CALIFORNIA ENERGY COMMISSION

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ENERGY RESEARCH AND DEVELOPMENT DIVISION

FINAL PROJECT REPORT

Accelerated Deployment of Irrigation Pumping Demand Flexibility

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PREFACE

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

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 solutions, foster regional innovation, and bring ideas from the lab to the marketplace. The EPIC Program is funded by California utility customers under the auspices of the California Public Utilities Commission. The CEC 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 CEC 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.

Accelerated Deployment of Irrigation Pumping Demand Flexibility is the final report for EPC-20-019 conducted by Polaris Energy Services. The information from this project contributes to the Energy Research and Development Division's EPIC Program.

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

ABSTRACT

In agricultural operations across California (and many western states), irrigation pumping is a major energy consumer and offers a compelling opportunity to synchronize with electricity grid needs. California's agricultural industry uses almost 7 percent of the state's electricity, mostly for pumping water to irrigate crops. Installing technology that helps manage and control irrigation pumps in response to pricing signals from utilities can help irrigators reduce their electricity costs and shift demand to a period when power is more affordable and available. Despite the advantages load management technology provides, it is used only sparingly in the agricultural sector. By combining traditional demand response expertise and technology used with time-of-use strategies and dynamic rates pilots, Polaris Energy Services was able to recruit and install an additional 40 megawatts of flexible peak load, with interesting implications for commercial irrigation channels that have historically not been involved with energy incentives.

Keywords: demand flexibility, irrigation pumping

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Background

California's agricultural industry uses almost 7 percent of the state's electricity, mostly for pumping water to irrigate crops. Installing technology that helps manage and control irrigation pumps in response to pricing signals from utilities can help irrigators reduce their electricity costs and shift demand to a period when power is more affordable and available. Increasing the flexibility of irrigation loads will help California achieve energy goals like those outlined in Senate Bill 846 (Dodd, Statutes of 2022, Chapter 239), which targets 7,000 megawatts of demand flexibility by 2030 to support a cleaner and more reliable grid. Demand flexibility enables customers with smart devices to adjust their electricity use based on grid conditions — using more when renewable energy is available and reducing consumption when demand is high.

Project Purpose and Approach

This project aimed to demonstrate and expand irrigation load flexibility through technology, market participation, and policy collaboration. Polaris Energy Services specializes in helping agricultural customers reduce energy costs and participate in demand flexibility programs by integrating automation and real-time price signals into irrigation management.

To build on existing demand response efforts, Polaris developed a new "shift" strategy alongside its established "shed" strategy for managing irrigation load. While traditional demand response focuses on temporary reductions in energy use during peak periods, load shifting allows irrigators to schedule pumping for times when electricity is cheaper and more abundant.

To achieve these goals, the project focused on three key objectives:

- Technology Deployment: Expanding automation hardware and software to enable real-time irrigation scheduling and energy management
- Program and Market Participation: Increasing irrigator enrollment in demand response and load shifting programs while improving program performance
- Policy and Industry Collaboration: Working with regulators, utilities, and industry partners to refine dynamic pricing models and enable long-term adoption

Through this effort, Polaris partnered with Valley Clean Energy and Pacific Gas and Electric Company (PG&E) to implement a dynamic pricing pilot that allowed irrigators to automate their response to hourly electricity prices. The project demonstrated how clear price signals, automation, and flexible load management can reduce energy costs for irrigators while enhancing grid stability.

Key Results

Polaris successfully showed that with the right incentives and automation, irrigators can shift up to two-thirds of their irrigation load away from peak hours — thereby lowering costs and reducing stress on the grid.

Key accomplishments include:

- Forty megawatts of peak load shed or shifted through the Polaris platform.
- Expanded irrigator participation in demand flexibility programs, thus integrating automation for easier participation.
- Successful launch of PG&E's new Hourly Flex Pricing pilot, building on lessons from Valley Clean Energy's Agricultural Flexible Irrigation Technology pilot.
- Improved hardware and software solutions to support real-time irrigation scheduling.

One of the most significant outcomes of this project was the transition from a small-scale pilot to a larger, utility-led program. Based on the results of this project, PG&E launched its new Hourly Flex Pricing pilot on November 1, 2024, giving irrigators an expanded opportunity to optimize energy use based on real-time pricing. This represents a major step forward in making dynamic pricing a scalable, long-term solution for agricultural load flexibility.

Knowledge Transfer and Next Steps

The successful expansion of dynamic pricing models creates new opportunities for irrigators and utilities to further integrate automation and flexible load management. Polaris will focus on:

- Supporting the implementation and scaling of PG&E's Hourly Flex Pricing pilot, ensuring irrigators can easily participate.
- Expanding access to automation technology, including the integration of irrigation automation with Netafim, a leading manufacturer of irrigation equipment. This collaboration aims to streamline field valve automation, improving water and energy efficiency.
- Collaborating with regulators and utilities to refine and scale dynamic pricing programs.
- Enhancing software capabilities to provide more user-friendly scheduling tools for irrigators.
- Increasing awareness and participation through updated digital resources, including a redesigned Polaris website that provides information on demand flexibility programs for irrigators, water districts, automation providers, utilities, and community choice aggregators.
- Advocating for policy and incentive structures that encourage long-term investment in demand flexibility programs.

By integrating smart technology, strategic energy planning, and dynamic pricing, California's agricultural industry can become a key driver of grid stability and sustainability. PG&E's Hourly Flex Pricing pilot represents the next phase of agricultural energy flexibility, and Polaris will continue working to expand participation and refine program benefits.

CHAPTER 1: Introduction

Demand or load management technology is still deployed sparingly in the agricultural sector. In agricultural operations across California (and many western states), irrigation pumping is a major energy consumer and offers a compelling focus for orchestrating usage with the grid. Accordingly, the purpose of this project is to increase the current use of demand management technology in agriculture while simultaneously laying groundwork for integration with emerging load management standards.

There are two specific areas where Polaris, in advancing market adoption of technology, has unlocked new insight. First, the refinement of Polaris technology has generated new features, use cases, and values for customers, all while exposing a narrower set of challenges to further market adoption. Second, deploying Polaris technology in new scenarios, like dynamic rates programs, has further strengthened the case to increase lateral adoption across both specific utility program options and areas of agriculture.

California's clean energy and climate goals underpin the direction of the project. The risks associated with increasingly challenging grid emergencies are clear, and the lion's share of Polaris deployments are directly or indirectly related to load shedding or demand response (DR) capabilities during stressed grid conditions. Moreover, one of the most exciting aspects to this project is directly focusing irrigation pumping load response toward shifting away from peak hours (5:00 p.m. to 8:00 p.m.) via automation, rather than relying on economic signals via rate design. These two impactful areas will play a key role in the collective efforts to address challenges stemming from emerging scenarios from the evolving "duck curve" in California. The "duck curve," where energy use falls during the day and increases in the afternoon, creating a shape that looks like a duck when plotted as a line chart, depicts the challenge of ensuring there is adequate energy supply when energy demand peaks throughout the day.

Why aren't these market needs and opportunities for grid orchestration being met today? Polaris has identified segment-specific headwinds that the team has addressed in the past, tackled directly during this project, and foresees as remaining to some extent well into the near future. Foremost, there remains a continued, urgent need for more DR resources. Despite years of growth and innovation in California, forecasts continue to identify a gap in DR that will be needed in future years to meet California's ambitious clean energy and grid reliability goals. Table 1 shows the estimates of load shift broken down by program in 2022. Load shift still has a long way to go to meet the targets of 2030 as outlined in the Senate Bill 846 Load-Shift Goal Report (Neumann and Lyon, 2023).

