Hours




An alternative method to estimate the impact of the alerts is to evaluate the long-term trend in electricity use patterns. Wexus started sending peak usage alerts to the Berry farm in July 2016. Figure 78 shows the trend in peak period electricity use over time, summarized weekly during the summer peak demand surcharge months. The gray lines show multiple years of pre-alert data for the meter, which are useful as a baseline of normal operating conditions. The red lines show the peak period electricity use values in the time period when alerts were sent (summer of 2016 & 2017). Superimposed in the background are number of alerts sent each week, which can range from 0 to 5.

**Figure 78: Proportion of Electricity Used During Peak Hours for the Berry Farm**

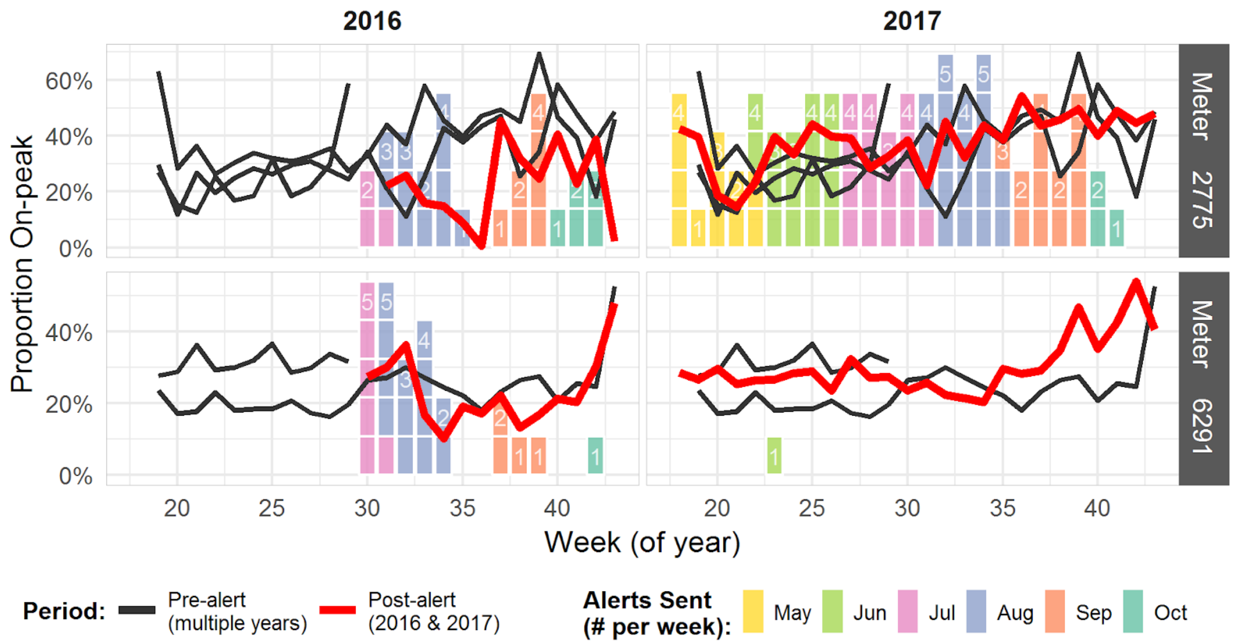
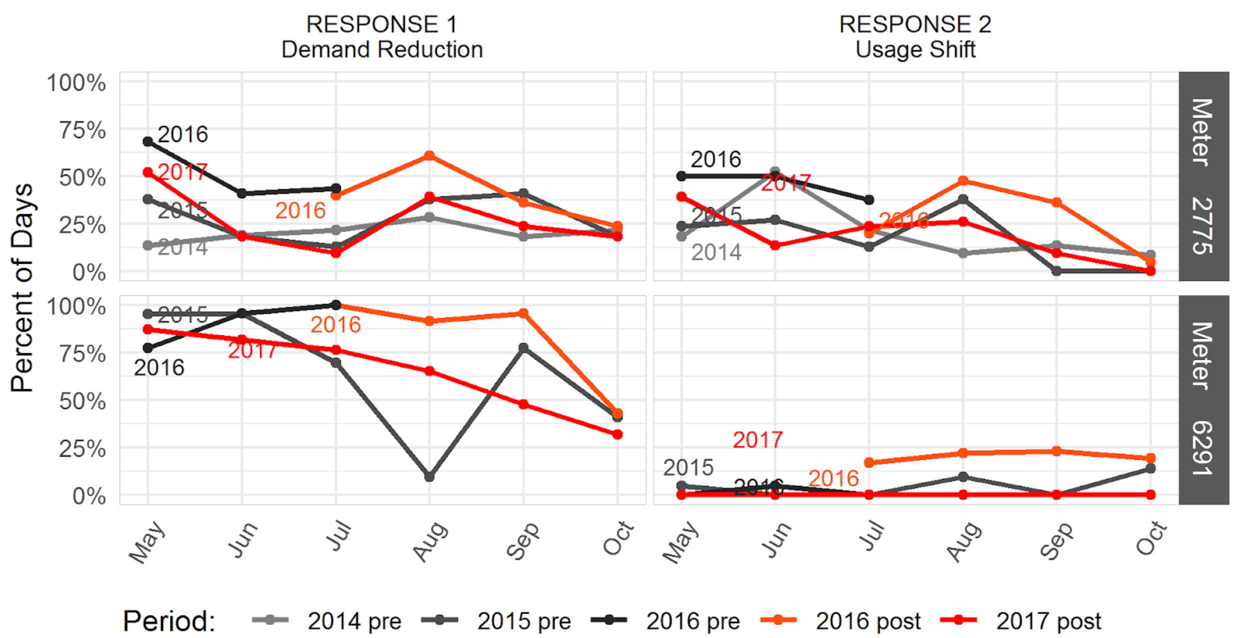



Figure 79 shows the trend, using the rule-based conditions. Again, the gray lines show baseline pre-alert values, and the orange and red lines show values in the post alert periods. In this case, the data was summarized by month, showing the percentage of peak surcharge days when a response appears to have occurred.

**Overall, both of the Berry meters show reductions in the weeks following the introduction of peak period alerts. However, over time the Berry partner farm could not always curtail energy usage due to business needs.** Many alerts continued to be sent in 2017 for Meter 2775, and the Berry partner farm found these alerts to be informative, despite not responding by reducing demand or shifting usage on those days. This validated Wexus' hypothesis that partner farms want the option to receive alerts and that the peak surcharge costs do not take priority over crop and irrigation needs to earn the farm revenue.

**Figure 79: Trend in Responses Over Time, Pre- and Post-alert Periods for the Berry Farm**




**Water, GHG Emissions, and Cost Results**

**Total change in water usage (unadjusted) at the Berry farm was -8.3%.** Table 14 shows the changes in GHG emissions and Table 15 shows the change in electricity costs.

**Table 14: Change in GHG Emissions (lbs CO2e)* for Berry Farm**

| | Unadjusted Change | Adjusted Change |
|---|---|---|
| **Cumulative Total (Jan 2016 - Jun 2018)** | -175,000 | -88,000 |
| **Average Value Per Quarter** | -17,500 (-11.3%) | -8,800 (-5.6%) |
| *Calculated from electricity usage data (0.588 lbs CO2e/kWh) | | |

**Table 15: Change in Electricity Costs* for Berry Farm**

| | Unadjusted Change | Adjusted Change |
|---|---|---|
| **Cumulative Total (Jan 2016 - Jun 2018)** | -$42,200 | -$21,000 |
| **Average Value Per Quarter** | -$4,200 (-11.3%) | -$2,100 (-5.6%) |
| *Calculated from electricity usage data ($0.1418/kWh) | | |

## Row Crop Farm Savings Results

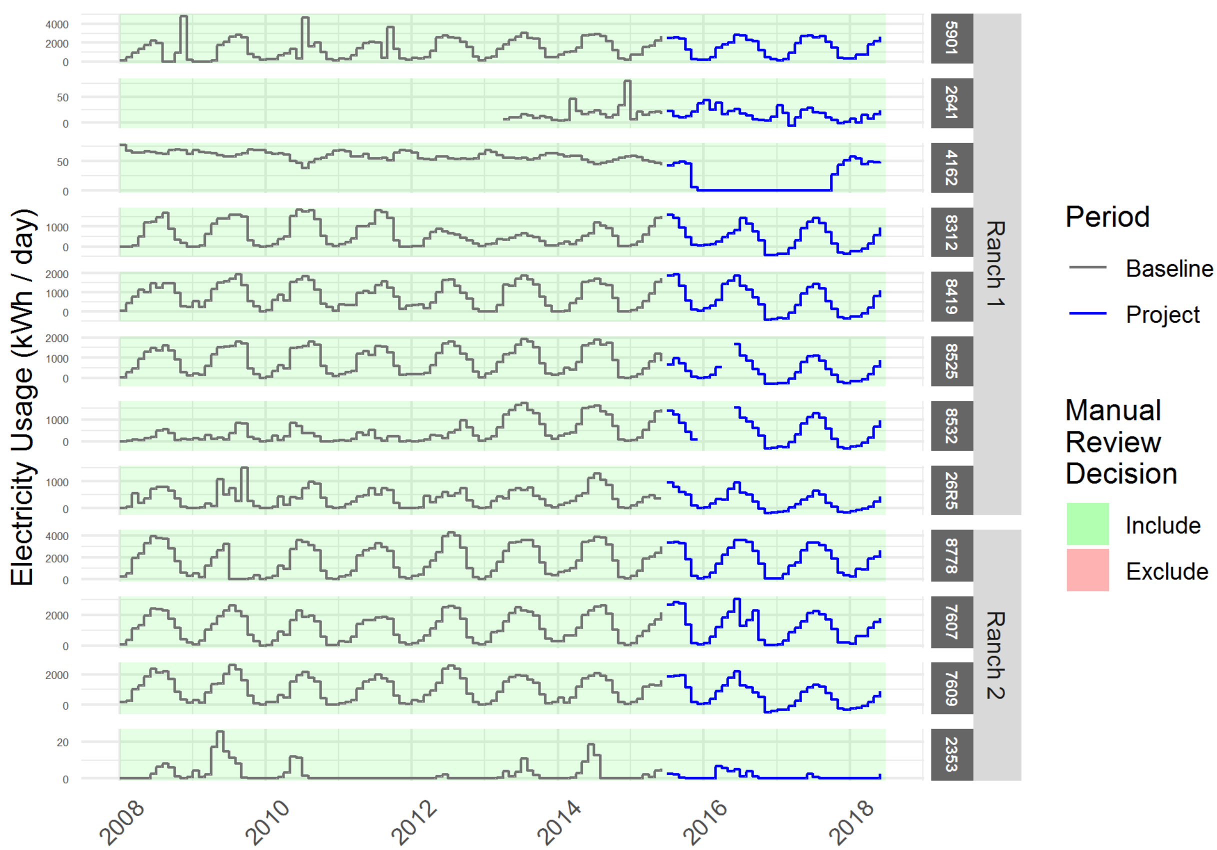
The Row Crop farm site is located near King City, California. A variety of vegetables is grown, and the primary crops are spring mix, celery, and onions. The grower has several different ranches in the area and selected two ranches to participate in this project, representing a total of approximately 1,600 acres. There is a total of sixteen pumps (either well, booster, or drip irrigation system pumps) and twelve electricity meters on the two ranches.

A summary of farm information by ranch is included in Table 16. Meter data was manually reviewed for quality and completeness, and all meters were included in the analysis. Figure 80 shows the electricity usage data for each meter for each ranch.

**Table 16: Row Crop Farm Summary by Ranch**

| Ranch | Acreage | Crop Type | No. Pumps | Comments |
|---|---|---|---|---|
| **Ranch 1** | 1115 | Onions/Row Crops | 9 | On 8 meters |
| **Ranch 2** | 498 | Onions/Row Crops | 7 | On 4 meters |

**Figure 80: Row Crop Farm Meter Data**




Vegetable row crops are planted and harvested throughout the year on a rotating basis. All of the row crops are irrigated with well water fed both directly from the wells or from reservoirs (filled with well water) and then pumped or gravity fed to the fields. Approximately forty percent of crops are irrigated with drip irrigation systems, while the remaining sixty percent are spray irrigated. Table 17 provides a summary of pump information for the Row Crop farm.

During hot weather months, some row crops, such as celery and baby lettuce, must be irrigated continually during the peak hours of the day to avoid plant damage. This limits the farmer's ability to respond to peak load shift alert for these types of crops, unless cooler weather conditions allow.

**Table 17: Row Crop Farm Pump Summary**

| Ranch | Meter ID (last 4 digits) | Pump Type | Pump HP | Water Data[7] | Polaris Data[8] |
|---|---|---|---|---|---|
| **Ranch 1** | 4162 | Booster | NA | No | No |
| | 8525 | Booster | NA | No | No |
| | 8532 | Booster | NA | No | No |
| | 2641 | Return | NA | No | No |
| | 26R5 | Well | 150 | Yes | No |
| | 8312 | Well | 150 | Yes | Yes |
| | 8419 | Well | 150 | Yes | No |
| | 5901 | Well (2) | 125/75 | Yes | No |
| **Ranch 2** | 2353 | Booster | NA | No | No |
| | 8778 | Booster (4) | 75/75/100/100 | Yes | No |
| | 7607 | Well | 150 | Yes | No |
| | 7609 | Well | 150 | Yes | Yes |

Additionally, this partner farm installed a 1 MW solar system during the project to realize additional energy savings. While the installation of this solar system is in line with the project goals to reduce overall energy usage from the electric utility grid and to reduce energy costs, it did complicate the analysis of results for this partner farm.

[7] Pump specification data available sufficient for estimating water data

[8] Polaris equipment installed for logging real-time water flow and energy use data, and data currently available

**Electricity Results**

Figure 81 shows the total electricity use time series for each of the Row Crop farm ranches.

**Figure 81: Monthly Total Electricity Use Time Series Data for the Row Crop Farm**

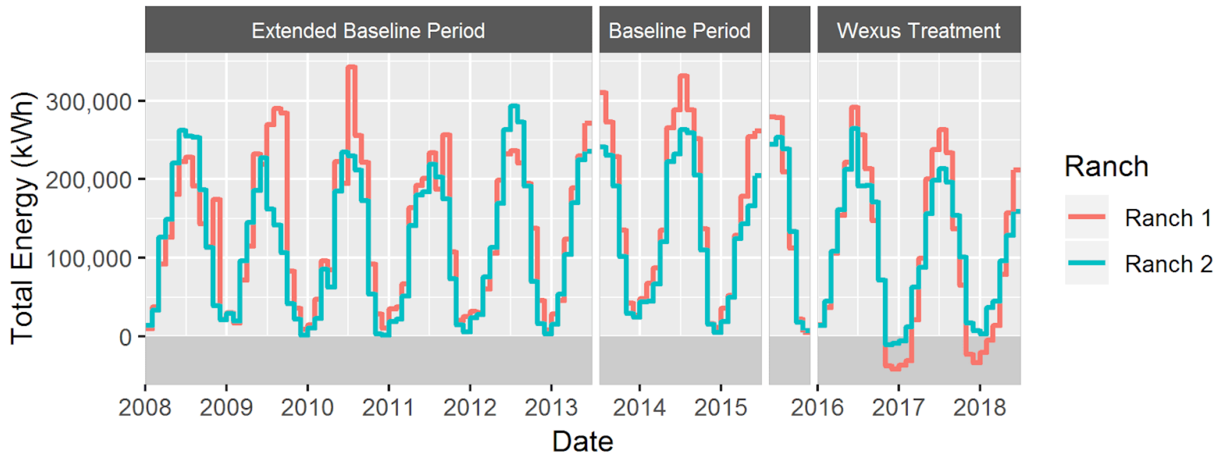



Table 18 shows the average quarterly electricity usage during the full baseline period. The magnitude and pattern of electricity use is similar on both ranches.

**Table 18: Row Crop Farm Baseline Electricity Usage (kWh, Jul 2013 - Jun 2015)**

| | Q1 | Q2 | Q3 | Q4 | Total |
|---|---|---|---|---|---|
| **Ranch 1** | 210,106 | 691,115 | 841,721 | 185,044 | **1,927,986** |
| **Ranch 2** | 175,472 | 544,713 | 694,937 | 143,155 | **1,558,278** |

Table 19 shows the total electricity use for each quarter during the Uptake and treatment periods.

**Table 19: Row Crop Farm Electricity Usage During the Project Period (kWh, Jul 2015 - Jun 2018).**

| | Uptake Period | | Treatment Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| **Ranch 1** | 766,751 | 139,694 | 158,013 | 667,421 | 617,543 | -6,260 | -45,080 | 537,972 | 633,075 | 9,755 | -10,240 | 447,807 |
| **Ranch 2** | 736,489 | 160,005 | 167,801 | 638,523 | 555,209 | 52,808 | 70,061 | 443,918 | 563,622 | 125,923 | 85,924 | 384,114 |

*Change in Total Electricity Use*

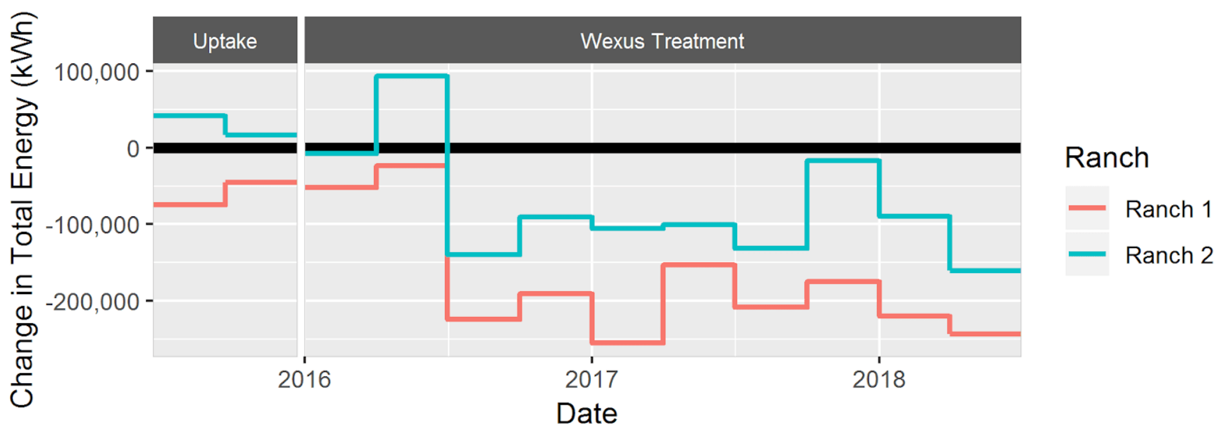
Table 20 shows the unadjusted change in total electricity use for each quarter, relative to the corresponding baseline quarter. **The average percent change in total electricity use for the Row Crop farm relative to baseline was found to be -29.0%.**

**Table 20: Row Crop Farm Electricity Usage, Difference Relative to Baseline (kWh)**

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Total |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| Ranch 1 | -74,970 | -45,350 | -52,093 | -23,694 | -224,178 | -191,304 | -255,186 | -153,144 | -208,645 | -175,289 | -220,347 | -243,309 | **-1,747,189** |
| Ranch 2 | +41,552 | +16,850 | -7,672 | +93,810 | -139,728 | -90,348 | -105,412 | -100,794 | -131,315 | -17,232 | -89,548 | -160,599 | **-748,838** |
| Total | **-33,418** | **-28,499** | **-59,764** | **+70,116** | **-363,906** | **-281,652** | **-360,598** | **-253,938** | **-339,960** | **-192,522** | **-309,895** | **-403,907** | **-2,496,027** |

Figure 82 plots the relative change values from Table 9.