Table 1: Statewide Load-Shift Goal by Intervention

Category	Intervention	2022 Estimate	2030 Goal
Load-Modifying (LM)	Time-of-use Rates	620–1,000 MW*	3,000 MW
	Dynamic Pricing	30 MW	
	LM Programs	7 MW	
Resource Planning and Procurement	Economic Supply-side DR	670–825 MW	4,000 MW
	Reliability Supply-side DR	740 MW	
	Point of Use DR Programs (Non-Independent System Operator)	210 MW	
Incremental and Emergency (I&E)	I&E Programs	800 MW	
	Emergency Back-up Generators**	375 MW**	
Total (nearest 100)		3,100–3,600 MW	7,000 MW

* Megawatt

** Includes backup generators with significant local emissions, which are part of the current emergency framework but not included in the 2022 load flexibility total. Only zero- and low-emission behind-the-meter-generation consistent with Assembly Bill 205 (Committee on Budget, Chapter 61, Statutes of 2022) is included in the load-shift goal.

Source: CEC staff, California Public Utilities Commission staff

Furthermore, specific to this sector, agricultural DR similarly remains a laggard relative to grid needs. Despite a sustained focus in the area over time, the levels of participation and value delivered to both the grid and energy users is underwhelming. While this is a notoriously difficult sector for technology applications based on operational cost structures and geographically disparate load, the opportunity for advancement is ripe because of the increasing contribution of energy to overall agricultural costs.

Another important element to the overall background discussion about increasing the prominence of load management technology in agriculture is the general lack of technology incentives for time-of-use (TOU) response and other similar load shifting opportunities. DR efforts are buoyed by thoughtful programs like automated demand response (ADR) and the associated kilowatts (kW) enrolled incentives; for load shifting, there is no actionable incentive bucket to tap for projects. In the near term, there are limited policies being discussed that would change this unfortunate situation.

Finally, in a similar lens to TOU response, there are bleeding edge pilots underway to test the efficacy of dynamic rates programs (and rates). While exciting and headline-grabbing in many instances, these pilots are just now beginning to have the structure to add substantive load, and nothing near the levels required by California’s clean energy and climate commitments.

Accordingly, this project aimed to ramp up the adoption of load management technology in the agricultural irrigation pumping segment. The project added hundreds of sites to the Polaris platform that did not previously participate in load response — in DR applications as well as TOU response and emerging dynamic rates pilots. Traditional DR success metrics and nascent approaches to the presentation of load shift measurement were employed. This project and associated data and research should be relevant to utility program stakeholders, agricultural technology stakeholders, and energy technology stakeholders.

CHAPTER 2: Project Approach

Polaris chose to focus on core capabilities of an existing technology and go-to-market solution combined with marginal improvements to customer positioning and recruitment methods, platform delivery, and program integrations. The focus and measurement of the marginal improvements that allowed for the technology to be applied in many, often more reasonable, use cases, provides for some of the most compelling research findings.

In terms of technology objectives, the project foremost concerned the recruitment of DR participants. This makes sense: in the world of agricultural irrigation pumping, there has been documented success with both recruiting businesses to participate in DR programs as well as applying a variety of levels of technology to better respond to grid emergencies or economic signals (via rates). At a base level, there is no way to test technology applications in this space without some sort of DR program, and accordingly, without a commitment from the end user to participate. So, to have any substantial technology applications and research in this area, there needs to be more agricultural irrigation pumping DR load recruited.

Next, the successful deployment of the Polaris solution was key. For context, the automation of irrigation pumps is relatively nascent, and challenges including but certainly not limited to in-field connectivity, hardware reliability (mostly weather, theft, and other accidental damage-related concerns), and user adoption of automation solutions have all hindered scaling efforts in the past. In the past, crude methods of irrigation, such as flood irrigation, delayed the ramping of automation technology because pump operation was relatively straightforward and did not comprise complicated scheduling or control methods. As targeted micro-irrigation, multiple valve systems, variable frequency drives, and other technological advancements were adopted, the benefits of automating irrigation pumps became clearer to end users. These trends, combined with the work of Polaris and other vendors to connect pump automation and operation with energy markets, has led to expanded appetite for specific versions of in-field pump automation. Still, economic challenges in two notable areas — smaller irrigation pumps, which Polaris typically considers around 30 kW and smaller, with less load and less ability to earn savings or incentive fundings, and multi-valve irrigation systems with high up-front capital expenditures required — have limited deployment of solutions to date.

Another major objective in this project was to connect pumps deployed on the Polaris platform to appropriate DR programs, and to deliver satisfactory program and customer results. In the past, this exercise was often limited by narrow program rules or overly specific intended customer outcomes. Ahead of the project and research, Polaris had identified several areas where existing DR program options could be delivered to customers via the Polaris platform outside of past approaches, and outside of past incentive frameworks.

Building on the opportunity for this project and research regarding DR, there was a similar opportunity to connect deployed pumps to strategies that deliver load shift and customer value based on their utility rate (that encourages load shift). This was much more difficult to do than the previous DR exercise, since there was usually only on-bill savings to point customers to (rather than cash flows received in many DR programs). Still, there is promise in this area since many irrigation pumps are already well on their way to shifting off peak (hours outside the 5:00 p.m. to 8:00 p.m. window) or have committed to locating technological aids to assist in their journey. Moreover, new pilots involving dynamic rates applications —notably, pilots based on the California Flexible Unified Signal for Energy (CalFUSE) framework — offer a new opportunity to connect pumps on the Polaris platform to load shifting strategies.

In general, a major objective of this project was to drive additional platform usage across all Polaris applications. Similar to some of the traditional hurdles to in-field hardware deployment, software adoption in the agricultural space also lags some traditional measures. There are many benefits to having a more engaged user base with regard to the Polaris platform — notably, the ability to move customer assets across programs or strategies as their energy usage changes over longer time frames — so this objective feeds directly back into many of the others listed already.

In the previous discussion about load shifting, the callout of new dynamic rates opportunities was significant and worth its own section for project objectives. Partnering with utility and regulatory stakeholders to implement new tariffs and rate designs (or price signals) was something that fit well within the scope of Polaris efforts. Over the past five years, there have been multiple dynamic rates agricultural pilots that Polaris has helped design, implement, measure, and review. Expanding the Polaris knowledge base and transferring these learnings to policy and program focused stakeholders was a large part of the research in this area.

Building on the idea of new programs, new market opportunities, and new customer needs (based on increasing adoption of automation technologies), one research objective of this project was to explore the need for new hardware configurations to meet market needs. This may comprise advanced, modern hardware applications, connections to other automation systems via third party partnerships or methods like application programming interface, or formal project integrations that have not been pursued in the past.

Finally, and perhaps most importantly, a key objective to this project was to (along with every other objective and research component detailed in this section) demonstrate an added 25 to 40 MW peak load shed/shift capability. This is by far the most impactful, significant quantitative objective and will drive success across every other objective documented.

For this project and research to succeed, a significant number of agricultural irrigators will need to partner with Polaris and manage their energy usage through the Polaris platform. That segment (participants) was by far the most important lever for project success. Other key partners included irrigation equipment installers, utility program stakeholders, and other irrigation automation hardware/software providers.

Polaris relied on two main methods for this project and research. The first was an irrigation operations frame that was developed for Polaris' software interface, which prioritized irrigation operations decisions — not necessarily energy decisions — to drive key energy outcomes. The second frame was an expanded, enhanced view of potential energy savings across different (and sometimes, competing and conflicting) utility program options across entire portfolios of irrigation pumps. These two frames and subsequent methods offered the best path to engaging project participants (irrigators).