**Figure 82: Change in Total Electricity Use, Relative to Baseline, for the Row Crop Farm**




The Row Crop grower installed a solar array early in the treatment period (Q2 2016). The impact of this is very clear in Figure 82. To try to adjust for this, a term was added to the regression model to estimate the net effect of the solar array. In addition, the following site-specific farm-level ETo and precipitation data were used in the analysis (see Figure 83).

**Figure 83: CIMIS Monthly ETo and Precipitation Data for the Row Crop Farm**

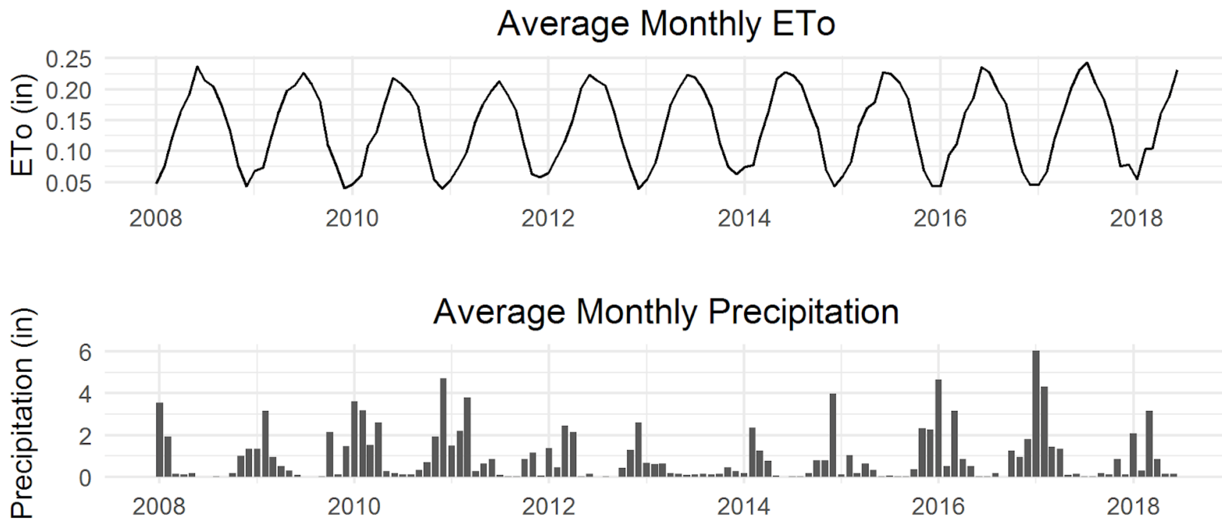



Table 21 summarizes the results from three variations of the farm-level regression model.

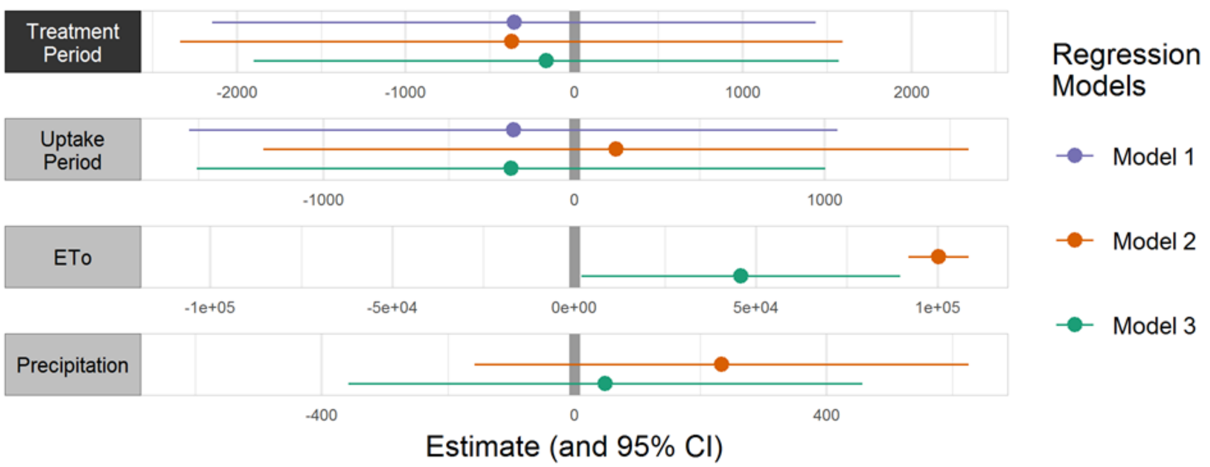
**Table 21: Row Crop Farm Regression Model Results**

| | (1) | (2) | (3) |
|---|---|---|---|
| **(Intercept)** | 2054.3 ** | 9569.5 *** | 5927.5 ** |
| | (654.2) | (320.9) | (1839.3) |
| **Project Uptake** | -242.9 | 166.4 | -252.4 |
| | (642.6) | (701.7) | (621.4) |
| **Project Treatment** | -358.1 | -372.8 | -166.3 |
| | (888.8) | (980.6) | (861.3) |
| **Solar** | -2666.0 ** | -2858.0 ** | -2884.0 ** |
| | (888.8) | (960.2) | (854.4) |
| **ETo (in)** | | 100168.4 *** | 45795.5 * |
| | | (4092.8) | (21696.7) |
| **Precipitation (in)** | | 233.1 | 49.3 |
| | | (195.3) | (201.9) |
| **Month Fixed Effect** | Yes | No | Yes |
| **N** | 60 | 60 | 60 |
| **R2** | 0.97 | 0.95 | 0.97 |
| **logLik** | -508.8 | -522.1 | -504.7 |
| **AIC** | 1049.5 | 1058.2 | 1045.4 |

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

In addition to the project time periods, both Uptake and Treatment, Model (1) uses a monthly fixed effect to model the seasonal variation. Model (2) uses the CIMIS ETo and precipitation data, which can explain a large amount of the seasonal variation, although the fit is not quite as good. Model (3) includes both the monthly fixed effect and the CIMIS weather variables, however in this case, it does not do much better than Model (1) (e.g., $R^2$ = 97% for both). All three models show consistent results, with a small estimated reduction in electricity use during the Wexus project period, however the magnitude of the effect is not significantly different than zero, given the available data.

**Figure 84: Regression Coefficients for the Row Crop Farm**




The model coefficients and the associated 95% confidence intervals are plotted in Figure 84. The estimated Wexus treatment effect (-166 kWh/day) from model (3) corresponds to a 1.8% reduction in electricity use relative to baseline.

*Change in Peak Period Electricity Use*

In general, the total amount of peak period electricity use will trend similarly with overall electricity use. As a result, the following results focus on the proportion of electricity used during peak hours. Figure 85 shows the trend in peak-period electricity usage for each ranch.

**Figure 85: Change in the Proportion of Peak-period Electricity Usage for the Row Crop Farm**

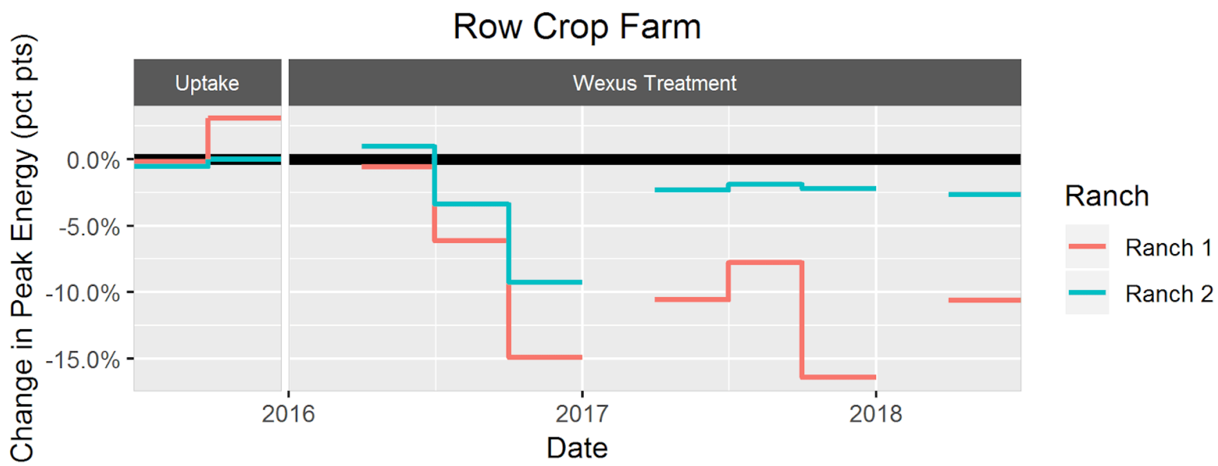



Table 22 shows the observed change in proportion of peak period electricity use (same data that is plotted in Figure 20) for the Row Crop farm, calculated as the difference relative to baseline. The **average proportion of electricity used during peak periods, across the Row Crop Farm, decreased by 6.3 percentage points during the Wexus treatment period, which may be attributed to the installation of the solar array midway through the project.**

**Table 22: Row Crop Farm Peak Electricity Usage, Average Difference Relative to Baseline (percentage points)**

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Average |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| **Ranch 1** | -0.2 | +3.1 | - | -0.6 | -6.1 | -14.9 | - | -10.6 | -7.8 | -16.4 | - | -10.6 | **-9.6** |
| **Ranch 2** | -0.5 | -0.0 | - | +1.0 | -3.4 | -9.3 | - | -2.3 | -1.9 | -2.2 | - | -2.7 | **-3.0** |
| **Average** | **-0.4** | **+1.5** | **-** | **+0.2** | **-4.8** | **-12.1** | **-** | **-6.4** | **-4.8** | **-9.3** | **-** | **-6.6** | **-6.3** |

*Change in Maximum Electricity Demand*

Table 23 shows the observed change in maximum demand on the Row Crop Farm. The maximum demand across the Row Crop Farm ranches increased by 17.8 kW on average during the Wexus treatment period.

**Table 23: Row Crop Farm Max Electric Demand, Average Difference Relative to Baseline (kW)**

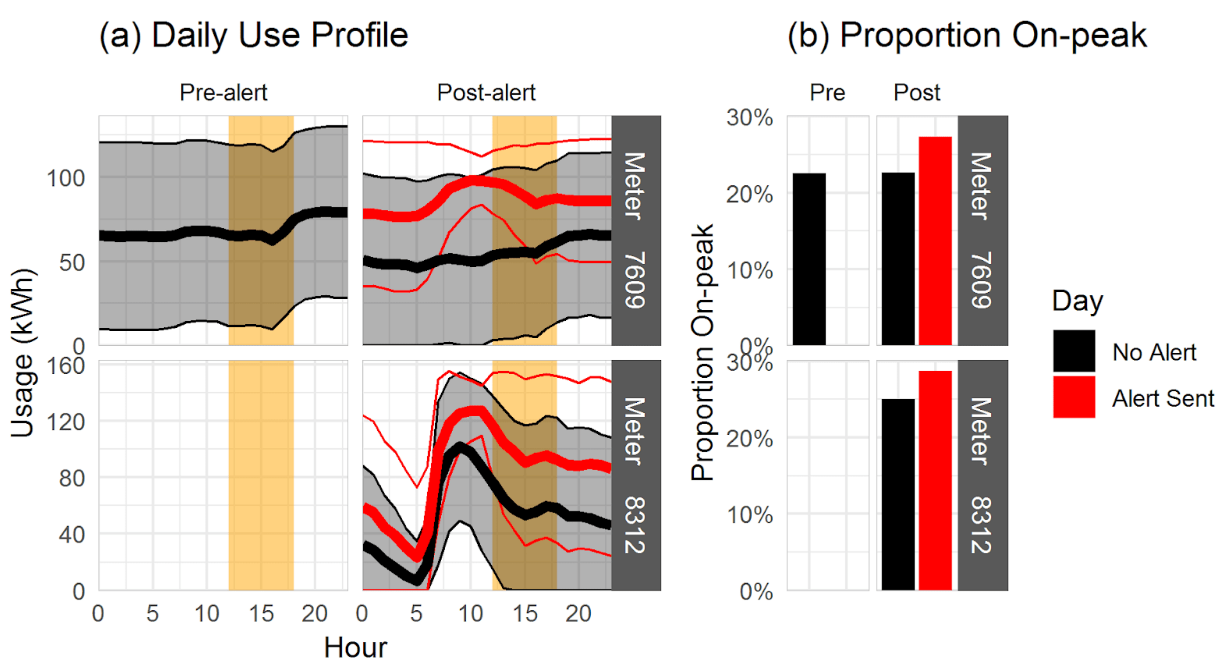
| | Uptake Period | | Wexus Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Average |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| **Ranch 1** | -0.7 | +1.0 | -4.2 | +1.3 | +17.5 | +263.7 | -305.0 | +21.8 | +18.1 | +125.3 | +150.4 | +41.6 | **+33.0** |
| **Ranch 2** | -7.7 | +1.9 | -5.1 | -5.7 | +11.9 | +83.5 | +53.5 | +4.5 | -1.2 | +46.0 | -74.2 | -87.2 | **+2.6** |

| | Uptake Period | | Wexus Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Average |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| Average | -4.2 | +1.5 | -4.6 | -2.2 | +14.7 | +173.6 | -125.7 | +13.2 | +8.4 | +85.7 | +38.1 | -22.8 | +17.8 |

*Peak Period Alert Response*

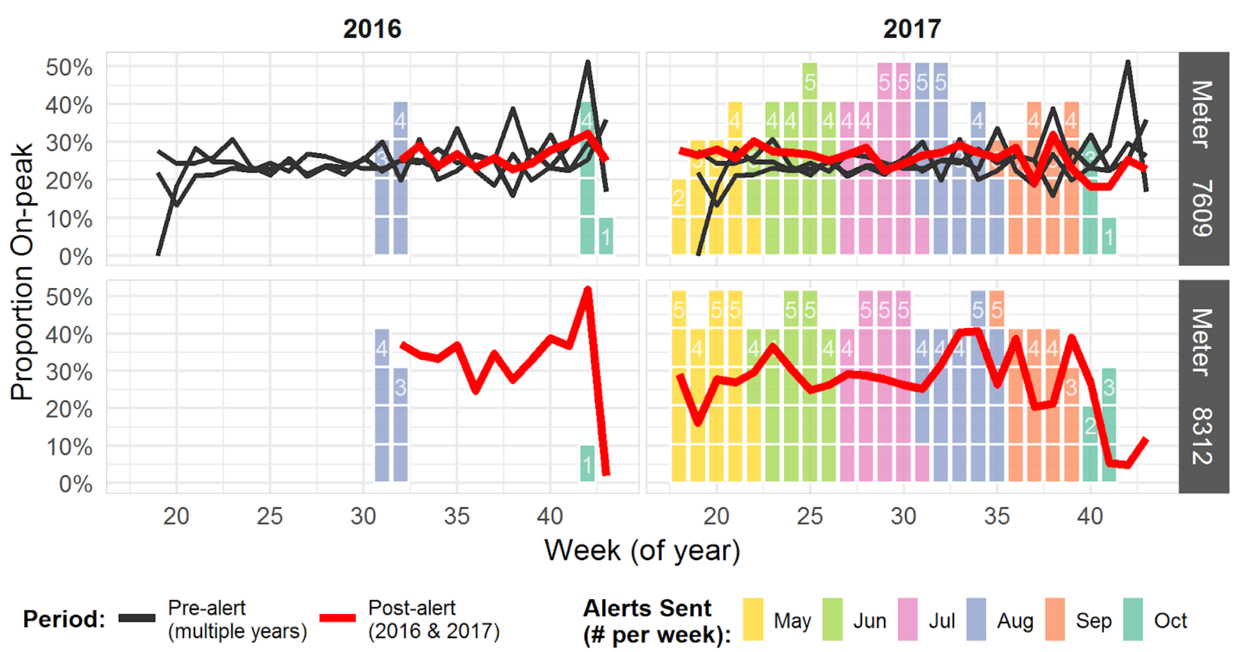
Figure 86 shows the daily usage profile for the two meters on the Row Crop farm which received peak period alerts. Meter 7609 (on Ranch 2) often has nearly constant usage throughout the day, while Meter 8312 (on Ranch 1) has more variability. Both show high levels of continued usage through peak hours, on both alert and non-alert days. **The ability of the Row Crop farm to respond to peak period alerts was largely reported as crop dependent.** Particular crops, such as celery and baby lettuce, must be irrigated continually during the peak hours of the day to avoid plant damage. This limits the farmer's ability to respond to peak load shift alert for these types of crops, unless cooler weather conditions allow.

**Figure 86: For the Row Crop farm (a) Daily Use Profile Pre- and Post-alert, Showing Alert and No Alert Days (b) Proportion of Daily Electricity Used During Peak Hours**



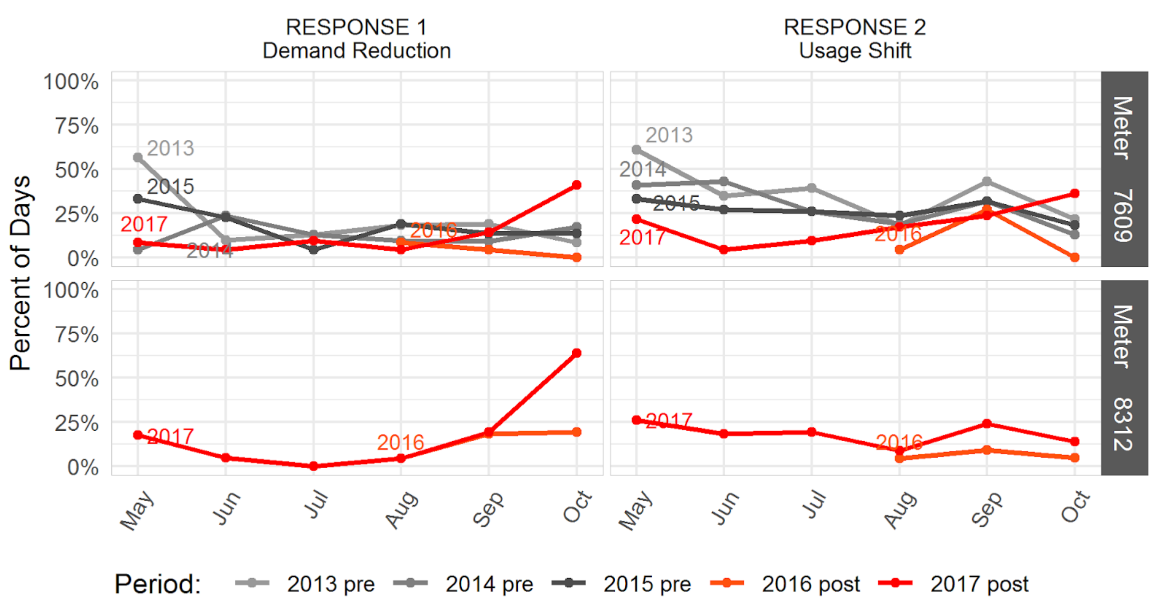

Wexus began sending peak usage alerts to the Row Crop farm in August 2016. Figure 87 shows the trend in peak period electricity use over time, summarized weekly during the summer peak demand surcharge months. The gray lines show multiple years of pre-alert data for the meter, which are useful as a baseline of normal operating conditions. The red lines show the peak period electricity use values in the time period when alerts were sent (summer of 2016 & 2017). Superimposed in the background are number of alerts sent each week, which can range from 0 to 5. Meter 7609 shows similar levels of peak period electricity usage following the alerts, as in the pre-alert baseline years. No baseline high-frequency interval data is available for Meter 8312.