CHAPTER 3: Results

In efforts to ramp up adoption of load management technology in agriculture — all while bridging gaps between current and emerging load management standards — the project focused on increasing grid reliability, improving technology, and enhancing capabilities to shift and/or shed additional load. There were nine specific areas where Polaris cataloged technology outcomes:

1. Enhanced capability to recruit DR participants
2. Deployed Polaris technology solution
3. Improved DR program results via platform adoption
4. Demonstrated ability to deliver load shift program results via platform adoption
5. Increased platform usage
6. Developed partnerships with utility and regulator stakeholders to implement new tariffs/price signals
7. Designed new hardware configurations to enable scheduling automation
8. Designed new scheduling software platform to enable irrigators to respond to dynamic rates on a weekly schedule
9. Demonstrated 25 to 40 MW peak load shed/shift capability via Polaris platform

In addition to these nine specific areas, Polaris documented a set of specific challenges and made recommendations for engaging a subset of broader audiences where project learnings have helpful applications.

Outcomes

Demand Response Recruitment

In terms of DR recruitment, this project was an overwhelming success. For background context, one of the most difficult and often frustrating parts of recruiting irrigation pumping load for DR is only being able to present a single strategy or program to a potential DR participant. This limiting factor often set up a "go or no-go" type of decision-making, which combines poorly with a generally cautious segment of energy users. A more successful frame is one that generates options for irrigators, and that's precisely what this project delivered via a "shift or shed" option for technology application.

Previous recruitment strategies in the irrigation pumping segment for DR relied on a pump-by-pump breakdown of what load could be contributed to a specific DR program, based on the narrow rules for that program (or incentive program, or both). Decision-making at that point usually involved making an operational decision (specifically, can that many pumps be shut down during a DR event?) or a financial decision (specifically, what do the incentive payments or program payments equal?). For this project, a new decision-making frame was introduced based on Polaris's ability to offer multiple strategies or programs at the same time, within the context of a single project or investment.

In this new conversation, the general starting point for deciding whether to consider the technology application focused on whether each individual pump could provide value to the grid via its flexibility. Then, with ability to present and recommend (and pair with incentives) both shift and shed options, the recruitment conversation with irrigators produced more follow-up questions, meetings, and ultimately recruited load. This makes intuitive sense; with a larger starting pool of suitable pumps to consider, and the ability to batch pumps into shift or shed options rather than just one, Polaris was more successful in identifying projects and ultimately recruiting load for DR programs. The ability to address and action the shift side of the conversation lead to greater success on the shed (or DR) side.

Polaris saw three specific positive outcomes as they relate to an improved capability for DR recruitment. First, there was a noticeable improvement in speed to market. With traditional DR-only programs and technology incentive frameworks, there are built-in limits to when a project can come together. These include seasonal constraints (when pumps are running and can add value via flexibility), program enrollment criteria, and lagging-indicator kW incentive valuation criteria. Within the context of this research and this project, where those constraints were not present or could be mitigated through the flexibility of the research project, Polaris saw an increased speed to market because of the ability to get pump automation equipment installed, tested, and executing shift or shed strategy on irrigator timelines (as opposed to utility program management timelines, which generally do not have seasonal flexibility). Overall, the ability to offer different ways for irrigators to monetize the value of their flexibility via technology aligned project goals for all stakeholders to get projects done faster.

The second positive outcome related to DR recruitment was a marked increase in customer satisfaction and experience during the recruitment phase. Having a clear picture of what irrigation pumps were shift or shed candidates, and the ability to review and decide on a project comprising elements from each was clearly a better situation than having to make separate decisions about DR participation and then the balance of options (including other DR programs, time-of-use strategies, and other options).

Finally, there was a notable increase in Polaris's confidence in the reliability of recruited DR irrigation pumps. This is mainly because of the ability to better sort shift and shed focused resources. For example, in the traditional recruitment approach, the goal is often to maximize the DR resource, as measured in kW. This can lead to marginal resources being included, some of which arguably could be better deployed as shift resources. However, in this project, it was very positive to see a better sorting up front and the expected reliability increase by maximizing shed and shift resources, since there were promising shift programs to sort those resources into.

Deploying Polaris Technology

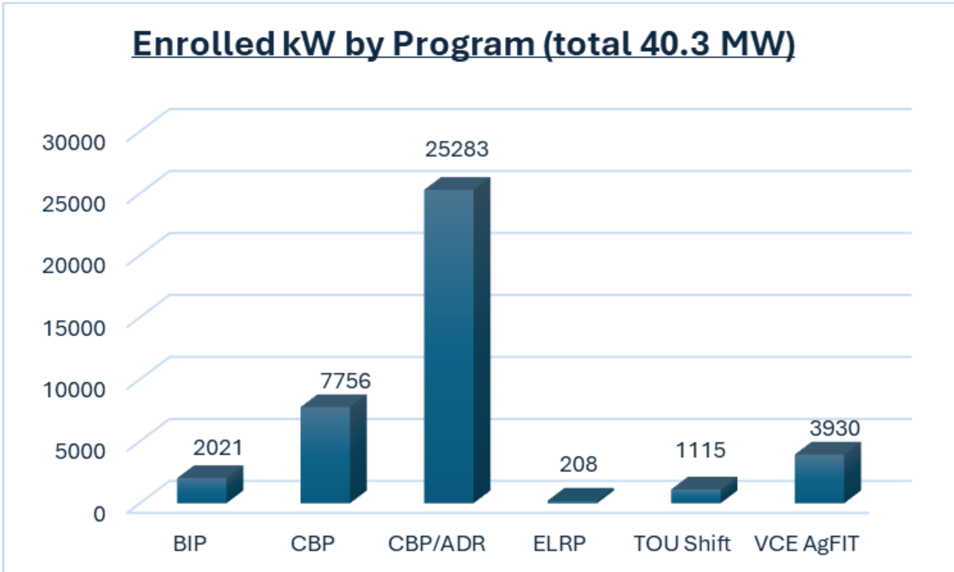
Moving on to another key technology outcome, the project's deployments of Polaris technology were within expectations. While there were notable barriers and challenges faced with regard to automation technology generally (documented later in this section), Polaris was able to deploy technology as needed for the project.

In terms of technology outcomes for DR program results, there were two main positive results. First, in "core" DR program enrollment (mainly, PG&E's capacity bidding program), the technology application delivered both positive customer outcomes (incentive payments to compensate their time and effort to enable load flexibility) and positive grid outcomes in terms of load shed. Additionally, there was demonstrated interest in technology related applications for other DR programs, including the Emergency Load Response Program as well as options in Southern California Edison territory. There is a myriad of DR programs, four of which are worth highlighting, alongside two load shift strategies. They are as follows:

- **Base Interruptible Program:** This program provides load reduction on a day-of basis when the California Independent System Operator (CAISO) issues a dispatch notification. It is an annual program, and customers can enroll either directly with PG&E or with an aggregator.
- **Capacity Bidding Program (CBP):** CBP is an aggregator managed program that provides capacity load May 1 through October 31 each year. This is a day-ahead option program.
- **Capacity Bidding Program with Automated Demand Response (CBP/ADR):** Customers in this category enrolled in a CBP program and used automation incentives by enrolling in automated demand response (ADR). ADR helps automate the load that is dispatched during CBP events.
- **Emergency Load Response Program:** This is a seven-year pilot program that incentivizes customers to reduce energy consumption during time of grid stress or emergencies. This program is dispatched on a voluntary basis and does not impose any penalties for non-performance.
- **TOU Shift:** This is not a load shift program, but an agricultural rate class that has large benefits and penalties for avoiding or using during peak hours (5:00 p.m. to 8:00 p.m.), respectively. Since usage during these peak hours can swing a bill dramatically, there is a practice and strategy in shifting usage in accordance with this tariff.
- **Valley Clean Energy AgFIT (Agricultural Flexible Irrigation Technology):** This pilot program, which will be discussed in detail in the Load Shifting section, is based around a new rate class called dynamic rates, where prices can vary by hour and are able to be scheduled up to seven days in advance.