**Figure 87: Proportion of Electricity Used During Peak Hours for the Row Crop Farm**




The trends in the rule-based responses (Figure 88) similarly show relatively low response rates.

**Figure 88: Trend in Responses Over Time, Pre- and Post-alert Periods for the Row Crop Farm**



### Water, GHG Emissions, and Cost Results

Total change in water use was not estimated for the Row Crop Farm, because the electricity data that is used to estimate water use is substantially impacted by the solar array. Table 24 shows the changes in GHG emissions, and Table 25 shows the change in electricity costs.

**Table 24: Change in GHG Emissions (lbs CO2e)* for Row Crop Farm**

| | Observed Change | Modeled Effect |
|---|---|---|
| **Cumulative Total (Jan 2016 - Jun 2018)** | -1,468,000 | -89,000 |
| **Average Value Per Quarter** | -146,800 (-29.0%) | -8,900 (-1.8%) |
| *Calculated from electricity usage data (0.588 lbs CO2e/kWh) | | |

**Table 25: Change in electricity costs* for the Row Crop farm.**

| | Observed Change | Modeled Effect |
|---|---|---|
| **Cumulative Total (Jan 2016 - Jun 2018)** | -$354,000 | -$22,000 |
| **Average Value Per Quarter** | -$35,400 (-29.0%) | -$2,200 (-1.8%) |
| *Calculated from electricity usage data ($0.1418/kWh) | | |

## Dairy Farm Savings Results

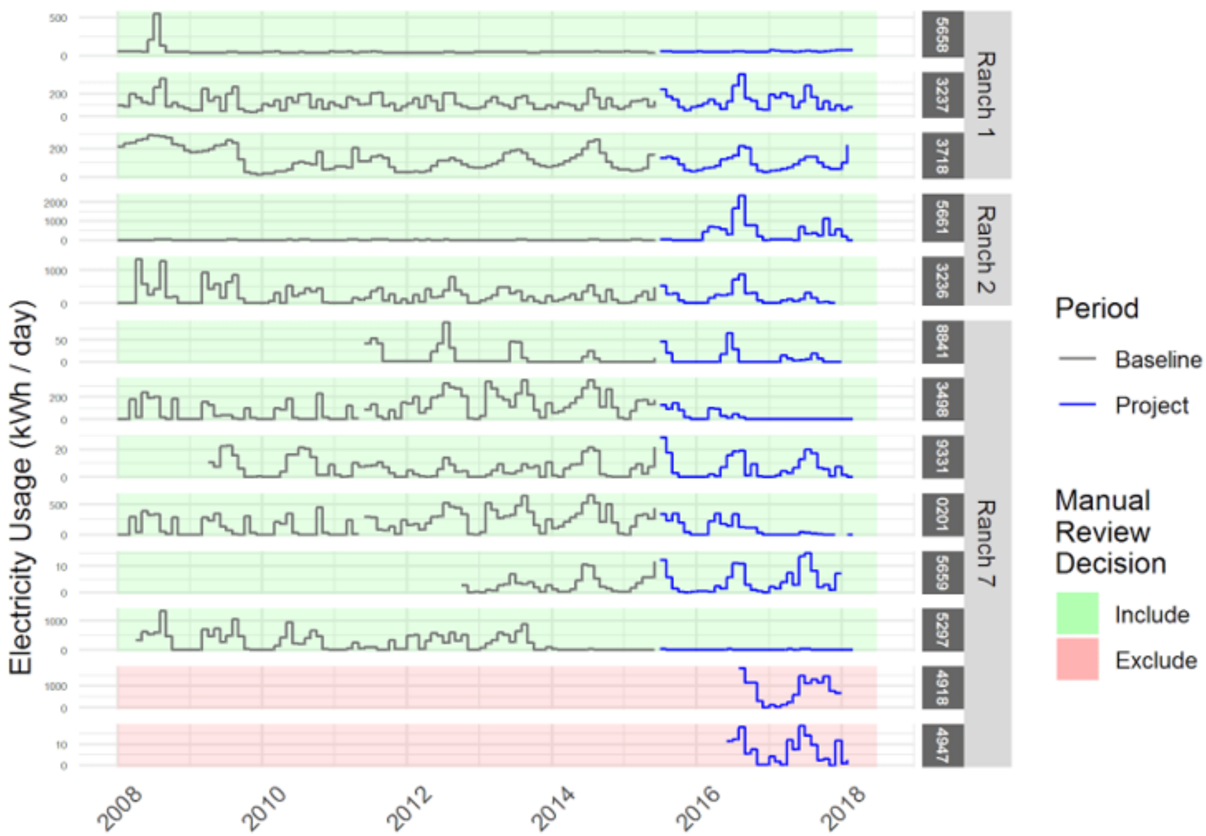
The Dairy Farm site is located near Hanford, California, and it includes dairy operations and irrigated cropland, including alfalfa, silage, and almonds. The dairy operation is a zero-water waste production. All wastewater from the dairy flows into a pond where it is later applied to silage and alfalfa crops. Electricity use was evaluated on three ranches, including a total of fourteen pumps related to irrigation operations (either well, booster, or drip irrigation system pumps) and a total of eleven electricity meters. A summary of the ranch information is included in Table 26.

**Table 26: Dairy Ranch Summary**

| Ranch | Acreage | Crop Type | No. Pumps | Comments |
|---|---|---|---|---|
| **Ranch 1** | 55 | Dairy (no crops) | 5 | On 3 meters |
| **Ranch 2** | 180 | Silage | 3 | On 2 meters |
| **Ranch 7** | 490 | Silage/Alfalfa/Almonds | 8 | 2 meters excluded from analysis |

Originally thirteen meters on the three ranches were reviewed to determine whether to be included in the analysis. Based on this review, two meters from Ranch 7 were excluded due to insufficient baseline or treatment period data (see Figure 89).

**Figure 89: Dairy Farm Meter Data**




The timing of planting and harvesting alfalfa crops varies but silage (both corn and wheat) is harvested in the early fall. The alfalfa and silage crops are irrigated via flood irrigation with wastewater or well water.

Approximately 400 acres of cropland on the farm includes recently planted almond trees that were not yet producing almonds. Almond crops are harvested in the late summer and the first harvest was expected in 2018 after the technical phase of the project was complete. (Almond processing will occur offsite.) The trees are irrigated every other day throughout the year with well water via automated drip irrigation systems, which are newly installed and have not yet been optimized. The irrigation systems include filtration systems and soil moisture probes installed in the soil to monitor irrigation needs.

Prior to planting the almond trees, these 400 acres were used to grow alfalfa and silage (half the acreage was planted in almonds in 2014, and the other half in 2015). **It is very common for farms to rotate crops or convert to permanent crops, and this must be carefully considered for baselines and the methodology used for analysis.**

Table 27 provides a summary of pump information for the Dairy farm. Due to lower well production during the long period drought between 2012-2016, more time was required to irrigate the alfalfa and silage crops. For this reason, the farm was not able to shut off pumping during these irrigation periods. The dairy has a diesel gas generator that can be operated to meet peak energy usage when needed.

The automated drip system on the almond crop was optimized to irrigate only during off peak hours to avoid peak demand surcharges. The system was recently installed, and the farmer reported plans to shut off well pumps between the hours of noon and 6:00pm during the weekdays.

**Table 27: Dairy Farm Pump Summary**

| Ranch | Meter ID (last 4 digits) | Pump Type | Pump HP | Water Data[9] | Polaris Data[10] |
|---|---|---|---|---|---|
| **Ranch 1** | 3237 | Lagoon | NA | No | No |
| | 3718 | Well | 200 | No | No |
| | 5658 | Return | NA | No | No |
| **Ranch 2** | 3236 | Well/Ditch | 75 | Yes | No |
| | 5661 | Return | NA | No | No |
| **Ranch 7** | 5297 | Ditch | NA | No | No |
| | 9331 | Return | 300 | No | No |
| | 8841 | Ditch | NA | No | No |
| | 5659 | Return | NA | No | No |
| | 0201 | Well | 40 | Yes | No |
| | 3498 | Well | NA | No | No |

### Electricity Results

Figure 90 shows the total electricity use time series for each of the Dairy Farm ranches. Total electricity use data was complete during the near Baseline and Treatment periods for three of the ranches. Data was available for two of the ranches spanning the entire extended baseline period.

[9] Pump specification data available sufficient for estimating water data

[10] Polaris equipment installed for logging real-time water flow and energy use data, and data currently available

**Figure 90: Monthly Total Electricity Use Time Series Data for the Dairy Farm**

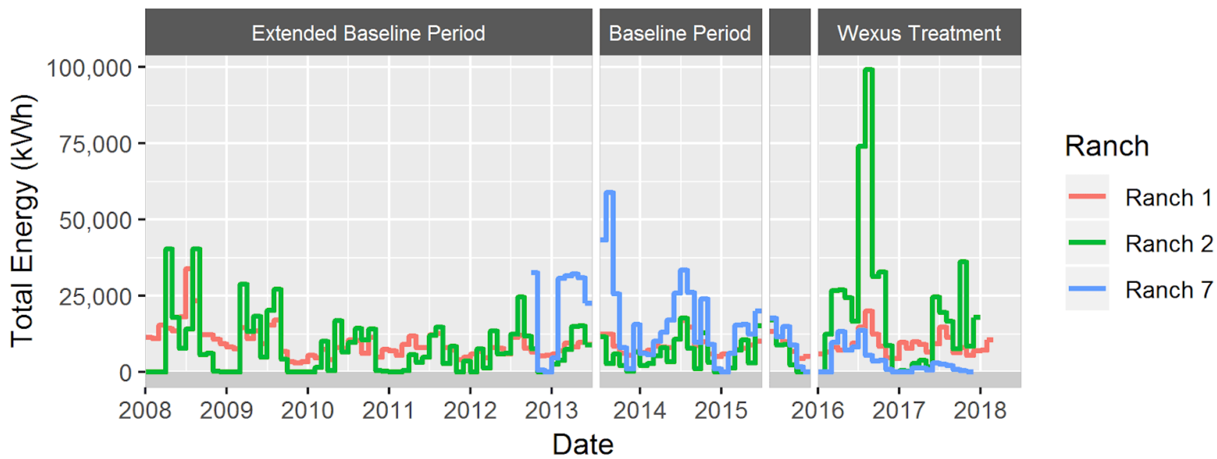



Table 28 shows the average quarterly electricity usage during the baseline period. The amount of electricity used on each farm was variable and shifted dramatically between the baseline and treatment periods.

**Table 28: Dairy Farm Average Baseline Electricity Usage (kWh, Jul 2013 - Jun 2015)**

| | Q1 | Q2 | Q3 | Q4 | Total |
|---|---|---|---|---|---|
| **Ranch 1** | 20,647 | 26,779 | 36,651 | 19,558 | **103,635** |
| **Ranch 2** | 9,276 | 25,311 | 23,301 | 12,386 | **70,275** |
| **Ranch 7** | 21,636 | 51,897 | 98,424 | 29,267 | **201,224** |

Table 29 shows the total electricity use for each quarter, during the Wexus uptake and treatment periods. Due to changes in the way Southern California Edison (SCE) managed their customer data Green Button Connect platform, electricity usage data was not able to be accessed for the Dairy partner farm in 2018. Wexus is working with SCE to resolve this issue going forward.

**Table 29: Dairy Farm Total Electricity Usage During Project Period (kwh, Jul 2015 - Jun 2018)**

| | Uptake Period | | Treatment Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| **Ranch 1** | 34,514 | 16,246 | 20,690 | 23,696 | 46,940 | 17,385 | 27,170 | 24,820 | 32,691 | 20,386 | - | - |
| **Ranch 2** | 34,927 | 2,320 | 39,158 | 68,023 | 204,458 | 41,450 | 3,386 | 30,128 | 43,789 | 62,402 | - | - |
| **Ranch 7** | 44,283 | 10,512 | 9,852 | 28,850 | 22,768 | 4,620 | 1,462 | 4,886 | 5,441 | - | - | - |

*Change in Total Electricity Use*

Table 30 shows the unadjusted change in total electricity use for each quarter, relative to the corresponding baseline quarter. The average percent change in total electricity use for the farm, relative to baseline was found to be +1.8%; however, this is heavily influenced by the variability of pump usage and long periods of non-use during the Baseline and Treatment periods.

**Table 30: Dairy Farm Electricity Usage, Difference Relative to Baseline (kWh)**

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Total |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| Ranch 1 | -2,136 | -3,312 | +43 | -3,083 | +10,289 | -2,173 | +6,523 | -1,959 | -3,960 | +828 | - | - | **+6,508** |
| Ranch 2 | +11,627 | -10,066 | +29,881 | +42,712 | +181,157 | +29,064 | -5,891 | +4,816 | +20,488 | +50,016 | - | - | **+352,244** |
| Ranch 7 | -54,141 | -18,754 | -11,784 | -23,047 | -75,656 | -24,646 | -20,174 | -47,011 | -92,983 | - | - | - | **-295,301** |
| **Total** | **-44,651** | **-32,132** | **+18,140** | **+16,581** | **+115,791** | **+2,245** | **-19,542** | **-44,154** | **-76,455** | - | - | - | **+63,451** |

Figure 91 plots the relative change values from Table 30.

**Figure 91: Change in Total Electricity Use, Relative to Baseline for the Dairy Farm**

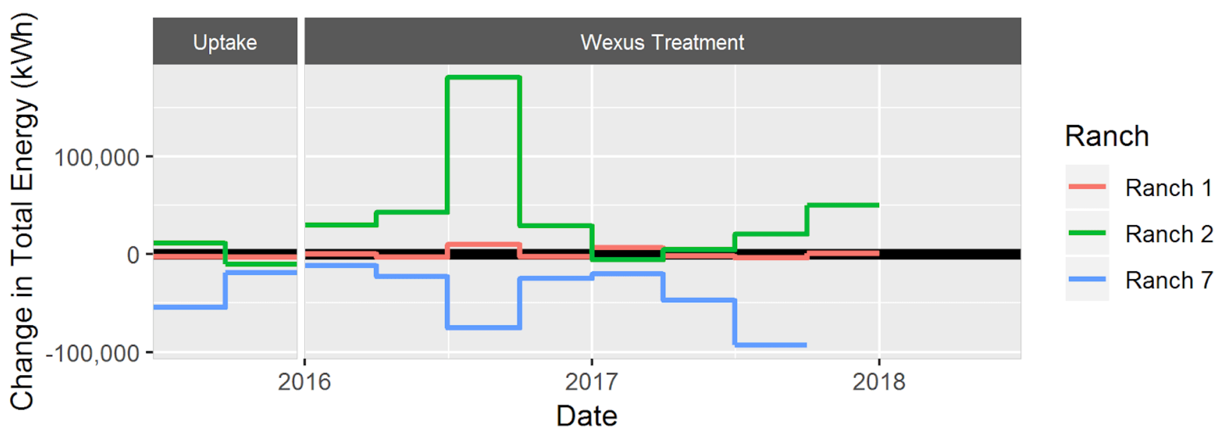
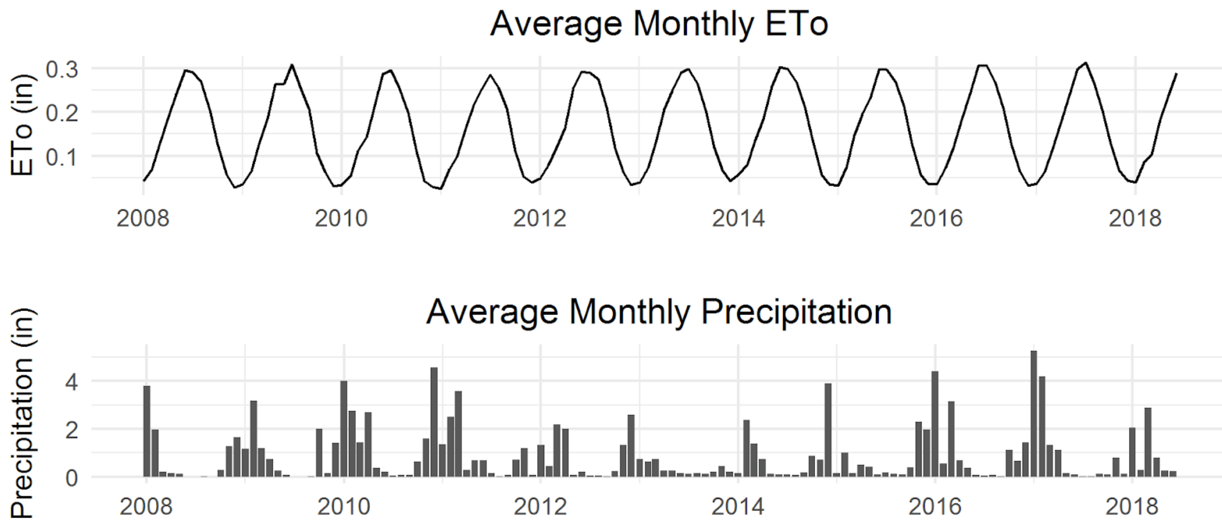



Figure 92 shows average monthly reference evapotranspiration and precipitation values for the Dairy Farm.

**Figure 92: CIMIS Monthly ETo and Precipitation Data for the Dairy Farm**




The regression model described in the Methodology section was used to account for the impact of external factors (such as ETo, precipitation, and seasonal variation) on the raw electricity change values, in order to estimate the remaining marginal change in total electricity use during the project period. Table 31 summarizes the results for the three variations of the farm-level regression model.

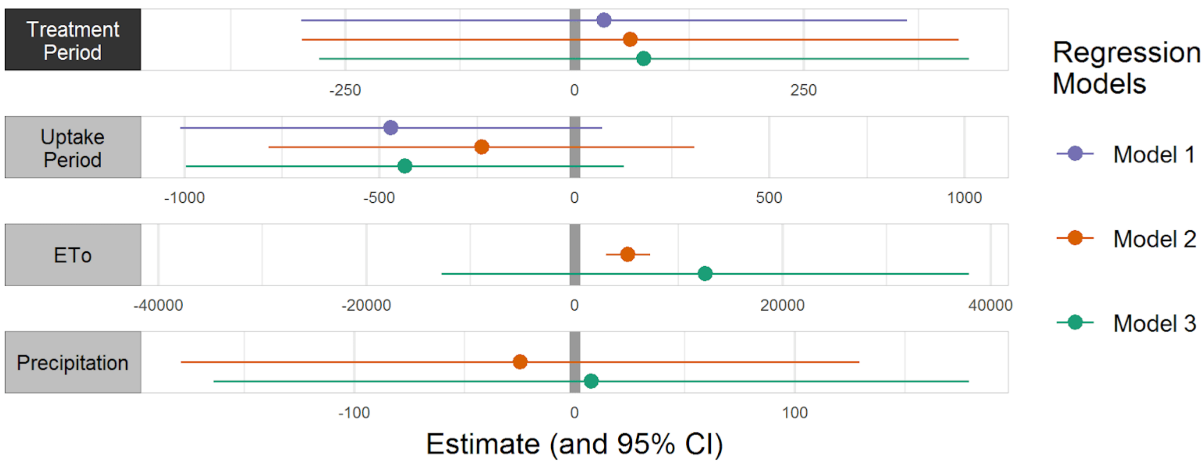
**Table 31: Dairy Farm Regression Model Results**

| | (1) | (2) | (3) |
|---|---|---|---|
| **(Intercept)** | 278.0 | 1020.3 *** | 1840.9 |
| | (290.6) | (122.8) | (1559.7) |
| **Project Uptake** | -470.5 | -238.3 | -435.1 |
| | (267.3) | (271.6) | (277.0) |
| **Project Treatment** | 32.0 | 60.6 | 75.8 |
| | (163.2) | (178.1) | (174.8) |
| **ETo (in)** | | 5127.5 *** | 12558.6 |
| | | (1055.1) | (12511.5) |
| **Precipitation (in)** | | -24.8 | 7.6 |
| | | (76.6) | (84.6) |
| **Month Fixed Effect** | Yes | No | Yes |
| **N** | 53 | 53 | 53 |
| **$R^2$** | 0.61 | 0.46 | 0.62 |
| **logLik** | -402.2 | -411.0 | -401.5 |
| **AIC** | 834.5 | 833.9 | 837.0 |

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

In addition to the experimental time periods, Model (1) uses a monthly fixed effect to model the seasonal variation. Model (2) uses the CIMIS ETo and precipitation data, which can explain a large amount of the seasonal variation, although the fit is not quite as good. Model (3) includes both the monthly fixed effect and the CIMIS weather variables, and it has the best fit to the data by some measures (e.g., R2 = 62%), however it does not do much better than Model (1).

**Figure 93: Regression Coefficients for the Dairy Farm**




The model coefficients and the associated 95% confidence intervals are plotted in Figure 93. All three models show consistent results, with a small increase in electricity use during the project treatment period, <u>however the estimated effect is not significantly different from zero</u>. The estimated Wexus treatment effect (+75.8 kWh/day) from model (3) corresponds to a 7.3% increase in electricity use relative to baseline. **It is very unlikely that the project itself is causing increased electricity use. Most likely, increases in use are just an indication that there are remaining uncontrolled variables that are biasing the model.**

*Change in Peak Period Electricity Use*

Figure 94 shows the trend in peak-period electricity usage for the Dairy farm. Limited data was available and the same unique usage patterns affecting the electricity usage analysis also affect these results.

Figure 94: Change in the Proportion of Peak Period Electricity Usage for the Dairy Farm

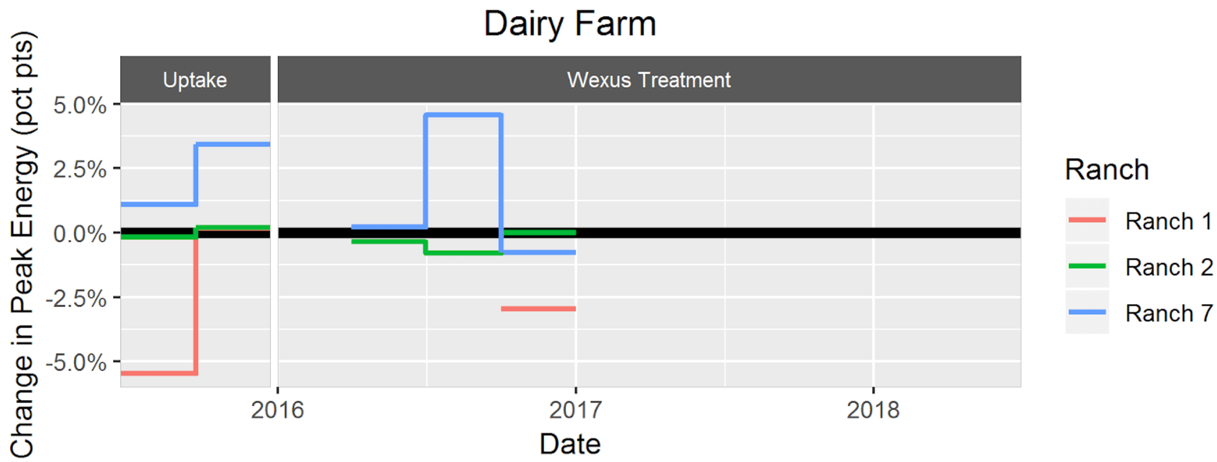



Table 32 shows the observed change in proportion of peak period electricity use (same data that is plotted in Figure 28) for the Dairy, calculated as the difference relative to baseline. **Not enough peak period electricity use data was available for the Dairy to estimate the overall change relative to baseline.**

Table 32: Dairy Farm Peak Electricity Usage, Difference Relative to Baseline (percentage points)

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Average |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| **Ranch 1** | -5.5 | +0.2 | - | - | - | -3.0 | - | - | - | - | - | - | - |
| **Ranch 2** | -0.2 | +0.2 | - | -0.4 | -0.8 | +0.0 | - | - | - | - | - | - | - |
| **Ranch 7** | +1.1 | +3.4 | - | +0.2 | +4.6 | -0.8 | - | - | - | - | - | - | - |
| **Average** | **-1.5** | **+1.3** | **-** | **-** | **-** | **-1.2** | **-** | **-** | **-** | **-** | **-** | **-** | **-** |

*Change in Maximum Electricity Demand*

Maximum demand data for the dairy was not available for most meters.

*Peak Energy Alert Response*

**Peak usage alerts were not sent to the Dairy partner farm per users' choice.** This site was heavily impacted by the long drought period from 2012 and 2016. Due to low well levels, additional irrigation time was needed for the alfalfa and silage crops.

**Water, GHG Emissions, and Cost Results**

Measured water or pump test results were not available for enough meters to estimate water savings for the Dairy due to difficulty of obtaining pump test reports in the SCE territory. Note that associated GHG emissions (Table 33) and cost changes (Table 34) results shown below were based on incomplete data for the Dairy (not for the full project period).

**Table 33: Change in GHG Emissions (lbs CO2e)* for Dairy Farm**

| | Observed Change | Modeled Effect |
|---|---|---|
| **Cumulative Total (Jan 2016 - Jun 2018)** | +7,400 | +41,000 |
| **Average Value Per Quarter** | +1,100 (+1.8%) | +4,100 (+7.3%) |
| *Calculated from electricity usage data (0.588 lbs CO2e/kWh) | | |

**Table 34: Change in Electricity costs* for Dairy Farm.**

| | Observed Change | Modeled Effect |
|---|---|---|
| **Cumulative Total (Jan 2016 - Jun 2018)** | +$1,800 | +$7,000 |
| **Average Value Per Quarter** | +$300 (-1.8%) | +$1,000 (+7.3%) |
| *Calculated from electricity usage data ($0.1418/kWh) | | |

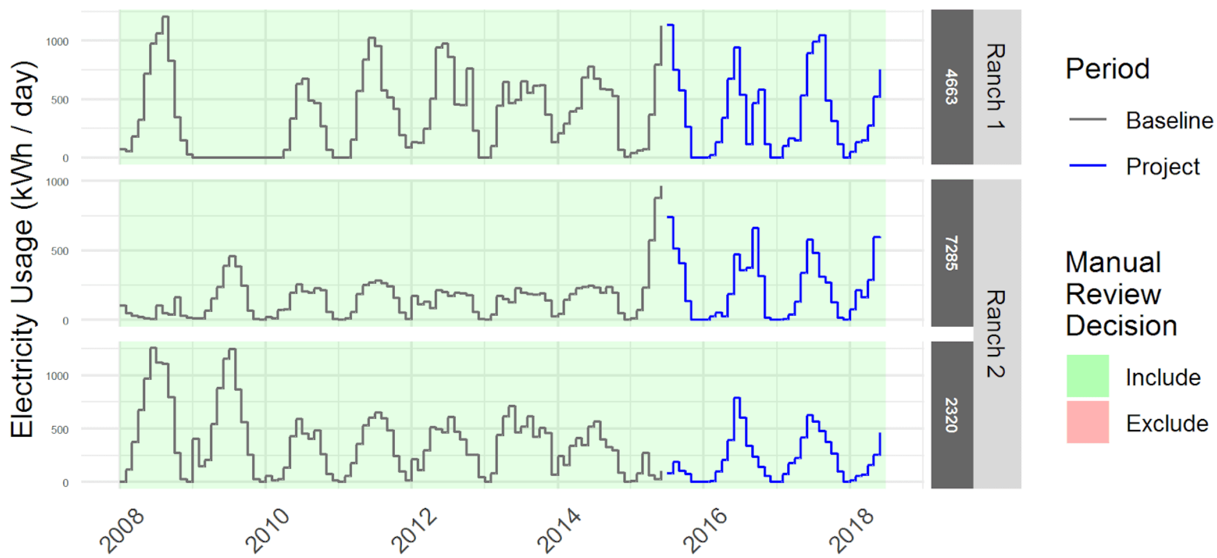
## Vineyard Savings Results

The Vineyard deployment site is located near Soledad, California and includes a vineyard production facility and approximately 500 acres of vineyards on two separate ranches. There is a total of five pumps and three electricity meters. A summary of Vineyard information is included in Table 35 and meter data in Figure 95.

**Table 35: Vineyard Ranch Summary**

| Ranch | Acreage | Crop Type | No. Pumps | Comment |
|---|---|---|---|---|
| **Ranch 1** | 224 | Wine grapes | 2 | On 1 meter |
| **Ranch 2** | 284 | Wine grapes | 3 | On 2 meters |

**Figure 95: Vineyard Meter Data**




Wine grapes are harvested once a year, typically beginning in August and through October, depending on weather and grape conditions. The grapes grown at the Vineyard partner farm are a mixture of red and white varietals.

Table 36 provides a summary of pump information for the Vineyard farm. All the vines are irrigated with drip irrigation systems, which include filtration systems. Well pumps feed the irrigation systems directly, and one of the ranches has a booster pump used to irrigate multiple irrigation blocks when needed. Soil moisture sensors are used to track irrigation events. The grower estimates that they use approximately six to twelve gallons per vine per week, depending on the time of year.

**Table 36: Vineyard Pump Summary**

| Ranch | Meter ID (last 4 digits) | Pump Type | Pump HP | Water Data[11] | Polaris Data[12] |
|---|---|---|---|---|---|
| **Ranch 1** | 4663 | Well/Reservoir | 125 | Yes | Yes |
| **Ranch 2** | 7285 | Well/Booster | 50/75 | Yes | Yes |
| | 2320 | Well | NA | No | No |

**Electricity Results**

Figure 96 shows the total electricity use time series for each of the Vineyard ranches. The dataset is complete during all periods.

[11] Pump specification data available sufficient for <u>estimating</u> water data

[12] Polaris equipment installed for logging real-time water flow and energy use data, and data currently available

**Figure 96: Monthly Total Electricity Use Time Series Data for the Vineyard**

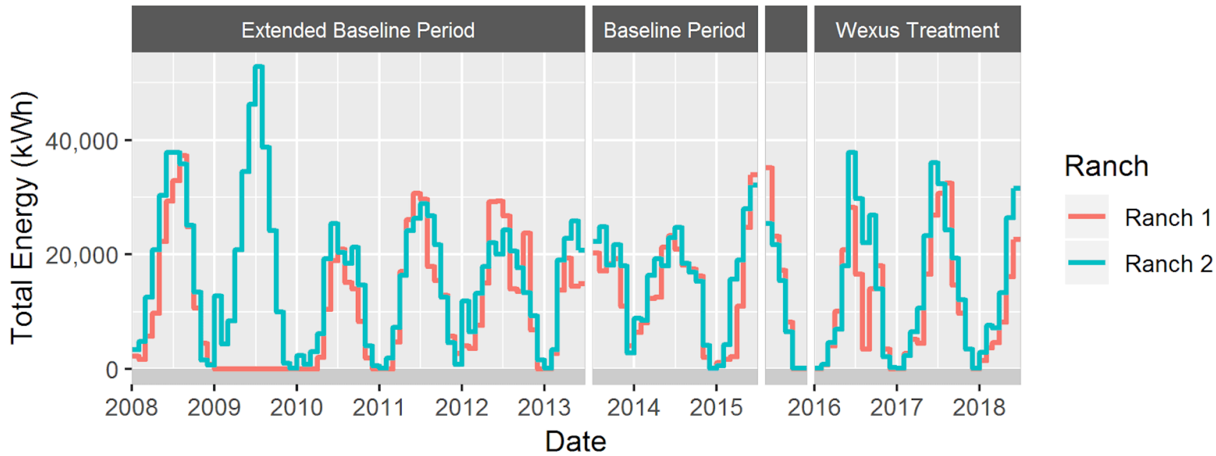



Table 37 shows the average quarterly electricity usage during the baseline period. The magnitude and pattern of electricity use is similar on both ranches.

**Table 37: Vineyard Baseline Electricity Usage (kWh, Jul 2013 - Jun 2015)**

| | Q1 | Q2 | Q3 | Q4 | Total |
|---|---|---|---|---|---|
| **Ranch 1** | 15,892 | 63,350 | 56,137 | 26,300 | **161,679** |
| **Ranch 2** | 27,112 | 69,661 | 62,665 | 31,064 | **190,503** |

Table 38 shows the total electricity use for each quarter, during the Wexus uptake and treatment periods.

**Table 38: Vineyard Electricity Usage During the Uptake and Treatment Periods (kWh, Jul 2015 - Jun 2018)**

| | Uptake Period | | Treatment Period | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| **Ranch 1** | 75,632 | 8,243 | 4,755 | 59,204 | 34,064 | 21,537 | 7,818 | 47,879 | 77,831 | 13,172 | 9,774 | 46,959 |
| **Ranch 2** | 62,598 | 6,641 | 5,567 | 62,727 | 78,627 | 16,385 | 9,079 | 69,920 | 75,998 | 15,656 | 17,728 | 71,240 |

*Change in Total Electricity Use*

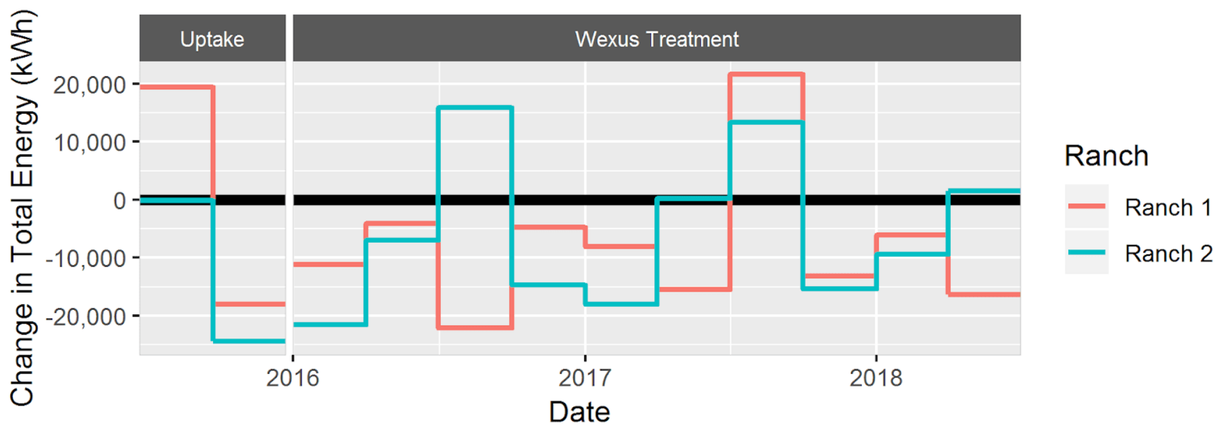
Table 39 shows the unadjusted change in total electricity use for each quarter, relative to the corresponding baseline quarter. **The average percent change in total electricity use for the farm, relative to baseline was found to be -15.3%.**

**Table 39: Vineyard Electricity Usage, Total Difference Relative to Baseline (kWh)**

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Total |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| **Ranch 1** | +19,495 | -18,057 | -11,138 | -4,146 | -22,073 | -4,762 | -8,074 | -15,471 | +21,694 | - 13,127 | -6,118 | -16,391 | **-79,606** |
| **Ranch 2** | -67 | -24,424 | -21,545 | -6,933 | +15,962 | - 14,680 | -18,033 | +260 | +13,333 | - 15,409 | -9,384 | +1,580 | **-54,851** |
| **Total** | **+19,428** | **-42,481** | **-32,683** | **-11,079** | **-6,111** | **-19,442** | **-26,107** | **-15,212** | **+35,027** | **-28,536** | **-15,503** | **-14,811** | **-134,457** |

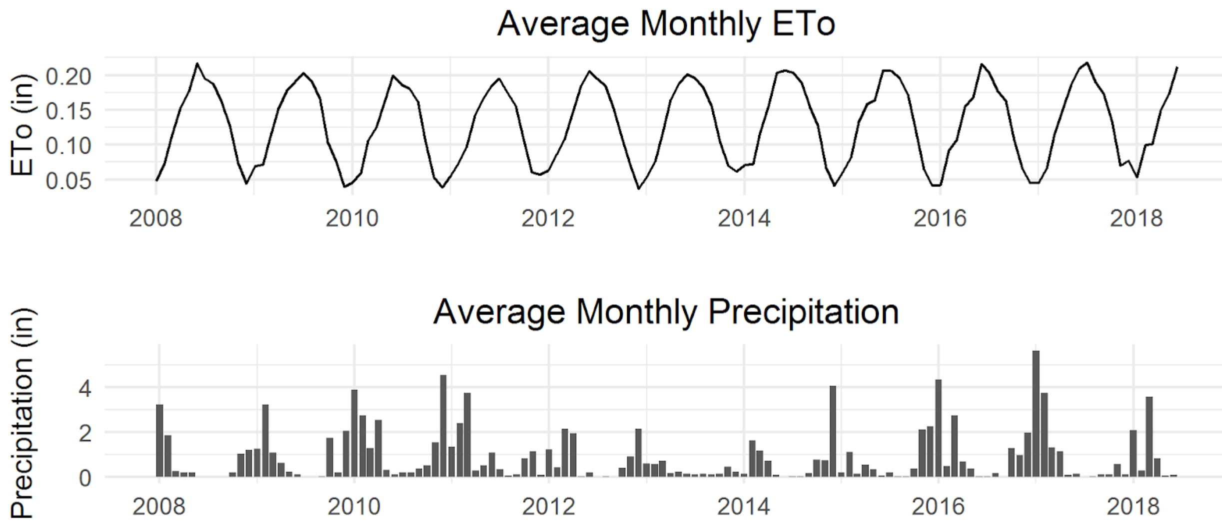
Figure 97 plots the relative change values from Table 21.