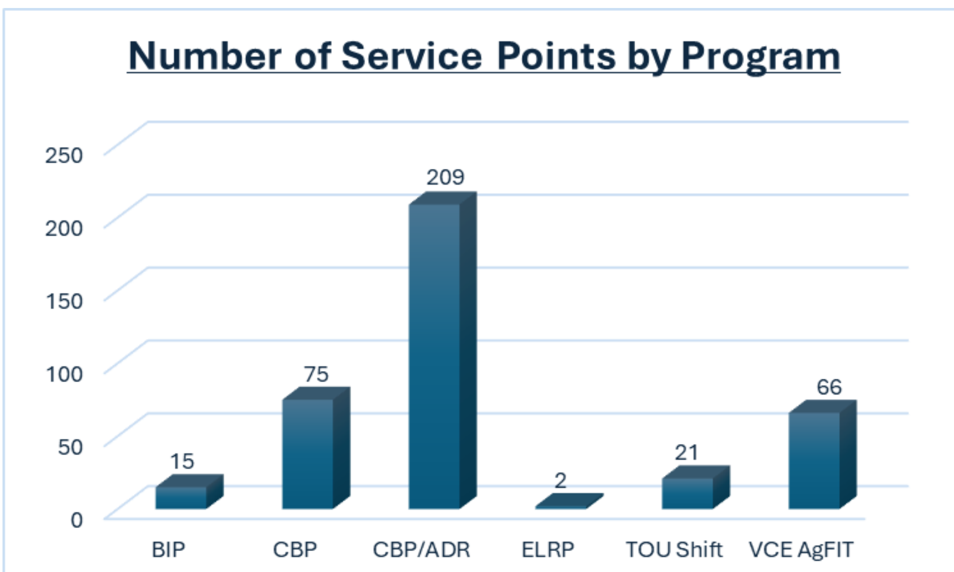
Figures 1 through 4 highlight project enrollments in the demand flexibility programs. Customers are intentionally anonymous for shared load.

Figure 1: Enrolled kW by Program



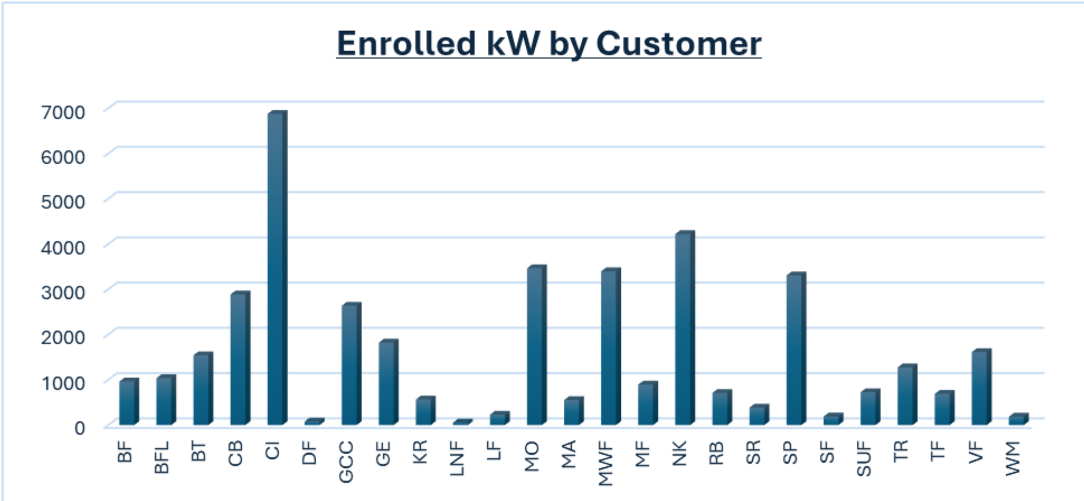
Source: Polaris Energy Services

Figure 2: Number of Service Points by Program



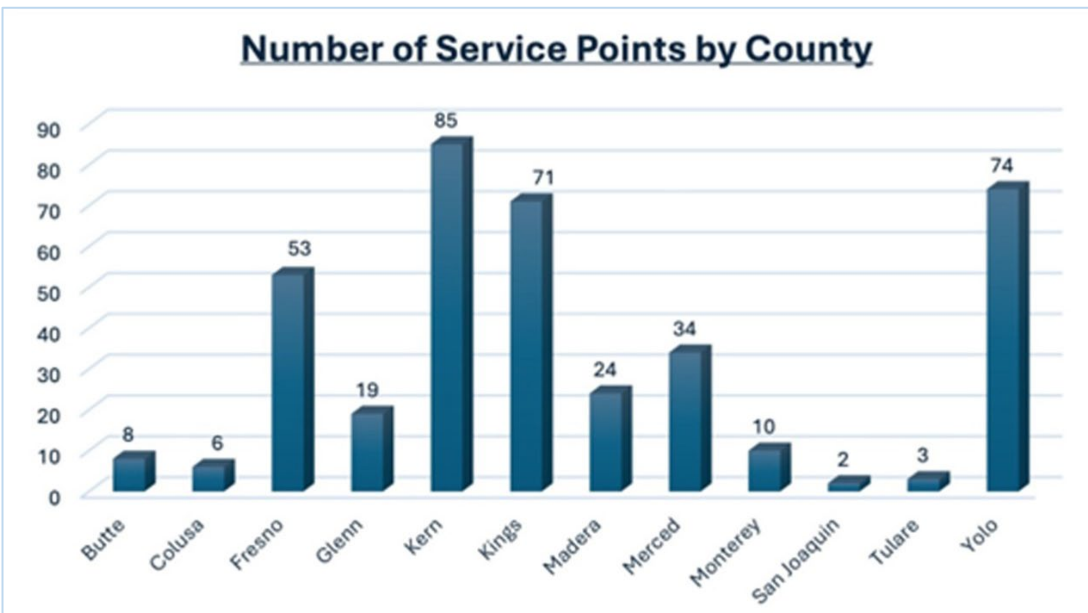
Source: Polaris Energy Services

Figure 3: Enrolled kW by Customer



Source: Polaris Energy Services

Figure 4: Number of Service Points by County



Source: Polaris Energy Services

Load Shifting

Changing focus to load shifting programs and technology outcomes, results were more mixed. On one hand, the project was able to incubate, grow, and foster some pioneering work with regard to CalFUSE and dynamic rates pilots. On the other hand, there was limited success in enabling TOU shifting via Polaris technology applications (again, documented later in this section).

Initial work on the AgFIT" dynamic rates pilot with Valley Clean Energy and the subsequent work to build an expanded dynamic rates pilot with PG&E was one of the runaway successes of this project. In 2021, a new pilot program proposed by Valley Clean Energy was approved by the California Public Utilities Commission, designed to prepare for potential extreme weather during the summers of 2022 to 2024.

As per Valley Clean Energy's advice letter on January 5, 2022, "the pilot will include automation of agricultural pumping loads to respond to dynamic prices and implementation of an experimental rate that incorporates energy and delivery costs in hourly prices. Customers who successfully respond to the prices and shift load out of expensive hours — typically the ramp hours — are projected to enjoy bill savings while contributing to grid reliability." Simply put, the purpose of the pilot was to test the use of dynamic rates to provide incentives for large agricultural customers to pump water when it is least costly to do so.

Polaris was a key partner in this pilot, providing end-to-end customer relationship management (recruitment through customer success), the software that displayed the dynamic rates, and an automation device provider option. The results for AgFIT are best broken up by each summer of participation. This will focus on a few aspects: scheduling adoption, load shift, and bill savings. Summer 2022 results are summarized in Table 2. Although still a notable number of hours scheduled, since this was the first summer of the program, there were only two early adopters who participated. A big factor that impacted the hours scheduled was weather. This season came off a very dry winter with very high summer temperatures, so pumping started early.