**Figure 97: Change in Total Electricity Use, Relative to Baseline for the Vineyard**




The Vineyard did not report any major changes in overall farm operations, or new water efficiency improvements, on the monitored ranches. However, the following site-specific farm-level ETo and precipitation data — which could have an impact —were used in the analysis (see Figure 98).

**Figure 98: CIMIS Monthly ETo and Precipitation Data for the Vineyard**




The regression model described in the Methodology section was used to account for the impact of external factors (such as ETo, precipitation, and seasonal variation) on the raw electricity change values, in order to estimate the remaining marginal change in total electricity use during the Wexus treatment period. Table 40 summarizes the results for the three variations of the farm-level regression model.

**Table 40: Vineyard Regression Model Results**

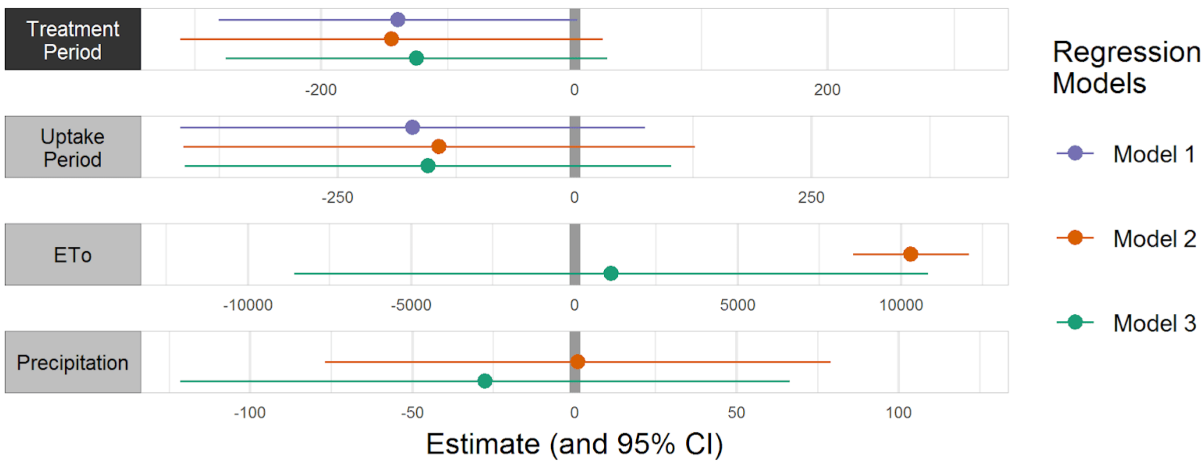
| | (1) | (2) | (3) |
|---|---|---|---|
| **(Intercept)** | 223.6 | 962.4 *** | 344.2 |
| | (121.9) | (61.1) | (359.5) |
| **Project Uptake** | -170.8 | -142.9 | -154.7 |
| | (121.9) | (134.6) | (127.4) |
| **Project Treatment** | -139.4 | -144.6 | -124.8 |
| | (70.4) | (83.3) | (74.7) |
| **ETo (in)** | | 10305.0 *** | 1116.2 |
| | | (884.9) | (4818.4) |
| **Precipitation (in)** | | 1.1 | -27.6 |
| | | (38.9) | (46.6) |
| **Month Fixed Effect** | Yes | No | Yes |
| **N** | 60 | 60 | 60 |
| **$R^2$** | 0.88 | 0.81 | 0.88 |
| **logLik** | -409.8 | -423.4 | -409.1 |
| **AIC** | 849.6 | 858.8 | 852.1 |

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

In addition to the experimental time periods, Model (1) uses a monthly fixed effect to model the seasonal variation. Model (2) uses the CIMIS ETo and precipitation data, which can explain a large amount of the seasonal variation, although the fit is not quite as good. Model (3) includes both the monthly fixed effect and the CIMIS weather variables, and it has the best fit to the data (e.g., R2 = 88%). The model coefficients and the associated 95% confidence intervals are plotted in Figure 99.

All three models show consistent results, with a reduction in electricity use during the Wexus treatment period, however the estimated effect is not significantly different from zero, given the available data.

**Figure 99: Regression Coefficients for the Vineyard**




The model coefficients and associated 95% confidence intervals are plotted in Figure 32. The estimated Wexus treatment effect (-125 kWh/day) from model (3) corresponds to a 12.7% reduction in electricity use relative to baseline.

*Change in Peak Period Electricity Use*

Figure 100 shows the trend in peak-period electricity usage for the Vineyard ranches.

**Figure 100: Change in the Proportion of Peak-period Electricity Usage for the Vineyard**

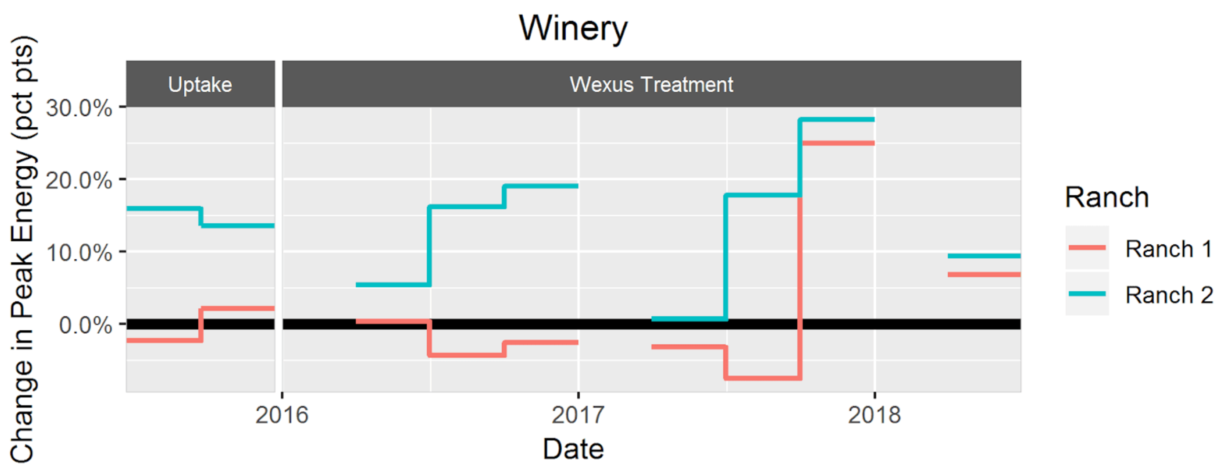



Table 41 shows the observed change in proportion of peak period electricity use (same data that is plotted in Figure 100) for the Vineyard, calculated as the difference relative to baseline. The average proportion of electricity used during peak periods, across the Vineyard ranches, increased by 8.0 percentage points during the Wexus treatment period**. However, this increase was due to additional pump load being added to the site during the project, and these site changes were not considered in this analysis.**

**Table 41: Vineyard Peak Electricity Usage, Difference Relative to Baseline (percentage points)**

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Average |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| **Ranch 1** | -2.3 | +2.2 | - | +0.4 | -4.3 | -2.6 | - | -3.1 | -7.5 | +24.9 | - | +6.8 | **+2.1** |
| **Ranch 2** | +15.9 | +13.5 | - | +5.4 | +16.2 | +19.0 | - | +0.7 | +17.8 | +28.3 | - | +9.4 | **+13.8** |
| **Average** | **+6.8** | **+7.8** | **-** | **+2.9** | **+5.9** | **+8.2** | **-** | **-1.2** | **+5.1** | **+26.6** | **-** | **+8.1** | **+8.0** |

*Change in Maximum Electricity Demand*

Table 42 shows the observed change in maximum demand on the Vineyard. The maximum demand across the Vineyard ranches increased by 2.2 kW on average during the Wexus treatment period. However, this increase was due to additional pump load being added to the site during the project, and these site changes were not considered in this analysis.

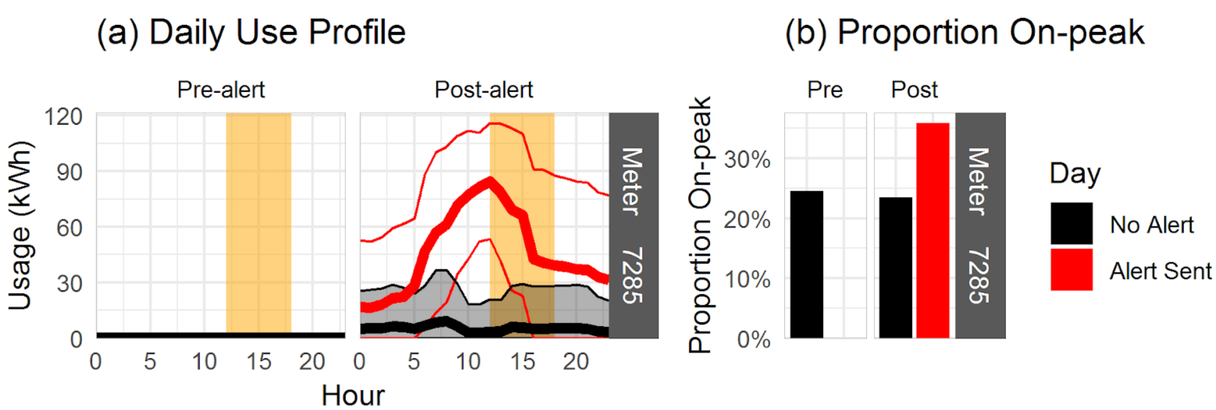
**Table 42: Winery Max Electric Demand, Average Difference Relative to Baseline (kW)**

| | Uptake Period | | Treatment Period | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2015 | | 2016 | | | | 2017 | | | | 2018 | | Trt Per Averag e |
| | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | |
| **Ranch 1** | -0.0 | -0.6 | -1.1 | +0.6 | +2.0 | +0.9 | +0.9 | -1.1 | -1.2 | - | - | - | **+0.1** |
| **Ranch 2** | +26.9 | +19.7 | -41.9 | -3.7 | +17.2 | +18.6 | +1.4 | +1.2 | +16.9 | +8.5 | +16.8 | +6.8 | **+4.2** |
| **Average** | **+13.4** | **+9.5** | **-21.5** | **-1.6** | **+9.6** | **+9.7** | **+1.1** | **+0.1** | **+7.9** | **+8.5** | **+16.8** | **+6.8** | **+2.2** |

*Peak Energy Alert Response*

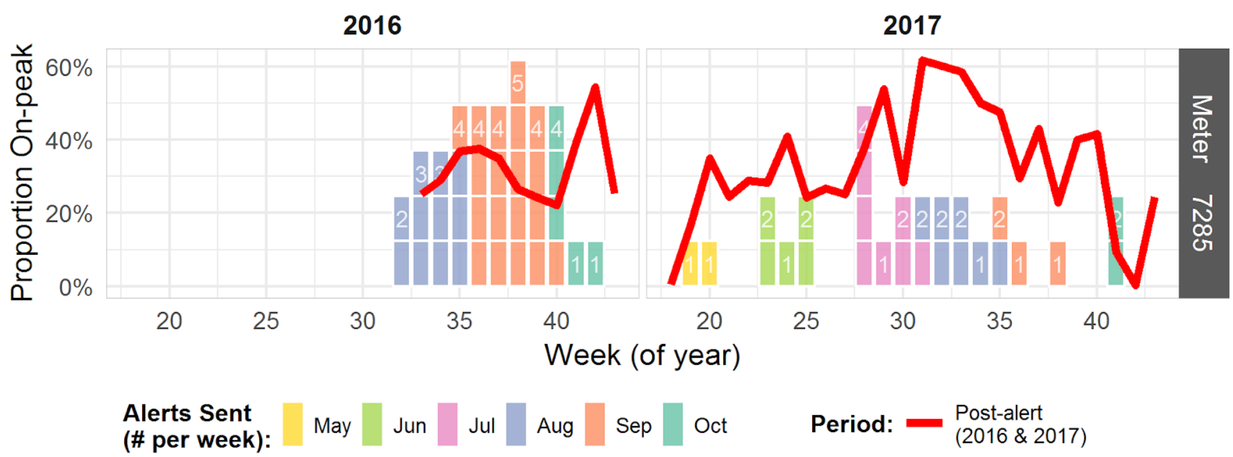
The Vineyard grower responded to peak energy alerts which were sent for two irrigation pumps that had real-time monitoring equipment installed. Figure 101 shows the daily usage profile for the single meter on the Row Crop Farm which was receiving specific alerts. Meter 7285 (on Ranch 2) has substantially different usage patterns on alert vs. non-alert days. Non-alert days correspond to days then the pumps were not in operation because the alerting system only works when a pump is on. Also, note that there is essentially no high frequency, pre-alert baseline data for the meter.

**Figure 101: For the Vineyard (a) Daily Use Profile Pre- and Post-alert, Showing Alert and No Alert Days (b) Proportion of Daily Electricity Used During Peak Hours**



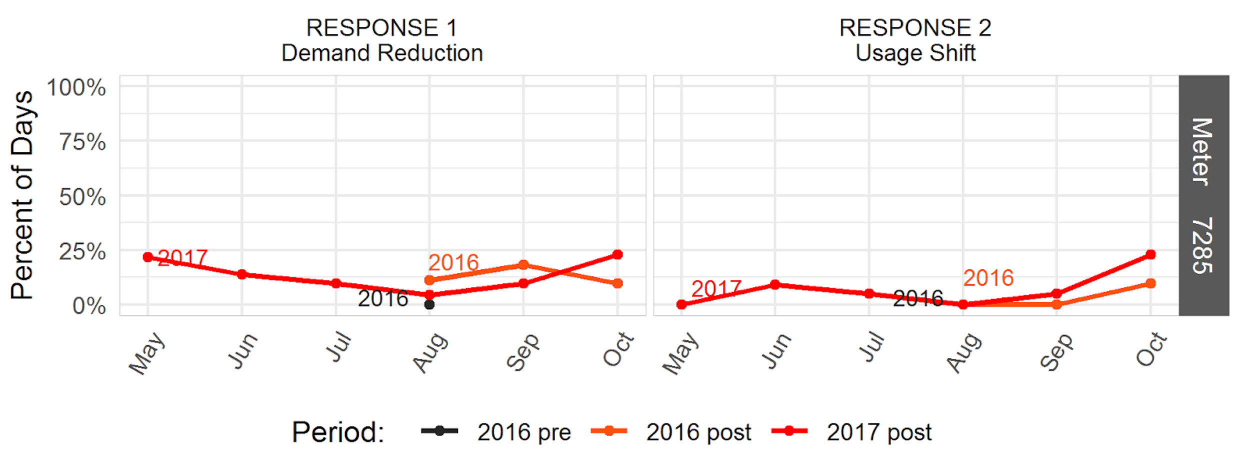

Wexus started sending peak usage alerts to the Vineyard in August 2016. Figure 102 shows the trend in peak period electricity use over time, summarized weekly during the summer peak demand surcharge months between May and October. The red lines show the peak electricity use values in the time period when alerts were sent (summer of 2016 & 2017). Superimposed in the background are number of alerts sent each week, which can range from 0 to 5. There is no baseline data available for comparison due to lack of ability to isolate external factors in CWEE's model.

**Figure 102: Proportion of Electricity Used During Peak Hours for the Vineyard**




The trends in the rule-based responses (Figure 103) are below.

**Figure 103: Trend in responses over time, pre- and post-alert periods for the Vineyard.**




**Water, GHG Emissions, and Cost Results**

**Total change in water use (observed) for the Vineyard was -8.9%.**

Table 43 shows the changes in GHG emissions, and Table 44 shows the change in electricity costs.

**Table 43: Change in GHG Emissions (lbs CO2e)* for Vineyard**

| | Observed Change | Modeled Effect |
|---|---|---|
| **Cumulative Total (Jan 2016 - Jun 2018)** | -79,000 | -67,000 |
| **Average Value Per Quarter** | -7,900 (-15.3%) | -6,700 (-12.7%) |

| | Observed Change | Modeled Effect |
|---|---|---|
| *Calculated from electricity usage data (0.588 lbs CO2e/kWh) | | |

**Table 44: Change in Electricity Costs* for Vineyard.**

| | Observed Change | Modeled Effect |
|---|---|---|
| **Cumulative Total (Jan 2016 - Jun 2018)** | -$19,000 | -$16,000 |
| **Average Value Per Quarter** | -$1,900 (-15.3%) | -$1,600 (-12.7%) |
| *Calculated from electricity usage data ($0.1418/kWh) | | |

# Conclusion of Savings Results

In addition to supporting the development of the Wexus technology platform, the project objectives included aiding partner farms to reduce their overall energy usage by providing actionable energy and cost data, with a target of reducing energy usage by up to ten percent from baseline usage. **On average, Wexus helped partner farms reduce energy usage and achieved the targeted 10% reduction as compared to unadjusted baselines.** The calculated total net impact on GHG emissions was a reduction of 92 MT CO2e, and the total net impact on adjusted electricity costs during the project treatment period was a savings of $41,200 unadjusted and $52,000 adjusted

**Significant uncertainty remains in the adjusted models, so additional work needs to be completed in the future to refine this methodology. A robust farm- or ranch-specific methodology is important to develop so that the agricultural industry can participate in a meaningful and fair way in future energy efficiency programs.** Unadjusted and adjusted electricity savings on the Berry Farm (11.3% and 5.6%, respectively) and the Vineyard (15.3% and 12.7%, respectively) were significant. Additionally, the Berry and Vineyard partner farms reduced water usage by 8.3% and 8.9%, respectively. The unadjusted and adjusted savings on the Row Crop Farm was between 29% and 1.8%, and it was difficult to separate the effects of a large solar array installation from other Wexus project work. The change in electricity use on the Dairy Farm was estimated to increase; however, this increase is likely due to uncontrolled variables, including significantly large variability in pump usage over time and long periods of non-use of irrigation pumps due to crop cycles as well as gaps in electric usage data in 2018 due to changes in SCE's data platform.

Wexus works with partner farms to develop a comprehensive and varied energy and cost savings plans. This project was wide-ranging with the potential of affecting electricity use in several different ways, many of which were dependent on the behavioral response of farm managers. **At a program-level (not for site-specific savings), this type of program could be more effectively evaluated with a large-scale randomized controlled trial (RCT), which would provide the necessary controls and sample size to more accurately estimate the overall impact.** One difficulty with developing a control group trial for agriculture is the identification of appropriate and comparable sites. Electricity service accounts on an agricultural rate structure (tariff) can include a lot of non-pump or irrigation related energy uses (e.g., compressors, lamps, freezers). One method to estimate for this is to use a classification model to identify meters that are likely to be attached to pump irrigation equipment. Meters with known irrigation equipment attached can be used to create a training dataset for the classification model. Another potential limitation of control group study is the ability to group meters by "ranches" or as part of a larger farm. Based on how agribusinesses operate, it is important to perform analysis at a ranch or farm-level and not at the meter-level. Unfortunately, detailed grouping is not possible using publicly available data sources, and it would require program participation from sites with no energy savings activity undertaken. A program-level evaluation of this type is possible, but it comes with its own set of challenges.

# CHAPTER 6: Technology/Knowledge Transfer

The goal of Technology and Knowledge Transfer scope is to disseminate the knowledge gained, experimental results, and lessons learned from the *Wexus Energy and Water Management Mobile Software for the Agricultural Industry* project to the public and key decision makers. Additionally, the Wexus team will leverage the results of the project to increase the market awareness of the Wexus mobile software for the agricultural industry.

This chapter outlines the activities to be undertaken to achieve this goal. It includes an explanation of the intended user types of the project results. The report provides a detailed description of the activities and schedule for how applicable knowledge will be made available to each type of user, including outcomes for activities completed to date. Lastly, the technology/knowledge transfer report addresses engagement with policy decision makers and how this project informs policy development related to California agribusinesses' energy and water usage.

## User Types and Purpose of Use

This section provides a description of the purpose of the technology/knowledge transfer task, including intended users of the project results. Wexus will focus on disseminating project results to three key user types:

- Agribusinesses, i.e. current and potential Wexus customers;
- Electric service providers, including investor owned utilities (IOUs), municipal utilities, and community choice aggregators (CCAs); and
- Hardware vendors, including channel partners and renewable energy providers.

Providing these three key types of users with access to information about the project is important, because the agricultural sector in California has historically been an underserved market. California's agricultural industry is one of the states' largest users of energy and water, but it has not had scalable access to effective and innovative efficiency technologies. The agricultural industry is rapidly transitioning to the next generation of technology: mobile, cloud-based software, big data, and connected devices in the field. The combination of rising energy rates, increasing regulation and reporting, drought and changing weather patterns is driving demand for new agricultural energy efficiency solutions.

Agribusinesses have not been a target market for the software technology sector until recent years, and utilities are not poised to be the primary technology conduit for agribusinesses. Research has shown that, even with more technologies and products available, farmers generally lack awareness and familiarity with technology solutions. This is particularly true for the Internet of Things (IoT), which is applicable to the Wexus technology. (IoT refers to a network of devices connected over the internet to deliver real time insights and make data-based actions and decisions.) For example, when the research firm Alpha-Brown surveyed farmers about IoT in early 2018, "less than 5% admitted to having knowledge of the subject; 68% of farmers were hearing the term for the first time" (as reported by Agfunder News, 2018 about Alpha-Brown's report: *Agriculture IoT Solutions - Market Potential*).

The agricultural industry also receives less access to utility account management support due to lack of personnel resources, technical understanding of the agricultural industry, and appropriate tools and products. Small farms, defined typically as having an annual energy spend of less than $200,000, are often not assigned a dedicated utility account manager. The absence of utility account management translates to a shortage of access to utility programs for agribusinesses to fund and realize energy efficiency savings and energy efficient equipment retrofits and sensor upgrades.

Wexus' knowledge transfer plan is critical to ensure that these project results reach these user types in the fastest time possible and thus lead to increased adoption of the Wexus' product and of ag-energy IoT products in general. In turn, increased adoption of the Wexus product will increase energy efficiency (EE) savings, promote greater electric reliability, and lower energy costs for agribusinesses.

## User Type: Agribusinesses

As Wexus' primary customer, agribusinesses are a key user type when considering the project results. Wexus has found that farmers have difficulty relating their daily operational activities to energy usage, and they are particularly receptive to technologies which provide "actionable insights" (Agfunder News, 2018). The Wexus mobile software platform leverages existing utility advanced meter infrastructure (AMI) to gain maximum scalability and lower onboarding costs. It helps agribusinesses to quickly access energy usage and spending data from virtually anywhere on both desktop and mobile devices.

During this project, Wexus developed and improved upon a rich feature-set for agribusinesses, including energy usage and cost savings dashboards; equipment status tracking; and irrigation pump efficiency and health alerting. The platform allows growers to quickly respond to changes in energy usage, adjust and optimize equipment in the field, and reduce operational expenses due to energy costs. Knowledge of the project results will lead to increased implementation of the Wexus mobile software at more agribusinesses and collectively to greater energy efficiency savings and greenhouse gas reductions.

It is also important to share findings with existing Wexus customers so that they have knowledge of new features and solutions developed during the project and can consider expanding their use of the software. Many existing customers would benefit from deploying additional IoT monitoring devices in the field on key pieces of infrastructure like irrigation pumps, buildings (for example, offices), greenhouses, processing or packaging lines, and renewable solar arrays.

In addition, the agricultural sector is a very network and community-based industry. So existing customers will further aid in the dissemination of knowledge by referring the Wexus product to other agribusinesses via word-of-mouth referrals. Agribusiness users will use the knowledge of the project to directly realize energy efficiency savings and lower energy costs.

## User Type: Electric Service Providers

Electric service providers, including IOUs, municipal entities, and CCAs, are a key user of the project results because they provide services to agribusinesses in the form of electricity procurement, distribution, transmission, reliability, and efficiency program administration. Knowledge of the project results will provide electric service providers with awareness of Wexus' product and program opportunities. The Wexus offering developed during this project can further a service provider's ability to create new energy efficiency programs and drive energy efficiency savings for their electricity consumers, in this case agribusinesses.

Wexus can support electric service providers by serving as account management and technical support to agribusinesses, especially in cases where the utilities are unable to provide resources to the entire market with their own account managers. Wexus has already established an on-going Ag-Energy program with Pacific Gas & Electric (PG&E) to serve agribusinesses in the PG&E service territory. This program has been a very effective channel for both PG&E and Wexus to reach more farms in PG&E's service territory. Knowledge of this project could lead to an expansion of the program with PG&E and other utilities. Wexus also plans to utilize the projects results to apply for and to deliver third party EE programs under the new California utility energy efficiency portfolio administration structure (per CPUC Decision 18-01-004).

Community Choice Aggregators (CCAs), as a sub-category of the electric service provider user type, are an important group to address in the knowledge transfer plan. While the individuals at these organizations have deep experience in energy, CCAs are relatively new to the utility sector and often do not have the resources and program offerings developed yet for the agribusinesses they serve. In general, CCAs are extremely committed to developing energy efficiency and renewable programs, which aligns well with Wexus' mission and this project. CCAs are also very committed to developing programs customized for their specific community and customers' needs. Wexus believes that this approach provides a great opportunity to bring programs to agribusinesses, and Wexus will pay attention to CCAs as an important sub-type user.

## User Type: Hardware Providers

Hardware providers are a critical component of the Wexus mobile software solution to enable agribusinesses to realize additional EE savings and data insights, as well as a channel partner to collaborate on outreach to agribusinesses. These hardware providers include manufacturers of hardware products, such as well depth sensors, flow meters, pressure sensors etc.; integrators, such as developers of centralized monitoring and control devices to log and transmit data wirelessly through cloud networks; and renewable energy providers, such as solar installers and project developers. The Wexus product provides a platform and channel for all of these partners to work effectively with agribusinesses.

Knowledge of these project results will enable hardware providers to identify Wexus as a key partner in distributing their energy and water efficient solutions to agribusinesses. Wexus has had success working with hardware providers in all of these capacities and creating a turnkey ecosystem of stable, useful and trusted solutions for energy efficiency and cost savings. The purpose of targeting hardware providers is to deepen and broaden software platform integration functionality and to establish new channel partner relationships.

# Activities and Schedule

This section provides an explanation of the activities and schedule for Technology/Knowledge Transfer. It describes how the knowledge gained from the project will be made available to the general public and the targeted users described above. A summary table is provided in this section.

## Key Activities

The key activity for dissemination of project results to the general public will be in the form of an online blog. The Wexus team hosts a blog at www.wexusapp.com which is publicly available to site visitors (no login required) and can be found through online search results. In addition, any member of the general public can subscribe to the blog and will receive an email notification each month after new posts are published. Subscribers to the blog already include a population of agribusinesses, electric service providers, and hardware providers. Wexus also highlights blog posts on its active social media accounts, including Facebook, Twitter, and LinkedIn. The Wexus team will post a blog article with a summary of the key findings and lessons learned from this project. It will include a link to download the final project fact sheet and the final project report.

The Wexus team has and will continue to disseminate project results to agribusinesses through its existing marketing channels. These activities include regular product feature updates to project partner farms and existing customers, which highlight relevant features developed during this project. The team also conducts regular marketing through advertisements in agricultural trade publications and email campaigns to applicable industry groups and sub-sectors of agribusinesses. Lastly, Wexus has and will attend key agricultural industry events, such as conferences and seminars, and will distribute the final project fact sheet as appropriate.

The Wexus team has and will continue to engage with IOU's and CCA's through its existing business development and programmatic conversations and attendance at utility industry events. Electric service providers also host and attend some of the industry events for agribusinesses, so there will be a natural overlap for knowledge transfer to multiple groups in one place. In addition, there are several events hosted specifically for electric service providers, particularly for the CCA sub-type. Wexus' team attended several of these conferences in 2018 and is exploring further participation and speaking opportunities.

## Schedule

The summary Table 45 provides a list of each of the activities, an estimated schedule to complete, and the target user(s) of the project results. Some of the activities are still under determination and/or are not discrete events.

**Table 45: Summary Table of Technology/Transfer Plan Activities**

| Activity | Schedule | General Public | Agri-business | Electric Service Provider | Hardware Provider |
|---|---|---|---|---|---|
| Blog post with summary of project and download link to final project fact sheet | By 2/28/19 | X | X | X | X |
| Blog post follow-up with download link to final project report | By 3/29/19 | X | X | X | X |
| Product Feature Email Update to include link to blog post | Once a month on average | | X - Current Customer Only | | |
| Ads in targeted ag trade publications | By 5/31/19 | | X | | X |
| Conference for farm industry and distribute final project fact sheet | By 5/31/19 | | X | X | X |
| Conference for utility industry – distribute final project fact sheet | By 5/31/19 | | | X | X |
| Participate in solicitation for 3rd party EE program implementers with CA IOUs | Estimated Q1 2019 | | | X | |

## Policy Development

This section discusses how this project informs policy development related to California agribusinesses' energy and water usage and how the Wexus team will engage with policy decision makers to share project results.

Wexus Technologies Inc was originally founded in part as a response to the severe drought in California starting in 2011. This drought also led to an increase in policy activity in California related to the water-energy nexus. By May 2012, the California Public Utilities Commission filed Decision 12-05-015, which included guidance to expand on water-energy nexus efficiency portfolios, programs, and cost-effectiveness calculations. Investor-owned utilities, the water sector, industry partners, and the public began collaborating in a series of workshops to progress the development of solutions (CPUC 2016). Prior to the drought and these policy drivers, technologies and a framework did not exist for approaching the unique intersection of water and energy.

There are many additional underlying policy drivers in California related to energy efficiency, which have supported the Wexus team's work to date:

- California Global Warming Solutions Act of 2006 (A.B. 33)
- Integrated Energy Policy Report (California Energy Commission 2018)
- California Clean Energy Jobs Plan (California Energy Commission 2017)
- California Public Utilities Commission's Long-term Energy Efficiency Strategic Plan (CPUC 2008 and 2011)

The California Public Utilities Commission (CPUC) also designated the California Energy Commission an administrator for rate-payer funded research and development for clean energy technologies. In August 2014, the California Energy Commission initiated a competitive grant solicitation: *PON-14-304 Electric Program Investment Charge (EPIC) Bringing Energy Efficiency Solutions to California's Industrial, Agriculture and Water Sectors*. This program funded this project and enabled the Wexus team to make technological advancements to overcome barriers preventing achievement in the state's statutory energy goals.

As an outcome of this project the Wexus team will continue to inform regulatory bodies about the project results to feed back into the water-energy nexus policy conversations, which are on-going. One desired outcome is additional policy in support of turnkey, water-energy nexus programs specifically for agricultural customers with the use of scalable Internet of Things (IoT) technology platforms similar to Wexus. This project helped farms solve key problems related to labor, regulation and reporting, and rising energy/water costs, by providing them with data to make informed decisions; mobile, accessible-on-the-go applications for use in the field; and interconnected, real-time monitoring devices.

The Wexus team also recognizes that the outlook for farms is constantly changing with availability of new technologies, changing weather patterns, and changing policy. The team has identified several new challenges in 2018 that policy decision makers need to be aware of as they continue to research and fund programs in the water-energy nexus. Solving these issues for the agricultural industry will ultimately help California achieve its long-term energy goals of 100% renewables by 2045:

- **Solar photovoltaic (PV) system net metering** is a complex utility billing system that is difficult to interpret, and farms often do not have the tools to determine whether PV systems (often +1MW in size) are generating as expected. This problem needs to be solved in order to incentivize continued investment in solar (and other renewable energy sources) by agricultural customers, who often do have land available for such resources.

- **Financing options for IoT hardware and sensors** (both public and private) is necessary to help low-margin agribusinesses invest in solutions that will enable data-driven decision-making and energy conservation.
- **Community Choice Aggregation (CCA) in California** provide customers with access to local and high-renewable-mix electricity; however, access to CCA energy costs are not accessible through the IOU's Green Button Connect platforms and agricultural customer's utility bills are further complicated (already comprise dozens or hundreds of meters per farm). Programs and tools need to be put in place to enable access to data and cost comparison of CCA rates compared to others.
- **Inputs for advanced Cost Calculator tools**, including additional agronomic data, such as weather and crop type energy intensity, are necessary to determine accurate energy and cost savings. The development of these tools will require funding and access to many sources of data, including utility rates, actual customer costs, and large groups of same crop meters.
- **Utility time of use (TOU) rate changes** scheduled in California in 2019 and 2020 will affect farms, as they evaluate the best options for their operations. Software-as-a-service, such as that which Wexus provides, will be necessary to provide education, analysis, and guidance on how farms can save money while also placing less stress on the utility grid.

As a first step in this conversation, the Wexus team will compile project results and lessons learned into presentation materials for a California Energy Commission-sponsored conference and/or workshop.

# CHAPTER 7: Production Readiness Plan

The Production Readiness Plan outlines the steps that will lead to further commercialization of the project's results. One of the primary goals of this project was "to provide wider proof-of-concept and use cases for scaling the Wexus mobile software platform throughout IOU regions in California." Over the course of this project, Wexus has already succeeded in commercializing the product in California with particular focus on the Pacific Gas & Electric (PG&E) electric service territory.

This plan will outline the strategy to maintain the product and to expand the product deployment throughout California in 2019 and 2020. It will discuss Wexus' strategy for commercialization with a focus on the Ag-Energy program with PG&E, expansion into additional California electric service territories, third party energy efficiency program implementer structure, and partnerships with local channel partners. It will also detail the critical personnel resources needed to produce a commercially viable product.

## Strategy for Commercialization

Wexus' objective is to continue to commercialize and scale the Wexus product in the California investor owned utility market through 2020. According to the 2012 United States Department of Agriculture Census, there are over eighty thousand (80,000) farms and ranches in California that collectively spend over $2 billion dollars per year on energy, which includes electricity and fuel. Assuming a seven percent (%) share of market estimate, the potential for Wexus is to address an agricultural customer base with over $140 million annual energy spend in California.

The strategy for further commercialization in California will be a four-step approach:

- Continue to the drive growth in the PG&E service territory through the on-going Ag-Energy program.
- Expand into additional electric service territories in California, including Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), and public municipalities with advanced metering infrastructures (AMI).
- Serve as a Third-Party Energy Efficiency (EE) Program Implementer (or subcontractor) under the new California Public Utilities Commission (CPUC) mandated rolling portfolio structure.
- Expand partnerships with local channel partners (for example, hardware providers) in targeted agricultural markets.

These approaches will be explained in more detail below.

## Ag-Energy Program with PG&E

During the course of this project, Wexus has established and pioneered an ongoing Ag-Energy program with PG&E. This program has been a very effective channel for both PG&E and Wexus to engage more farms in the PG&E service territory.

The Wexus business development and marketing teams work closely with the PG&E product and account managers to identify agribusinesses which would benefit from Wexus' solution. The PG&E account managers make introductions and assist with any issues related to the agribusiness utility accounts, rebates, incentives, and programs. This relationship provides Wexus with access to over 20,000 agribusiness accounts. Wexus will continue to work closely with PG&E on the on-going Ag-Energy program and to expand its offering in this service territory in 2019.

## Expansion into Additional California Electric Service Territories

Wexus will continue to explore expansion to agribusinesses in additional California electric service territories, including SCE, SDG&E, and public municipalities with AMI. To date, Wexus has engaged a relatively smaller portion of the California agribusiness addressable market of $2 billion with its product. Growth into additional territories will require further business development to grow working relationships with these utilities. Wexus will use the field-proven Ag-Energy program with PG&E as a model for other partnerships and utilize the EPIC project results as described in the Technology and Knowledge Transfer Plan to inform conversations.

In addition, Wexus will need to coordinate with the appropriate data management providers to access customer data in these territories. Wexus will target territories with advanced metering infrastructure (AMI) and Green Button Connect data platforms. As part of this project, Wexus developed the technical integration to connect with PG&E and SCE's Green Button Connect data platforms. Wexus will need to continue to maintain these connections and respond to future improvements to these platforms. For new service territories, Wexus will need to conduct due diligence on the data connection platforms and build the necessary features to support these regions.