Table 2: Summer 2022 AgFIT Results

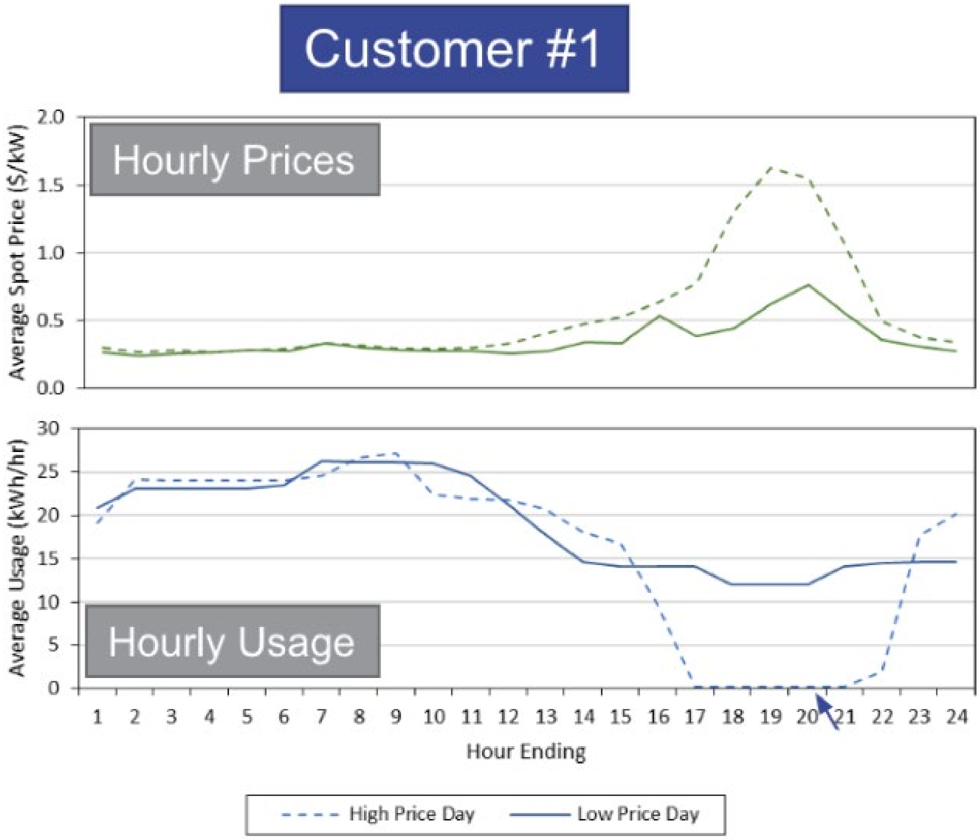
Participation	Amount
Customers	2
Load	839 kW
Service Points	16
Hours of Schedules Created	25,611 from April to September

Source: Polaris Energy Services

Since this was a pilot program, the first year came with a fair number of kinks to work out. One of those kinks was calculating bill savings. Official bill savings have not been presented to customers; however, it is actively being worked on by other program partners. The date for sharing this is still to be determined, as there are issues with the data; however, the goal is to share this in 2025.

Figures 5 and 6 compare the average spot price with the average usage for high- and low-priced days. Load shift in response to prices is evident by the dip in the graph showing usage, when there is a peak in the graph showing prices. These graphs were compiled by Christensen Associates for the Preliminary Assessment of Valley Clean Energy's Agricultural Pumping Dynamic Rate Pilot.

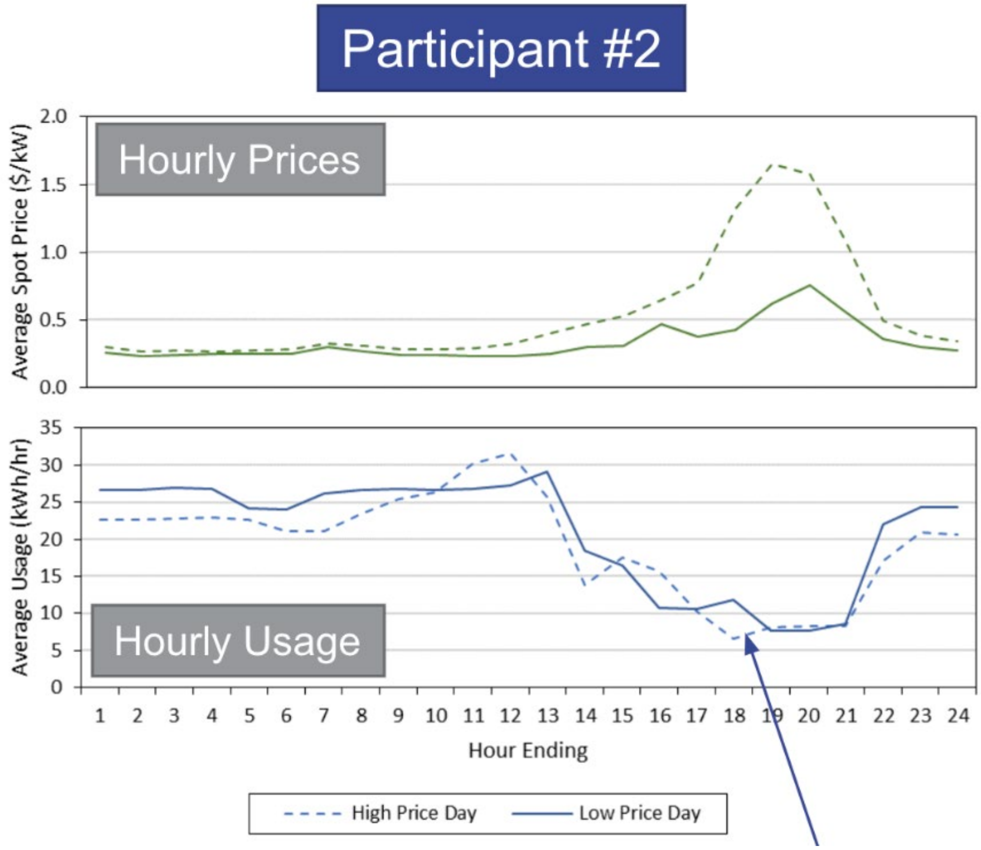
Figure 5: Response on High- vs Low-Priced Days, Participant 1



High-Priced Days: September 6 through7; Low-Priced Days: August 23 through 25.

Source: Christensen Associates

Figure 6: Response on High- vs Low-Priced Days, Participant 2



High-Priced Days: September 6 through7; Low-Priced Days: August 23 through 25.

Source: Christensen Associates

Summer 2023 results are summarized in Table 3. The 2023 growing season came off a very wet winter with milder summer temperatures, so pumping started later in the season than in 2022. Also, many participants had access to surface water that year that negated their need to turn on their well pumps. These results can be seen by the number of customers and load participating increasing much quicker than the hours of schedules, when compared to 2022.

Table 3: Summer 2023 AgFIT Results

Participation	Amount
Customers	5
Load	2,283 kW
Service Points	33
Hours of Schedules Created	38,107 from July to September

Source: Polaris Energy Services

The 2023 growing season had the added benefit of having data available to produce shadow bills. Shadow bills are the bills produced in the program to show costs on the dynamic rate.

They are then compared to the Otherwise Applicable Tariff bill, to calculate the annual credits, which are seen in Table 4.