## Third Party EE Program Implementer Structure

Under the new CPUC-mandated rolling energy efficiency portfolio structure, Wexus will look to serve as a Third-Party Energy Efficiency (EE) Program Implementer (or subcontractor). CPUC Decisions 16-08-019 and D.18-01-004 provided new rolling portfolio program guidance. It requires that 60% of the utility's EE portfolio budget will be designed and implemented by third parties by the end of 2020. IOUs will serve as portfolio administrators and solicit responses from third parties, such as Wexus, to serve as program implementers. The Wexus team will monitor the solicitation requests for each IOU and will design and respond to Requests for Abstracts and Requests for Proposals as applicable.

PG&E has streamlined and grouped its portfolio structure and will solicit responses by customer type. For the "Agricultural" sector, PG&E will target "strategic partnerships to work within the current market structure and encourage energy efficiency at every level, while also looking for ways to save water; and data access tools that enable agricultural customers to view their energy usage holistically, observe trends, and make smart energy efficiency investments" (PG&E, *Energy Efficiency Business Plan: 2018-2025*, page 4). PG&E's strategy for this sector is an excellent fit for the Wexus product developed during this project. In preparation for PG&E solicitations, Wexus team members attended PG&E's day-long EE Platforms Training in June 2018 to understand the platform structure and next steps. PG&E expects to release the first wave of Requests for Abstracts (RFA's) in Q4 2018 – Q1 2019, and Wexus plans to respond.

### Partnerships with Local Channel Partners

The Wexus team will continue to develop and expand partnerships with local channel partners including hardware vendors in targeted agricultural markets. Hardware vendors are a critical component of the Wexus mobile software for higher-level plans with additional real time monitoring, controls and alerting features. But they also serve as invaluable channel partners for introductions and customer reference points. The team will utilize the project results as described in the Knowledge Transfer Plan to inform business development conversations with potential partners.

## Plan and Resources

This section will describe the plan and resources needed to expand commercialization and to maintain the features of the Wexus product developed during this project. Since the Wexus product is software-as-a-service for agribusinesses, the critical resources required come in the form of personnel and related support systems like cloud-based software tools. Wexus will need to continue to grow the organization; maintain and expand the product feature-set; and drive business development and market awareness as described in the Technology/Knowledge Transfer Plan and Report.

The following resources and systems will be discussed in more detail in this section:

- Business Development and Marketing;
- Operations;
- Product Development; and
- Partnerships with Hardware Providers.

### Business Development and Marketing

To deliver upon the commercialization approach described in the sections above, it will be critical for the Wexus team to have the appropriate Business Development and Marketing resources. Business development will focus on forging partnerships with product vendors and utilities and will represent Wexus at agricultural conferences. The team will also continue to use a software-as-a-service (SaaS) customer acquisition model, which makes technology adoption easier and more flexible for business-to-business (B2B) customers and allows for quickly scaling the business strategy.

The Wexus team has determined that it is critical to hire and retain key business development personnel with strong, deep network within the agribusinesses, energy industry, and utility industry. These relationships will help Wexus grow its channel partnership network. The energy and agricultural industries also have deep networks and personal relationships are particularly important.

In addition, the water-energy nexus space is complex, and agribusinesses are suspicious of individuals who do not have knowledge and appreciation of their operations and specific business challenges due to regulation and reporting. The Wexus team has been very successful to date with a minimal marketing budget, instead focusing on building relationships through word-of-mouth referrals, introductions through partners, and in-house, targeted email campaigns. Wexus' business development team members are geographically co-located with their end-use customers and partners and will continue with this strategy in following years.

In order to continue to support the business development team and to scale efficiently, the Wexus team will also continue to streamline the customer sign-up and on-boarding processes. During this project, an online sign-up process was improved and was well received by new customers. Wexus will look to further iterate on user experience and expand existing feature sets through ongoing product development. Wexus will also continue to maintain and grow its existing online presence through the company marketing website and its cloud-based software tools.

## Operations

The Wexus product is a software-as-a-service product, so Operations personnel and support are important pieces to support commercialization. The operational team members provide account management services with on-boarding, training, and continuously engaging and advising agribusiness customers. They also support customers in developing and implementing energy savings plans. Operations will focus on expanding customer support, training, analytics, and reporting.

Expansion into new territories may require additional Operations resources in order to set up new programs and engage more customers. In addition, Wexus offers customers increased dedicated support on the higher-level plans, especially those with IoT hardware deployments. Higher level plan customers each have a dedicated energy engineer to consult on EE measures and manage hardware deployment projects. As the subscription-plan mix and regions evolve, the team will re-evaluate the level of operational staffing and product improvements needed in order to ensure that customers always receive high quality features and support.

## Product Development

The Product Development team will continue to support product feature improvement, scaling and commercialization. The team will maintain existing software features and remain focused on key agricultural market changes and shifting needs for new product features.

Throughout this project, the Product Development team has solicited customer feedback and created useful product features specifically designed for agricultural customers. The Wexus team places a strong emphasis on engaging and learning from ag customers in the field and then incorporating this information into the product design to continually improve it. This feedback loop will continue as Wexus continues to commercialize and scale the product platform.

## Partnerships with Hardware Providers

The higher tier Wexus SaaS plans and features that provide real time data, controls and alerts depend upon technical integrations and partnerships with IoT hardware providers. During the course of this project, the Wexus team collaborated with Polaris Energy Services Inc to deploy hardware monitoring devices at partner farm sites. The Wexus team plans to maintain this relationship and to work with an expanding network/ecosystem of IoT hardware providers.

To scale and commercialize adequately, the Wexus team will ensure its hardware partners deliver on-time and on-budget equipment through a deep network of subcontractors and installers in the field. Partners with experienced staff will need to meet customer timelines and deliverables, maintain equipment supply chains, and meet channel partner contractual agreements with Wexus' team.

# CHAPTER 8: Conclusions

## Goals and Objectives

This project achieved its goals to engage agricultural partner sites in California to use the Wexus mobile software to identify energy and costs savings at their sites. The Wexus team provided wider proof-of-concept for several use cases and demonstrated the ability to scale the Wexus IoT software platform to help agribusinesses solve key problems including:

- **Labor**: reduce wasted labor by remotely tracking equipment status and send real-time SMS text message and in-app alerts for important labor-related events, such as irrigation pump efficiency and maintenance.
- **Regulation and Reporting**: reduce time spent and manual effort required to report on energy and water usage by aggregating paper utility bills into an easy-to-navigate dashboard and by exporting data in pre-formatted files approved by local regulatory agencies.
- **Costs**: provide growers with information about whether irrigation schedules were being followed and the associated costs; allow them to adjust and optimize irrigation equipment in the field, which may be experiencing efficiency or water aquifer problems; and reduce operational expenses due to energy costs by increasing efficiency with real time TOU SMS text alerts before hitting peak hours.

Overall, results show that three of the four farms had substantially lower average electricity usage during the project period relative to baseline values**, achieving the targeted ten percent reduction from baseline values.** In total, **partner farms reduced electricity usage by 1.14 GWh/year or 17.2% on average unadjusted.**

## Key Lessons Learned

Through this project, the Wexus team gained valuable insight about **the critical need to validate all product features and on-site hardware installations with continuous feedback from partner farms to ensure the highest level of usability of features and to solve real problems for agribusinesses**:

- The four partner farms participating in this project represented a cross section of the agricultural industry with different verticals/crop types and different business operations. However, **the Wexus team found common issues and needs among all of them in terms of energy and water management.** By soliciting constant feedback, the Wexus team also gained valuable insight to further increase the value of product features and to make them as relevant to farmers as possible.
- These common issues and needs were then **identified and incorporated into scalable IoT software product features.** For example, having the ability to view water usage in a variety of units of measure (including gallons and acre-feet) across multiple years and

comparing the differences in usage and costs as well as ensuring that installed flow meter equipment had digital displays for workers to take independent readings in the field.

- The agricultural industry is driven by personal relationships and networks, is very active in local communities, and **trust is a critical component of doing business**. In order to solve energy and water challenges across California and to meet the state's energy goals in the future**, it is critical for policy makers (i.e. the CA legislature and the CPUC), the Clean Energy Comission, the IOUs and technology vendors like Wexus to continue to listen and solicit feedback from growers, food processors, irrigation districts and others in the agricultural industry in order to build effective and useful energy and water programs and technologies that actually solve energy, water and labor problems instead of creating new ones.**
- Before this project, there were few (if any) M&V models to calculate energy and water savings built specifically for the agricultural industry. The Wexus team found that when building M&V models for agriculture, it can be difficult to isolate and control for multiple external variables at farm sites with total confidence. **California farmers face multiple challenges including** unpredictable weather patterns like extremely dry drought years followed by very wet precipitation years, and changes to labor and farm operations including variable crop types and irrigation schedules. **In order to build upon this project's findings and continue to refine an M&V model specifically designed for agriculture, it will be critical to incorporate and test energy and water data from multiple years and hundreds of crop types from thousands of farms.** Wexus looks forward to continuing to refine this M&V savings model.

## Project Benefits to California and Next Steps

The Wexus team will continue to focus on transferring knowledge of this project in order to educate key stakeholders about the critical need to engage the historically underserved agricultural industry. **Agriculture is a key component of California's energy goals.** The faster that the Wexus team can disseminate these project results, the faster that adoption will increase of the Wexus product and of ag-energy IoT products in general. The Wexus team's objective is to continue to commercialize and scale the Wexus product in the California IOU market through 2020:

- **Continue to drive growth in the PG&E service territory through the existing Ag-Energy program that the Wexus team pioneered.** This program helps agricultural partner farms save money, energy and water with access to utility rebates and efficiency incentives and gives PG&E account managers better visibility and analytics to engage their partner farms and provide better, more reliable service.
- **Expand into additional electric service territories in California**, including Southern California Edison (SCE), San Diego Gas & Electric (SDG&E), and public municipalities with advanced metering infrastructures (AMI).

- **Serve as a Third-Party Energy Efficiency (EE) Program Implementer (or subcontractor)** under the new California Public Utilities Commission (CPUC) mandated rolling portfolio structure.
- **Expand partnerships with local channel partners** (for example, hardware providers) in targeted agricultural markets throughout California.

**It is critical for energy policy makers to understand that farmers are running a business and energy consumption is a cost of doing business for them, not a primary revenue driver.** Technology platforms like Wexus that automate laborious reporting and accounting tasks like tracking energy and water consumption and utility bills and costs (and that relate them to the actual farming operation with historical trends and real-time alerts), can help drive overall energy markets awareness, behavioral change, and improved net operating income for farms. The Wexus team will continue to incorporate farmers' feedback and these project results to improve the effectiveness of peak period alerts and other key software features.

As of late 2018, several new challenges are on the horizon that Wexus is eager to address in future projects. The Wexus team **highly encourages the California Energy Commission, the California Public Utilities Commission (CPUC) and Investor Owned Utilities (IOU's) to research, provide funding, and create efficiency programs to help solve these ongoing issues for the agricultural industry** which will ultimately help California achieve its long-term energy goals of 100% renewables by 2045:

- **Financing options and rebate programs for IoT hardware and sensors** (offered by both utilities and third parties) will be increasingly important as more AgTech and IoT solutions become available to agricultural customers. Farmers will need different mechanisms to help pay for these solutions, since agriculture is typically a low-margin business driven by fluctuations in crop prices and weather patterns and available cash to invest in new technologies is scarce.
- **Community Choice Aggregation (CCA) in California** has become more widespread in 2018, particularly in the Salinas Valley where there is a significant concentration of agricultural businesses. CCAs provide customers with another option to purchase electric generation versus their existing investor-owned utility (IOU) along with access to different energy generation mixes (like 100% renewables), cost savings, and rebate programs. However, it can be extremely complicated to determine whether enrolling in a CCA versus staying with an IOU will actually reduce energy costs, and once a customer is enrolled in a CCA it can be very difficult to track actual costs and bills to ensure their enrollment was worth the effort and to opt out of the CCA if necessary.
- **Cost Calculator feature** will provide the next level of real time, predictive energy and cost management tools and will incorporate more granular agronomic data, particularly ranking energy intensities by crop type and more specific weather data.
- **Utility time of use (TOU) rate changes** which are expected to launch in both PG&E and SCE territories in 2019 and 2020. Farms will need tools to manage these new rates, to help compare and contrast the best options, and to manage irrigation pumping

operations around new TOU hours to optimize their costs and place less stress on the utility grid.

- **Solar photovoltaic (PV) system net metering** is a pain point for farmers who converted available farmland, bought large (+1MW), expensive ground-mounted solar PV systems, and often do not have the tools to validate their systems energy generation/ performance and return on investment (ROI). Even interpreting their monthly utility solar bills is a significant challenge.

# GLOSSARY

| Term | Definition |
|---|---|
| AF | Acre-feet, a measurement of water consumption typically used in agriculture |
| Agile | Agile is a project and product development process, which emphasizes “individuals and interactions rather than processes and tools; working software over comprehensive documentation; customer collaboration over contract negotiation; and responding to change over following a plan” (Manifesto for Agile Software Development). |
| Agribusiness | Business of agricultural production, including but not limited to farmers, indoor and outdoor growers, food processing facilities, dairies, and ranches |
| Agri-food | Industry related to producing food through agriculture, inclusive of supporting sectors such as food processing and irrigation districts |
| AgTech | Technology entrepreneurship focused on solving agribusiness problems |
| AMI | Advanced metering infrastructure, including measurement, collection, and communication systems to provide electricity usage information from end-use, remote sites to a centralized entity such as a utility |
| API | Application Programming Interface, a set of tools or communication protocols for building and connecting software platforms |
| Build-Measure Learn | A methodology for new product development, which aims to minimize waste in the process of building, launching, and scaling new products in the market (Ries and Blank, 2011). There are three phases:<br>1. Build: Ideas and Hypotheses<br>2. Measure: Code and Tests<br>3. Learn: Data and Key Performance Indicators |
| CCA | Community Choice Aggregation/Aggregators, program that allows cities and counties to buy and/or generate electricity for residents and businesses within their areas |
| CEC | California Energy Commission |
| Click rate | The percentage rate opening of an email where the recipient clicks a specific link |
| CPUC | California Public Utilities Commission |
| CWEE | Center for Water-Energy Efficiency at University of California Davis |

| | |
|---|---|
| EE | Energy Efficiency |
| EPIC (Electric Program Investment Charge) | The Electric Program Investment Charge, created by the California Public Utilities Commission in December 2011, supports investments in clean energy technologies that benefit electricity ratepayers of Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company |
| ETo | Evapotranspiration, water that leaves the soil due to combination of evaporation and transpiration to plants |
| GHG | Greenhouse gas |
| Green Button Connect | Standardized, open protocol for downloading and connecting to utility usage data, led by Green Button Alliance |
| IoT | Internet of Things, a network of devices connected over the internet to deliver real time insights and make data-based actions and decisions |
| IOU | Investor-owned utility |
| KPI | Key Performance Indicator |
| M&V | measurement and verification |
| Open rate | The percentage of the emails sent out that are opened by the recipient |
| PG&E | Pacific Gas and Electric |
| Platform | The web application that the Wexus team created |
| PV | Photovoltaics (as in renewable solar energy generation) |
| SaaS | Software as a Service |
| SCE | Southern California Edison |
| SDG&E | San Diego Gas & Electric |
| SMS | Short Message Service as in text messages received on mobile phones |
| TOU | Time of Use |
| UI | User Interface |
| User persona | An archetype of a farm employee defined by their roles, interactions, motivations, and demographics |
| UX | User Experience |
| Wexus™ | Water-Energy-Nexus, i.e. Wexus Technologies, Inc. |

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# APPENDIX A: Interview Questions for Partner Farms

## Quarterly Questions

Per the M&V plan, to inform adjustments in the regression analysis and general analysis of M&V quarterly results, the following questions will be asked on a quarterly basis by Wexus.

1. Have you implemented any major changes in farm operations that would impact energy use (e.g. fallowing of fields, significant changes in planting or harvesting schedules, major changes to crop type, etc.)?
2. Have you adopted any new water or energy efficiency technologies since the farm started using the Wexus platform (e.g. installation of soil moisture sensors, change in irrigation method, new irrigation pumps, etc.)?
3. Have there been any modifications to existing wells (e.g. increasing the pump depth), or any new well installations?
4. Have there been any major modifications to existing pumps (e.g. pump replacement, motor upgrades/repairs, or installation of a VFD)?

## Semiannual Questions

Per the M&V plan, interviews will be scheduled (by Wexus) semiannually to gain a better understanding of how farm energy consumption has changed with either the continuation or the end of the current California drought that started in 2011. Information gained from these interviews will be included in the analysis of project savings to provide qualitative insight of trends or unexpected results of project savings.

1. How have general operations changed as a response to the drought? Have crop type and number of acres planted changed?
2. Have wells gone dry or decreased in yield? If the information is known, how much has the yield decreased from pre-drought years? Has well yield improved so far in 2016 given the fairly average rainfall totals from the 2015-2016 rainy season?
3. Has the farm had to irrigate more than normal during drought years? Is there an understanding of the percent increase in water use due to the drought?
4. Have any of the following occurred to minimize the impacts of reduced well water supplies?
    a. Increasing the depth of well pumps (if so, which ones?)
    b. Constructing new wells
    c. Temporarily discontinuing use or limiting use of existing wells (if so, which ones?)
    d. Using high-yield wells more to make up for low-yield wells (if so, which ones were used more?)
    e. Making improvements to pump energy efficiency

5. In general, how has farm energy use changed with the drought? Is there an understanding of the percent increase in energy consumption to pump the same or less amount of water?

# Appendix B:
# Partner Farm Site Visits

The Wexus project team conducted a number of additional site visits as necessary in order to meet with partner farm sites and audit additional equipment. The results of such visits were prepared and submit to CAM as part of Customer Site Visits Reports corresponding monthly in the progress reports. Activities performed during such visits included, but were not limited to:

- auditing operations and equipment
- documenting farm site/ranch names, acreages, and locations
- confirming meter names/numbers, locations, and utility billing account data
- identifying existing energy using equipment types, locations, equipment operating hours, and specifications.

Additional information was documented such as site operations and working hours through one-on-one interviews with owners, facility managers, and employees.

## Timeline of Partner Farm Visits

Most site visits were performed at the beginning or end of the farming season from July 2015 through March 2018. A timeline of activities is outlined in Figure 104 through Figure 107.