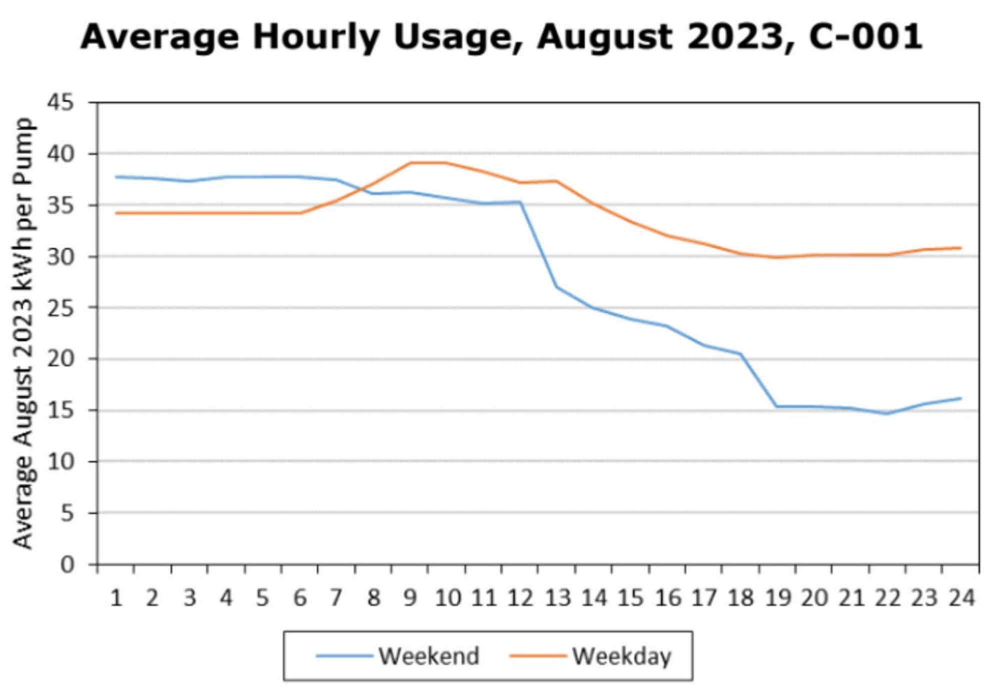
Table 4: Summary of 2023 Bill Savings by Customer

Customer	Annual Bill Credit	Participating Service Points
BF	$12,926.50	7
BT	$25,163.00	15
MO	$9,738.40	8
RB	$5,574.80	1
SF	$3,714.70	2

Source: Polaris Energy Services

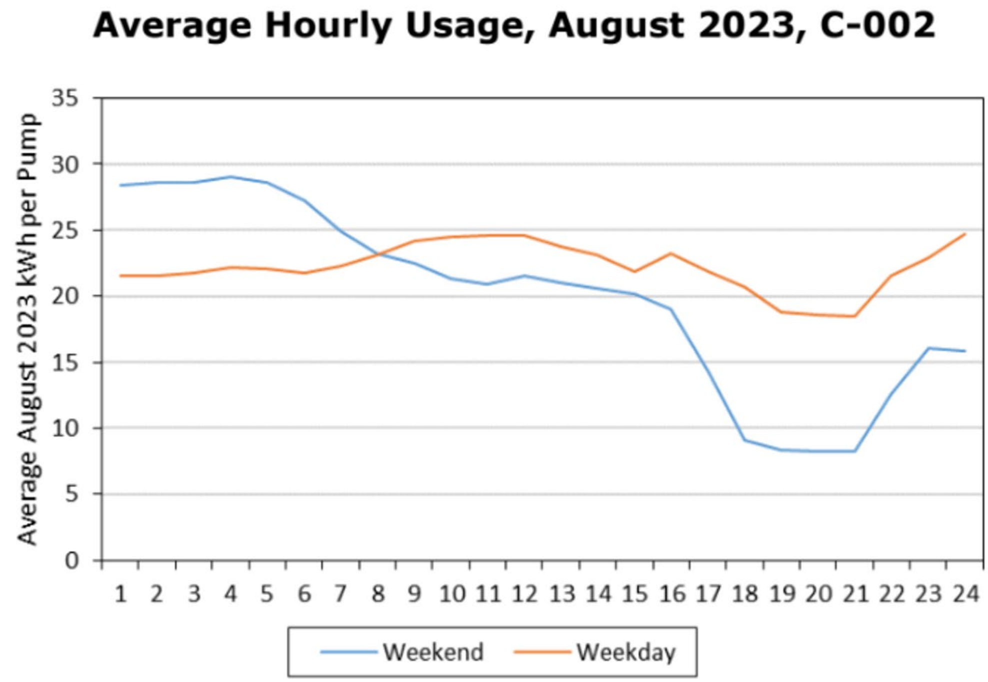
Figures 7 through 11 show the average hourly usage, broken down by participant, for the entire month of August. Although there were varying levels of response, there was a dip in usage during the later afternoon hours from each participant. This is promising, as one of the main goals of the AgFIT program was to see how automation technology and visibility into prices impacted when growers ran their pumps — specifically, if they would run their pumps during lower priced hours. The graphs show this to be true and were compiled by Christensen Associates for the Mid-Term Evaluation of Valley Clean Energy's Agricultural Pumping Dynamic Rate Pilot.