**Figure 104: Timeline of Partner Farm Site Visits in 2015**

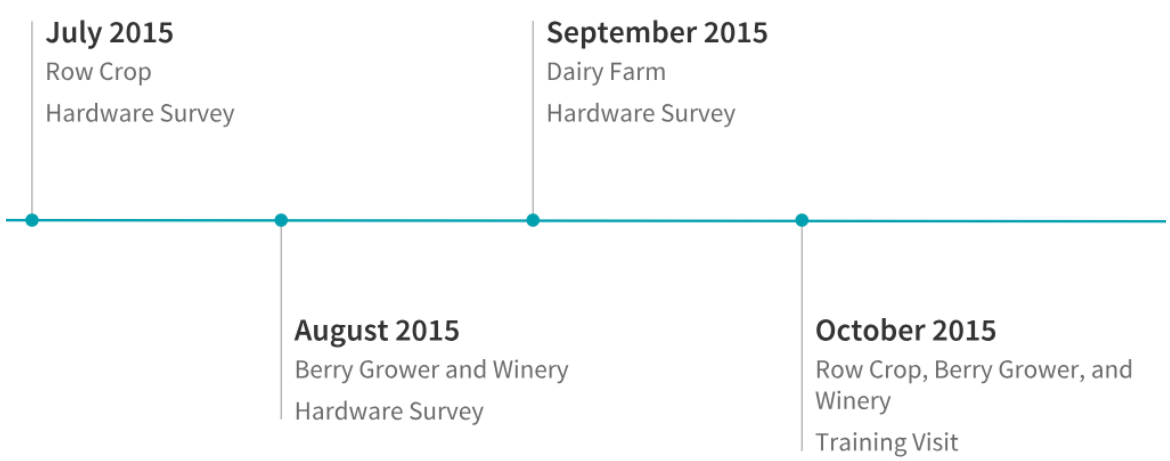


**Figure 105: Timeline of Partner Farm Site Visits in 2016**


**Figure 106: Timeline of Partner Farm Site Visits in 2017**

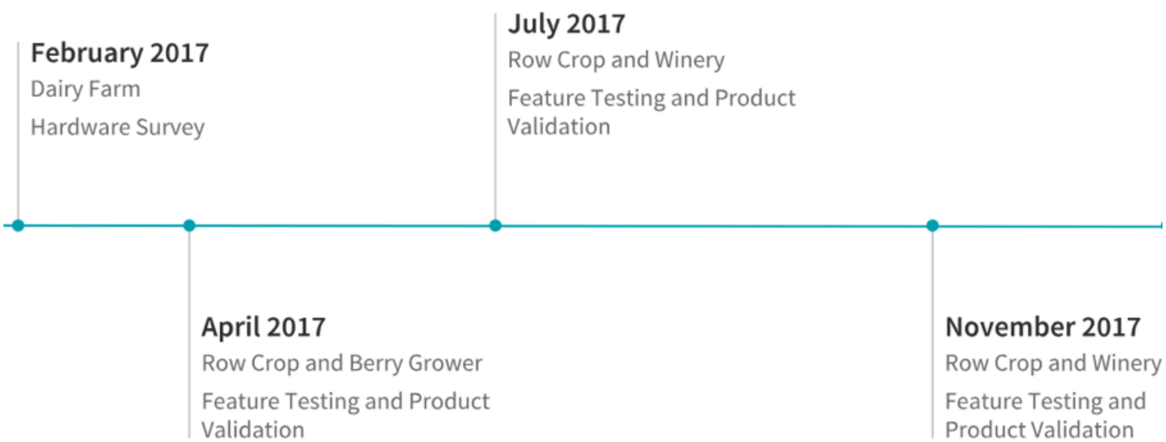
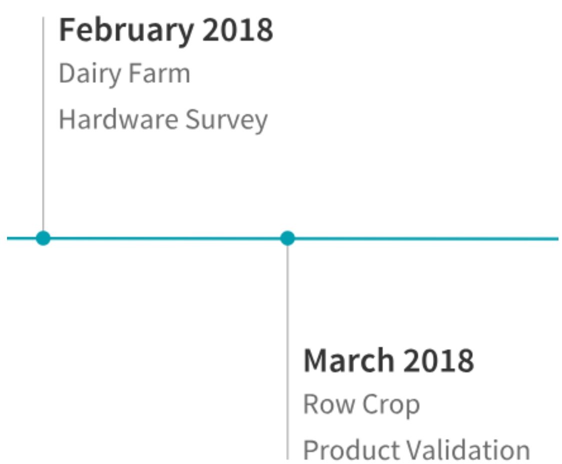



**Figure 107: Timeline of Partner Farm Site Visits in 2018**



## Row Crop: Site Visits

### Row Crop: July 2015 - Hardware Survey

**Figure 108: Irrigation pump, utility pole, transformer, electric meter & analog flow meter survey with the Row Crop Farm sustainability manager, Wexus, UC Davis & Polaris Energy Services teams.**

**Figure 109: Irrigation pump & analog flow meter survey.**


**Figure 110: Row crops and a soil moisture probe/weather station, irrigation pump, utility pole, transformer, electric meter & analog flow meter survey.**

Figure 111: Utility smart meter and analog flow meter survey.

**Row Crop: October 2015 - Training Visit**

The purpose of the visit was to train farm staff on how to use the Wexus software platform and learn more about partner site farming operations and energy usage patterns.

**Row Crop: November 2015 - Hardware Survey**

Figure 112: Flow meter interface and sectional view post installation.

**Figure 113: On-site reservoir and Inspection of flow meter installation at Sandhill Well 1.**

## Row Crop: March 2016 - Hardware Survey

**Figure 114: Wexus team members inspecting a partner site irrigation pump in the Salinas Valley.**

## Row Crop: March 2017 - Site Survey & Feature Testing

**Figure 115: Row Crop Farm survey.**

**Figure 116: Row Crop Farm survey.**

**Figure 117: Row Crop Farm reservoir pump survey.**

**Figure 118 and 30: Row Crop Farm reservoir pump survey.**

### Row Crop: July 2017 - Feature Testing

On July 28, 2017, members of the Wexus Technologies team visited the Row Crop site in King City and the Vineyard in Salinas Valley. The team: (1) audited the farming operations with respect to energy usage practices, (2) reviewed software specific feature updates, (3) solicited feedback for current features

### Row Crop: July 2017 - Hardware Survey & Product Validation

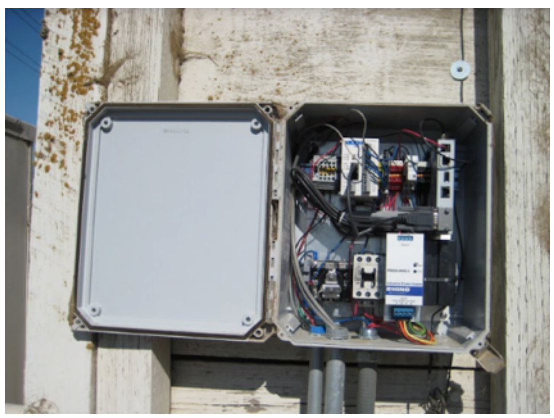
**Figure 119: PG&E electric meter, flow meter, motor and Doud well pump**

**Figure 120: PG&E electric meter**

**Figure 121: Ranch with surrounding crops and active pump operation/irrigation.**

Figure 122: Doud Well flow meter.


Figure 123: Polaris monitoring device and associated wiring.



**Row Crop: March 2018 - Product Validation**

On March 19, 2018, members of the Wexus Technologies team visited the Row Crop Farm Partner Site in King City, CA. The team audited (1) farming operation with respect to energy usage practices and (2) the installed Polaris Energy Services energy and water monitoring and controls.

## Dairy: Site Visits

### Dairy: September 2015 - Hardware Survey

**Figure 124: R5 pump installation site and almond ranch pump filtration system survey.**

**Figure 125: Goshen Ranch almond ranch pump filtration system survey.**

**Figure 126: Pump data plate and pump utility meter survey.**

**Figure 127: Surveying pump site converting from diesel to electric with new transformer and Dairy operations & cattle feeding pens.**

**Figure 128: Inspecting pump flow meter installed at the Goshen Ranch almond orchard**

### Dairy: February 2016 - Hardware Survey

**Figure 129: Newly installed Southern California Edison (SCE) electric utility meter and recently installed section of pipe, flow meter, pressure sensor, and associated wiring.**

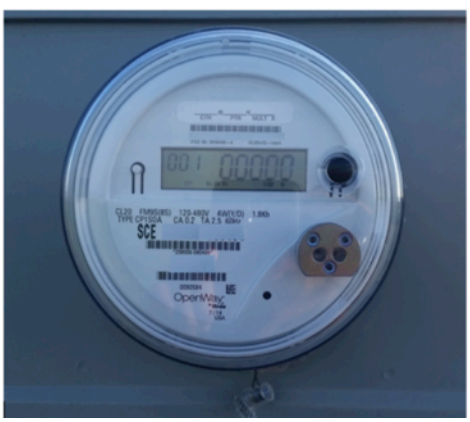



Figure 130: Close up of a recently installed flow meter and pressure sensor.

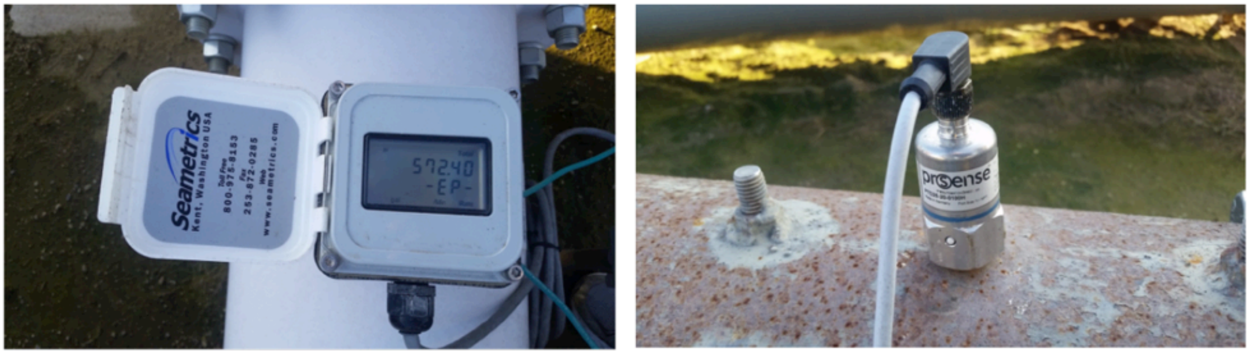



Figure 131: Irrigation pump piping, flow meter and overflow

Figure 132:  Irrigation pump and flow meter

Figure 133: Installed section of pipe, flow meter, pressure sensor, and wiring at the Dairy Well.

Figure 134: SCE meter, main service and motor electrical disconnect at the Dairy Well.

## Dairy: October 2016 - Hardware Survey

Figure 135: Goshen Ranch: Wexus UX Designer with Dairy/Almond Farmer near the Polaris device, well pump, variable frequency drive, and utility main service enclosure.

Figure 136: Goshen Ranch Polaris device and antenna installed at Well 1 variable frequency drive

**(VFD) enclosure**

**Figure 137: Goshen Ranch close up of Polaris device and wiring**


**Figure 138: Goshen Ranch close up of Well pump motor**

**Figure 139: Dairy/Almond Farmer explaining the operation of the Goshen Ranch Well 1 filtration**

**system**

**Figure 140: Dairy Farm W5 Pump & Polaris device installed with antenna and wireless modem**

**Figure 141: Dairy Farm W5 Pump, piping and oil reservoir**

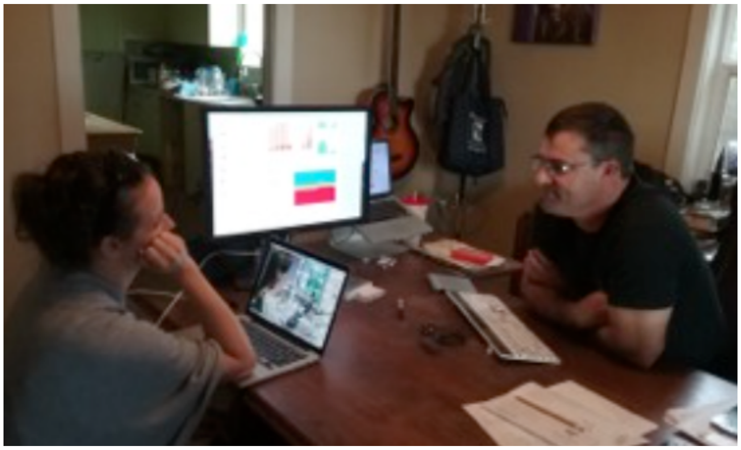
**Figure 142: Dairy Farm silage fields post-harvest**

**Figure 143: Remnoy Ranch Well Pump in operation, the smaller ditch pump was not operating when this photo was taken**

**Figure 144: Remnoy Ranch close up of Southern California Edison utility meter**

Figure 145:  Remnoy Ranch reservoir

Figure 146:  Wexus UX Designer conducting a user test with Dairy/Almond Farmer per the Build-Measure-Learn process and data collection



## Dairy: February 2017 - Hardware Survey

Figure 147:  Installed Polaris Automation Controller Dairy Well

## Berry Farm: Site Visits

### Berry Farm: August 2015 - Hardware survey

**Figure 148: Irrigation well pump house and analog flow meter survey with Berry Farm staff, Wexus team, UC Davis CWEE & Polaris Energy Services.**

**Figure 149: Irrigation row crops, torn down irrigation pump and associated hardware survey with Berry Farm staff, Wexus team, UC Davis CWEE & Polaris Energy Services**

**Figure 150: Water storage with a temporary irrigation pump and utility SMART Meter survey.**

**Berry Farm: October 2015 - Training Visit and Hardware Survey**

The purpose of the visit was to train farm staff on how to use the Wexus software platform and learn more about partner site farming operations and energy usage patterns. The Wexus team was able to survey installed monitoring equipment at Sandhill Reservoir Well site.

**Figure 151: Pump flow meter and irrigation pump post installation.**

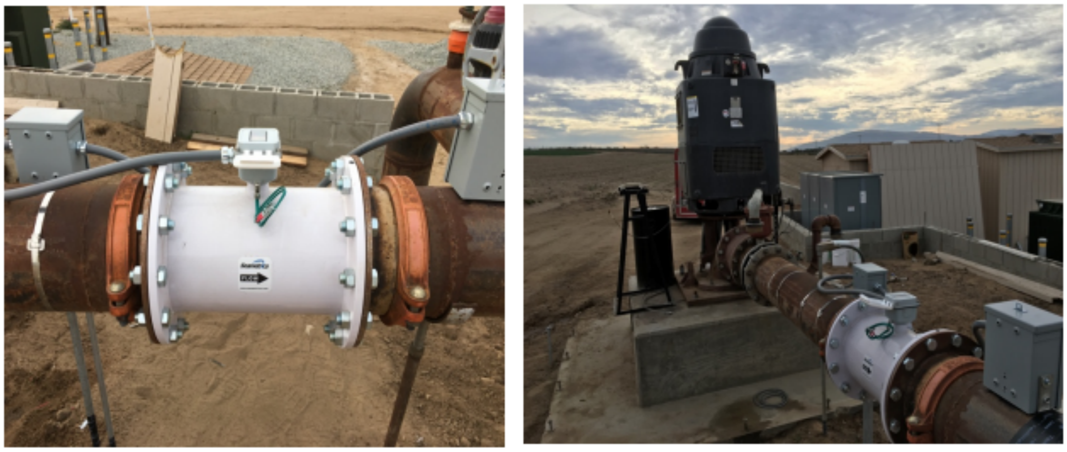


**Figure 152: Flow meter interface and sectional view post installation.**


**Berry Farm: April 2016 - Hardware Survey**

**Figure 153: Pump flow meter installation with farm operator Davis Well #2.**

**Figure 154: Pump flow meter at Davis Well #2**


**Figure 155: PG&E electric meter at Davis Well #2**

**Figure 156: Pump Automation Controller installed at Davis Well #2**

**Figure 157: Sandhill Ranch well pump and reservoir pumping equipment**

**Figure 158: Sandhill Ranch reservoir pumps and filtration equipment.**

Figure 159: Well pump variable frequency drive and equipment at Sandhill Ranch.


Figure 160: Sandhill Ranch well pump.

Figure 161: Sandhill Ranch Polaris Energy Services Pump Automation Controller.

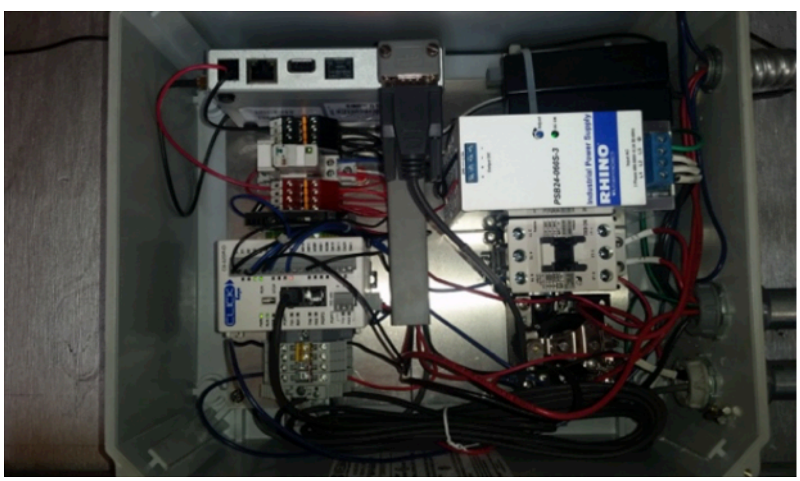


Figure 162: Sandhill Ranch energy monitoring meters.

**Berry Farm: April 2017 - Product Validation**

The purpose of the visit was to train farm staff on how to use the Wexus software platform and learn more about partner site farming operations and energy usage patterns. No photos taken.

**Berry Farm: June 2018 - Site Survey**

Figure 163: Sandhill Pump & Pump House.

Figure 164: Reservoir & Booster Pumps.

Figure 165: Monitoring Device Electrical CTs and Enclosure.

Figure 166:Polaris Monitoring Device Cellular Modem.

Figure 167: Sandhill ranch well reservoir flow Meter and Piping

## Vineyard: Site Visits

### Vineyard: August 2015 - Hardware Survey

**Figure 168: Wine barrel facility, and irrigation pump and associated hardware survey with vineyard staff, Wexus team, UC Davis CWEE & Polaris Energy Services.**

**Figure 169: Irrigation pump, electrical meter and analog flow sensor survey.**

**Figure 170: Well pump and vineyard row crop survey with project staff.**

Figure 171:  Well pump and irrigation pump with associated hardware survey with project staff.

**Vineyard: October 2015 - Training Visit**

The purpose of the visit was to train farm staff on how to use the Wexus software platform and learn more about partner site farming operations and energy usage patterns.

**Vineyard: March 2016 - Hardware Survey**

No photos taken.

**Vineyard: July 2017 - Hardware Survey & Product Validation**

Figure 172:  Site Visit at the Vineyard with partner farmer inspecting the filtration system.

Figure 173:  Installed monitoring device at well site.

Figure 174:  Surrounding crops mid growth cycle pre-harvest grapes

## Vineyard: November 2017 Hardware Survey

Figure 175:  Irrigation pump survey

Figure 176: Irrigation pump and flow meter survey

Figure 177: Flow meter survey


Figure 178: Utility meter and Polaris monitoring device

**Figure 179: Surrounding crops mid growth cycle pre-harvest grapes**