Figure 7: Average Hourly Usage, August, Participant 1



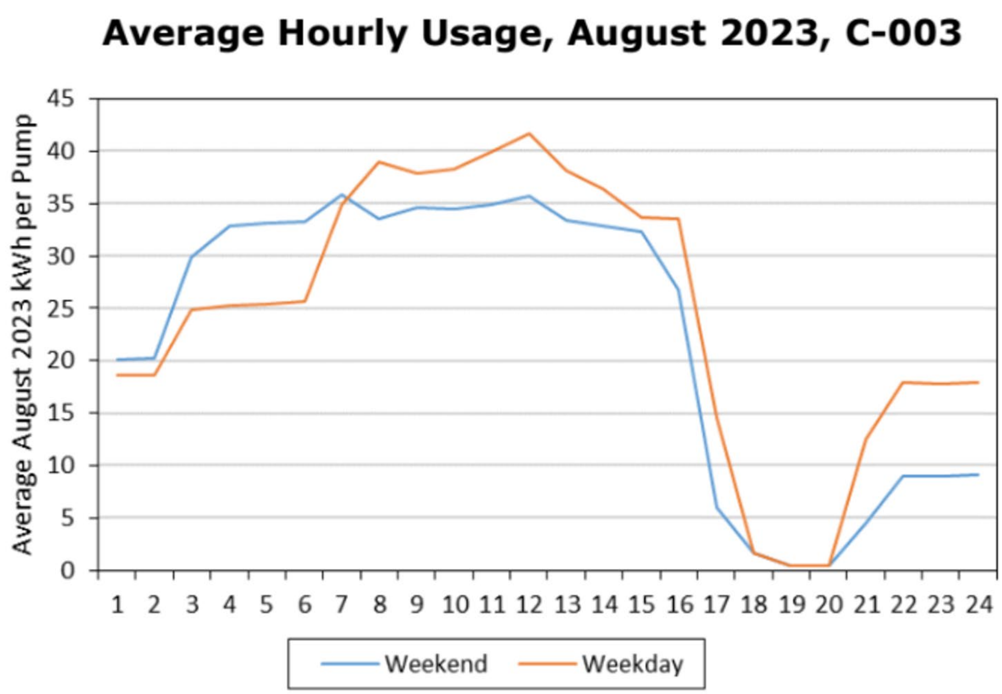
Source: Christensen Associates

Figure 8: Average Hourly Usage, August, Participant 2



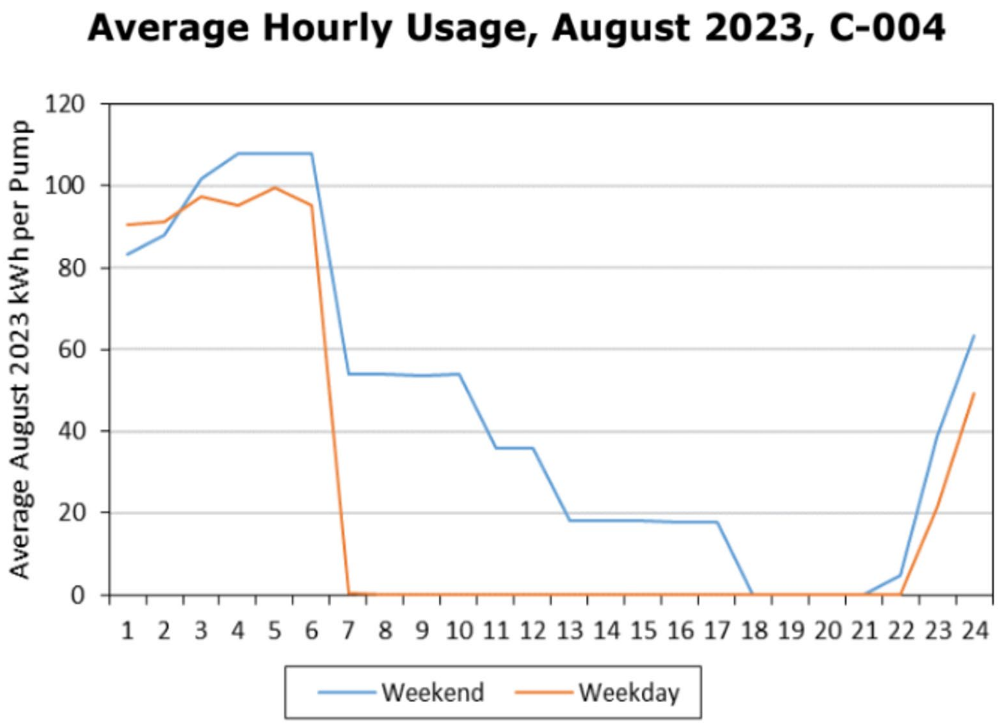
Source: Christensen Associates

Figure 9: Average Hourly Usage, August, Participant 3



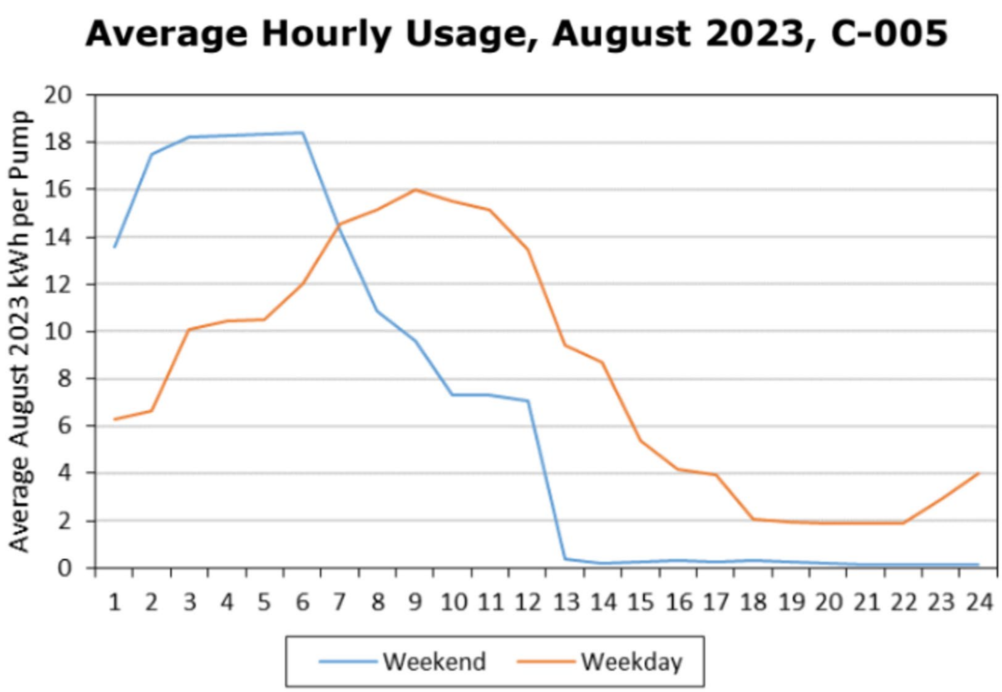
Source: Christensen Associates

Figure 10: Average Hourly Usage, August, Participant 4



Source: Christensen Associates

Figure 11: Average Hourly Usage, August, Participant 5



Source: Christensen Associates

Lastly, summer 2024 results are summarized in Table 5. Again, an increase in customers, load, and service points participating can be seen. Official 2024 data, including bill savings, has not been finalized or presented to customers. There is a lengthy review process required by all program partners before data can be shared; however, that is already underway. The goal is to finalize and share this data in first quarter of 2025.

Table 5: Summer 2024 AgFIT Results

Participation	Amount
Customers	7
Load	3,004 kW
Service Points	48
Hours of Schedules Created	In progress, data not yet available

Source: Polaris Energy Services

Platform Usage

With all the added load to the Polaris platform — most focused on dispatching for DR events, but some focused on dynamic rates and TOU — there was a modest increase in platform software usage. This is a positive technology outcome that can be built upon in the future.

Automation Cost Effectiveness

Irrigation automation technology is not easily accessible, mostly due to cost. It is expensive to invest in this kind of equipment, and the costs can increase significantly with the complexity of a system (specifically if there are field valves, filtration needs.). One of the major benefits of programs like AgFIT is the help to cover or reduce those costs. The AgFIT program offered $200/kW of enrolled load in funding that could be applied towards automation of irrigation pumps. For some growers, this opened the door for them to install automation, and for others it enabled the expansion of their current automation systems. In both cases, the funding for automation from programs increased its cost effectiveness.

New Tariffs and Price Signals

Related to the technology deployments and work on dynamic rates, there were also positive outcomes with the speed of development for the tariffs used in the expanded dynamic rates pilot approved on January 25, 2024 by the California Public Utilities Commission, as well as the buy-in from the various stakeholders needed to make these exciting new pilots a reality. The fact that Polaris formed partnerships with utility and regulatory stakeholders to implement new tariffs/price signals for irrigation pumping customers was achieved is a successful outcome.

New Hardware Configurations

In terms of new hardware configurations shipped during the project, Polaris updated the pump automation controller (PAC) control unit to a new version with a new embedded systems platform designed to provide more reliable field service and support more robust on-site load monitoring and load scheduling applications. In select instances, Polaris installed ancillary sensors to enable growers to understand what load management they could safely use without putting crops at risk. These included flow meters to provide instantaneous and totalized flow information and reservoir depth sensors that helped growers know they could safely curtail deep well pumps that filled reservoirs to carry out load shifting operations aligned with their economic interests.

In addition, Polaris partnered with Netafim (acquired by Orbia) to develop a combination pump and field valve controller and integrated the controller into the Polaris platform. The device was developed and deployed at a beta customer site to test the viability of using this solution to manage end-to-end irrigation operations automatically under an hourly variable price rate design as part of the AgFIT program. The beta unit was deployed and operated reliably during the summer 2023 beta test period.

New Scheduling Software Platform

Dynamic pricing requires irrigators to be able to schedule their irrigation around hourly prices. Polaris developed and added weekly scheduling capability in the software platform. This was a significant development because irrigators can schedule their irrigation remotely and automatically instead of the previous capability of only monitoring and curtailment. When combined with the PAC, the scheduling software solution provides an integrated automation solution to respond to hourly prices.

Peak Load Shed and Shift

Finally, and perhaps most significantly, the project achieved an important outcome of demonstrating a large peak load shed/shift capability. Through project efforts, 40.3 MW of peak load was added to the Polaris platform.

Barriers and Challenges

Four main hurdles impacted the project enough to warrant a separate discussion. They are, in order of magnitude: supply chain and vendor challenges that followed the pandemic; difficulties illustrating on-bill time-of-use savings for customers; situational net energy metering and net energy metering aggregation challenges; and a steep, continued learning curve for in-field connectivity.

During the project, Polaris experienced numerous major events that delayed project deployment timelines. These events included:

- Covid-related impacts in PAC supply chain and contractor labor shortages during 2021 and 2022. Delays lasted upward of six months for some projects.
- Exceptional snowfall and rain during the winter of 2021/22. Delays lasted four or more months due to fields being under water or too muddy to plant. Some projects were abandoned altogether due to field damage.

The most serious pandemic-related challenge involved supply chain delays in procuring PAC field control units. These delays were caused by parts shortages of various sorts, including parts required for the manufacturer of the proprietary PAC printed circuit board (PCB). These shortages required Polaris to qualify new replacement parts and to roll the design of the PCB to include an updated bill of materials for the contract manufacturer. In addition to PCBs, various off-the-shelf components used in the PAC also experienced delays compared to usual procurement expectations. During 2021, the overall impact to Polaris was increasing PAC build times by approximately six or more months compared to the usual build-to-fulfillment timeline of about three weeks. These supply chain delays resulted in corresponding delays in field deployments for projects during 2021 and early 2022.

Additionally, Polaris experienced labor shortages with electrical contracting firms during 2021 and 2022. These shortages slowed the pace of field deployments somewhat. By 2023 these shortages had been resolved, and contractors were able to scale up installation crews to meet Polaris' needs.

The next major barrier to positive technology outcomes involved the quantifying of and acceptance by customers of TOU savings. While seemingly straightforward, delivering savings via technology applications from shifting load away from peak periods into lower-cost off-peak periods remained somewhat elusive. The reason was twofold. First, achieving the savings at each service account involves major operational commitment and often significant automation expertise. The commitment needed from irrigators was not several times a year like many DR programs, but rather every single day. Even with good operational procedures, TOU savings suffer from being "on-bill" rather than cash driven, like many DR programs. Being on-bill adds risk of savings being lost in other bill changes, such as year-over-year rate increases, different levels of monthly usage, and so forth. Also, without a good counterfactual evidence to show what an irrigator would have paid otherwise, it is difficult to frame savings. Even with something akin to a counterfactual, it is difficult to get buy-in from a customer about what may have occurred versus what did.

With regards to dynamic rates pilots, calculating program savings and delivering shadow bills to customers with net energy metering or net energy metering aggregation (NEMA) rates proved difficult. The main obstacles were the well-documented difficulties with regards to utility billing and sharing that data with technology vendors like Polaris. Net energy metering and net energy metering aggregation rates impact bills in a way that require onerous, if not sometimes impossible, steps to reconcile with data available via third-party authorization (such as Share My Data).

Finally, a common and ongoing challenge for enabling local field controls was field control connectivity to the automation platform via cellular connection. The cellular network in rural communities is generally less robust than in more populated urban centers, and cellular connectivity issues are further compounded by land topography, plant cover, and other physical barriers. Cellular connectivity issues can result in the failure of the automation solution to execute load curtailment and restoration events, thus impacting load flexibility outcomes. In a handful of instances enabling sites were delayed by up to two months while repeated visits were made to attempt to improve connectivity.

To address these issues, Polaris took several steps to improve solution reliability. These measures included using more powerful directional antennas where beneficial and using two antennas in more challenging situations. In a few exceptional circumstances, Polaris installed 20-foot galvanized steel poles at pumping sites and the antennas were mounted atop these to maximize the available cellular signal. In mid-2023 to early 2024, Polaris began experimenting with a new cellular modem with a goal of improving connectivity. This new modem was better able to independently manage network drop out events and restore connectivity without impacting irrigation operations. As of early 2024, Polaris had adopted this modem as the default for all field installations.

Implications for Broader Audience

The research and project work has learnings and relevant takeaways beyond the typical energy stakeholders. Foremost, the lessons from this project potentially have immediate impact in the irrigation and irrigation automation channels. In those sectors, agronomy and water considerations typically drive investment decision-making and technology adoption. Yet, as seen in this project, energy considerations surely can drive additional value. This is particularly true if a focus on the irrigation channel were to be paired with the next key stakeholder: policy working groups. The care, thought, and speed of various working groups in advancing dynamic rates ideas to pilot stage is an excellent example of what can be accomplished here. A deep dive into aligning incentives (and adjusting some traditional assumptions) for the irrigation channel is an important step. Finally, any third-party evaluator interested in irrigators as an asset for grid flexibility would likely have follow-up questions about this research.

CHAPTER 4: Conclusion

Fully unlocking the flexibility of irrigation electricity load is an immense opportunity for California. Increasing the flexibility of irrigation loads will help California achieve energy goals such as those related to Senate Bill 846, which targets 7,000 MW of demand flexibility by 2030 to enable a cleaner and more reliable grid.

Building on the success of and addressing known limitations of a single view toward agricultural DR, this project offers a path to expand the frame used to engage agricultural irrigators with programs and incentives to increase grid flexibility. Concisely, Polaris recommends that policy and regulatory stakeholders look closer at:

1. Combining shed programs (DR) and incentives with shift pilots and incentives (like dynamic rates) so that irrigators can get a single, comprehensive, and actionable view of their grid flexibility and how to monetize it. Too often the decision for irrigators is program x or program y, rather than program x and program y.
2. Building on this, there is an opportunity to overlay options and create even more powerful flexibility. For example, it is not difficult to imagine an emergency DR program option, overlayed atop a dynamic rate program, with a technology incentive to encourage both.
3. The market and ecosystem for functional, in-field irrigation automation is still nascent when it comes to the (high) demands of electricity grid orchestration. More incentives and investments in programs are required.

GLOSSARY AND LIST OF ACRONYMS

Term	Definition
ADR	automated demand response
AgFIT	agricultural flexible irrigation technology
CalFUSE	California Flexible Unified Signal for Energy
CBP	Capacity Bidding Program
CBP/ADR	Capacity Bidding Program with Automated Demand Response
CEC	California Energy Commission
DR	demand response
EPIC	Electric Program Investment Charge
I&E	incremental and emergency
kW	kilowatts
LM	load-modifying
MW	megawatts
NEM	net energy metering
NEMA	net energy metering aggregation
PAC	pump automation controller
PCB	printed circuit board
PG&E	Pacific Gas and Electric Company
TOU	time-of-use

References

Hansen, Daniel G., and Michael Ty Clark. 2023. *Mid-Term Evaluation of Valley Clean Energy's Agricultural Pumping Dynamic Rate Pilot.* Christensen Associates. December 22, 2023. Available at www.calmac.org/publications/VCE_AgFIT_Pilot_Mid-Term_Evaluation_Report.pdf.

Neumann, Ingrid and Erik Lyon. May 2023. *Senate Bill 846 Load-Shift Goal Report*. California Energy Commission. Publication Number: CEC-200-2023-008. Available at https://www.energy.ca.gov/publications/2023/senate-bill-846-load-shift-goal-report.

Project Deliverables

The Project Deliverables include a bulleted list of the deliverables noted in the key technical tasks — as identified in the Agreement and Scope of Work.

The project includes the following deliverables:

- Final Report Outline
- Draft Final Report
- Final Report
- CPR Report
- Monthly Reports
- Quarterly Reports
- List of TAC members
- TAC meetings summaries
- Kick-off Meeting presentation
- Kick-off Meeting Benefits Questionnaire
- Mid-term Benefits Questionnaire
- Final Meeting Benefits Questionnaire
- Project Case Study (Draft & Final)
- High Quality Digital Photographs